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Cover photographs

Front cover, from left: blue-eye trevalla (top), deepwater flathead, orange roughy, jackass morwong, blue-eye trevalla, pink ling

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2006-2007

Volume 2: 2007

G.N. Tuck
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Report 2006/813

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2006-2007

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1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2007

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OBJECTIVE:

- Provide quantitative and qualitative species assessments in support of the five SESSFAG resource assessment groups.

1.1 Outcomes Achieved

The 2007 assessments of stock status of the key Southern and Eastern Scalefish and Shark fishery species are based on the methods presented in this report. Documented are the latest quantitative assessments for key SESSF quota species. Typical assessment results provide indications of current stock status, in addition to an application of the recently introduced Commonwealth fishery harvest control rules that determine a Recommended Biological Catch (RBC). These assessment outputs are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

1.2 General

Yield, Total Mortality Estimates and Tier 3 Harvest Control Rule

This chapter provides yield and total mortality estimates for major commercial fish species from the shelf and slope in the South East Fishery. Yield estimates are made using a yield-per-recruit model with the following input: selectivity-at-age, length-at-age, weight-at-age, age-at-maturity, and natural mortality. Total mortality values corresponding to various reference equilibrium biomass depletions were calculated for each species.

Recent average total mortality was estimated from catch curves constructed from length frequency information. Length frequency data were from ISMP port measurements.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to decide the Recommended Biological Catch (RBC) for next year. Tier 3 RBC values for flathead, morwong, school whiting and ling were all less than recent average catches. Tier 3 RBC values for Redfish, Spotted warehou, Blue warehou, John dory and Mirror dory were equal to or greater than recent average catches. Due to probable dome-shaped selectivity for silver trevally caught by trawl, it has been recognized that simple catch curve methods as these should not be applied to that species.

Catch rate standardisation

Catch-per-unit-effort (CPUE) data is an important input to many of the stock assessments conducted within the South East and Southern Shark Fishery (SESSF) where it is used as an index of relative abundance through time. The catch and effort log-book data from the SESSF, which is the source of CPUE data, derives from a wide range of vessels, areas (zones), months, depths, and fishing gears. The catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, what gear was used, did fishing occur during the day or night. The intent is to focus on any changes in catch rates that occurred between years as a result of changes in stock size rather than changes brought about by any of these other factors.

Catch rates, generally as kilograms per hour fished, were natural log-transformed to normalize the data and stabilize the variance. The statistical models were subsets of the form: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. For some fisheries weeknumber or gear type was also included. Generally, only those vessels which had been active in each fishery for more than two years were included in the analysis and often a restriction focusing on vessels that had captured more than some minimum annual catch were included (for example, median annual catches greater than 1 tonne). This was used as a preliminary data selection to focus attention on those vessels contributing significantly to each fishery.

The catch rates for twenty four different stocks for thirteen different species were analysed including School Whiting, Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver Warehou, Blue Warehou, Pink Ling, and Ocean Perch.

Tier 4 Harvest Control Rule

The Tier 4 assessments are empirical rule based assessments based on trends in catch rates and catches, where the catches include all Commonwealth catches as well as State catches and discards. The Tier 4 analysis considers the gradient in catch rates over the previous four years and adjusts the recommended biological catch accordingly, increasing the RBC if the gradient is positive and decreasing it if it is negative.

A total of twenty one analyses were completed on sixteen different species: Blue Eye Trevalla, Blue Grenadier, Blue Warehou, Tiger Flathead, Gemfish, Jackass Morwong, John Dory, Mirror Dory, Ocean Perch, Pink Ling, Redfish, Ribaldo, Royal Red Prawn, School Whiting, Silver Trevally, and Spotted/Silver Warehou.

The Tier 4 analyses are designed for those species for which available data is limited; their outcomes should be more precautionary than those possible from higher Tier analyses.

1.3 Slope Species

Blue Grenadier

Blue grenadier (*Macruronus novaezelandiae*) are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue grenadier are caught by demersal trawling. The global agreed TAC in 2006 was 3530 tonnes, down from 3,730t in 2006, 4200t in 2005 (which includes a voluntary industry reduction of 800t), 7000t in 2004, 9000t in 2003 and 10000t the previous year, the level at which it had been since 1994.. There are two defined sub-fisheries: the winter spawning fishery off Tasmania and the non-spawning fishery (all other areas and times). The non-spawning fishery catches have been relatively consistent over the last few years (at just under 2000t), whereas the spawning fishery catches showed a marked increase during the mid-1990s before decreasing from 2003. The spawning and non-spawning fishery catches are currently at similar levels.

The 2007 assessment of blue grenadier uses the age-structured integrated analysis model developed during 1998 and 1999. The assessment has been updated by the inclusion of data from the 2006 calendar year. In addition, age reading error and new biological parameters relating to the proportion spawning and the length at maturity, first introduced in August 2006, have been used. Estimates of spawning biomass from acoustic surveys from 2003-2006 (method of Cordue (2000); 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included. This corresponds to the ‘Low’ model. The High model uses acoustic biomass estimates that are much larger in magnitude and are derived from using the target strengths suggested by Macauley (2004).

Results conclude that the female spawning biomass in 2006 is around 47% of the reference biomass and the depletion in 2008, used for the harvest control rules, will be approximately 44%. This compares with 40% for the 2005 depletion and 36% for the 2007 depletion in the 2006 assessment. These increases relative to the reference biomass are in part due to recent estimated biomasses being shifted upward through the increased level of the 2006 acoustic estimate and the increased cpue in both sub-fisheries. The Recommended Biological Catches (RBCs) for 2008 are between 3,275 t and 4,687 t (landed catch and discards), depending on the harvest control rule that is applied. The long-term RBCs are around between 5,000 and 6,000 t. For the High model the 2008

RBCs are much more dependent on model assumptions and vary between 4,500 t and 9,500 t. The long term RBCs for the High model are up to 18,500 t.

The recruitment of 2004 is estimated to be about twice that expected from the stock-recruitment relationship. While a positive sign for the stock and fishery following several years of poor recruitment, this recruitment is not estimated to be as large as the recruitments of the mid-1990s.

Blue eye Trevalla

A paucity of length and age data for blue eye (*Hyperoglyphe antarctica*) collected in 2006 (no age data and limited length data) precluded an updating of the catch curve analyses used to calculate RBC multipliers under the tier 3 HCR conducted in 2006. Updated CPUE standardizations for blue eye caught by trawl suggest slightly increasing trends in eastern areas, and a declining trend in the west. Analyses of blue eye length data using multivariate techniques were conducted with an aim at identifying fleet structure to inform future stock assessments for blue eye. These analyses suggest differences in the length composition data between eastern and western zones, and differences between the length compositions of trawl catches and those captured by hook and line methods. There was little evidence to suggest that length compositions from dropline and longline catches are different.

A Management Strategy Evlauation (MSE) is being conducted for blue eye trevalla, in order to assess the performance of alternative tier 3 harvest control rules used to calculate the RBC for this species. The methodology, scope, and timeline for the MSE analyses are outlined, with analyses focusing on: the implications of including multiple fleets and spatial population structure when applying the various control rules, performance of the tier 3 HCR relative to tier 1, and adjustments to the tier 3 HCR for alignment with the precautionary intent of the tier framework.

Pink Ling

The catch of pink ling (*Genypterus blacodes*) in 2006 was 1201 tonnes, divided between the east (474 t trawl, 262 t, non-trawl) and the west (252 t trawl, 213 t, non-trawl). The 2007 pink ling stock assessment was updated following a review in December 2006 and advice from the July SlopeRAG meeting. The technical deficiencies identified in the model last year were rectified. The 2007 pink ling assessment assumed separate stocks in the east and west of the fishery. The data was updated to include 2006 data. This updated assessment included estimates of female and male growth parameters and of natural mortality. The non-trawl catch rate data are being re-evaluated and were not used in 2007.

The new reference case estimated the spawning biomass at the end of the 2007 at 28% of the virgin spawning biomass in the east and 52% in the west. The RBC for 2008 using the 20:40:48 Tier 1 rule is 688 tonnes (68 t from the east and 620 t from the west). With the 20:40:40 rule, the RBC is 858 tonnes (84 t in the east and 774 t in the west). Projections suggest a long term sustainable yield of between 1,450 and 1,600 tonnes.

The assessment was generally considered by SlopeRAG to be an internally consistent description of the status of the SESSF pink ling resource. But industry members expressed concerns that the outputs of the model were at odds with their perceptions of stock status in both the eastern and western regions. Industry felt that the assessment for the eastern region was overly pessimistic, because of the recent increases in CPUE, and overly optimistic for the western region. This discrepancy may to some extent reflect the recent differences in stock trajectories mentioned above.

Industry was also of the view that the western stock could only sustain lower catches than the eastern stock, whereas the assessment model estimates that the western stock could sustain catches in the long term that were about 16% higher than those possible for the eastern stock.

Silver Warehou

A full stock assessment for silver warehou was last performed in 2004. The 2007 assessment of silver warehou (*Seriolella punctata*) in the SESSF uses data up to 1 May 2006 and is performed using the stock assessment package SS2, which has enabled several technical improvements to be made. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, and (b) the addition of updated length frequencies, catches and catch-rates.

The base-case assessment estimates that current (2006/07) spawning stock biomass is 49% of virgin stock biomass. Fits to the length, age, and catch-rate data are reasonable. The fit to the catch rate index is substantially improved compared to previous assessments. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, M. Likelihood profiles show that values for M larger than the base-case value of 0.25 are preferred.

The projected depletion in 2007/08 from the base-case model is 45%. The RBCs for the base-case model for 2007/08 are 2,244 t and 1,709 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,987 t and 1,814 t respectively.

1.4 Shelf Species

Eastern Gemfish

Eastern gemfish (*Rexea solandri*) in the SESSF was examined using data up to 31 December 2006. A partial stock assessment for eastern gemfish was last performed in 2000 by Punt (2000). The 2007 assessment was performed using the stock assessment package SS2, which provides a standardised platform for doing stock assessment. Catch data were incorporated from 1968, state catches were included and additional length composition data was used dating back to 1975. Changes from the 2000 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data (c) the addition of updated length frequencies, catches and catch-rates, (d) the inclusion of discards and (e) including ageing error was in the model.

The base-case assessment estimates that 2007 spawning stock biomass is 10% of unexploited stock biomass. Fits to the length, age, and catch-rate data were reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements and the history of the fishery. Exploration of model sensitivity showed that the model outputs were sensitive to the value assumed for natural mortality, *M*.

A further assessment was conducted that incorporated 2007 data. Changes from the preliminary assessment included updated 2007 catches for the non-trawl (mainly dropline), winter targeted trawl (survey), summer trawl and winter bycatch trawl fleets. Also included were 2007 length-frequencies for the non-trawl, winter targeted and winter bycatch trawl fleets, as well as age-compositions from the winter targeted trawl fleet (the 2007 survey). A 2007 CPUE value for the winter targeted fleet was calculated and used in the assessment, and the 2006 ISMP CPUE series was used as an index for the winter bycatch trawl fleet. As in the preliminary assessment, this assessment included: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data, (c) the addition of updated length-frequencies, catches and catch-rates, (d) the inclusion of discards and (e) allowance for ageing error.

The base-case assessment estimated that current (2007/08) spawning stock biomass was 14% of the unexploited spawning stock biomass. Fits to the length, age, and catch-rate data were reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements, and the history of the fishery. Exploration of model sensitivity shows that the model outputs are sensitive to the recent (2007) CPUE trawl survey index.

School Whiting

Eastern school whiting (*Sillago flindersi*) occur from southern Queensland to western Victoria. School whiting are commonly found on sandy substrates to depths of about 60m in the eastern regions of the SESSF and Bass Strait. The majority of the catch from 1947-1995 has been taken using Danish seine (mainly in Bass Strait) although the fraction of the catch taken by otter trawl has increased recently, and has averaged more than 65% of the total catch since 1995. Catches by otter trawl occur predominantly in NSW waters, with most of this catch taken by state registered trawlers.

A stock assessment for school whiting was last performed in 2004 by Cui *et al.* (2004) using data from 1991 through until 2003, and this assessment was only able to give biomass levels relative to 1991. The 2007 assessment uses the stock assessment package SS2. Catch data were incorporated from 1947, state catches were included and additional length composition data were used dating back to 1983. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data (c) the addition of updated length frequencies, catches and catch-rates, (d) the inclusion of discards and (e) including ageing error in the model.

The base-case assessment estimates that current (2008) spawning stock biomass is 35% of unfished stock biomass. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*, the length at 50% maturity and the projected catch used in 2007. Likelihood profiles support the use of a base case value for *M* of $0.6yr^{-1}$.

Depletion across all sensitivities varied between 22% (age at 50% mortality=18cm) and 47% (age at 50% mortality=14cm). Exploration of model sensitivity also shows that the model outputs are sensitive to the value assumed for the 2007 catch. The RBCs for the updated base-case model for 2008 are 1,185 t and 904 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,848 t and 1,685 t respectively.

School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very rapid impact on the fish stock. As a result there will always be some uncertainty about the status of the stock. Further exploration of some biological parameters, such as age and length at maturity may help reduce this uncertainty, but the high mortality rate and short expected life time for this species mean that rapid changes are always possible and projections will always be subject to uncertainty relating to very recent recruitment events which are poorly informed until these cohorts fully enter the fishery.

Tiger Flathead

An assessment update was carried out for Tiger flathead (*Neoplatycephalus richardsoni*) in 2007 that was a projection of the 2006 assessment. It used catches that were known for 2006 and estimated for the 2007 calendar years.

The case chosen for management purposes from the 2006 assessment was that which included the Tasmanian region as part of the eastern stock, and had the Tasmanian fishing fleet treated separately in terms of selectivity.

An estimate of the relationship of B_{mey}=1.03xB_{msy} for tiger flathead has been provided by ABARE (T. Kompas pers comm, via A. Morison pers comm). Application of this calculation to the target B_{msy} in the RBC calculations results in a target B_{msy} of 40%x1.03=41.2% (A. Morison pers comm), which here has been rounded to 41%. Therefore, an additional B_{targ} level of 41% has been included in the RBC calculations. The projected RBC value using the 41% B_{msy} target was 2,743t including discards.

Jackass Morwong

In 2007 the assessment of jackass morwong (*Nemadactylus macropterus*) in the eastern areas of the SESSF was updated to provide estimates of stock status at the end of 2007. This assessment was performed using the stock assessment package SS2, which enabled some technical improvements to the previous assessment, such as the addition of discard information, and the estimation of growth parameters within the assessment. Other changes included the adddition of extra length-frequency information, and the addition of 2006 data.

The base-case assessment for the eastern areas estimated that current spawning stock biomass is 19 % of unexploited stock biomass. This assessment is largely driven by the recent catch rate indices, which indicate a 70 % decline in the stock over the last 20 years. The age and length data when fitted in the absence of the catch rate indices do not indicate the same magnitude of decline. In order to fit to the catch rate indices, the model has estimated that recruitments have largely been below average in the last 25 years, although there is some evidence for an above average recruitment in 2003. Depletion across all sensitivities varied between 11% and 28%.

A preliminary assessment of western zone jackass morwong using data from 1986-2006 was also performed. This assessment indicated that the stock has declined in recent years as fishing pressure has increased, but spawning stock biomass is still considerably higher than the target level. The longterm RBCs estimated for the western stock are comparable with current catch levels.

1.5 Great Australian Bight Species

Deepwater Flathead and Bight Redfish

This chapter presents assessment results for deepwater flathead (*Neoplatycephalus contatus*) and Bight redfish (*Centroberyx gerrardi*) populations in the GABTF. The 2007 assessments attempted to incorporate most of the available data collected from the fishery that had not been previously used for stock assessment - particularly length-frequencies. Age-frequencies were no longer used explicitly. The models used original age-at-length measurements to fit growth curves, better allowing for interaction between selectivity and growth parameters. These improvements greatly increased the amount of data available to the assessments and allowed an integrated approach to modelling growth. There were three years of fishery independent surveys, greatly increasing the value of this data source.

There is a trade-off between good fits of length or age frequencies for Bight redfish. It is possible to much improve the apparent fit to age frequency by ignoring length-only data. Further work is required to improve the ability of the Bight redfish model to fit both age and length-frequency data.

The deepwater flathead assessment provided consistent results across all of the input data sets, giving more confidence in assessment results for that species.

The unexploited biomass estimates for the base case models were 8,836t and 18,685t for deepwater flathead and Bight redfish respectively. Current biomass was estimated to be at 56% of the unexploited level for deepwater flathead, and 82% for Bight redfish. Using the 20:40:48 catch control rule, the RBC was 1,154t for deepwater flathead and 3,607t for Bight redfish.

KEYWORDS: fishery management, southern and eastern scalefish and shark fishery, stock assessment, trawl fishery, non-trawl fishery

2. Background

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is a Commonwealth-managed, multi-species and multi-gear fishery that catches over 80 species of commercial value and is the main provider of fresh fish to the Sydney and Melbourne markets. Precursors of this fishery have been operating for more than 85 years. Catches are taken from both inshore and offshore waters, as well as offshore seamounts, and the fishery extends from Fraser Island in Queensland to south west Western Australia.

Management of the SESSF is based on a mixture of input and output controls, with over 20 commercial species or species groups currently under quota management. For the previous South East Fishery (SEF), there were 17 species or species groups managed using TACs. Five of these species had their own species assessment groups (SAGs) – orange roughy (ORAG), eastern gemfish (EGAG), blue grenadier (BGAG), blue warehou (BWAG), and redfish (RAG). The assessment groups comprise scientists, fishers, managers and (sometimes) conservation members, meeting several times in a year, and producing an annual stock assessment report based on quantitative species assessments. In addition to these five key species, quantitative assessments for several additional species each year were also conducted. Species for which such assessments have been conducted recently include school whiting, pink ling and spotted warehou. The previous Southern Shark Fishery (SSF), with its own assessment group (SharkFAG), harvested two main species (gummy and school shark), but with significant catches of saw shark and elephantfish.

In 2003, these assessment groups were restructured and their terms of reference redefined. Part of the rationale for the amalgamation of the previous separately managed fisheries was to move towards a more ecosystem-based system of fishery management (EBFM) for this suite of fisheries, which overlap in area and exploit a common set of species. The restructure of the assessment groups was undertaken to better reflect the ecological system on which the fishery rests. To that end, the assessment group structure now comprises:

- SESSFRAG (an umbrella assessment group for the whole SESSF)
- Slope Resource Assessment Group (Slope RAG)
- Shelf Resource Assessment Group (Shelf RAG)
- Deepwater Resource Assessment Group (Deepwater RAG)
- Shark Resource Assessment Group (Shark RAG)
- Great Australian Bight Resource Assessment Group (GAB RAG)

Each of the three depth-related assessment groups is responsible for undertaking stock assessments for a suite of key species, and for reporting on the status of those species to SESSFRAG. The Shark RAG is responsible for assessments of all chondrichthyan species, and the GAB RAG for those species in the Great Australian Bight.

The plan for the five resource assessment groups (Slope, Shelf, Deepwater, GAB and Shark RAGs) is to focus on suites of species, rather than on each species in isolation, which has tended to be the practice to date. This approach has helped to identify common factors affecting these species (such as environmental conditions), as well as consideration of marketing and management factors on key indicators such as catch rates. Assessments are also identifying where catches of two species are inversely related due to targeting.

The quantitative assessments produced annually by the Resource Assessment Groups are a key component of the TAC setting process for the Southern and Eastern Scalefish and Shark Fishery. To support the assessment work of the five Assessment Groups, the aims of the work conducted in this report were to develop new assessments, and update and improve existing ones for priority species in the SESSF.

3. Need

A stock assessment that includes the most up-to-date information and considers a range of hypotheses about the resource dynamics and the associated fisheries is a key need for the management of a resource. In particular, the information contained in a stock assessment is critical for selecting harvest strategies and setting Total Allowable Catches.

4. Objectives

- Provide quantitative and qualitative species assessments in support of the five SESSF resource assessment groups.

5. Species Characterizations within the SESSF: 1986 – 2006

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5.1 School Whiting (Danish Seine; Zone 60)

There are 84,934 records of School Whiting catches in the SESSF database when a selection of records is made between 1986 – 2006, for zones 10 – 60 in the SET fishery, where Catches >0. When these are limited to Danish Seine vessels there are 67,266 records. Inside Zone 60 there were 64,002 records, and among those there were only 58,734 records with both catches and effort data.

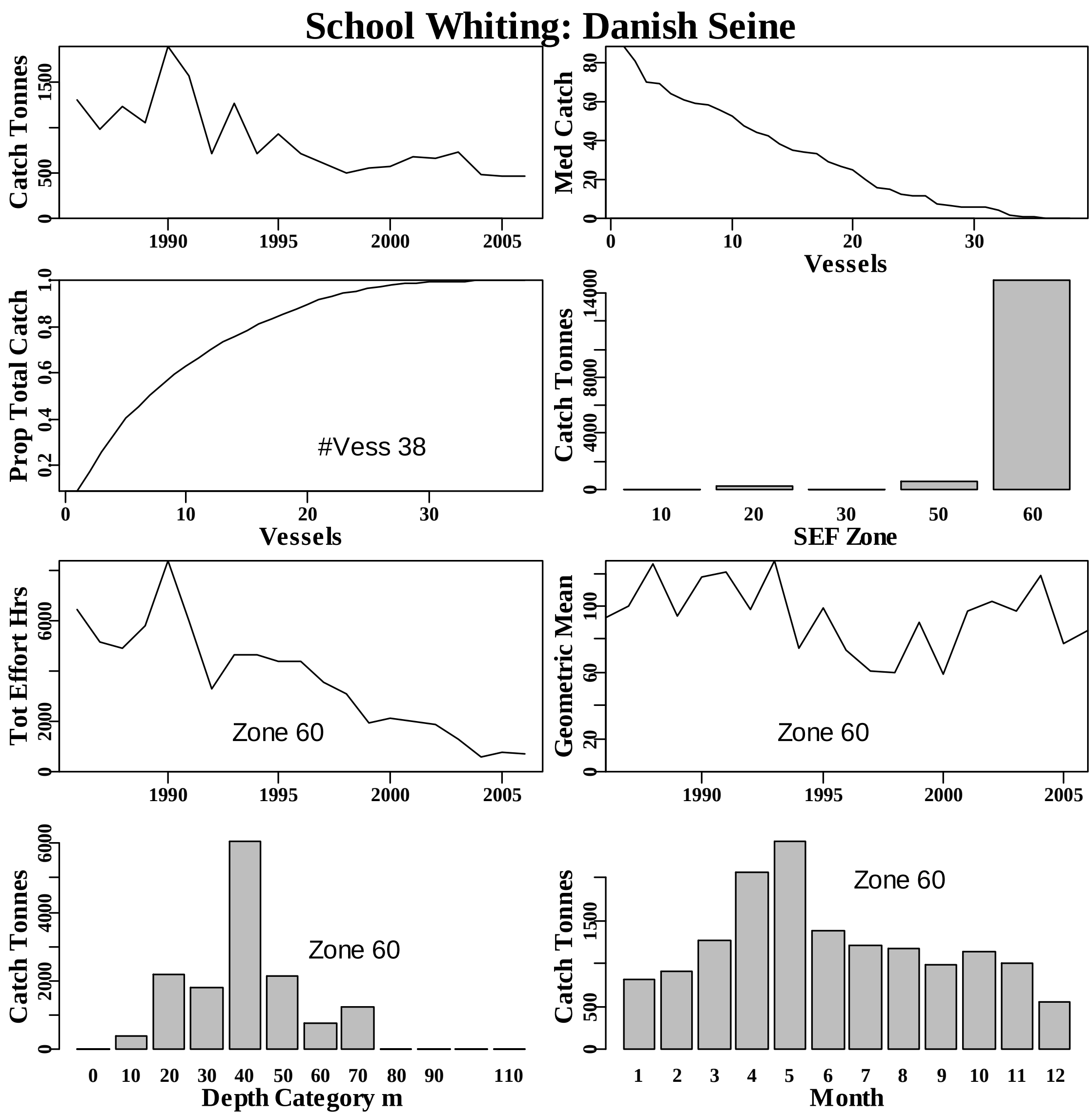


Figure 5.1. School whiting fishery characterization. Total catch is all methods and zones. Catches by zone are for Danish Seine only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present and are only for Zone 60. # Vess indicates the total number of Danish Seine vessels.

Table 5.1. Total catch of **School Whiting** in tonnes, all methods, by calendar year and by Zone from 1986 to 2006. In addition, only for Zone 60, the catch in tonnes by Month.

Year	Catch T		Zone	Catch T	Percent
1986	1294.081		10	4.604	0.029
1987	979.695		20	190.527	1.217
1988	1238.072		30	1.500	0.010
1989	1046.703		50	552.468	3.529
1990	1879.916		60	14903.850	95.214
1991	1562.125				
1992	707.097				
1993	1270.609				
1994	720.446		**Month**	**Catch T**	**Percent**
1995	935.048		1	983.226	5.733
1996	711.442		2	1126.563	6.569
1997	606.724		3	1489.917	8.688
1998	501.353		4	2264.969	13.207
1999	544.528		5	2634.530	15.362
2000	572.617		6	1571.402	9.163
2001	679.498		7	1386.238	8.083
2002	656.995		8	1332.562	7.770
2003	734.552		9	1147.933	6.694
2004	481.062		10	1295.715	7.555
2005	463.895		11	1209.840	7.055
2006	462.182		12	706.417	4.119

Table 5.2. Median annual catches of **School Whiting** taken by each of 38 **Danish Seine** vessels across all zones and years (1986 – 2006) with the number of years where catches are recorded. In addition, the total catch in tonnes in an array of different 10 m depth categories for Zone 60.

Vessel	Median T	Count	Depth Cat	Catch T	Percent
7	42.418	13	0	20.771	0.142
27	5.861	16	10	407.402	2.781
39	60.391	12	20	2176.774	14.861
43	0.903	4	30	1813.342	12.380
84	6.200	9	40	6042.047	41.249
101	0.008	1	50	2143.606	14.634
103	33.030	18	60	761.139	5.196
160	43.740	8	70	1237.549	8.449
165	52.247	5	80	3.137	0.021
182	7.929	11	90	5.092	0.035
191	12.716	4	100	2.423	0.017
193	80.414	7	110	0.890	0.006
271	58.718	5	120	3.635	0.025
299	5.938	5	130	3.241	0.022
314	47.399	21	140	1.869	0.013
326	55.883	13	150	2.475	0.017
342	6.736	14	160	2.949	0.020
370	87.564	15	170	1.260	0.009
390	57.901	21	180	2.540	0.017
403	38.220	4	190	0.615	0.004
404	11.502	17	200	0.246	0.002
420	0.175	1	210	0.535	0.004
421	0.784	3	220	0.220	0.002
433	63.985	21	230	0.513	0.004
463	4.010	15	250	0.726	0.005
466	11.696	20	260	0.330	0.002
476	24.848	5	280	1.675	0.011
477	1.919	3	290	0.705	0.005
507	15.040	2	300	0.200	0.001
529	34.909	6	340	1.708	0.012
583	29.082	16	350	0.150	0.001
614	26.886	21	360	3.304	0.023
626	16.177	21	370	1.750	0.012
665	20.005	14	390	0.127	0.001
675	68.830	21	400	0.020	0.000
1086	34.444	11	410	1.947	0.013
1290	0.100	1	420	0.300	0.002
1314	69.461	1	430	0.025	0.000
			440	0.101	0.001
			460	0.165	0.001
			470	0.100	0.001
			480	0.105	0.001

5.2 Eastern Gemfish

There are 80,720 records of Gemfish (*Rexea solandri*) catches in the SESSF database when a selection of records is made between 1986 – 2006. When these are restricted to Eastern Gemfish (Zones 10, 20, and 30) there were 54,335 records although when Danish Seine vessels were excluded this dropped to 54,256 records. Of these there were only 54,102 records with both catches and effort data that could be used for the analysis of catch rates.

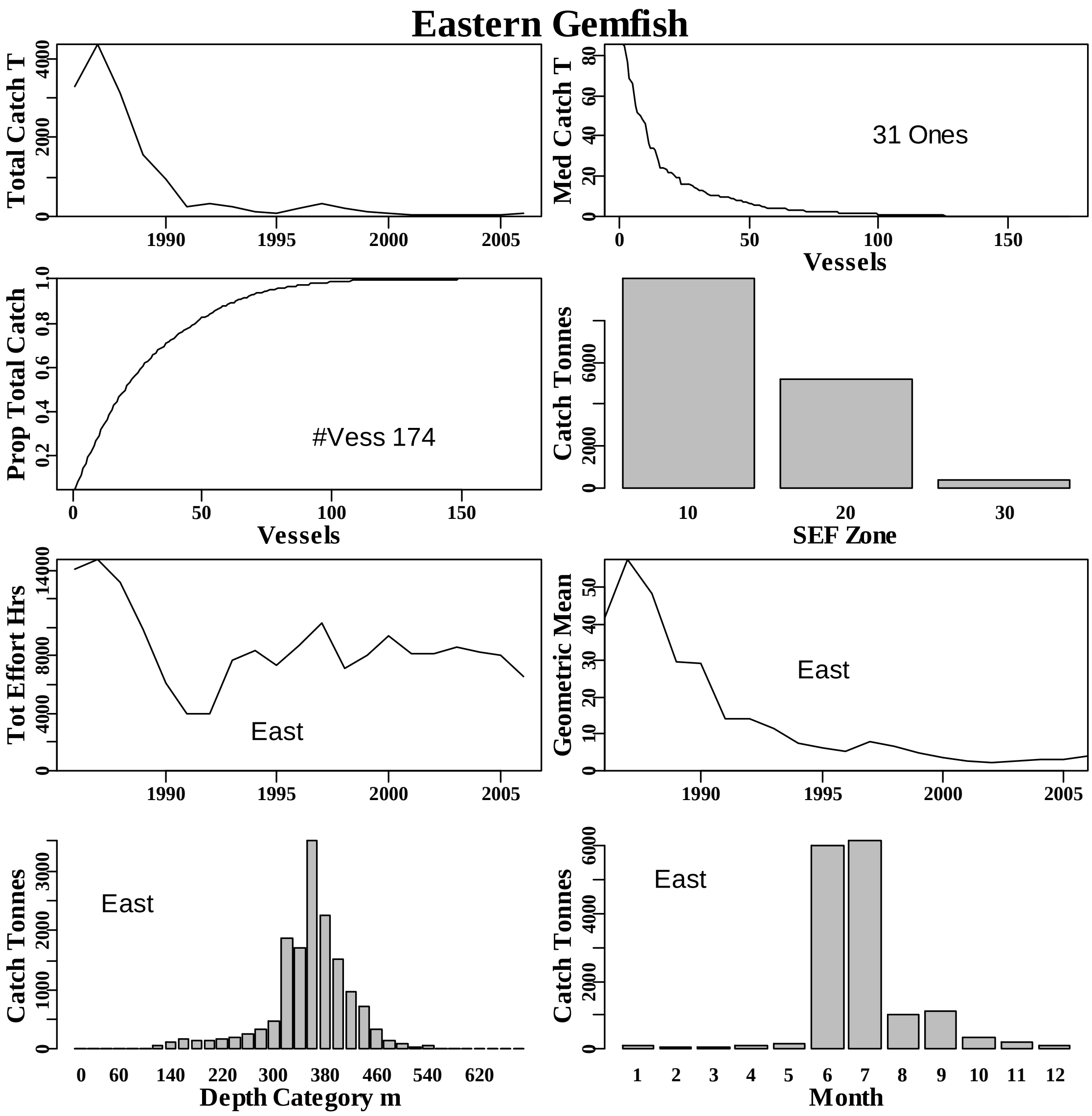


Figure 5.2. Eastern Gemfish fishery characterization. All graphs relate to the Eastern Zones (10, 20, and 30) for trawl only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.3. Total catch of **Eastern Gemfish** in tonnes by trawler, by calendar year (Zone 10, 20, and 30) from 1986 to 2006.

Year	**Catch**	**Zone**	**Catch T**	**Percent**
1986	3294.101	10	9986.805	64.282
1987	4345.104	20	5197.727	33.456
1988	3144.679	30	351.436	2.262
1989	1558.815			
1990	947.744			
1991	252.129			
1992	328.210			
1993	235.468			
1994	113.118	**Month**	**Catch T**	**Percent**
1995	71.480	1	132.884	0.855
1996	189.113	2	77.380	0.498
1997	333.028	3	68.559	0.441
1998	190.325	4	128.375	0.826
1999	118.146	5	168.429	1.084
2000	69.161	6	5997.134	38.602
2001	63.803	7	6119.208	39.387
2002	41.326	8	1012.849	6.519
2003	52.208	9	1117.333	7.192
2004	58.680	10	353.210	2.273
2005	62.379	11	222.892	1.435
2006	68.175	12	137.718	0.886

Table 5.4. Total catches by trawler of Eastern Gemfish (Zones 10, 20, and 30) in 20m depth categories from 1986 – 2006.

Depth Cat	Catch T	Percent
0	0.085	0.001
20	3.668	0.024
40	15.940	0.103
60	8.719	0.056
80	8.253	0.053
100	14.310	0.092
120	62.621	0.404
140	122.325	0.790
160	186.290	1.203
180	141.648	0.915
200	161.011	1.040
220	164.516	1.063
240	205.431	1.327
260	246.918	1.595
280	353.180	2.281
300	489.091	3.159
320	1877.970	12.129
340	1716.952	11.089
360	3507.109	22.651
380	2261.003	14.603
400	1503.016	9.707
420	978.606	6.320
440	710.897	4.591
460	337.880	2.182
480	142.308	0.919
500	88.001	0.568
520	46.434	0.300
540	69.484	0.449
>540	59.594	0.385

5.3 Western Gemfish

There are 80,720 records of Gemfish (*Rexea solandri*) catches in the SESSF database when a selection of records is made between 1986 – 2006. When these are restricted to Western Gemfish (Zones 40, 50, and 60) there were 26,385 records although when Danish Seine vessels were excluded this dropped to 26,365 records. Of these there were 26,317 records with both catches and effort data that could be used for the analysis of catch rates.

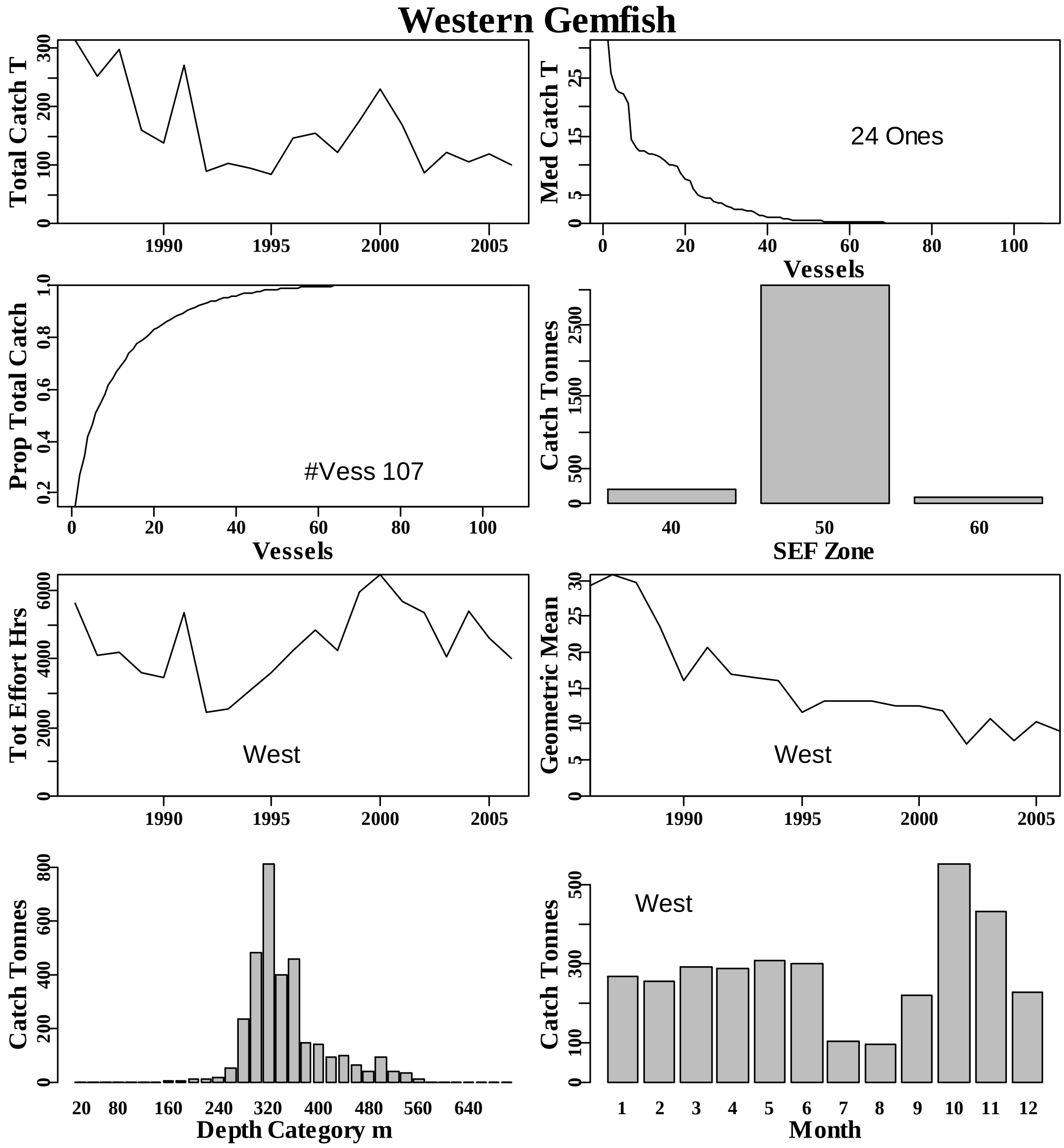


Figure 5.3. Western Gemfish fishery characterization. All graphs relate to the Western Zones (40, 50, and 60) for trawl only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.5. Total catch of **Western Gemfish** in tonnes by trawler, by calendar year (Zone 40, 50, and 60) from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	313.327	40	197.749	5.915
1987	251.773	50	3061.860	91.592
1988	298.207	60	83.336	2.493
1989	161.141			
1990	138.853			
1991	270.020			
1992	90.165			
1993	102.826			
1994	95.519	**Month**	**Catch T**	**Percent**
1995	84.866	1	266.777	7.980
1996	146.032	2	257.587	7.705
1997	153.890	3	292.738	8.757
1998	122.275	4	286.558	8.572
1999	176.566	5	306.268	9.162
2000	231.252	6	301.941	9.032
2001	169.840	7	105.208	3.147
2002	86.465	8	95.106	2.845
2003	123.232	9	218.569	6.538
2004	107.266	10	551.213	16.489
2005	118.673	11	431.390	12.904
2006	101.739	12	229.592	6.868

5.4 Spotted Warehou

There are 103,741 records of Spotted Warehou (*Seriolella punctata*) catches in the SESSF database when a selection of records is made between 1986 – 2006. When Danish Seine vessels were excluded this dropped to 102,938 records. Of these there were 102,527 records with both catches and effort data that could be used for the analysis of catch rates.

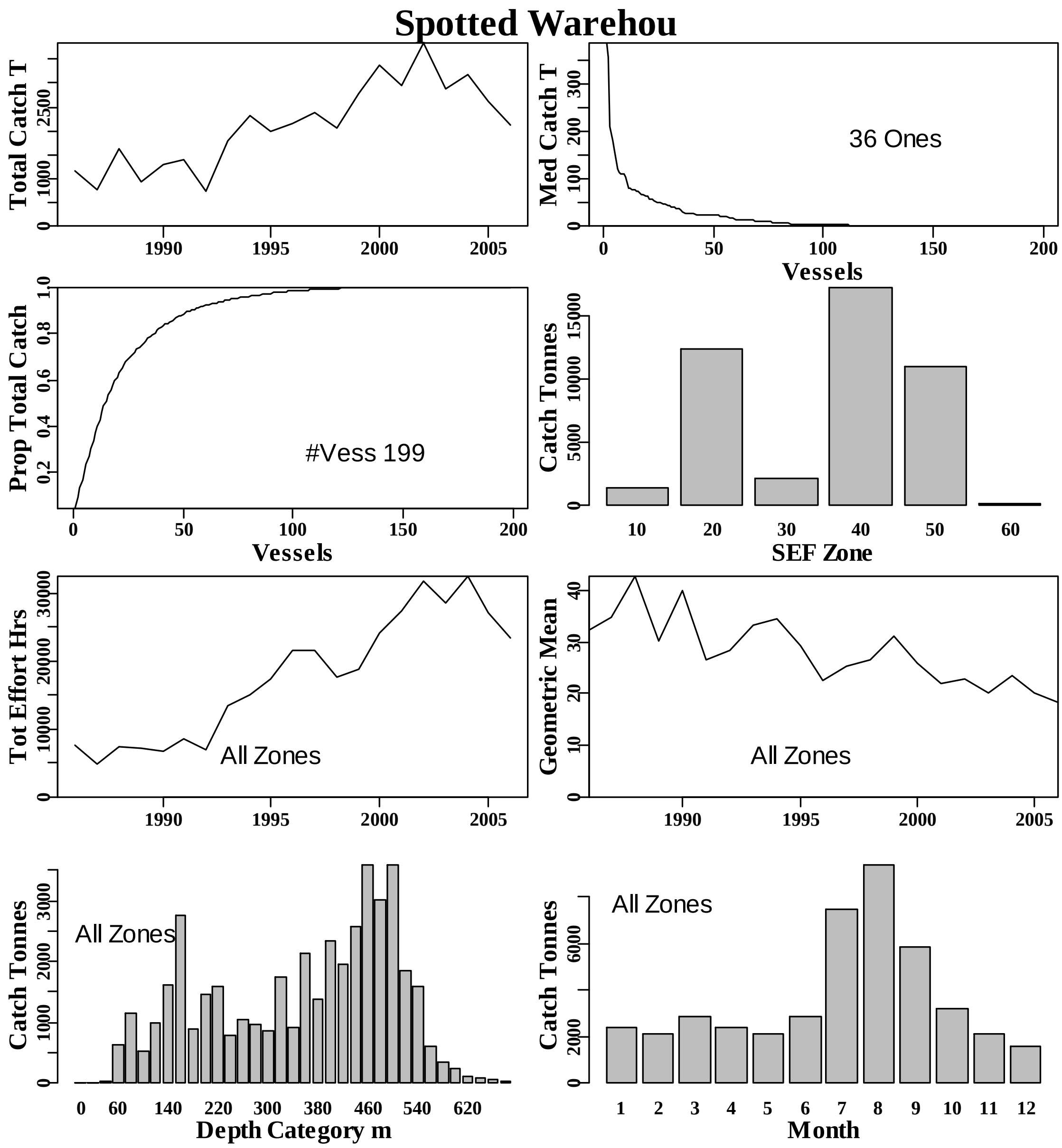


Figure 5.4. Spotted Warehou fishery characterization. All zones and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.6. Total catch of **Spotted Warehou** in tonnes by trawler, by calendar year for all zones from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	1149.393	10	1380.512	3.123
1987	766.524	20	12354.341	27.944
1988	1631.183	30	2126.499	4.810
1989	920.780	40	17287.851	39.103
1990	1299.059	50	10966.674	24.805
1991	1385.833	60	95.170	0.215
1992	722.893			
1993	1781.202			
1994	2305.048	**Month**	**Catch T**	**Percent**
1995	1997.398	1	2398.258	5.425
1996	2164.295	2	2122.904	4.802
1997	2373.737	3	2874.652	6.502
1998	2044.659	4	2364.205	5.348
1999	2767.754	5	2084.873	4.716
2000	3384.006	6	2841.457	6.427
2001	2944.409	7	7452.176	16.856
2002	3822.590	8	9351.451	21.152
2003	2870.900	9	5826.934	13.180
2004	3179.970	10	3218.540	7.280
2005	2607.898	11	2087.389	4.721
2006	2107.501	12	1588.208	3.592

5.5 Royal Red Prawn

There are 23,167 records of Royal Red Prawn (*Haliporoides sibogae*) catches in the SESSF database when a selection of records is made between 1986 – 2006. In Zone 10 there were 22,796 records (with no records from Danish Seine vessels). Of these there were 22,742 records with both catches and effort data that could be used for the analysis of catch rates.

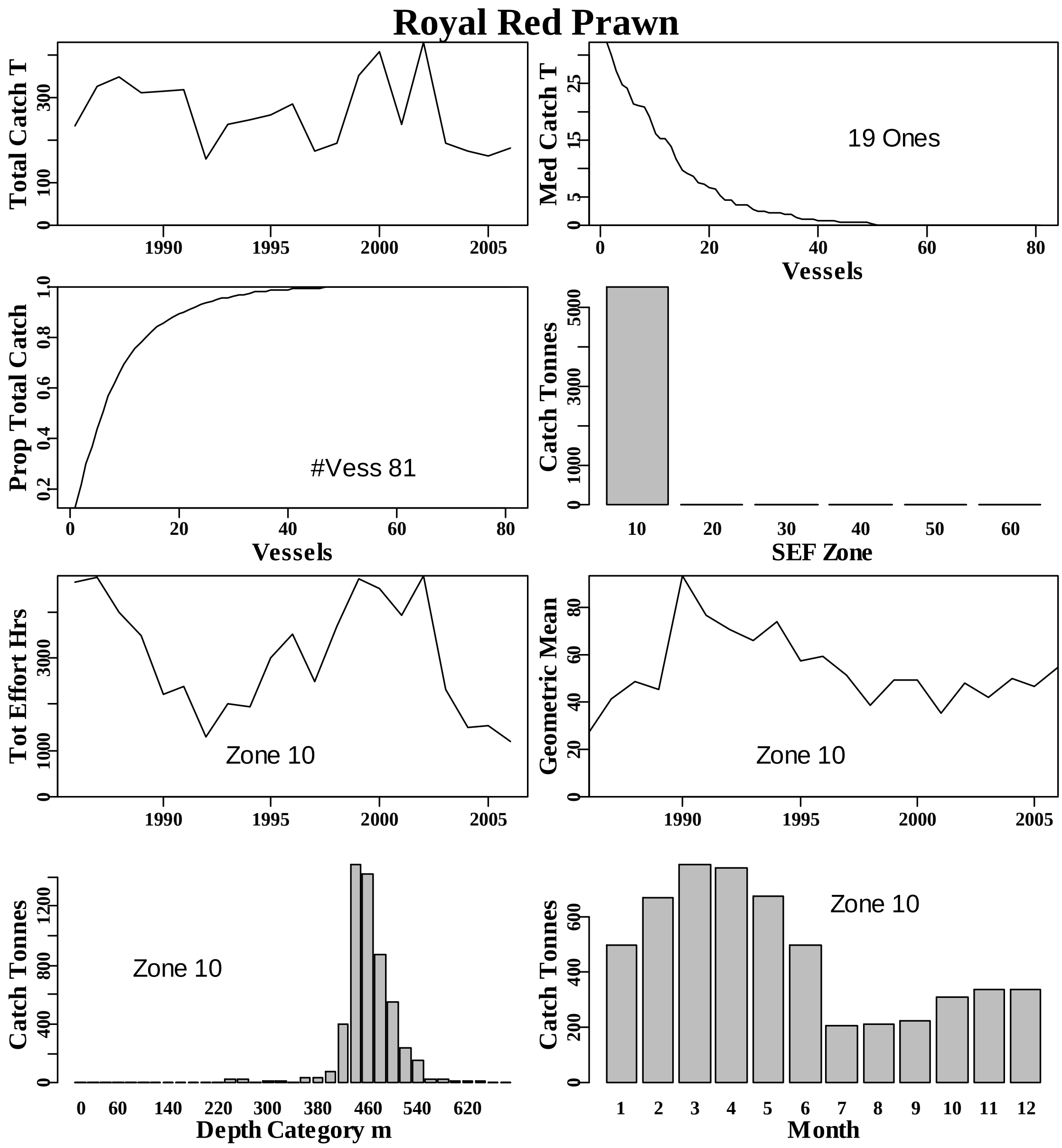


Figure 5.5. Royal Red Prawn fishery characterization. Zone 10 and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.7. Total catch of **Royal Red Prawn** in tonnes by trawler, by calendar year for Zone 10 from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	233.194	10	5530.285	99.743
1987	325.606	20	9.500	0.171
1988	348.146	30	0.264	0.005
1989	311.876	40	1.918	0.035
1990	314.803	50	1.759	0.032
1991	317.223	60	0.789	0.014
1992	154.473			
1993	236.413			
1994	249.793	Month	Catch T	Percent
1995	258.057	1	499.737	9.036
1996	283.458	2	668.988	12.097
1997	173.168	3	788.772	14.263
1998	192.568	4	777.255	14.055
1999	350.674	5	671.324	12.139
2000	407.344	6	494.889	8.949
2001	236.568	7	208.007	3.761
2002	427.255	8	212.462	3.842
2003	193.786	9	223.793	4.047
2004	173.023	10	307.206	5.555
2005	161.730	11	339.672	6.142
2006	181.127	12	338.180	6.115

5.6 Ribaldo

There are 16,754 records of Ribaldo (*Mora moro*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones (10 – 60). There was a single record from a Danish Seine vessel, leaving 16,753 records. Of these there were 16,715 records with both catches and effort data that could be used for the analysis of catch rates.

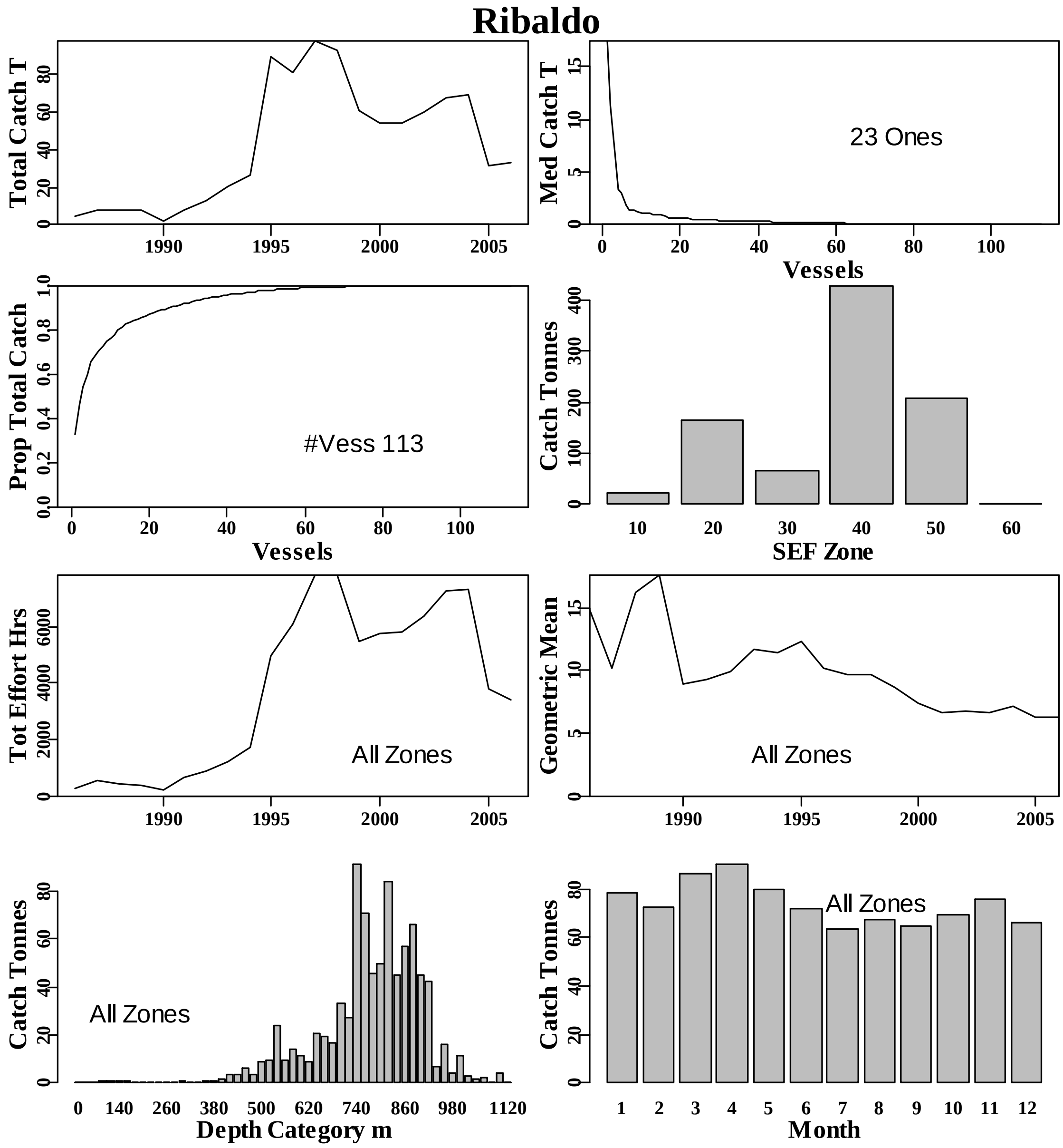


Figure 5.6. Ribaldo fishery characterization. All zones and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.8. Total catch of **Ribaldo** in tonnes by trawler, by calendar year for all Zones (10 – 60) from 1986 to 2006.

Year	Catch	Zone	Catch T	Percent
1986	4.104	10	21.486	2.420
1987	7.535	20	163.225	18.386
1988	8.219	30	65.138	7.337
1989	8.101	40	428.557	48.272
1990	2.309	50	208.947	23.536
1991	7.616	60	0.436	0.049
1992	12.948			
1993	20.777			
1994	26.099	Month	Catch T	Percent
1995	89.549	1	78.418	8.833
1996	81.318	2	72.837	8.204
1997	97.440	3	86.523	9.746
1998	92.384	4	90.437	10.187
1999	60.501	5	80.138	9.027
2000	54.310	6	72.047	8.116
2001	53.836	7	63.509	7.154
2002	59.850	8	67.444	7.597
2003	67.696	9	64.791	7.298
2004	69.101	10	69.382	7.815
2005	31.190	11	76.229	8.587
2006	32.905	12	66.017	7.436

5.7 Blue Warehou (Eastern Trawl)

There are 48,487 records of Blue Warehou (*Seriolella brama*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones, Within the Eastern zones (10, 20, and 30) there were 36,008 records, of which 35,078 were from trawlers. Of these there were 35019 records with both catches and effort data that could be used for the analysis of catch rates.

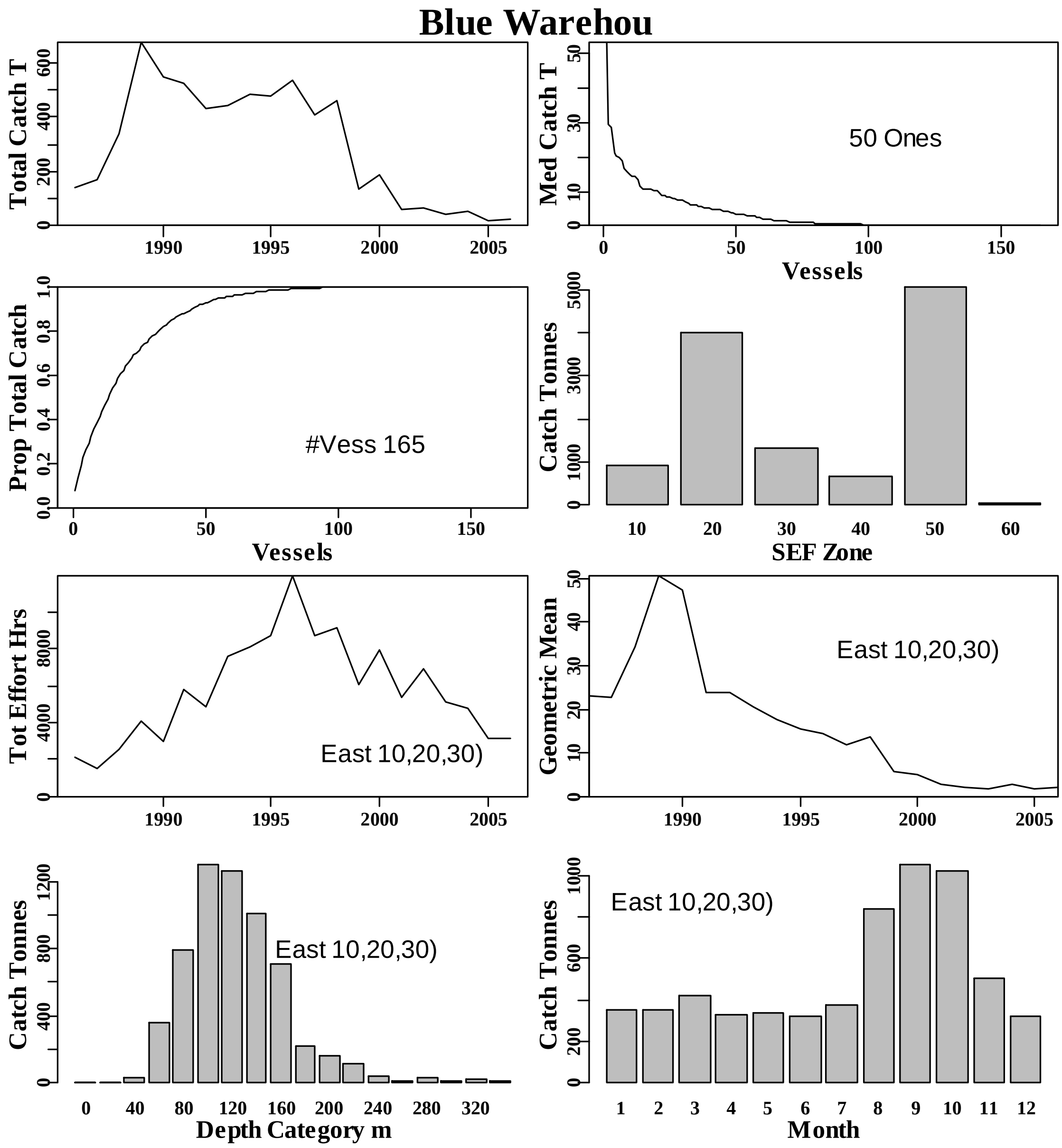


Figure 5.7. Eastern Blue Warehou fishery characterization. Eastern zones (10, 20, and 30) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.9. Total catch of **Blue Warehou** in tonnes by trawlers in the eastern zones (10, 20, 30), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	139.708	10	929.216	7.729
1987	169.007	20	3980.325	33.109
1988	338.816	30	1307.850	10.879
1989	671.802	40	677.194	5.633
1990	548.183	50	5070.368	42.176
1991	523.398	60	56.895	0.473
1992	432.137			
1993	444.275			
1994	482.139	**Month**	**Catch T**	**Percent**
1995	476.863	1	349.847	5.631
1996	533.651	2	351.495	5.658
1997	405.686	3	422.526	6.801
1998	459.726	4	325.841	5.245
1999	136.049	5	340.134	5.475
2000	187.132	6	317.946	5.118
2001	60.114	7	373.398	6.011
2002	63.800	8	834.837	13.438
2003	43.441	9	1050.719	16.913
2004	52.687	10	1021.911	16.450
2005	22.100	11	505.710	8.140
2006	26.677	12	318.005	5.119

5.8 Blue Warehou (Western Trawl)

There are 48,487 records of Blue Warehou (*Seriolella brama*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones, Within the Western zones (40, 50, and 60) there were 12,479 records, of which 11,226 were from trawlers. Of these there were 11196 records with both catches and effort data that could be used for the analysis of catch rates.

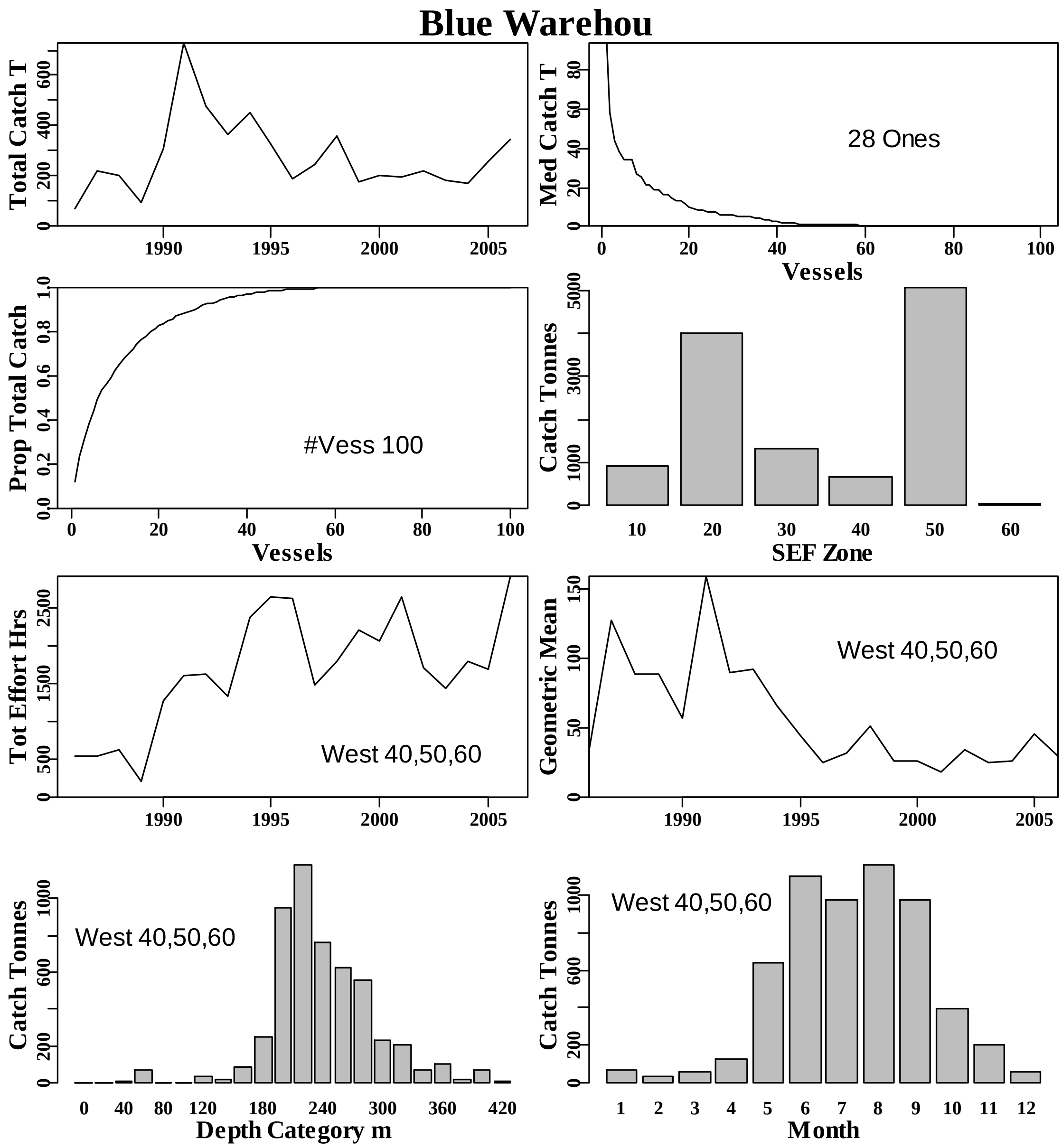


Figure 5.8. Western Blue Warehou fishery characterization. Western zones (40, 50, and 60) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.10. Total catch of **Blue Warehou** in tonnes by trawlers in the western zones (40,50,60), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	72.169	10	929.216	7.729
1987	218.860	20	3980.325	33.109
1988	202.928	30	1307.850	10.879
1989	95.701	40	677.194	5.633
1990	310.721	50	5070.368	42.176
1991	725.433	60	56.895	0.473
1992	480.705			
1993	365.973			
1994	453.040	**Month**	**Catch T**	**Percent**
1995	329.100	1	70.660	1.220
1996	187.609	2	36.883	0.637
1997	245.096	3	60.046	1.037
1998	358.912	4	129.680	2.240
1999	177.255	5	638.215	11.024
2000	204.088	6	1094.211	18.900
2001	196.280	7	973.177	16.809
2002	219.849	8	1156.455	19.975
2003	184.262	9	974.928	16.839
2004	173.439	10	394.457	6.813
2005	258.464	11	200.012	3.455
2006	344.574	12	60.818	1.050

5.9 Silver Trevally

There are 54,043 records of Silver Trevally (*Pseudocaranx dentex*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones, Within the main Eastern zones (10, 20) there were 53,225 records, of which 52,681 were from trawlers. Of these there were 52,475 records with both catches and effort data that could be used for the analysis of catch rates.

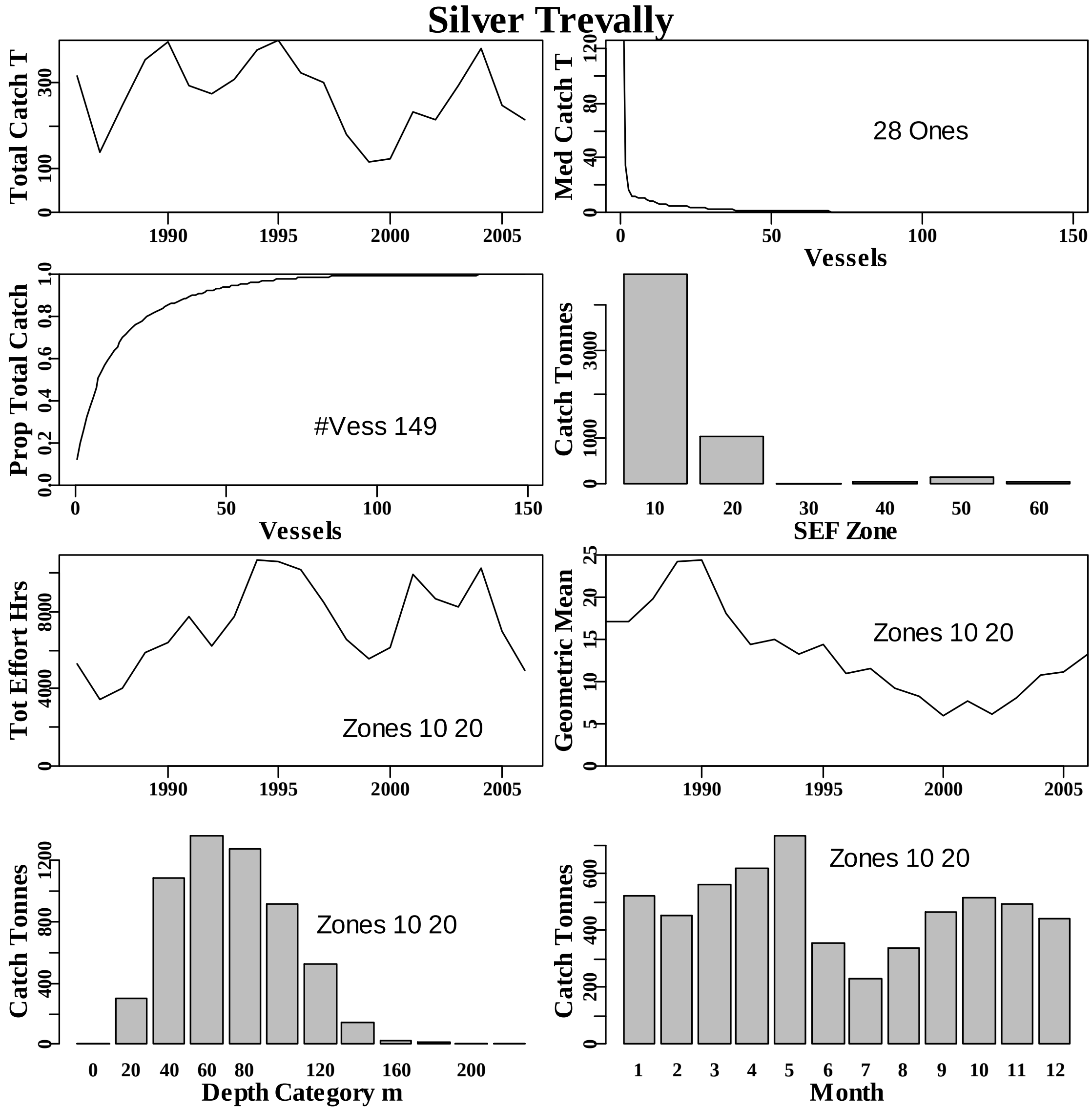


Figure 5.9. Silver Trevally fishery characterization. The main Eastern zones (10 and 20) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.11. Total catch of **Silver Trevally** in tonnes by trawlers in the main eastern zones (10, 20), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	315.468	10	4687.441	79.262
1987	140.088	20	1044.902	17.669
1988	247.341	30	5.821	0.098
1989	354.405	40	12.692	0.215
1990	393.481	50	146.520	2.478
1991	292.452	60	16.482	0.279
1992	274.915			
1993	306.714			
1994	378.028	**Month**	**Catch T**	**Percent**
1995	397.034	1	520.330	9.082
1996	323.967	2	452.757	7.903
1997	302.808	3	561.289	9.797
1998	180.136	4	622.323	10.863
1999	117.567	5	733.320	12.800
2000	123.696	6	355.497	6.205
2001	234.535	7	230.127	4.017
2002	215.371	8	339.482	5.926
2003	291.888	9	463.061	8.083
2004	378.614	10	515.984	9.006
2005	248.999	11	492.859	8.603
2006	214.838	12	442.037	7.716

5.10 Blue Eye (Trawl - East)

There are 23,453 records of Blue Eye Trevalla (*Hyperoglyphe antarctica*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers, Within the Eastern zones (10, 20, and 30) there were 13,002 records, of which 12,975 were from trawlers. Of these there were 12,929 records with both catches and effort data that could be used for the analysis of catch rates.

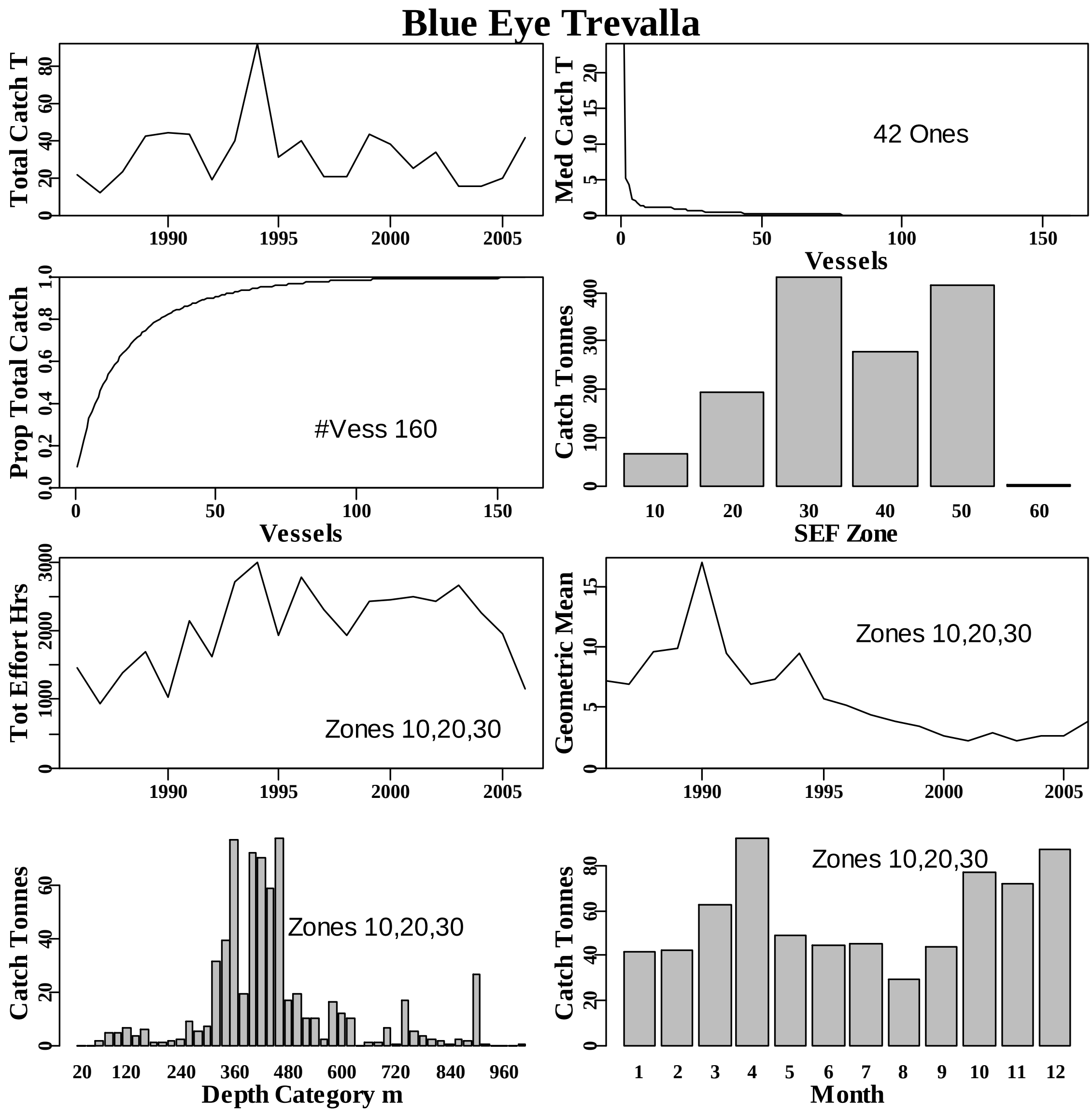


Figure 5.10. Blue Eye Trevalla trawl fishery characterization. The main Eastern zones (10, 20, and 30) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.12. Total catch of **Blue Eye Trevalla** in tonnes by trawlers in the main eastern zones (10, 20, and 30), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	21.829	10	65.478	4.734
1987	11.903	20	192.670	13.931
1988	23.547	30	430.324	31.114
1989	42.485	40	277.273	20.048
1990	44.511	50	415.340	30.031
1991	43.938	60	1.957	0.141
1992	19.185			
1993	40.043			
1994	91.905	**Month**	**Catch T**	**Percent**
1995	31.143	1	41.714	6.067
1996	40.415	2	42.402	6.167
1997	20.895	3	62.292	9.059
1998	20.763	4	91.711	13.338
1999	43.639	5	49.032	7.131
2000	38.662	6	44.631	6.491
2001	25.490	7	45.666	6.641
2002	34.240	8	29.972	4.359
2003	15.952	9	44.228	6.432
2004	15.487	10	76.745	11.161
2005	20.363	11	72.071	10.481
2006	42.076	12	87.146	12.674

5.11 Blue Eye Trevalla (Trawl – West)

There are 23,453 records of Blue Eye Trevalla (*Hyperoglyphe antarctica*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers, Within the Western zones (40 and 50) there were 10,382 records, all of which were from trawlers. Of these there were 10,360 records with both catches and effort data that could be used for the analysis of catch rates.

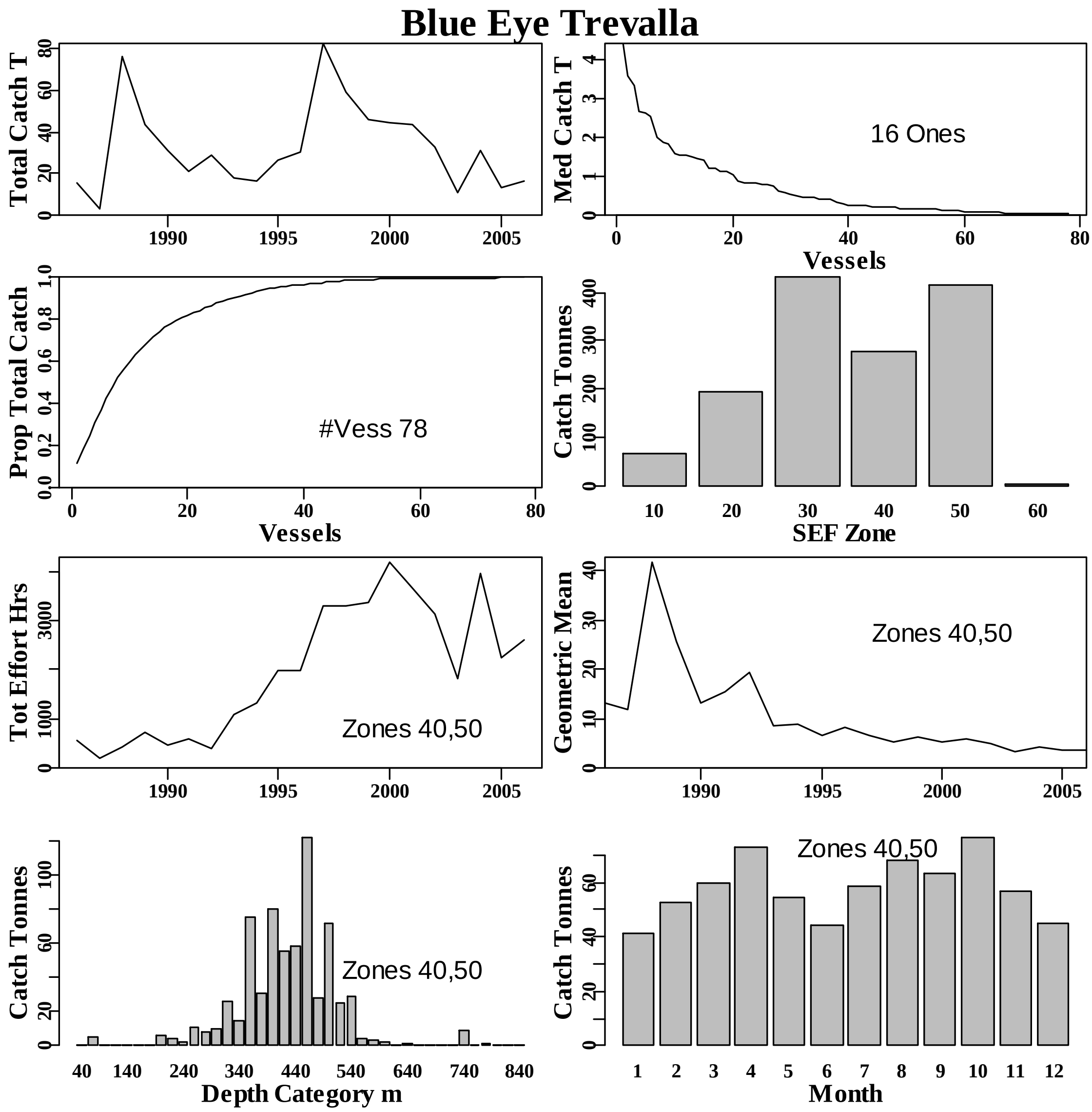


Figure 5.11. Blue Eye Trevalla trawl fishery characterization. The main Western zones (40 and 50) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.13. Total catch of **Blue Eye Trevalla** in tonnes by trawlers in the main western zones (40 and 50), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	15.985	10	65.478	4.734
1987	3.145	20	192.670	13.931
1988	76.410	30	430.324	31.114
1989	43.985	40	277.273	20.048
1990	30.910	50	415.340	30.031
1991	21.363	60	1.957	0.141
1992	29.168			
1993	18.109			
1994	16.282	**Month**	**Catch T**	**Percent**
1995	26.381	1	41.123	5.937
1996	30.184	2	52.668	7.604
1997	82.376	3	59.537	8.596
1998	58.976	4	72.646	10.489
1999	46.304	5	54.200	7.825
2000	44.729	6	44.403	6.411
2001	43.648	7	58.349	8.424
2002	32.508	8	67.821	9.792
2003	11.183	9	63.620	9.185
2004	31.427	10	76.352	11.024
2005	13.107	11	56.940	8.221
2006	16.434	12	44.954	6.491

5.12 Blue Eye Trevalla (Non-Trawl)

There are 10,987 records of Blue Eye Trevalla (*Hyperoglyphe antarctica*) catches in the SESSF database when a selection of records is made with data between 1997 – 2006 across all zones for the non-trawl sector. Of these there were 10,772 records with both catches and effort data. However, this effort was mixed among autolong lining, Drop lining, Bottom Lines (and others). A further problem was that the effort has been records either as total number of hooks or number of lines hauled.

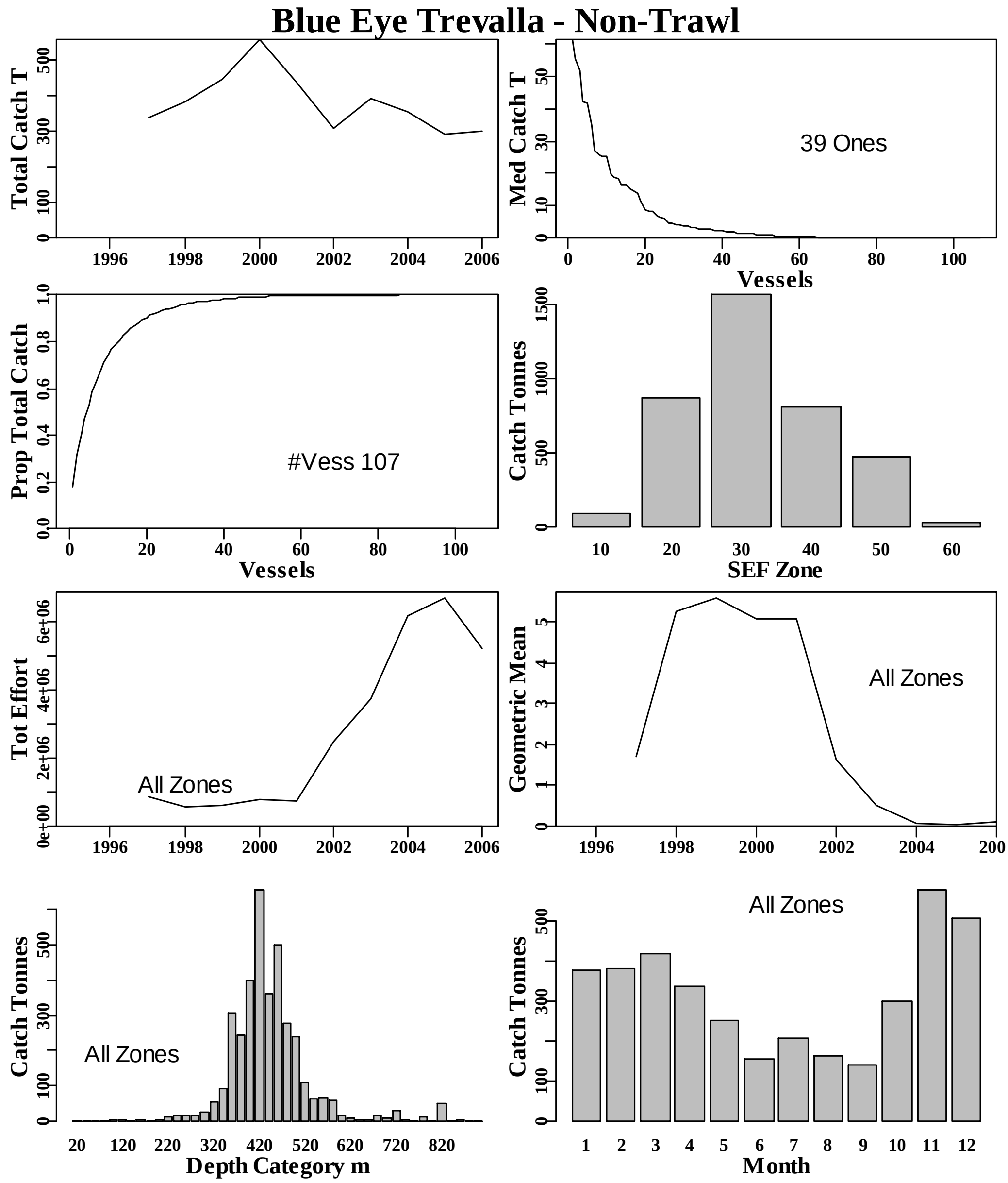
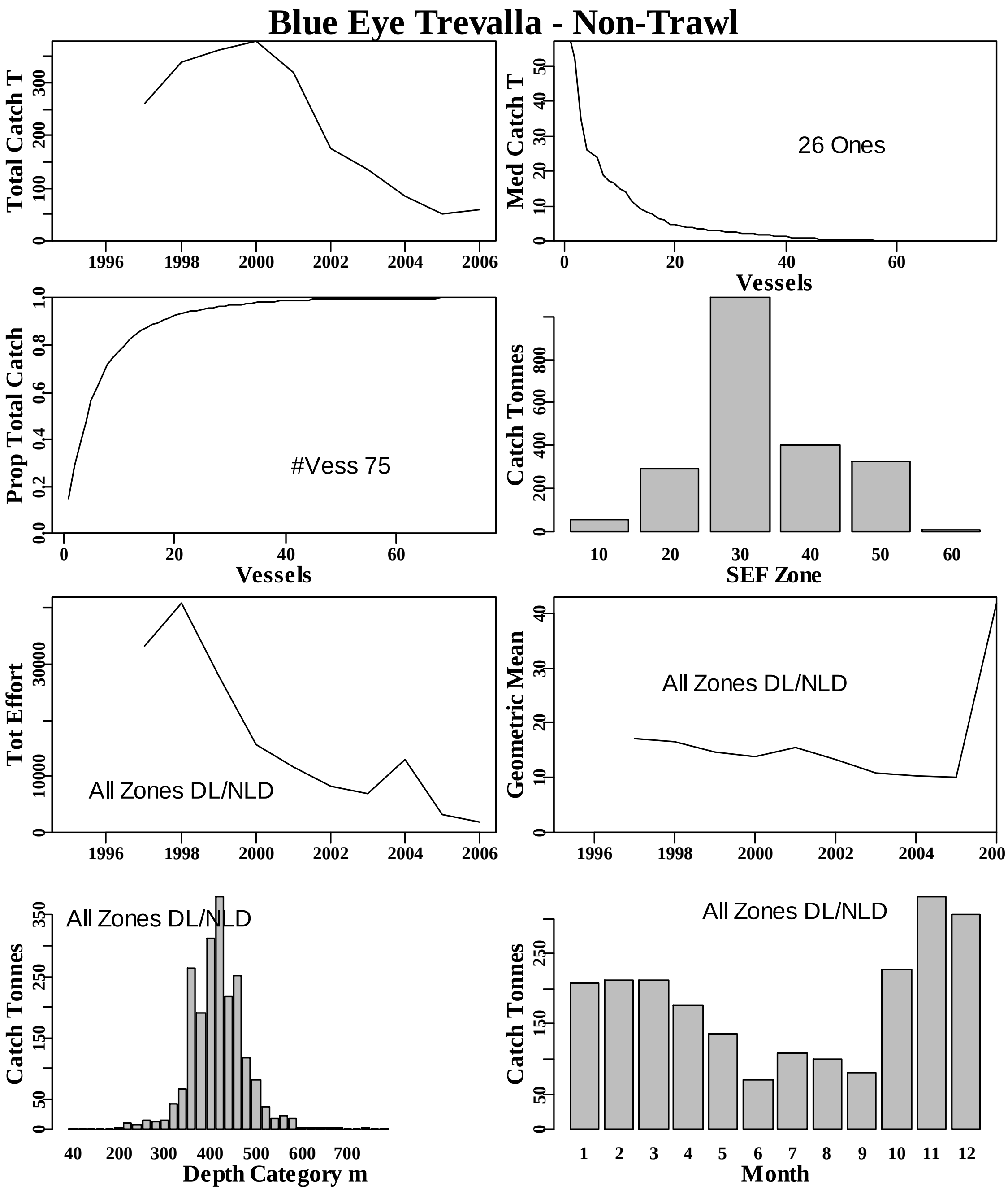


Figure 5.12. Blue Eye Trevalla non-trawl fishery characterization. Methods include Auto Longlining, Drop Lining, and Bottom Lining, with effort recorded as lines hauled or total hooks. The effort and catch rate graphs are therefore meaningless. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

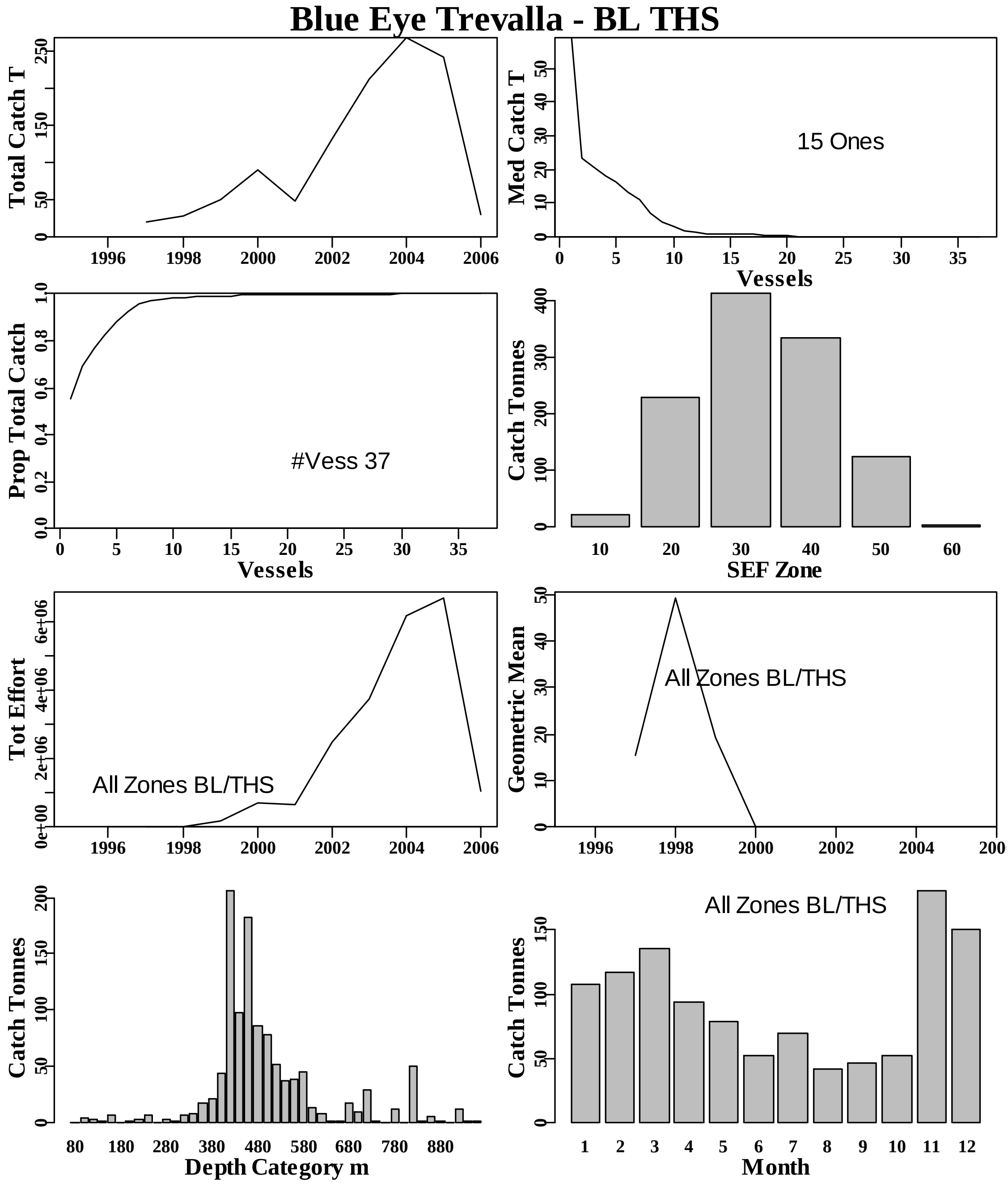
5.12.1 Blue Eye (Non-Trawl – Drop Line via NLD)

Only 5562 records with catch and effort data for Drop line (effort reported as Number of Lines hauled per day). Again the effort in 2006 appears to change character.



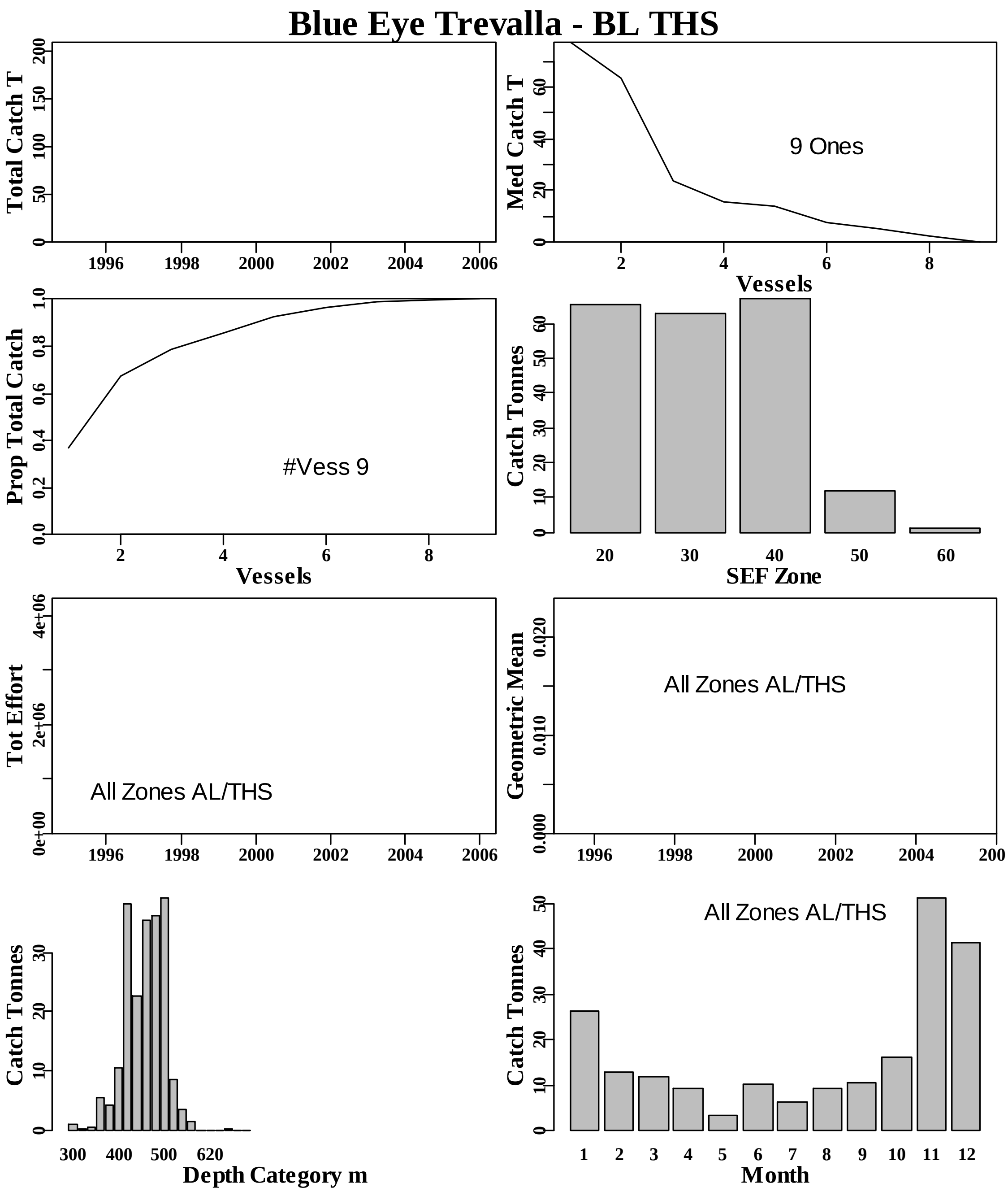
5.12.2 Blue Eye (Non-Trawl Bottom Line – Total Hooks Set)

Only 3300 records in the database. With the effort appearing to transfer to Auto longlineing in 2006.



5.12.3 Blue Eye (Non-Trawl Auto Longlining THS)

Only 458 records in 2006 in the database.



5.13 Ocean Perch

There are 110,684 records of Ocean Perch (*Helicolenus percoides*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers, Within the main Eastern zones (10 and 20) there were 83,043 records, of which 82,902 records were from trawlers. Of these there were 82,656 records with both catches and effort data that could be used for the analysis of catch rates.

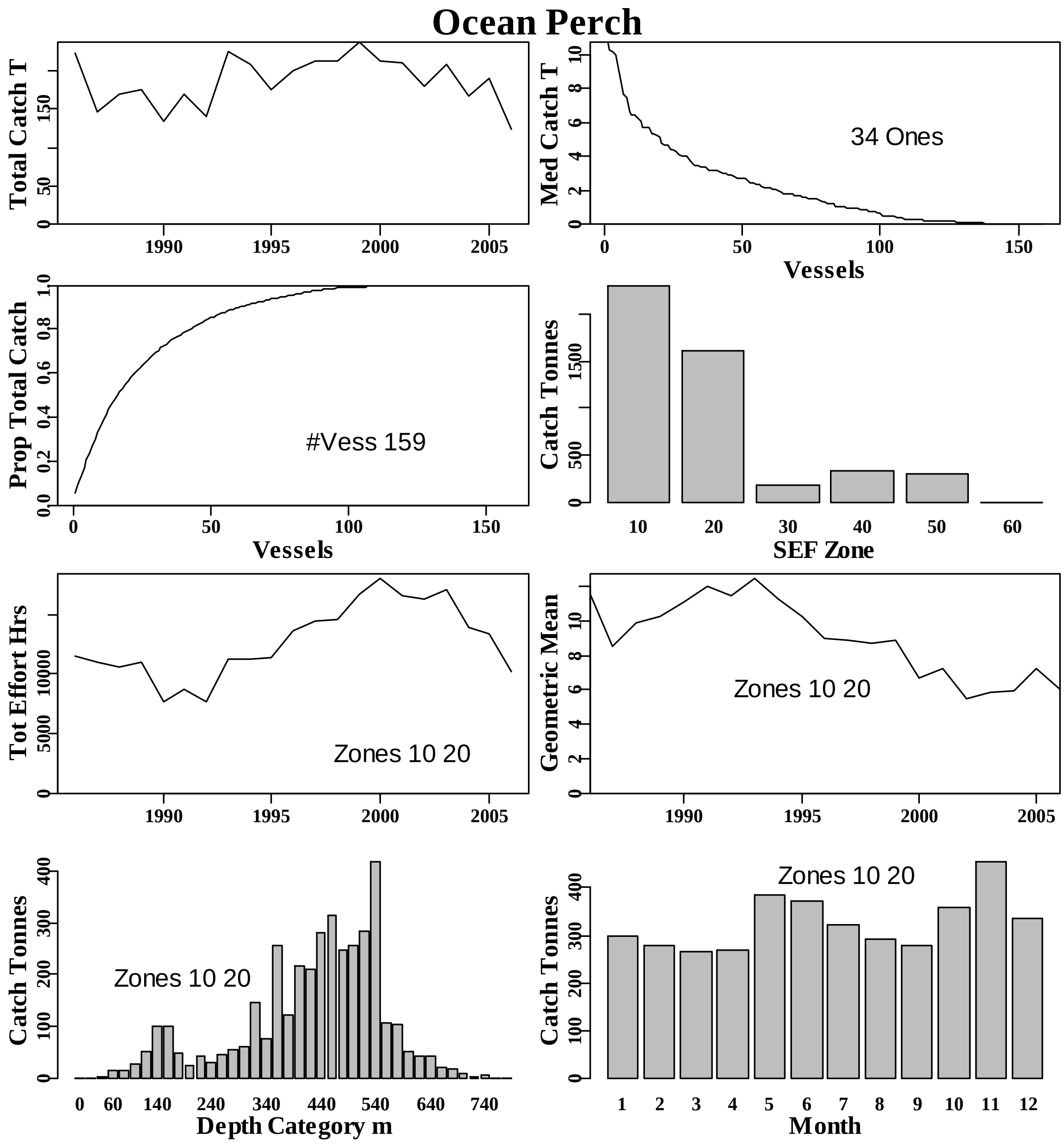


Figure 5.13. Ocean Perch trawl fishery characterization. The main Eastern zones (10 and 20) and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.14. Total catch of **Ocean Perch** in tonnes by trawlers in the main Eastern zones (10 and 20), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	222.487	10	2298.871	48.470
1987	145.251	20	1608.995	33.924
1988	167.891	30	194.103	4.092
1989	175.931	40	337.189	7.109
1990	133.108	50	298.842	6.301
1991	168.356	60	4.902	0.103
1992	140.260			
1993	225.062			
1994	207.237	**Month**	**Catch T**	**Percent**
1995	174.408	1	298.640	7.643
1996	199.918	2	277.440	7.101
1997	211.064	3	264.611	6.773
1998	211.142	4	269.325	6.893
1999	235.517	5	385.538	9.868
2000	212.804	6	372.732	9.540
2001	210.559	7	321.135	8.219
2002	178.186	8	293.283	7.506
2003	208.727	9	277.616	7.105
2004	166.914	10	359.281	9.196
2005	189.786	11	454.114	11.623
2006	123.258	12	333.416	8.534

5.14 Redfish (Zone 10)

There are 92,662 records of Redfish (*Centroberyx affinis*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers. Within the main Eastern zone (10) there were 66,672 records, of which 66,623 records were from trawlers. Of these there were 66,476 records with both catches and effort data that could be used for the analysis of catch rates.

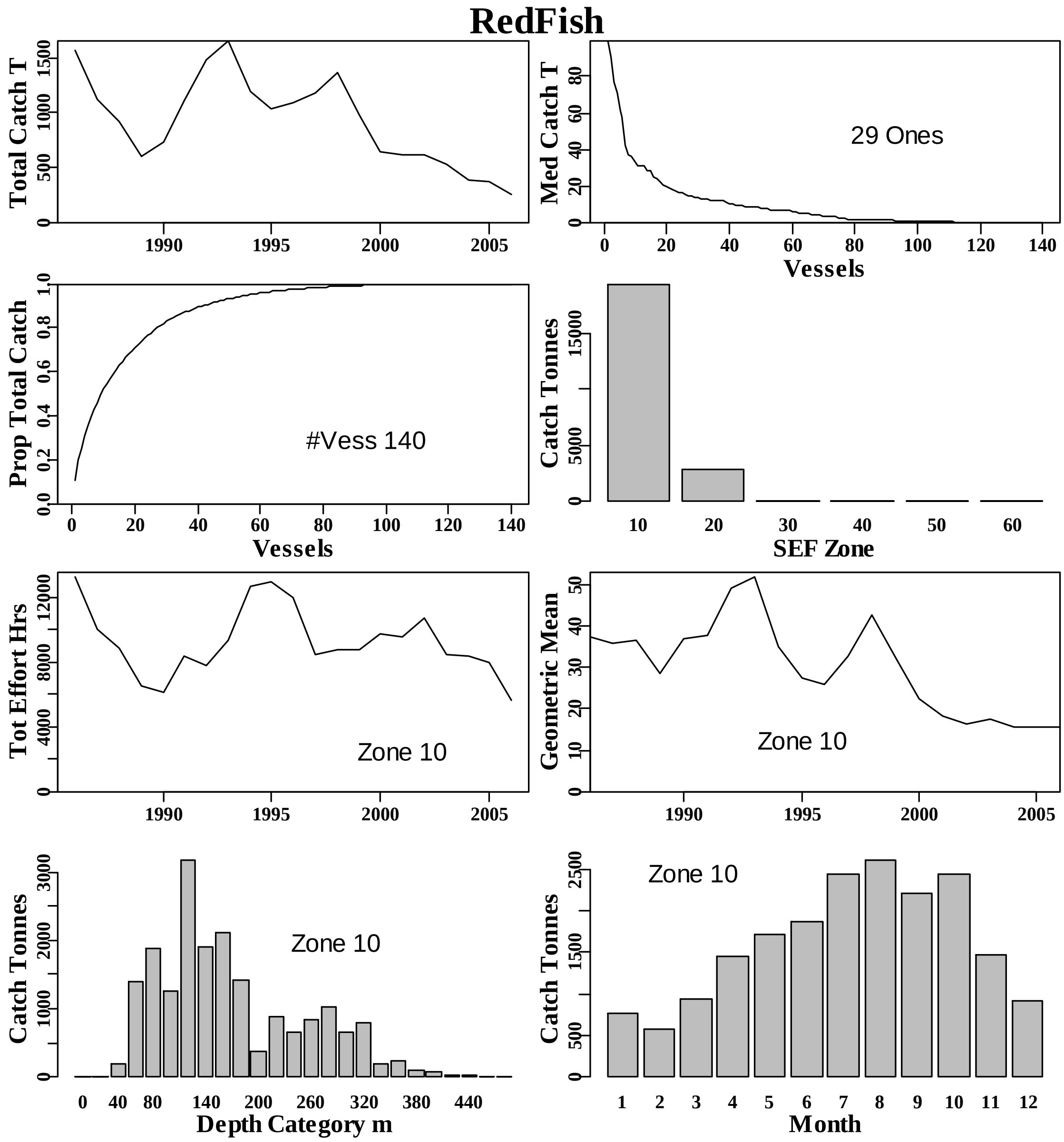


Figure 5.14. Redfish trawl fishery characterization from Zone 10, the main Eastern zone and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.15. Total catch of **Redfish** in tonnes by trawlers in the main Eastern zone (10), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	1561.560	10	19436.032	86.736
1987	1126.708	20	2892.098	12.906
1988	914.926	30	14.642	0.065
1989	604.227	40	18.295	0.082
1990	734.177	50	33.232	0.148
1991	1101.135	60	13.933	0.062
1992	1483.327			
1993	1643.855			
1994	1188.020	**Month**	**Catch T**	**Percent**
1995	1036.581	1	771.812	3.971
1996	1091.960	2	579.920	2.984
1997	1173.631	3	940.921	4.841
1998	1369.984	4	1446.895	7.445
1999	978.111	5	1712.490	8.811
2000	647.429	6	1879.873	9.673
2001	614.551	7	2447.473	12.593
2002	613.615	8	2614.246	13.451
2003	527.316	9	2209.446	11.368
2004	396.969	10	2444.480	12.578
2005	371.182	11	1473.057	7.579
2006	256.767	12	914.428	4.705

5.15 Redfish (Zone 20)

There are 92,662 records of Redfish (*Centroberyx affinis*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers. Within the secondary Eastern zone (20) there were 24,965 records, of which 24,609 records were from trawlers. Of these there were 24,558 records with both catches and effort data that could be used for the analysis of catch rates.

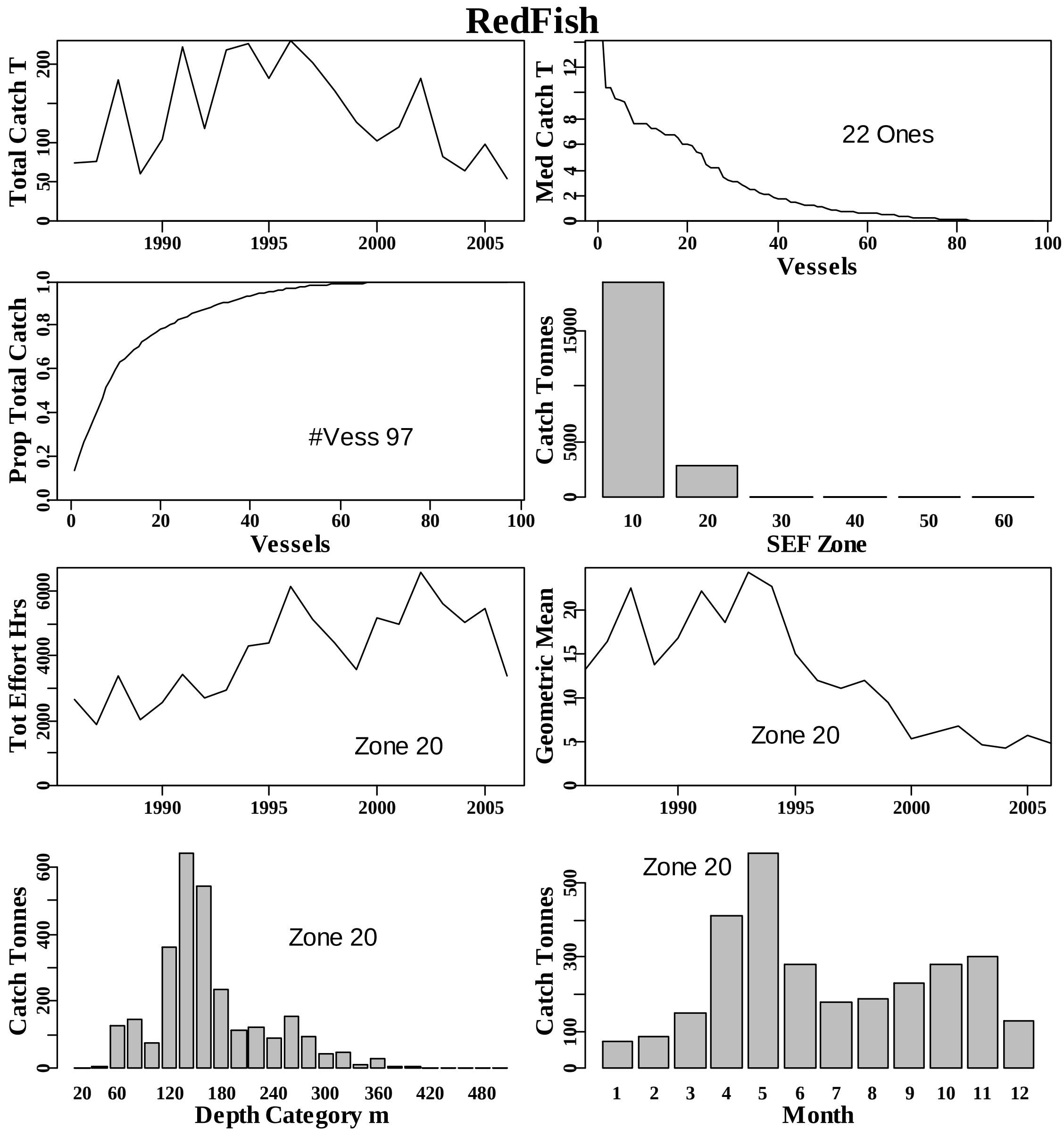


Figure 5.15. Redfish trawl fishery characterization from Zone 20, the secondary Eastern zone and trawl method only. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.16 FlatHead (Trawl)

There are 385,562 records of Tiger Flathead (*Neoplatycephalus richardsoni*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Trawlers made up 254,876 records, and within the Eastern zones (10, 20, and 30) there were 237,678 records. Of these there were 236,358 records with both catches and effort data that could be used for the analysis of catch rates.

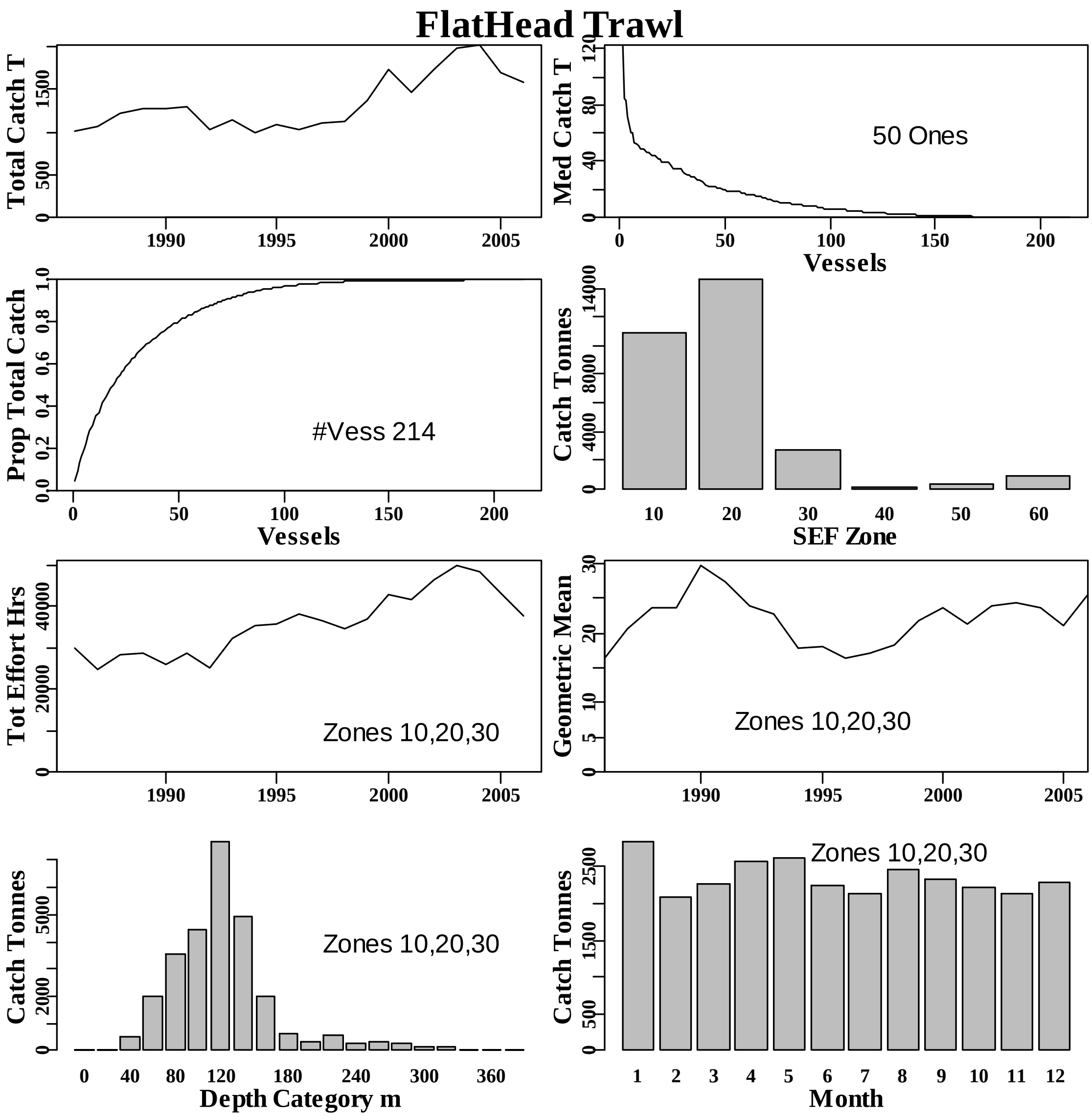


Figure 5.16. Tiger Flathead trawl fishery characterization from the Eastern zone (10, 20, and 30). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

Table 5.16. Total catch of **FlatHead** in tonnes by trawlers in the Eastern zone (10, 20, and 30), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	1009.116	10	10934.05	36.93088
1987	1070.366	20	14594.52	49.29449
1988	1222.765	30	2718.553	9.182194
1989	1286.706	40	63.219	0.213529
1990	1284.789	50	352.875	1.191872
1991	1291.548	60	943.579	3.187036
1992	1025.499			
1993	1146.044			
1994	988.075	**Month**	**Catch T**	**Percent**
1995	1080.041	1	2838.585	10.04911
1996	1027.148	2	2097.601	7.425894
1997	1105.155	3	2270.345	8.037438
1998	1120.718	4	2584.465	9.14948
1999	1381.48	5	2622.255	9.283266
2000	1735.747	6	2255.121	7.983544
2001	1463.131	7	2132.091	7.547994
2002	1736.719	8	2466.803	8.732939
2003	1989.76	9	2330.171	8.249234
2004	2012.432	10	2226.354	7.881701
2005	1692.69	11	2141.006	7.579557
2006	1577.189	12	2282.322	8.07984

5.17 FlatHead (Danish Seine – Zones 10 20)

There are 385,562 records of Tiger Flathead (*Neoplatycephalus richardsoni*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Danish Seiners made up 130,686 records, and within the main Eastern zones (10 and 20) there were 49,409 records. Of these there were 44,777 records with both catches and effort data that could be used for the analysis of catch rates.

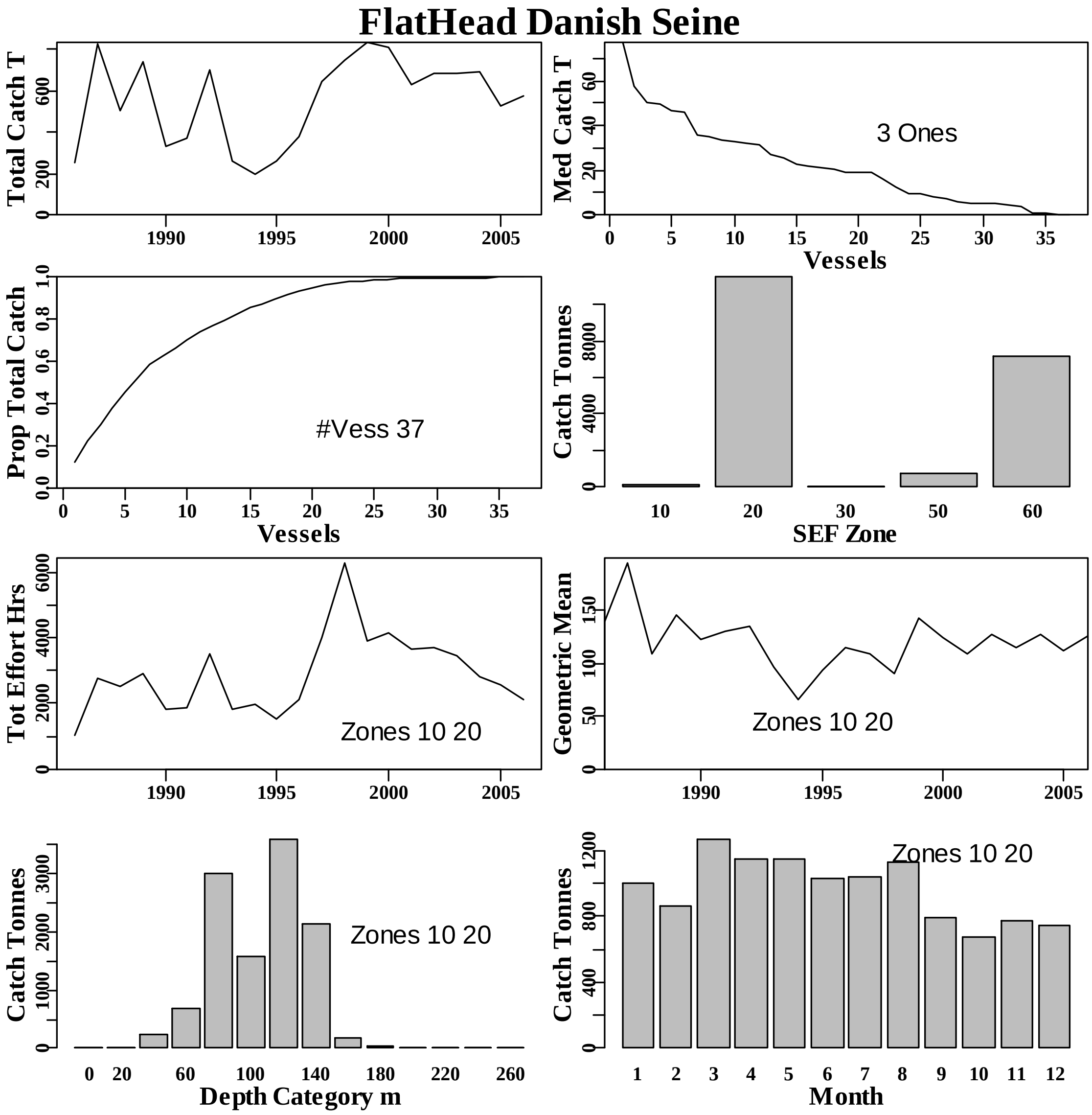


Figure 5.17. Tiger Flathead Danish Seine fishery characterization from the main Eastern zones (10 and 20). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.18 FlatHead (Danish Seine – Zones 50 60)

There are 385,562 records of Tiger Flathead (*Neoplatycephalus richardsoni*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Danish Seiners made up 130,686 records, and within the main Western zones (50 and 60) there were 81,160 records. Of these there were 70,740 records with both catches and effort data that could be used for the analysis of catch rates.

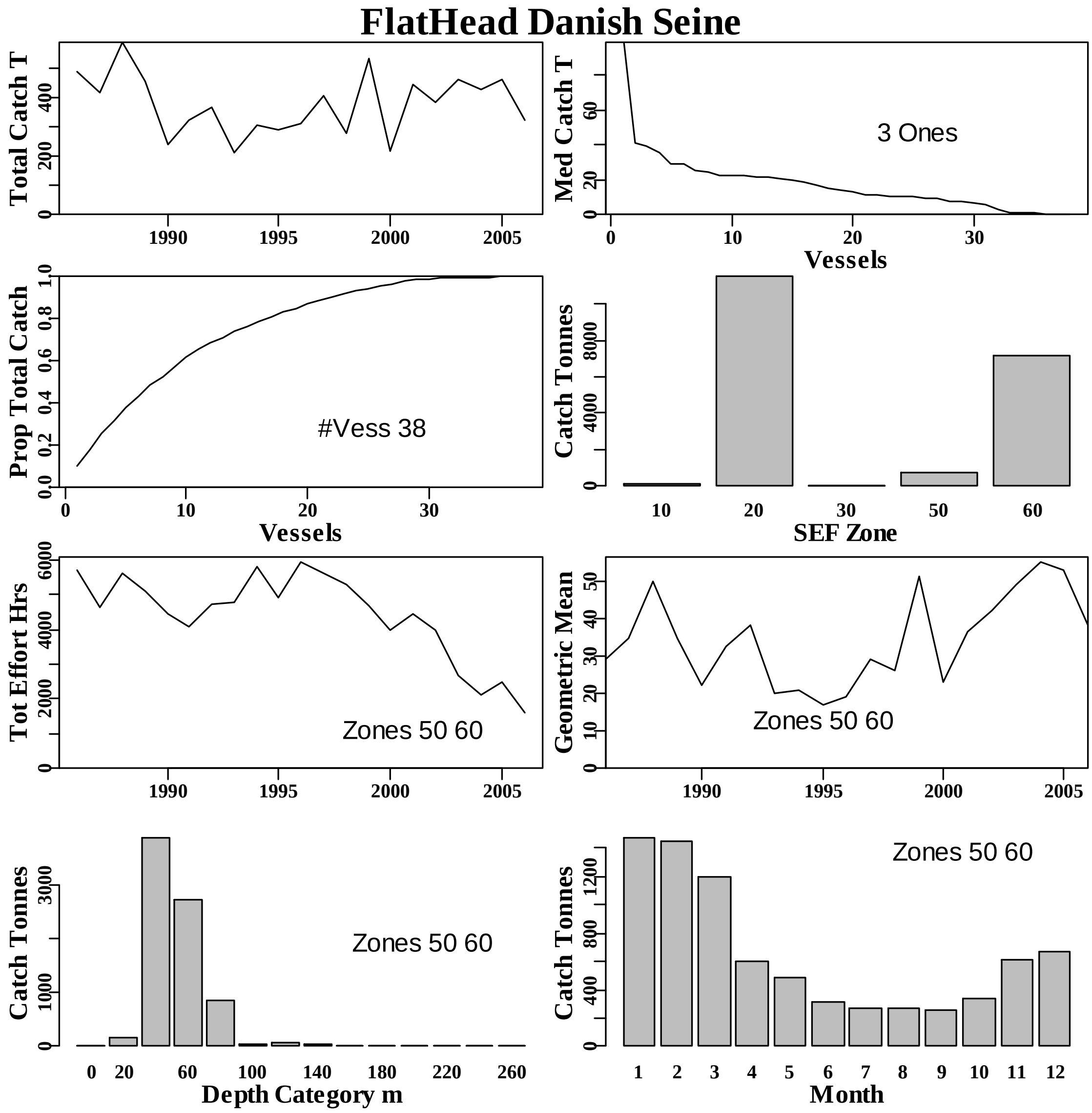


Figure 5.18. Tiger Flathead Danish Seine fishery characterization from the main Western zones (50 and 60). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.19 Mirror Dory

There are 102,923 records of Mirror Dory (*Zenopsis nebulosus*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Trawlers made up 101,436 records across all zones. Of these there were 101,026 records with both catches and effort data that could be used for the analysis of catch rates.

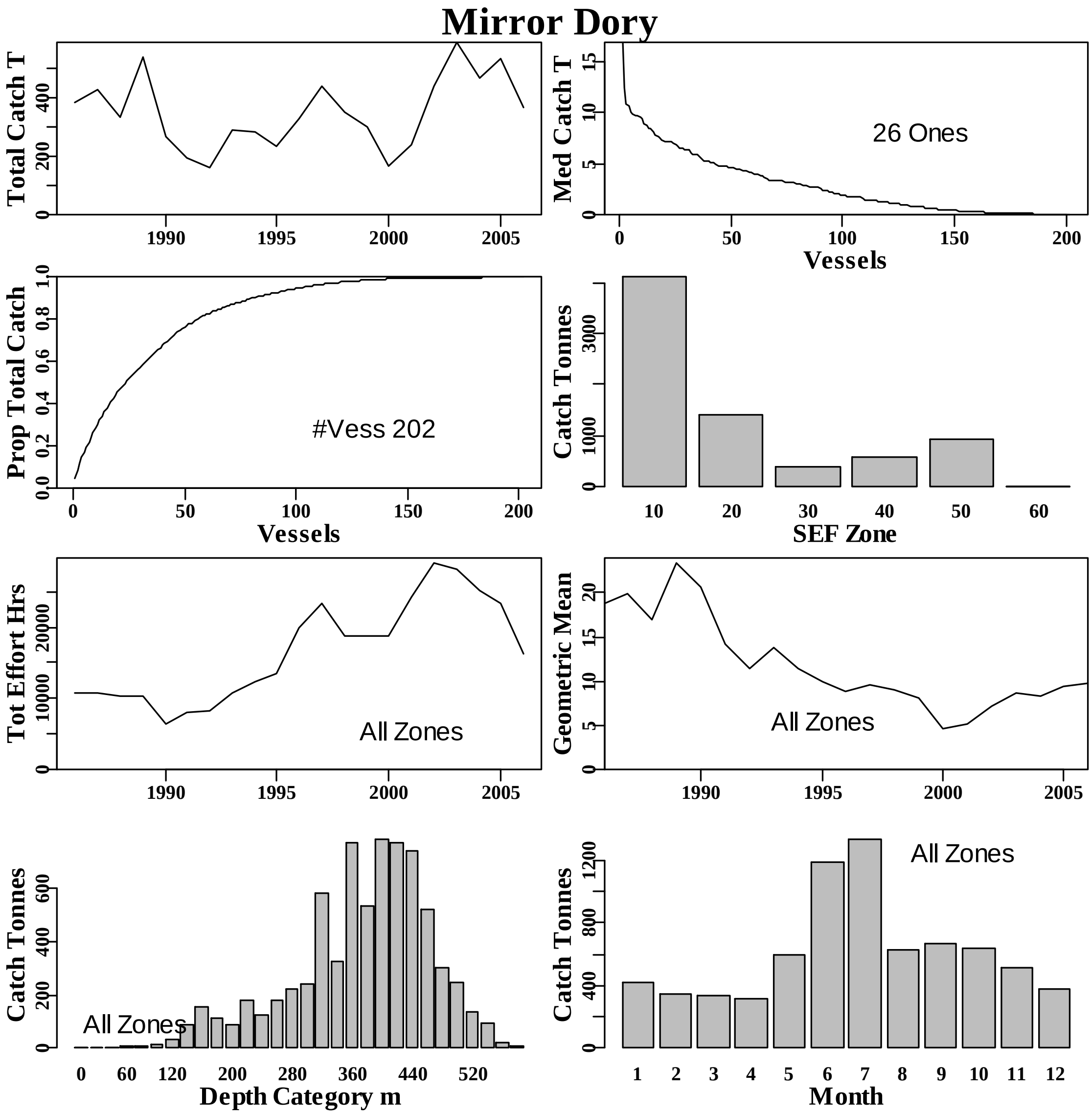


Figure 5.19. Mirror Dory trawl fishery characterization for all zones (10 – 60). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

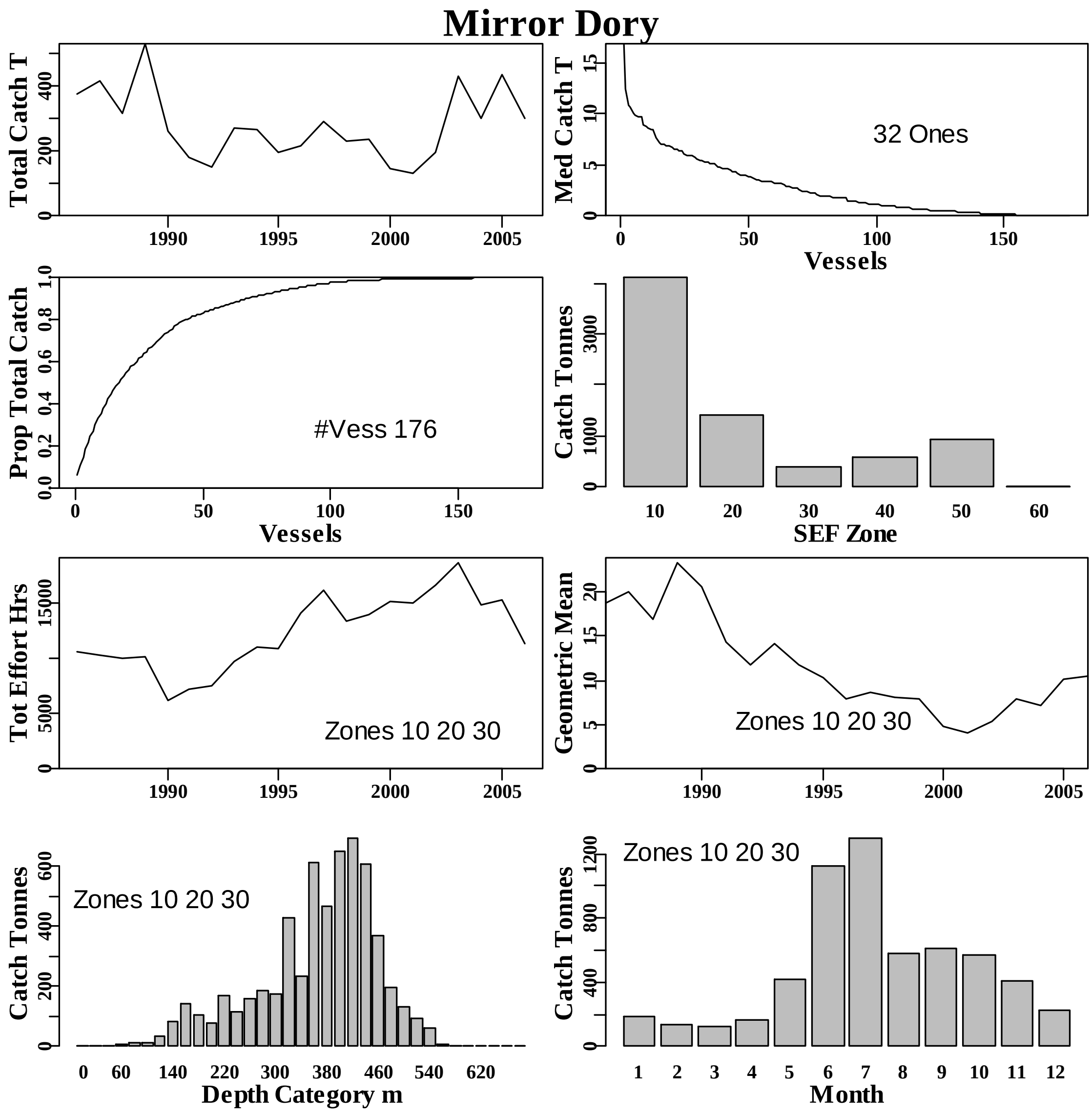


Figure 5.20. Mirror Dory trawl fishery characterization for Eastern zones (10, 20, and 30). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

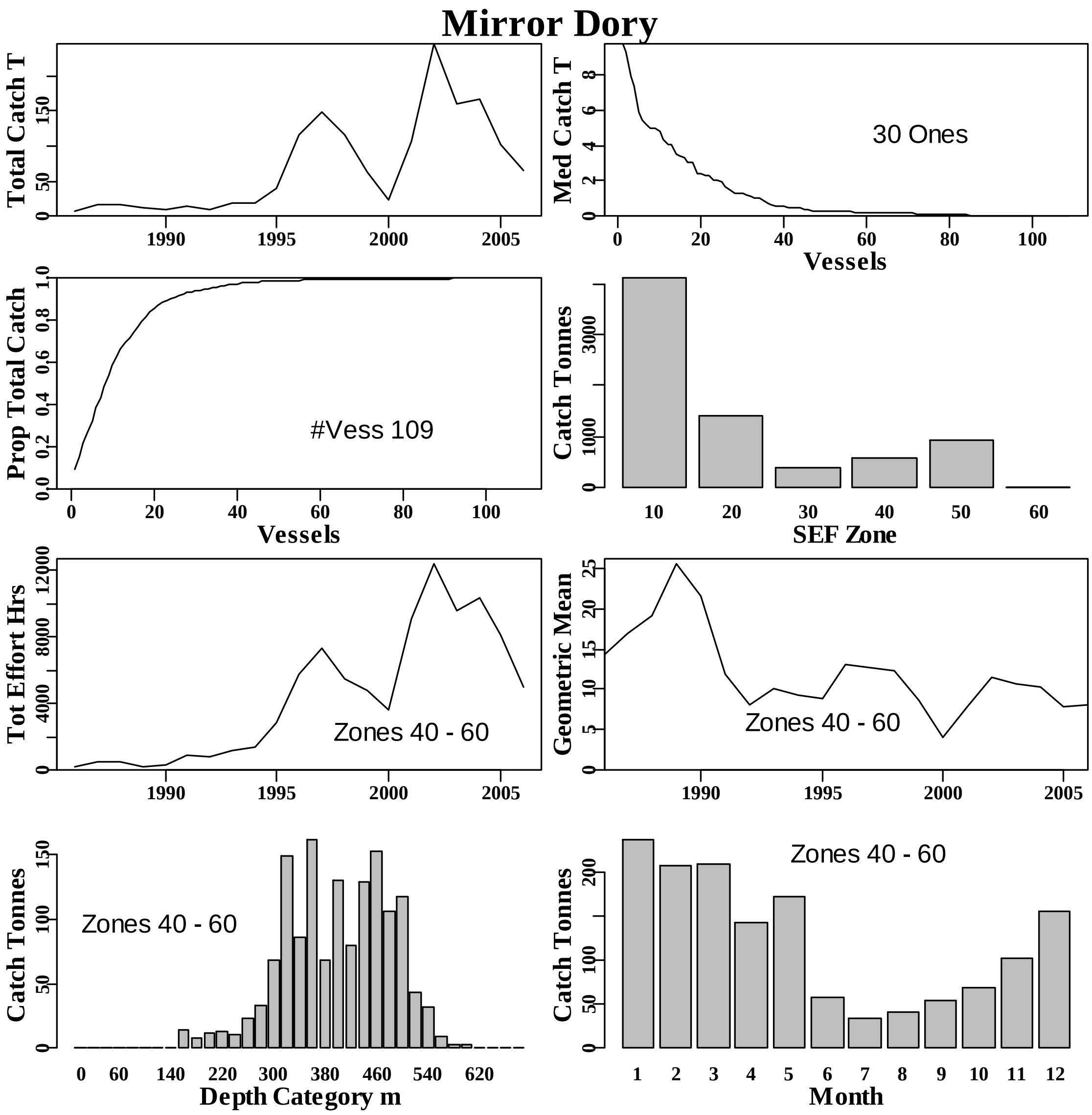


Figure 5.21. Mirror Dory trawl fishery characterization for Western zones (40, 50, and 60). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.20 John Dory

There are 155,654 records of John Dory (*Zeus faber*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Trawlers made up 125,509 records with 121,843 records in Zones 10 and 20. Of these there were 121,313 records with both catches and effort data that could be used for the analysis of catch rates.

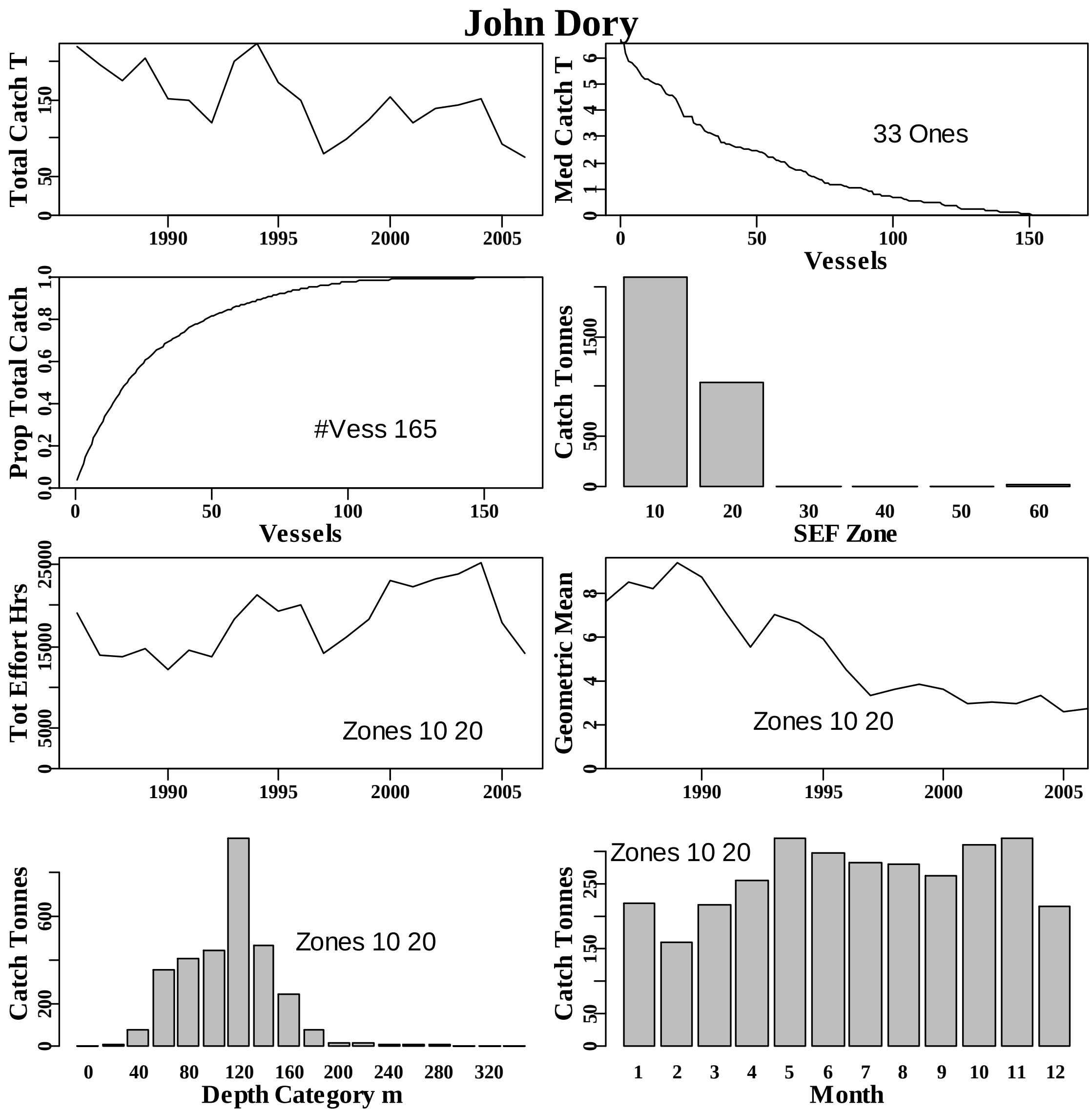


Figure 5.22. John Dory trawl fishery characterization for main Eastern zones (10 and 20). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

Table 5.17. Total catch of **John Dory** in tonnes by trawlers in the Eastern zones (10 and 20), by calendar year from 1986 to 2006.

Year	Catch T	Zone	Catch T	Percent
1986	219.322	10	2088.428	66.119
1987	195.719	20	1041.165	32.963
1988	173.466	30	4.094	0.130
1989	202.860	40	3.643	0.115
1990	151.538	50	3.921	0.124
1991	148.155	60	17.356	0.549
1992	119.629			
1993	199.902			
1994	221.616	**Month**	**Catch T**	**Percent**
1995	172.549	1	219.355	7.009
1996	150.161	2	160.081	5.115
1997	80.318	3	216.450	6.916
1998	99.054	4	254.882	8.144
1999	122.943	5	318.652	10.182
2000	152.534	6	296.804	9.484
2001	118.775	7	281.059	8.981
2002	139.379	8	279.641	8.935
2003	143.449	9	261.677	8.361
2004	151.464	10	308.165	9.847
2005	92.054	11	318.790	10.186
2006	74.707	12	214.040	6.839

5.21 Pink Ling (Trawl – All Zones)

There are 209,545 records of Pink Ling (*Genypterus blacodes*) catches in the SESSF database when a selection of records is made between 1986 – 2006 across all zones for trawlers and Danish Seiners. Trawlers made up 200841 records. Of these there were 200,232 records with both catches and effort data that could be used for the analysis of catch rates.

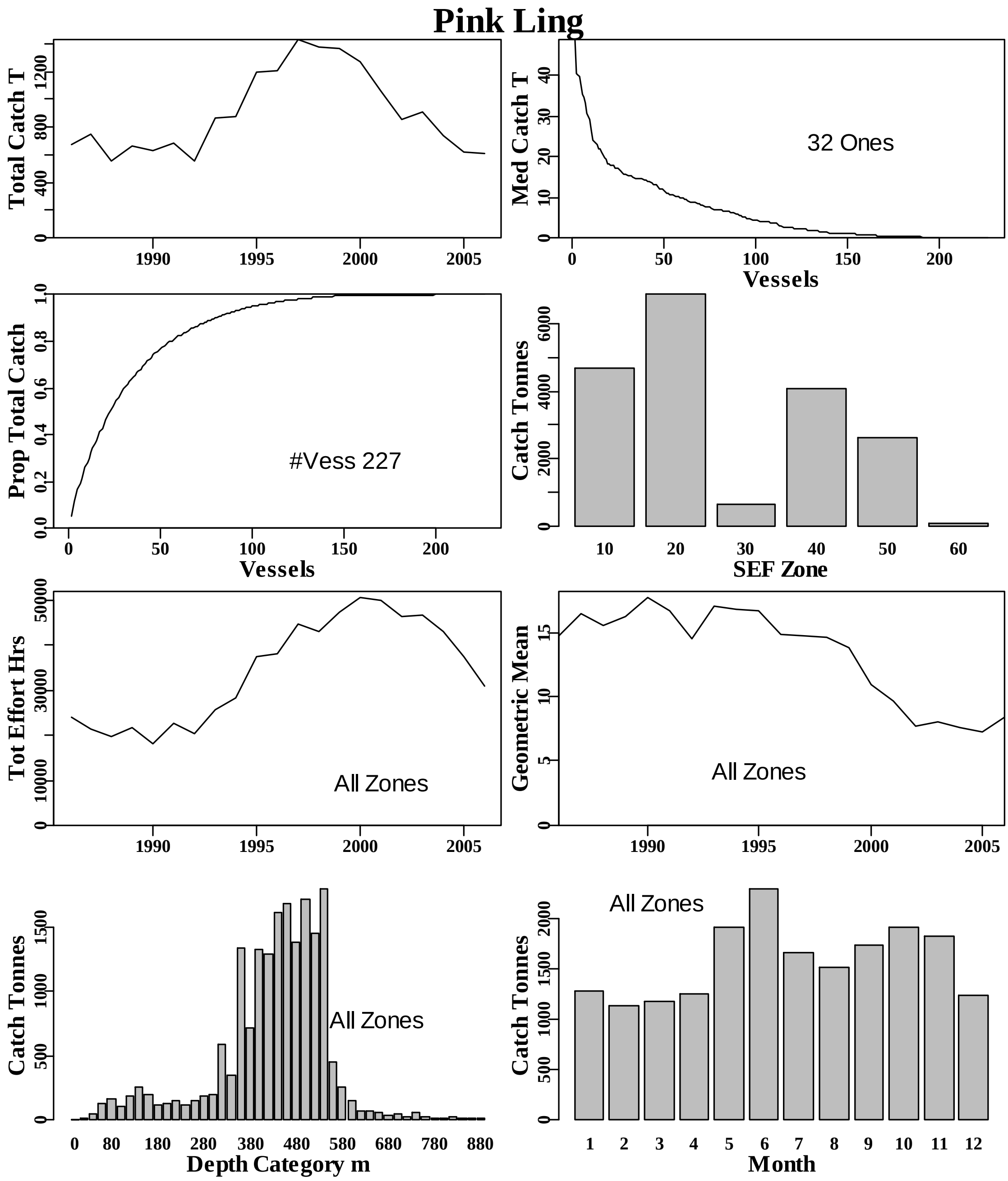


Figure 5.23. Pink Ling trawl fishery characterization for all zones (10 – 60). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.21.1 Pink Ling (Trawl – East)

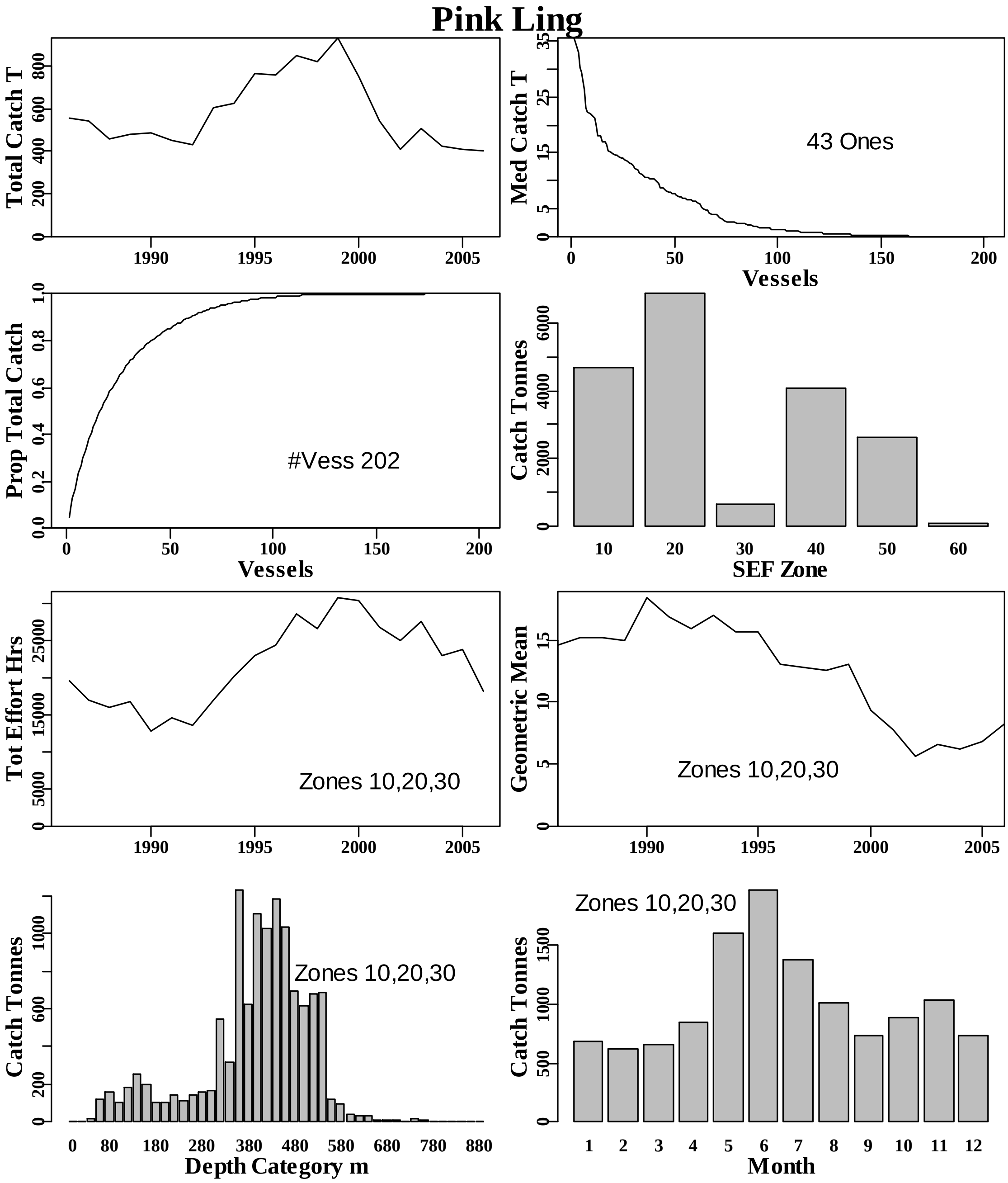


Figure 5.24. Pink Ling trawl fishery characterization for the eastern zones (10, 20, and 30). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

5.21.2 Pink Ling (Trawl – West)

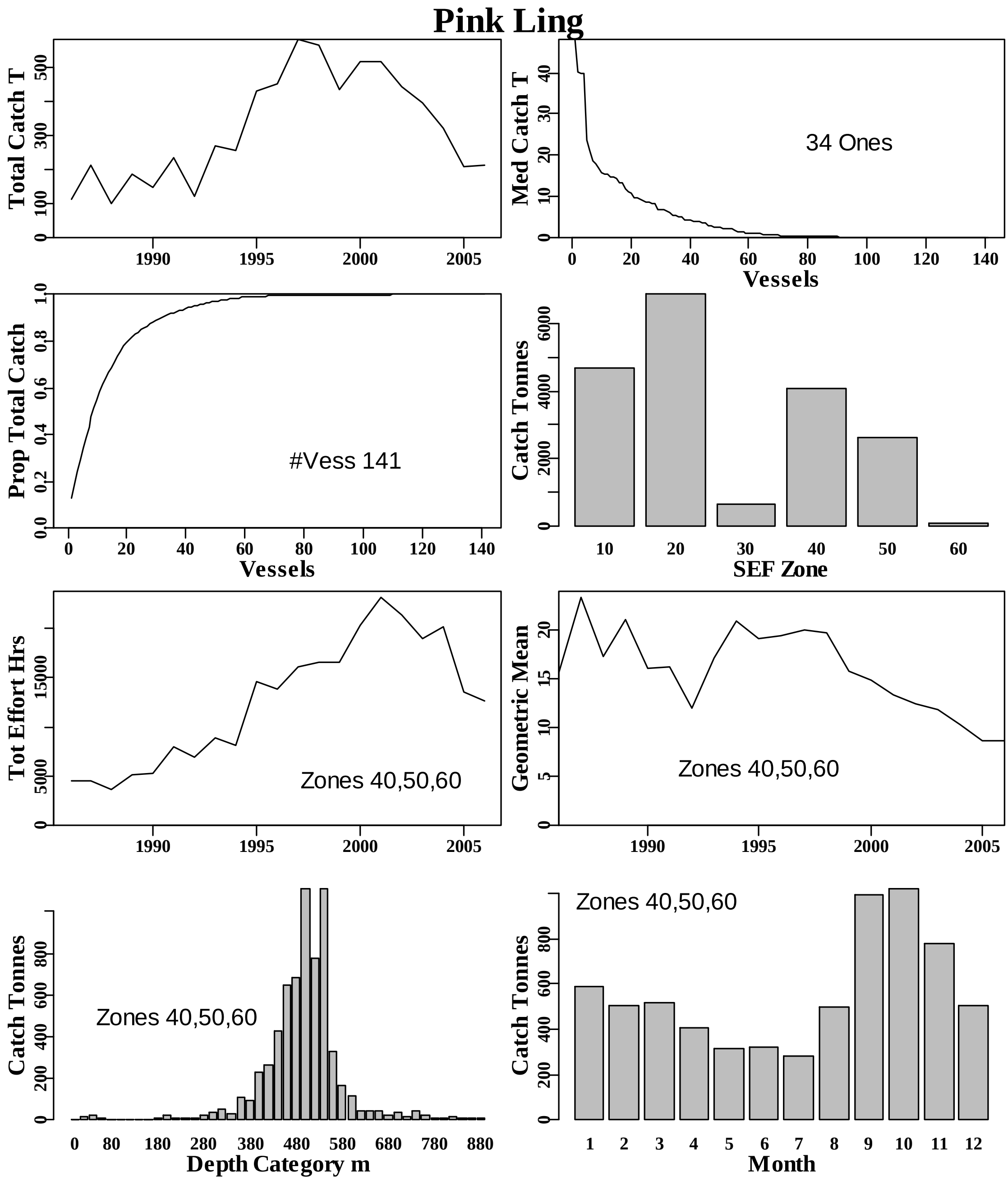


Figure 5.25. Pink Ling trawl fishery characterization for the Western zones (40, 50, and 60). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The "ones" are those vessels that only report in a single year.

5.22 Blue Grenadier (Winter)

There are 10,524 records of Blue Grenadier (*Macruronus novaezelandiae*) catches in the SESSF database when a selection of records is made between 1986 – 2006 for trawlers in the Winter Fishery (Zone 40, June, July, and August). Of these there were 10,502 records with both catches and effort data that could be used for the analysis of catch rates.

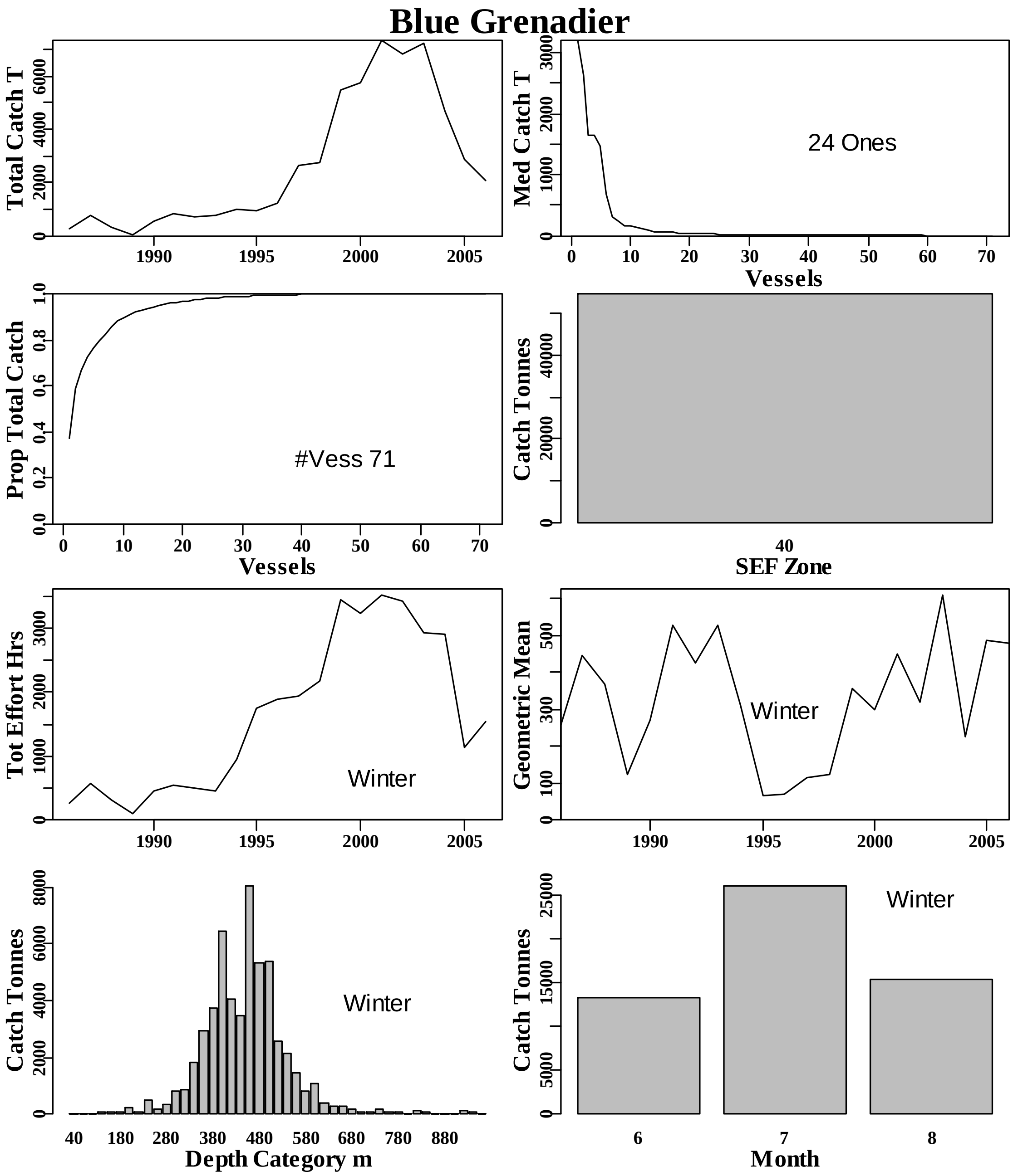


Figure 5.26. Blue Grenadier trawl fishery characterization for the Winter Fishery (Zone 40, June, July and August). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.23 Blue Grenadier (Summer)

There are 110,889 records of Blue Grenadier (*Macruronus novaezelandiae*) catches in the SESSF database when a selection of records is made between 1986 – 2006 for trawlers and Danish Seiners in the Summer Fishery (Not the Winter Fishery). Removing Danish Seine vessels left 110,873 record. Of these there were 110,564 records with both catches and effort data that could be used for the analysis of catch rates.

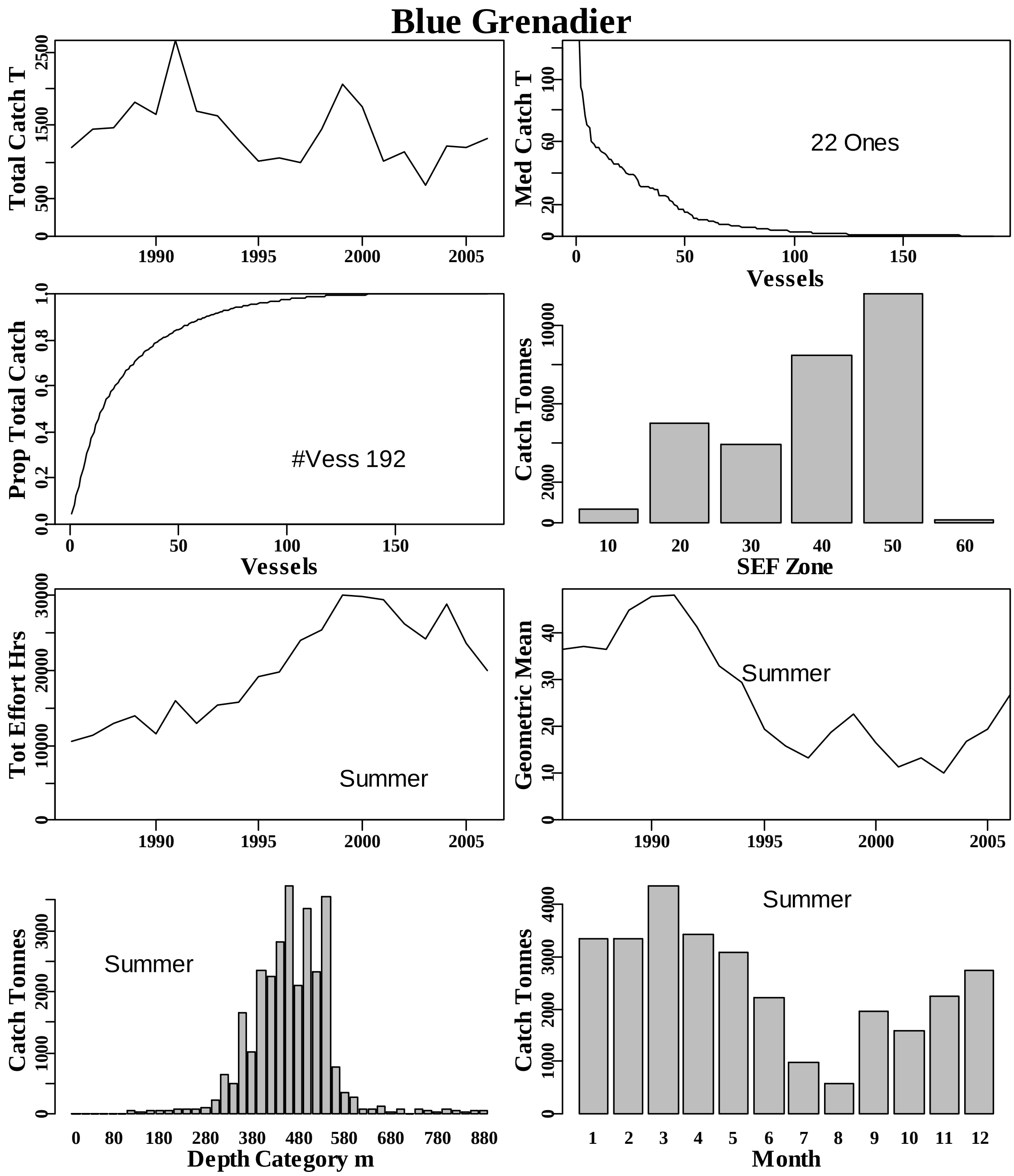


Figure 5.27. Blue Grenadier trawl fishery characterization for the Summer Fishery (Not the Winter fishery). Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.24 Jackass Morwong (Danish Seine)

There are 155,777 records of Jackass Morwong (*Nemadactylus macropterus*) catches in the SESSF database when a selection of records is made between 1986 – 2006 for trawlers and Danish Seiners in all zones. Danish Seine vessels accounted for only 17,070 record and of these there were only 15,298 records with both catches and effort data that could be used for the analysis of catch rates.

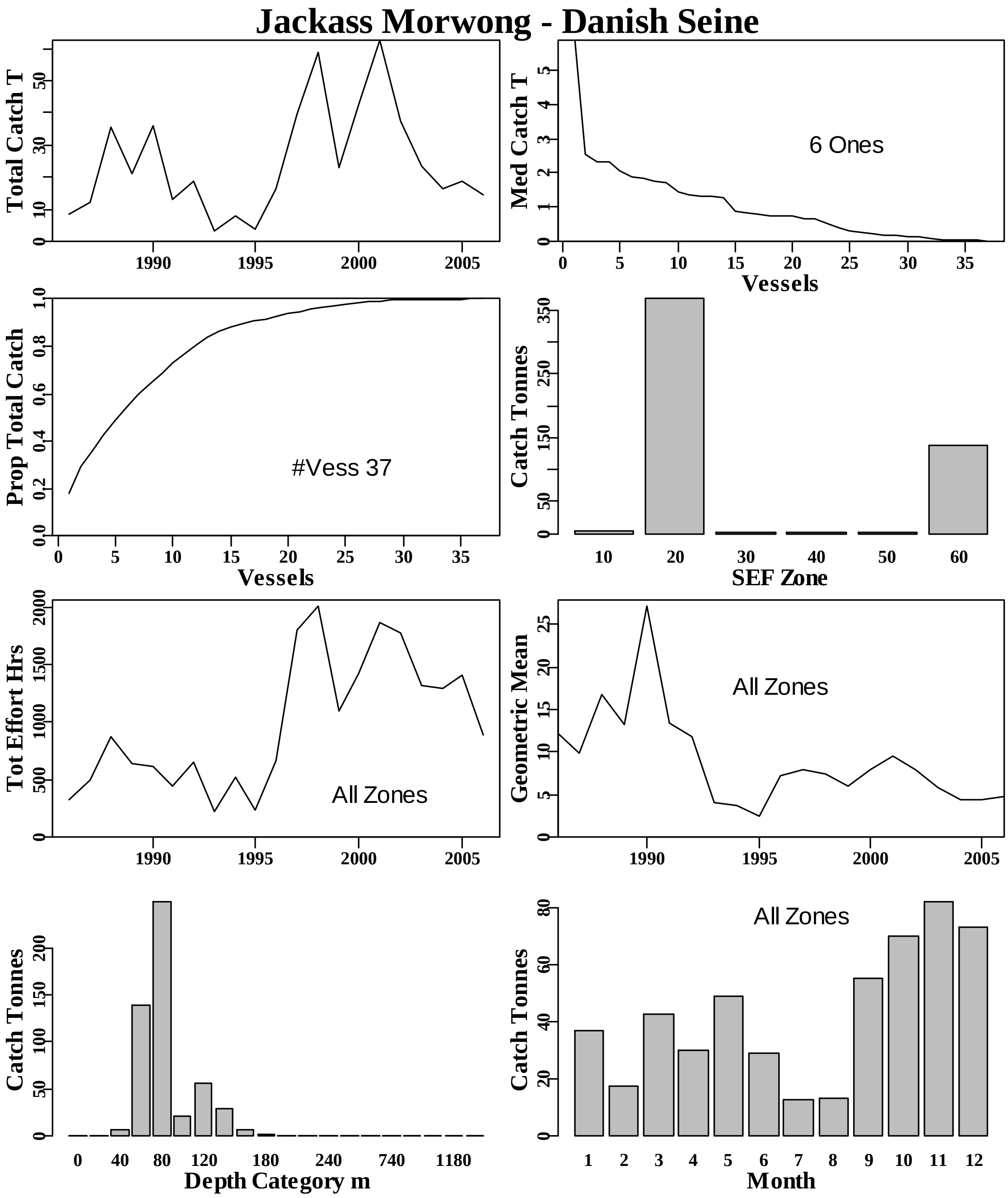


Figure 5.28. Jackass Morwong Danish Seine fishery characterization for all zones. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.

5.25 Jackass Morwong (Trawl)

There are 155,777 records of Jackass Morwong (*Nemadactylus macropterus*) catches in the SESSF database when a selection of records is made between 1986 – 2006 for trawlers and Danish Seiners in all zones. Trawl vessels accounted for 138,707 records and of these there were 138,075 records with both catches and effort data that could be used for the analysis of catch rates.

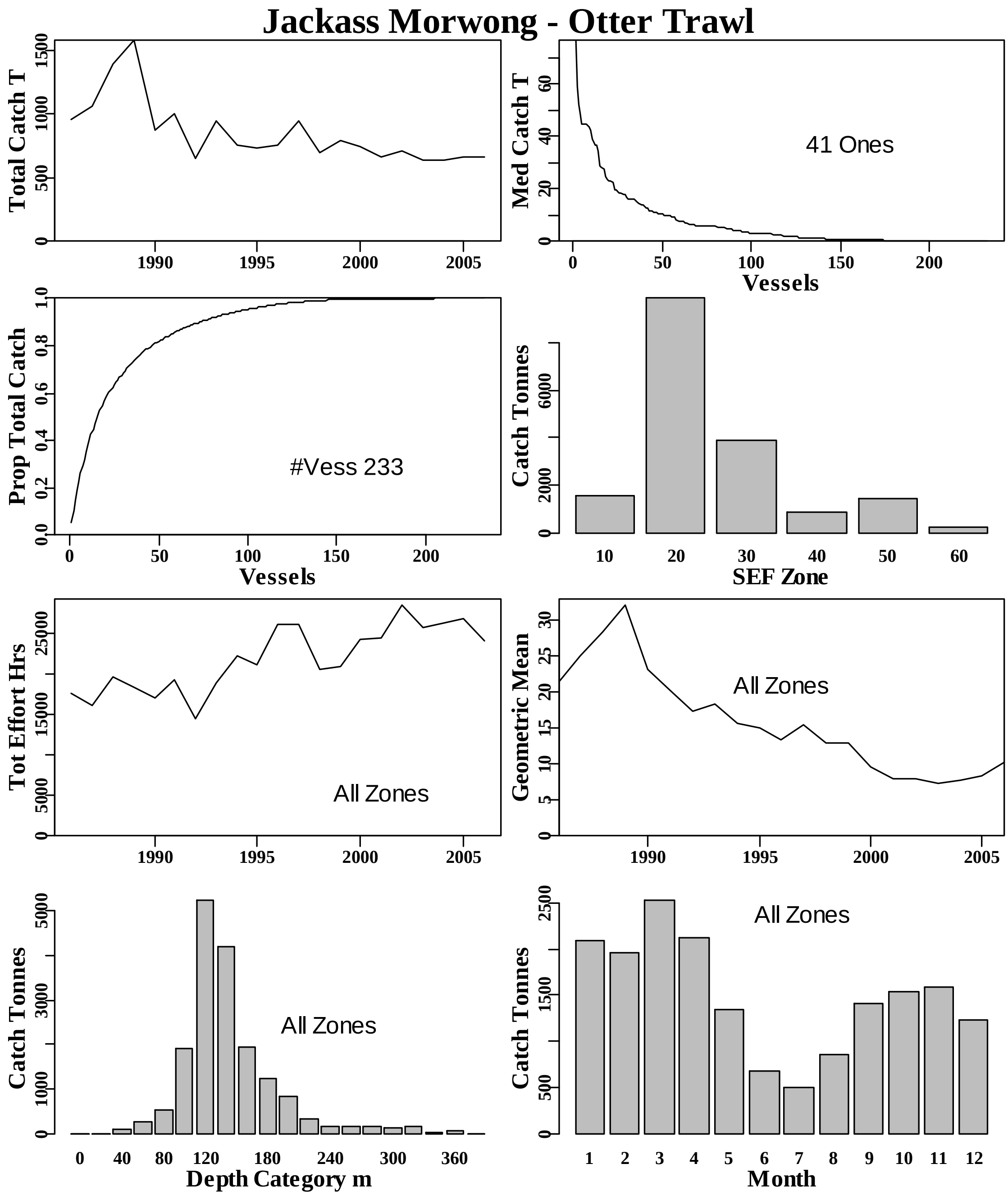
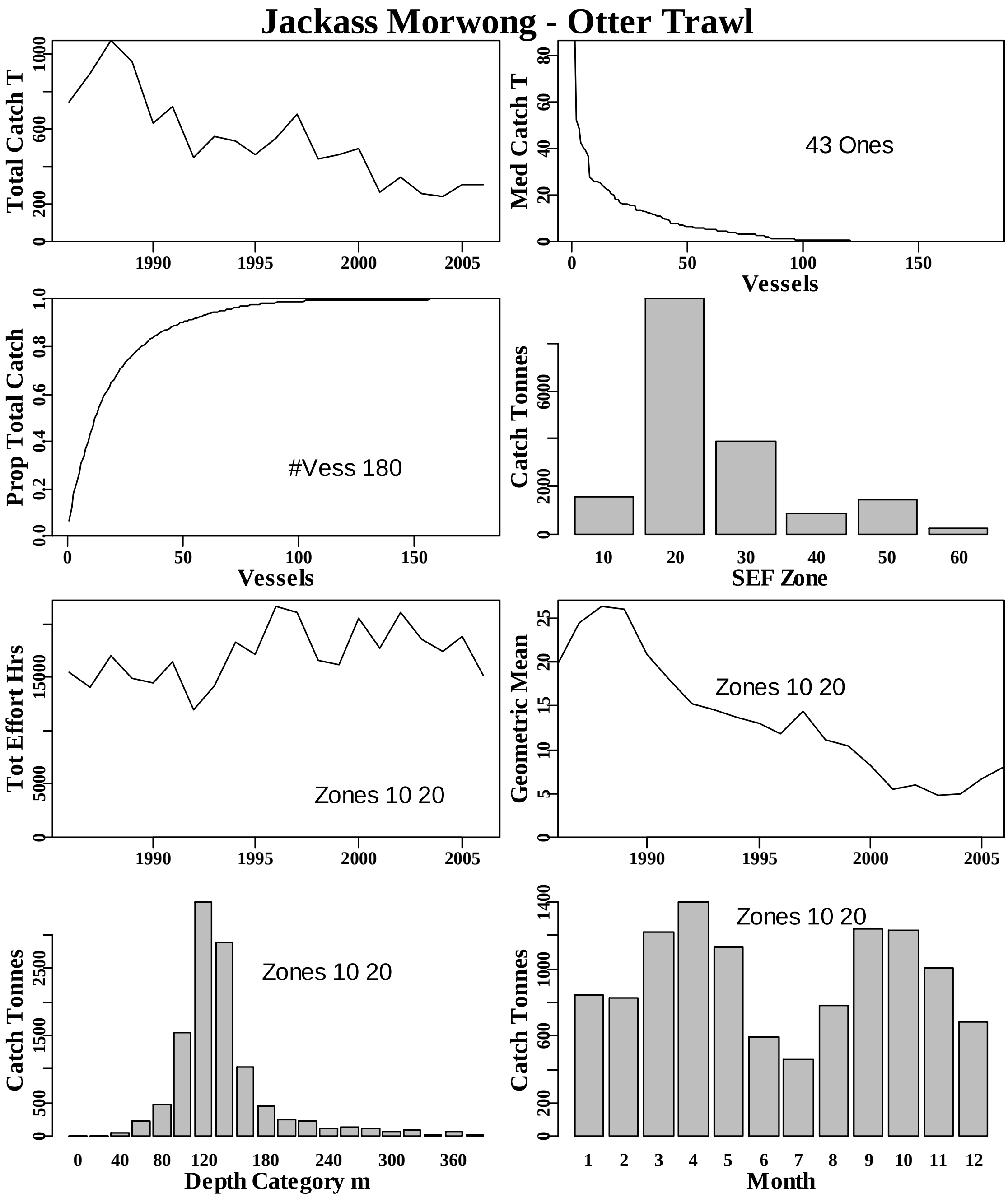


Figure 5.29. Jackass Morwong Otter Trawl fishery characterization for all zones. Effort, Geometric mean Catch Rates, and Catches by depths, and months are across year 1986 to present. # Vess indicates the total number of reporting trawl vessels. The “ones” are those vessels that only report in a single year.


Jackass Morwong - Otter Trawl
Total Catch T
0
200
600
1000
1990
1995
2000
2005
Med Catch T
0
20
40
60
80
43 Ones
0
50
100
150
Vessels
Prop Total Catch
0.0
0.2
0.4
0.6
0.8
1.0
#Vess 180
0
50
100
150
Vessels
Catch Tonnes
0
2000
6000
10
20
30
40
50
60
SEF Zone
Tot Effort Hrs
0
5000
15000
Zones 10 20
1990
1995
2000
2005
Geometric Mean
0
5
10
15
20
25
Zones 10 20
1990
1995
2000
2005
Catch Tonnes
0
500
1500
2500
Zones 10 20
0
40
80
120
180
240
300
360
Depth Category m
Catch Tonnes
0
200
600
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1400
Zones 10 20
1
2
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4
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6
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8
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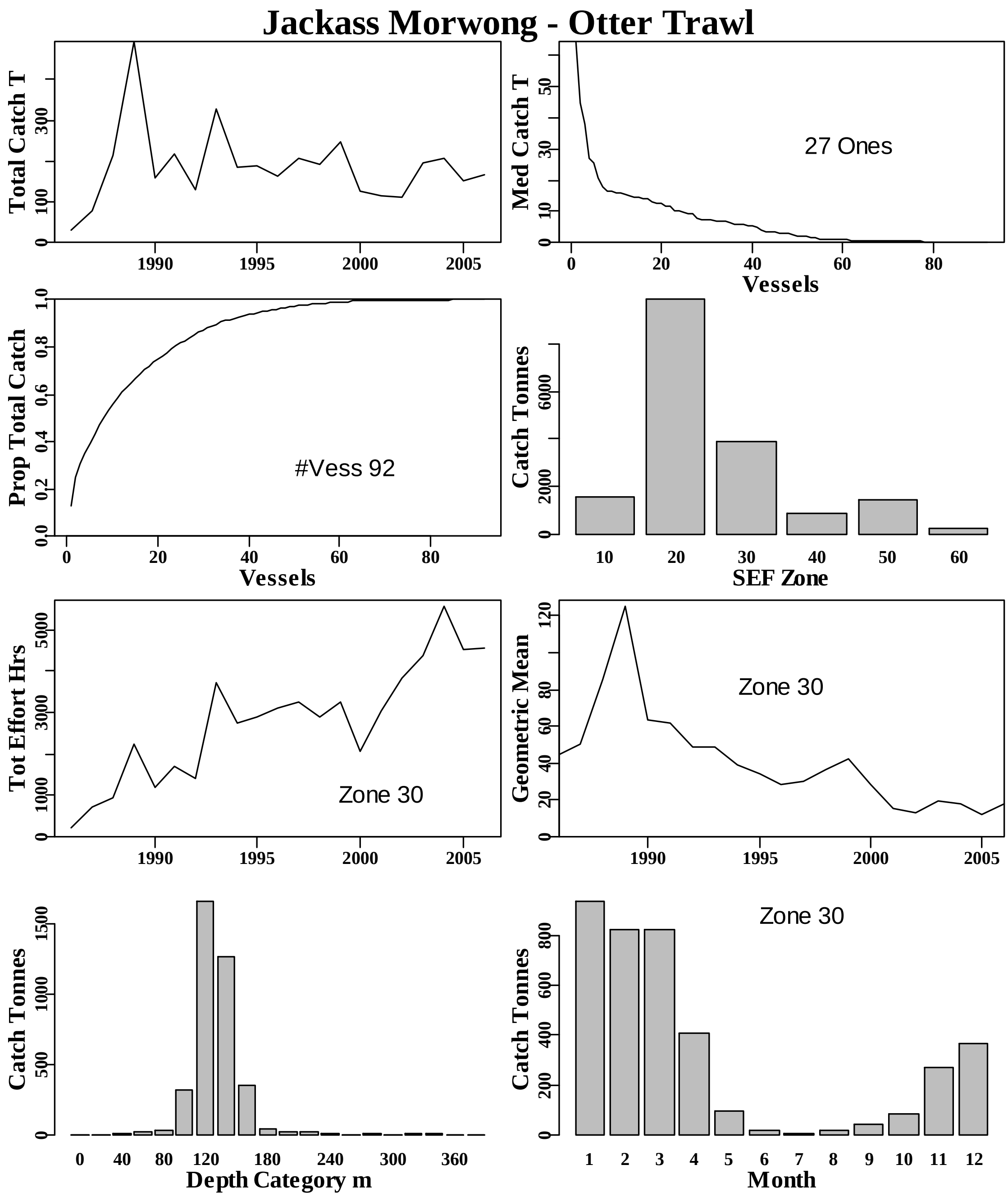
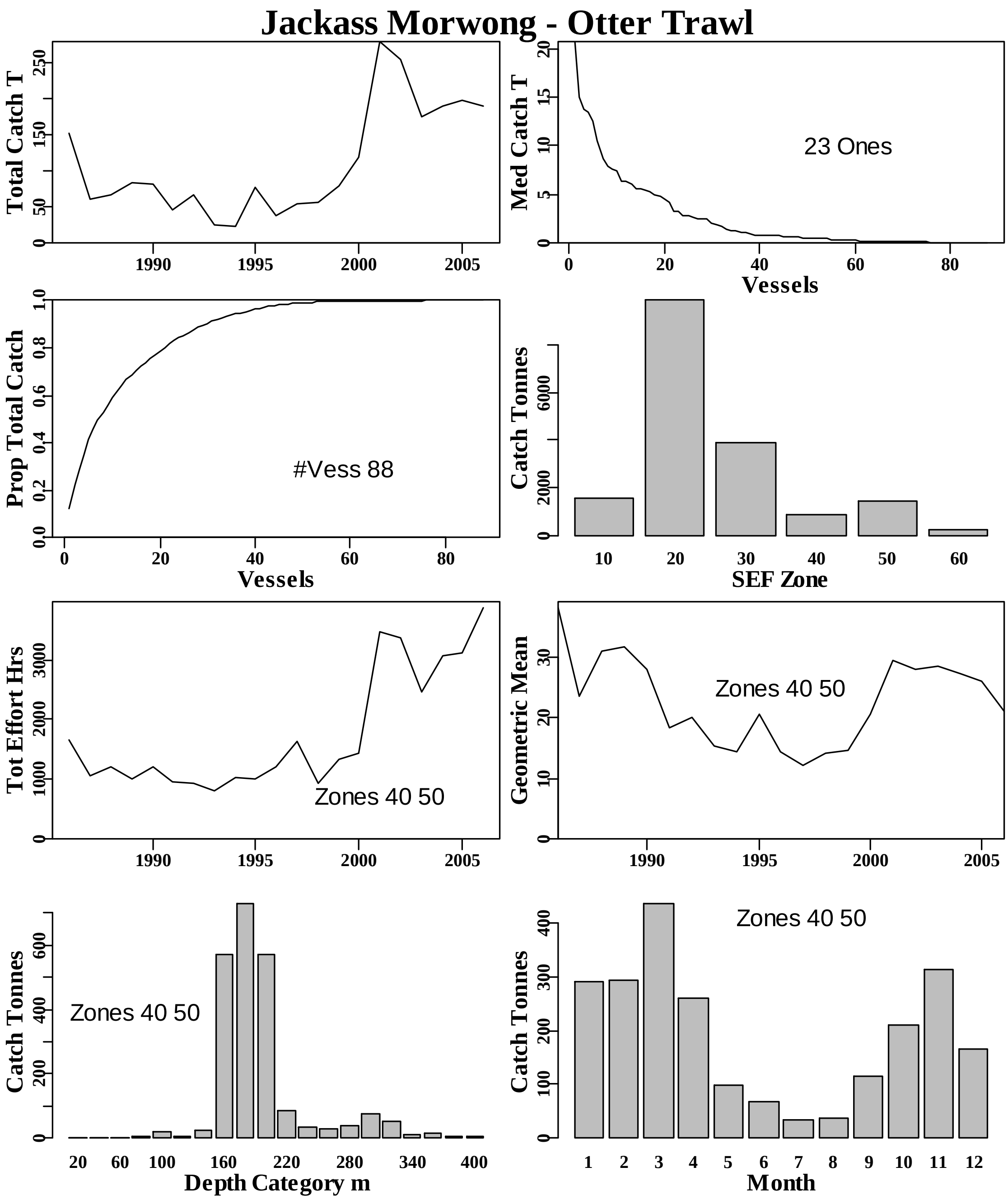
10
11
12
Month


Jackass Morwong - Otter Trawl
Total Catch T
Med Catch T
27 Ones
Vessels
Prop Total Catch
#Vess 92
Vessels
Catch Tonnes
SEF Zone
Tot Effort Hrs
Zone 30
Geometric Mean
Zone 30
Catch Tonnes
Depth Category m
Catch Tonnes
Zone 30
Month


Jackass Morwong - Otter Trawl
Total Catch T
Med Catch T
23 Ones
Vessels
Prop Total Catch
#Vess 88
Vessels
Catch Tonnes
SEF Zone
Tot Effort Hrs
Zones 40 50
Geometric Mean
Zones 40 50
Catch Tonnes
Zones 40 50
Depth Category m
Catch Tonnes
Zones 40 50
Month

6. Standardized Commercial Catch-Effort data for selected Shelf and Slope Assessment Group Species for 1986 - 2006

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6.1 Introduction

The catch and effort data available from the AFMA log-book database for the South East and Southern Shark Fishery (SESSF) derives from a wide range of zones (areas), vessels, months, depths, and fishing gears. All of this information has now been successfully transferred to an Access database held at CSIRO Hobart; all analyses in this report are based upon a copy of this CSIRO database.

It is well known that catch-rates can be affected by many factors (plus others unfortunately not recorded in the database). If the range of vessels that fish, or the areas and depths that are fished, vary from year to year, or the season of maximum fishing varies from year to year, we may observe changes in catch-effort which have nothing to do with changes in the stock biomass. Rather, such changes would be related to fleet dynamics and the distribution of fishing effort. We should therefore not simply average the available data to obtain representative catch-effort figures through time. Instead we should attempt to determine catch-effort figures standardized in terms of the factors depth, fishing zone, month, day-night and fishing vessel. After standardization, the catch-effort data should then provide a better indication of the relative status of the stock upon which the fishery is based. In effect, standardization acts to remove the effects, or at least reduce the obscuring effects, of the factors being included in the standardization (e.g. depth, season, zone, etc). Once the effects of these factors have been neutralized the remaining variation, or at least that associated with a year factor, should provide a better representation of the relative changes in catch rates through time.

As Kimura (1981, p211) says: “Since the 1950s it has been recognized that fishing power generally differs among vessels, and if c.p.u.e. is to be proportional to abundance, effort measurements must be standardized.” The most commonly used method of standardization is to include the various factors thought to effect catch rates into a generalized linear model and to include Year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Vignaux, 1992, 1993; Klaer, 1994).

We can only standardize using factors for which there is data available. It would be highly desirable, for example, to standardize for changes to the ability of fishing vessels to detect fish e.g. colour echo-sounders, improved engine and net technology. However, in the absence of information regarding when each vessel improved its technological support, we cannot include these factors into the standardization.

After standardization we are left with a set of yearly coefficients that represent the catch rate relative to some reference year (usually the first or last in the time series). Unfortunately, even if the standardization accounts for a large proportion of the variability in the data there are no guarantees that catch effort, even standardized catch effort, can act as a good proxy for stock size. Instead of the success of the standardization, one should be able to argue from the nature of the fishery and the species concerned whether or not there is likely to be even an approximate relationship between catch rates and stock size. This is an area of great debate and interest. An obvious question to ask is whether the inferences it is possible to draw from the catch effort information are consistent with the implications of the catch-at-age data. When both data types are consistent then confidence tends to be increased in the assessment. If the different data are inconsistent then it becomes clear that some form of uncertainty is not being accounted for in the modelling or data collection.

6.2 General Methods

As in previous years generalized linear models were fitted to different combinations of various factors for which information was available (year, month, depth category, vessel, daynight, and zone). Some of the interaction terms between various factors were also considered. These were limited to those combinations for which sensible interpretations could be ascribed; such as zone x month, which would relate to seasonal movement of effort between zones. In all cases SAS version 9.1.3 was used to generate the GLMs from which the standardizations are derived. This prevented any problems with computer memory limitations that could have arisen because of the large number of observations available (sometimes 100s of thousands of records).

All catch rates were log-transformed and a General Linear Model was used rather than using a Generalized Linear Model with a log-link; this has advantages in terms of normalizing the data while stabilizing the variance, which the Generalized Linear Model approach does not always achieve appropriately (Venables & Dichmont, 2004).

All factors are treated as dummy variables and the factors used in the various species and GLMs were:

Vessel – unique vessel identifier. In addition, a flag was present to enable Danish Seine vessels to be distinguished from trawlers.

Year – was the calendar year, or in some species a fishing year (from May 1st to April 30th). The parameters for this factor, once back-transformed from the logarithmic form, are used as the index of relative abundance in the assessment models. If a fishing year period is used then FYear is used as the variable name.

Month – was the ordinary calendar month

DepCat – depth category - a set of depth categories (for some species this was sometimes truncated at some given minimum and/or maximum depth to avoid unlikely data).

Zone – was a standard set of regions for each species, generally these were the same as in previous years (zones 10, 20, to 60).

DayNight – was a code that distinguished between whether the fishing was conducted mostly during daylight hours or during the dark hours. There were four categories, U unknown, M – mixed, D for daytime, N for night-time.
Weeknum was used with the Blue Grenadier spawning fishery, which only lasts about 12 weeks.

For the standardizations not all data records were always used. It was standard to use only those vessels active in the fishery for more than two years. The specific details of the selection criteria are given in the results for each species. The number of observations available in each year for each species for each analysis was also listed. In all cases the selection used provided a working solution.

It should be noted that the output from a GLM does not guarantee that a relation exists between stock size and standardized catch per unit effort. It is possible that factors not included in the GLM model (through no information being available) may be obscuring any effects of changes in stock biomass. In this case, however, there are no other data available to be included in the statistical models so the potential analyses are thus limited.

The statistical models used all have a form akin to:

LnCE = const+ year+ month+ zone + DepCat + Vessel + zone*month

which can contain single factors like zone, and interaction terms like zone*month.

6.2.1 The Statistical Models

It is possible to define the so-called 'full model' for the set of factors being considered. This would include all of the factors and the entire set of interaction terms possible between them. It would be difficult to provide a real interpretation for some of the interaction terms possible and their value in describing the data would be marginal. However, there is no doubt that the more parameters used in a statistical model the more likely we are to describe a larger proportion of the variation in the available data. But just adding more and more parameters to a model is not necessarily an improvement when parameter correlation exists. What is required is a compromise between the variability of the data described by the statistical model and its complexity. One way of selecting such a compromise is the use of the Akaike's Information Criterion (AIC). This is usually based around a maximum likelihood framework but, in the special case of a least squares estimation with normally distributed additive errors, the AIC can be expressed as:

$$\boldsymbol{AIC} = \boldsymbol{nLn}\left(\hat{\sigma}^2\right) + 2\boldsymbol{K}$$

where

$$\hat{\sigma}^2 = \frac{\sum \varepsilon^2}{\boldsymbol{n}}$$

is the maximum likelihood estimator of σ^2, ε^2 is the estimated sum of squared residuals for the candidate model, K is the total number of estimated parameters, including the intercept and σ^2, and n is the total number of observations (Burnham & Anderson, 1998). The criterion is selected which gives rise to the smallest AIC. In addition, the analyses were usually terminated when the impact of adding new factors or interactions had no visual affect on the yearly parameters derived from the GLMs. This was estimated more precisely by calculating the squared residual difference between each sequential statistical model. As this deviance estimate became very small additional factors made very little effect on the trends expressed by the yearly parameter estimates.

The parameters associated with the Year factor (treated as a categorical factor) represent the estimates of the standardized CPUE for each year on a natural log scale. To transform these back into a linear scale an exponential transformation is used, which includes a bias correction:

$$Y_t = e^{y_t + \sigma^2/2}$$

where

Y_t is the yearly index for year *t*,
y_t is the log-scale yearly parameter for year *t* from the general linear model, and
σ^2 is the estimated standard error for y_t.

6.3 Results

6.3.1 School Whiting (WHS - 37330014 - Sillago flindersi)

A phone hook up of the SHELF RAG, held on 12th June 2007, determined the following conditions for the analysis:
Danish Seine vessels only
Zone 60 only,
3 or more years in the fishery,
No limitation on median catch
<=100m depth
Effort as shot.

The need to use shot records as a measure of effort was decided to allow for the lack of information from early on in the fishery, when effort as hours was often imputed as 1.5 hours. No inter-species interactions were specified. With all data included there were 70,155 record and with the data restrictions above there were 68,334 records. Thus, 97.4% of records were used accounting for 97.3% of catches.

Table 6.1. Number of records used in the CPUE standardization for School Whiting in each year for Danish Seiners only, years in the fishery >2, CE >0, Average Depth <= 100m, and only Zones 60. The geometric mean and the optimum model (see Figure 6.1) are relative to 1986.

Year	Records Used	Geometric Mean (Model1)	Model 6
1986	5074	1.0000	1.0000
1987	3947	1.1479	1.1095
1988	3629	1.5021	1.4580
1989	4315	1.1118	0.9355
1990	6076	1.4490	1.4555
1991	4499	1.4556	1.2970
1992	2905	1.0741	0.9027
1993	4486	1.3356	1.2524
1994	4499	0.8235	0.7415
1995	4340	1.0794	0.9547
1996	4430	0.7199	0.6324
1997	3499	0.5703	0.4765
1998	3020	0.5656	0.4662
1999	2182	0.7654	0.5419
2000	2026	0.5770	0.5479
2001	2094	0.8277	0.7654
2002	2181	0.7822	0.8141
2003	2155	0.7580	0.7939
2004	1722	0.7021	0.8142
2005	1679	0.7176	0.8568
2006	1397	0.6595	0.7288

Six statistical models were considered for the data from School Whiting (Table 6.2). Model 1 represents the geometric mean catch rates and Model 6 is the optimum model. (Table 6.1; Figure 6.1).

Table 6.2. The structure of the six statistical models trialled with school whiting. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DayNight
model 4	Year Vessel DayNight Month
model 5	Year Vessel DayNight Month DepCat
model 6	Year Vessel DayNight Month DepCat Month*DepCat

The statistical outcomes for each model show a steady increase in variability accounted for by the various models (Table 6.3). The optimum model was Model 6 (Table 6.1; Figure 6.1).

Table 6.3. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 6, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	**68334**	**0.0480**	**20**	**68313**	**6852**	**135897**	**21**	**47021**
Model 2	68334	0.0786	52	68281	11222	131526	53	44851
Model 3	68334	0.1018	55	68278	14537	128211	56	43113
Model 4	68334	0.1231	66	68267	17574	125175	67	41497
Model 5	68334	0.1276	75	68258	18221	124528	76	41161
Model 6	**68334**	**0.1372**	**162**	**68171**	**19589**	**123159**	**163**	**40579**

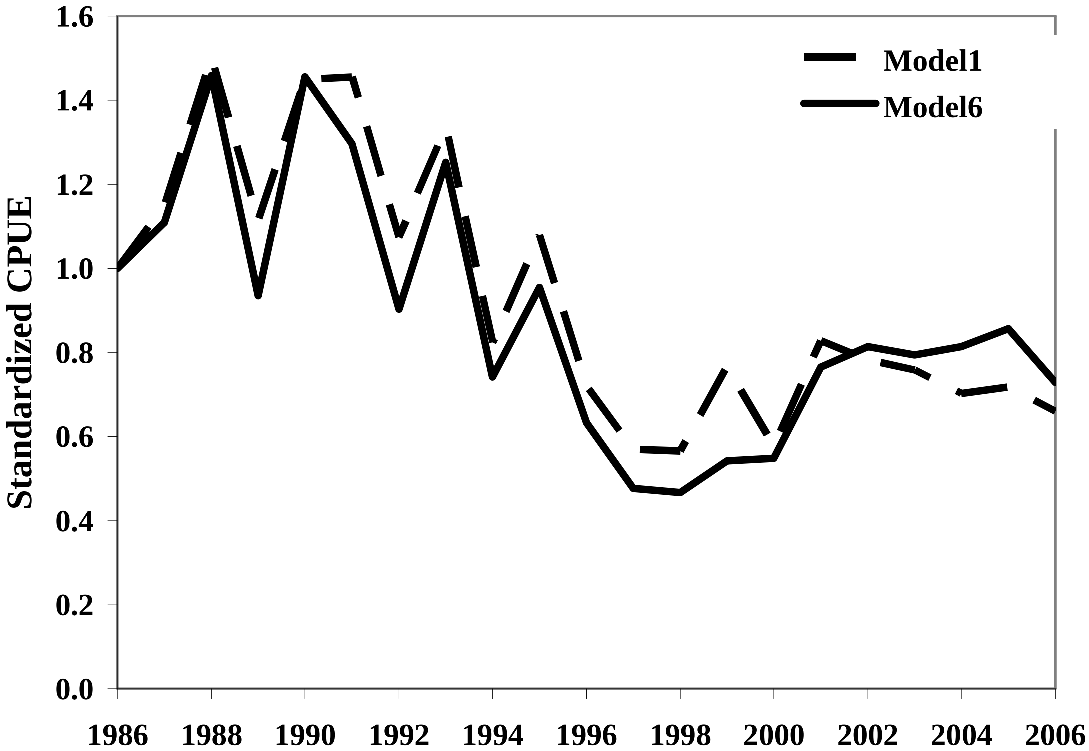

Figure 6.1. The standardized catch per unit of effort per year for school whiting relative to catch rates in 1986, as represented by the geometric mean (model 1 - dashes) the optimal model (model 6 – solid line). Model descriptions in Table 6.2.

6.3.2 Eastern Gemfish (GEM - 37439002 - Rexea solandri)

A phone hook up of the SHELF RAG, held on 12th June 2007, determined there were to be separate analyses made for the spawning period and for the non-spawning run:

6.3.2.1 Spawning Period (defined as bycatch)

Only use June through September from 1993 – 2006,
300-500m depth,
No limitation on median catch,
Catch effort > 0.0
3 or more years in the fishery,
Zones 10 - 30

There were a total of 12,084 records in the spawning fishery and, with the restriction above there were 11,743 records. Thus, 97.18% of records were used which accounted for 99.19% of the catches.

Table 6.4. Number of records used in the CPUE standardization for Eastern Gemfish in each year, years in the fishery >2, CE >0, Average Depth <= 100m, and only Zones 10, 20, and 30. The geometric mean and the optimum model (see Figure 6.1) are relative to 1986.

Year	Records Used	Geometric Mean (Model1)	Model 8
1986	2250		
1987	2375		
1988	1750		
1989	1413		
1990	1023		
1991	379		
1992	423		
1993	836	1.0000	1.0000
1994	827	0.6467	0.6515
1995	657	0.4091	0.4388
1996	786	0.6029	0.5617
1997	1233	1.0302	0.7605
1998	883	0.6353	0.5185
1999	1056	0.4691	0.4547
2000	1166	0.2712	0.3094
2001	831	0.2734	0.3211
2002	887	0.2056	0.2413
2003	939	0.2694	0.3412
2004	606	0.2636	0.3261
2005	618	0.2722	0.2922
2006	560	0.4453	0.4584

Eight statistical models were considered for the data from Eastern Gemfish (Table 6.5). Model 1 represents the geometric mean catch rates and Model 8 is the optimum model. (Table 6.6; Figure 6.1).

Table 6.5. The structure of the eight statistical models trialled with Eastern Gemfish (Spawning Run). The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DayNight
model 4	Year Vessel DayNight Month
model 5	Year Vessel DayNight Month DepCat
model 6	Year Vessel DayNight Month DepCat Zone
model 7	Year Vessel DayNight Month DepCat Zone DepCat*Month
model 8	Year Vessel DayNight Month DepCat Zone DepCat*Month Zone*Month

The statistical outcomes for each model show a steady increase in variability accounted for by the various models (Table 6.6). The optimum model was Model 8 (Table 6.6; Figure 6.1).

Table 6.6. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	**11743**	**0.1413**	**13**	**11729**	**3232**	**19636**	**14**	**6065**
Model 2	11743	0.2435	96	11646	5568	17304	97	4746
Model 3	11743	0.2458	99	11643	5622	17250	100	4715
Model 4	11743	0.2918	102	11640	6674	16198	103	3982
Model 5	11743	0.3162	112	11630	7232	15639	113	3590
Model 6	11743	0.3167	114	11628	7244	15628	115	3586
Model 7	11743	0.3229	144	11598	7385	15487	145	3539
Model 8	**11743**	**0.3338**	**150**	**11592**	**7633**	**15238**	**151**	**3361**

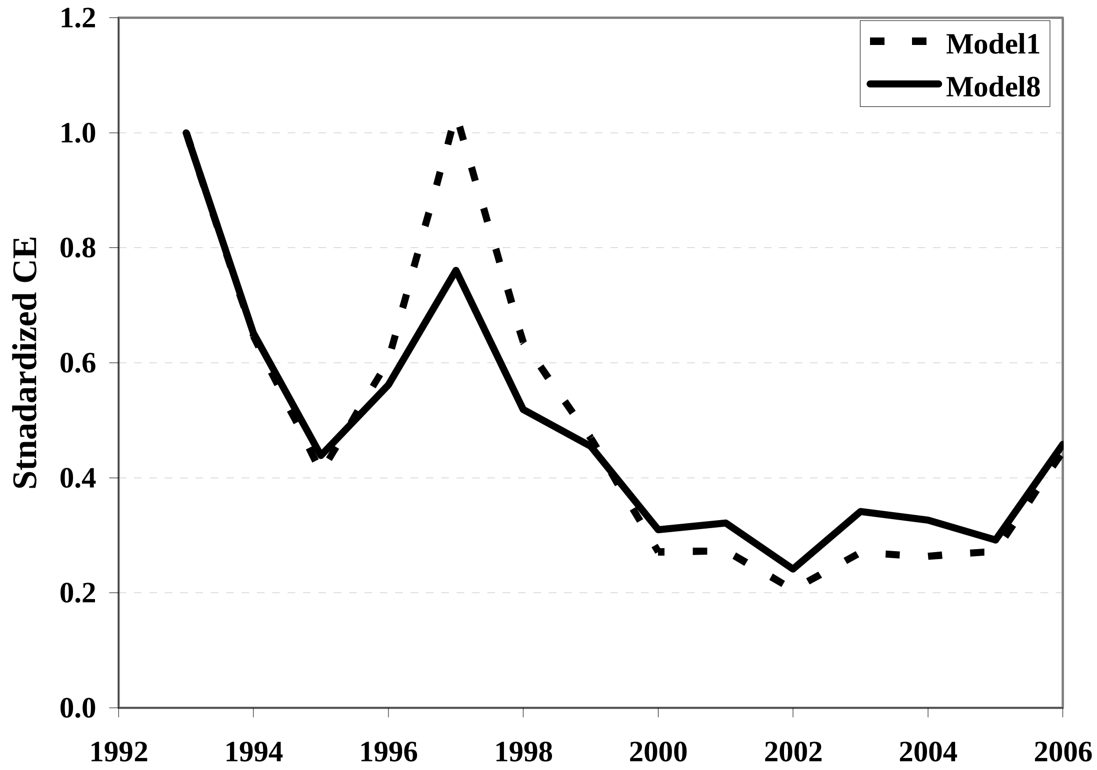

Figure 6.2. The standardized catch per unit of effort per year for Eastern Gemfish (Spawning Run) relative to catch rates in 1993, as represented by the geometric mean (model 1 - dashes) the optimal model (model 8 – solid line). Model descriptions in Table 6.5.

6.3.2.2 Non-Spawning Run

All records not in the spawning run June – September <300m
Use October to May 1986-2006, all depths,
June to September, < 300m depth,
No limitation on median catch,
3 or more years in the fishery,
Zones 10 – 30.

There were a total of 32,888 records in the spawning fishery and, with the restriction above there were 17,923 records. Thus, 54.5% of records were used which accounted for 67.02% of the catches.

Table 6.7. Number of records used in the CPUE standardization for the non-spawning run fishery for Eastern Gemfish in each year, years in the fishery >2, CE >0, Average Depth <= 100m, and only Zones 10, 20, and 30. The geometric mean and the optimum model (see Figure 6.1) are relative to 1986.

Year	Records Used	Geometric Mean (Model1)	Model 8
1986	1052	1.0000	1.0000
1987	1296	1.7969	1.4300
1988	1498	1.0554	1.1042
1989	908	0.5507	0.5956
1990	417	0.5657	0.5523
1991	349	0.6094	0.5465
1992	389	0.8224	0.6975
1993	784	0.5900	0.4972
1994	840	0.4072	0.3380
1995	890	0.3724	0.3181
1996	1108	0.2777	0.2557
1997	1079	0.2775	0.2605
1998	690	0.2962	0.2527
1999	716	0.2223	0.2002
2000	973	0.1841	0.1628
2001	797	0.1350	0.1306
2002	807	0.1078	0.1037
2003	690	0.1117	0.1038
2004	923	0.1632	0.1552
2005	937	0.1907	0.1814
2006	780	0.1719	0.1627

Eight statistical models were considered for the data from Eastern Gemfish (Non-spawning run) (Table 6.8). Model 1 represents the geometric mean catch rates and Model 8 is the optimum model. (Table 6.9; Figure 6.1).

Table 6.8. The structure of the eight statistical models trialled with Eastern Gemfish (non-spawning run). The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DayNight
model 4	Year Vessel DayNight Month
model 5	Year Vessel DayNight Month DepCat
model 6	Year Vessel DayNight Month DepCat Zone
model 7	Year Vessel DayNight Month DepCat Zone DepCat*Month
model 8	Year Vessel DayNight Month DepCat Zone DepCat*Month Zone*Month

The statistical outcomes for each model show a steady increase in variability accounted for by the various models (Table 6.9). The optimum model was Model 8 (Table 6.9; Figure 6.1).

Table 6.9. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	**17923**	**0.2805**	**20**	**17902**	**12039**	**30875**	**21**	**9790**
Model 2	17923	0.3713	137	17785	15934	26980	138	7607
Model 3	17923	0.3833	140	17782	16451	26464	141.0	7267
Model 4	17923	0.3952	151	17771	16691	25953	152.0	6939
Model 5	17923	0.4165	166	17756	17875	25039	167	6327
Model 6	17923	0.4181	168	17754	17942	24972	169	6283
Model 7	17923	0.4295	311	17611	18430	24484	312	6215
Model 8	**17923**	**0.4354**	**332**	**17590**	**18685**	**24229**	**333**	**6069**

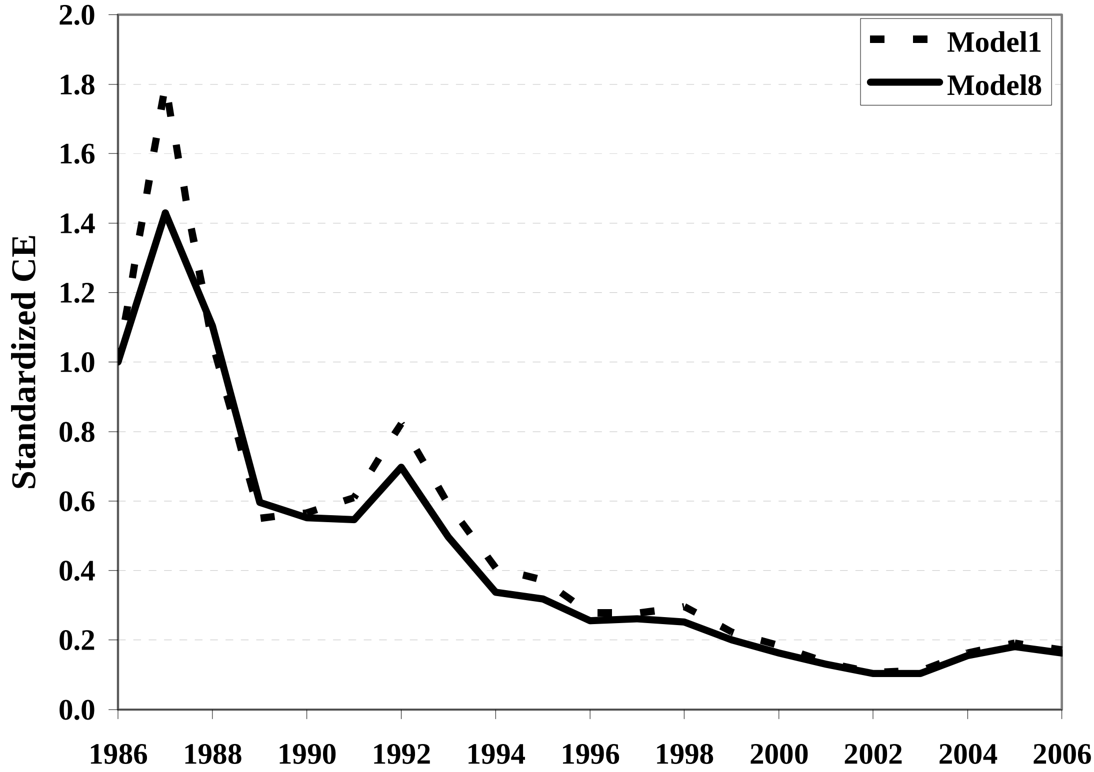

Figure 6.3. The standardized catch per unit of effort per year for Eastern Gemfish (non-spawning run) relative to catch rates in 1986, as represented by the geometric mean (model 1 - dashes) the optimal model (model 7 – solid line). Model descriptions in Table 6.8.

6.3.3 Jackass Morwong Zones 10, 20 (MOR - 37377003 - Nemadactylus macropterus)

Three standardizations were made to match the assessment; 1) Zones 10 and 20 for otter trawl, Zone 30 for otter trawl, and zones 40 and 50 for otter trawl.

The data restrictions used in selecting the data for analysis were:
Only data from zone 10 and 20 were used, with no limit on median catch,
three or more years in the fishery,
catch rates greater than zero,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths between 70 and 300 m.

With the conditions above there were 94,227 records available for analysis for Jackass Morwong taken by trawl in zones 10 and 20. With no restrictions years in the fishery and depth there would be 107,759 records. Thus, 87.44% of available records are used and these represent 90.75% of all catches (Table 6.10).

Table 6.10. Number of records used in the CPUE standardization in each year for Jackass Morwong from trawls only, years in the fishery >2, CE >0, Average Depth >=70 m and <=300 m, and only zones 10 and 20. The geometric mean (Model 1) and the optimum model (see Figure 6.3) are relative to 1986.

Year	Records	Model1	Model8
1986	4072	1.0000	1.0000
1987	4200	1.2299	1.1781
1988	5063	1.2813	1.1118
1989	4416	1.2881	1.0732
1990	4162	1.0249	0.8990
1991	4699	0.9195	0.8519
1992	3019	0.8196	0.6550
1993	3377	0.8403	0.7058
1994	4439	0.7606	0.6008
1995	4557	0.6671	0.5840
1996	6152	0.5935	0.5197
1997	5971	0.7141	0.5679
1998	4724	0.5553	0.4773
1999	4332	0.5748	0.4989
2000	5373	0.4591	0.4008
2001	4629	0.3135	0.2848
2002	5255	0.3347	0.3215
2003	4311	0.2902	0.2588
2004	3976	0.2828	0.2491
2005	4171	0.3427	0.2873
2006	3329	0.4325	0.3395

Eight statistical models were considered for the Jackass Morwong data from trawl vessels in Zones 10 and 20 (Table 6.11). Model 1 represents the overall geometric mean and Model 8 is the optimum model (Table 6.10, Table 6.12; Figure 6.4).

Table 6.11. The factors involved in each of the eight statistical models trialled with Jackass Morwong from trawlers in Zones 10 and 20. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel Daynight
model 4	Year Vessel Daynight Month
model 5	Year Vessel Daynight Month DepCat
model 6	Year Vessel Daynight Month DepCat Zone
model 7	Year Vessel Daynight Month DepCat Zone Month*DepCat
model 8	Year Vessel Daynight Month DepCat Zone Month*DepCat Zone*Month

Table 6.12. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
Model1	**94227**	**0.1125**	**20**	**94206**	**22147**	**174649**	**21**	**58186.79**
Model2	94227	0.2404	134	94032	47301	149495	135	43761.05
Model3	94227	0.2436	137	94089	47935	148861	138	43366.59
Model4	94227	0.2634	148	94078	51833	144962	149	40887.68
Model5	94227	0.2721	159	94067	53567	143229	160	39776.42
Model6	94227	0.2858	160	94066	56245	140551	161	37999.95
Model7	94227	0.2969	281	93945	58436	138360	282	36761.51
Model8	**94227**	**0.3011**	**292**	**93934**	**59253**	**137543**	**293**	**36225.46**

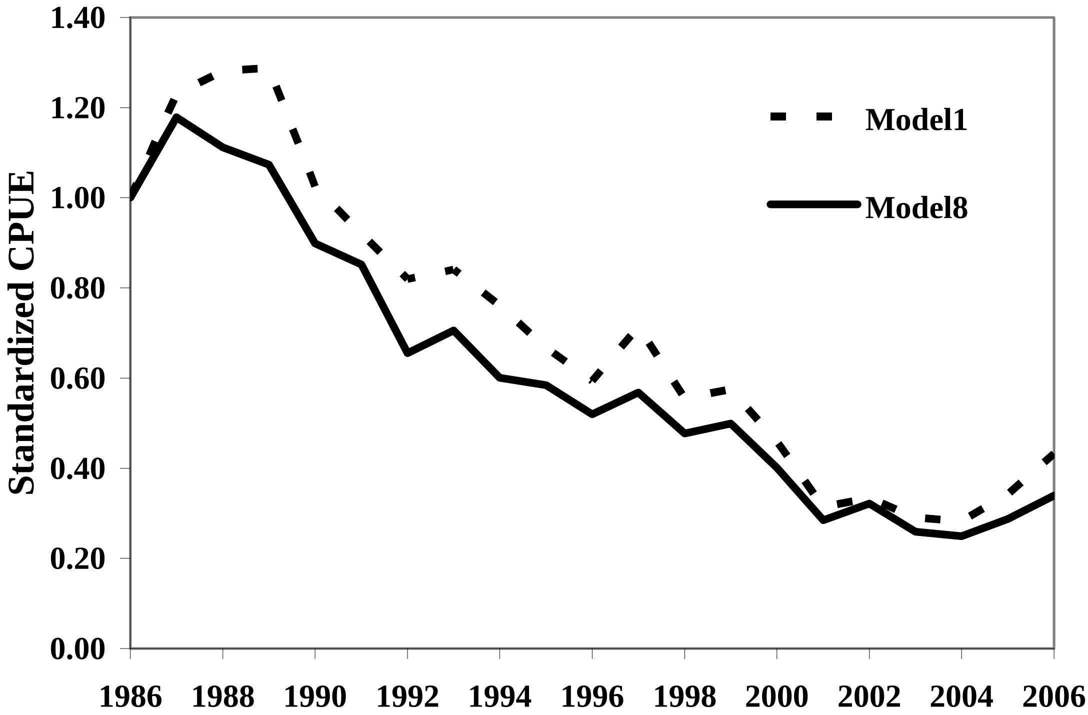

Figure 6.4. The standardized catch per unit of effort per year for Jackass Morwong taken by trawl vessels in Zones 10 and 20, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (model 8 – solid line) (see Table 6.10 for parameter values).

6.3.4 Jackass Morwong Zone 30 (MOR - 3737700 - Nemadactylus macropterus)

The data restrictions used in selecting the data for analysis were:

Only data from zone 30 were used, with no limit on median catch,
three or more years in the fishery,
catch rates greater than zero,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths between 70 and 300 m.

With the conditions above there were 41,284 records available for analysis for Jackass Morwong taken by trawl in zone 30. With no restrictions years in the fishery and depth there would be 60,245 records. Thus, 68.53% of available records are used and these represent 80.47% of all catches (Table 6.13).

Table 6.13. Number of records used in the CPUE standardization in each year for Jackass Morwong from trawls only, years in the fishery >2, CE >0, Average Depth >=70 m and <=300 m, and only zone 30. The geometric mean (Model 1) and the optimum model (see Figure 6.5) are relative to 1986.

Year	Records	Model1	Model8
1986	1013	1.0000	1.0000
1987	1217	1.3957	1.4261
1988	2149	1.2061	1.1940
1989	1914	1.4649	1.3670
1990	1632	0.9164	0.9204
1991	1750	0.8465	0.8047
1992	1550	0.7087	0.6566
1993	1652	0.7554	0.6667
1994	2367	0.5473	0.4526
1995	2183	0.5202	0.4648
1996	2449	0.5144	0.4398
1997	2849	0.6204	0.5017
1998	1952	0.5093	0.4256
1999	2086	0.4863	0.4594
2000	2706	0.4140	0.3810
2001	1858	0.2556	0.2364
2002	2016	0.2570	0.2479
2003	2252	0.2242	0.2191
2004	1787	0.2400	0.2187
2005	2071	0.2814	0.2475
2006	1831	0.3393	0.3031

Six statistical models were considered for the Jackass Morwong data from trawl vessels in Zone 30 (Table 6.14). Model 1 represents the overall geometric mean and Model 6 is the optimum model (Table 6.13, Table 6.15; Figure 6.4).

Table 6.14. The factors involved in each of the six statistical models trialled with Jackass Morwong from trawlers in Zone 30. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel Daynight
model 4	Year Vessel Daynight Month
model 5	Year Vessel Daynight Month DepCat
model 6	Year Vessel Daynight Month DepCat Month*DepCat

Table 6.15. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 6, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
Model1	**41284**	**0.1317**	**20**	**41263**	**12469**	**82235**	**21**	**28491**
Model2	41284	0.1661	59	41224	15734	78969	60	26896
Model3	41284	0.1723	62	41221	16316	78387	63	26597
Model4	41284	0.2182	73	41210	20660	74043	74	24265
Model5	41284	0.2243	84	41199	21244	73460	85	23961
Model6	**41284**	**0.2370**	**205**	**41078**	**22445**	**72258**	**206**	**23521**

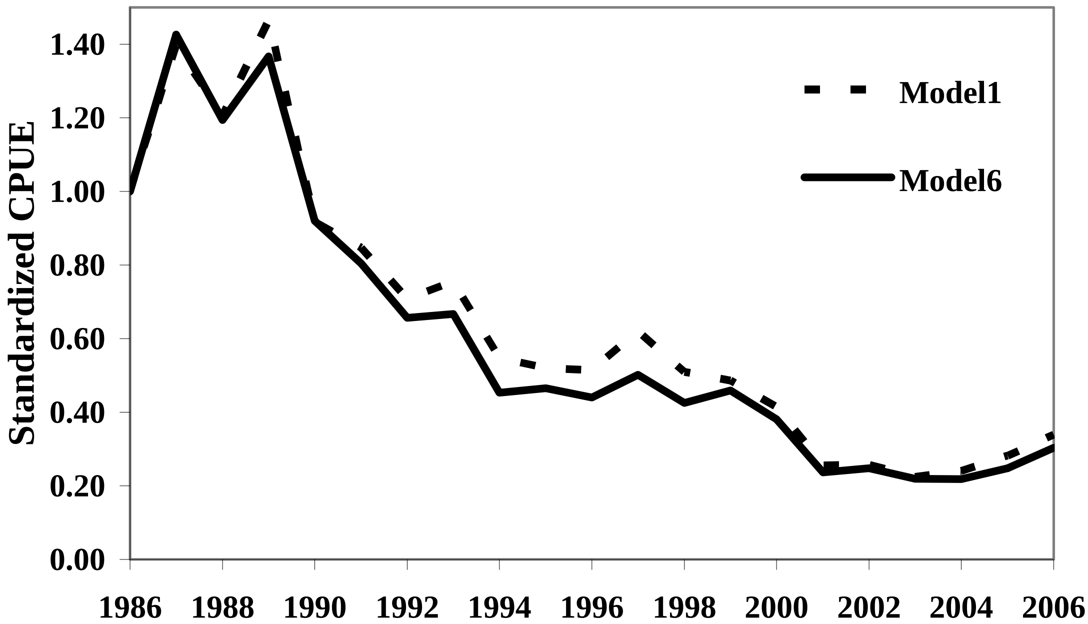

Figure 6.5. The standardized catch per unit of effort per year for Jackass Morwong taken by trawl vessels in Zone 30, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (model 6 – solid line) (see Table 6.13 for parameter values).

6.3.5 Jackass Morwong Zone 40 & 50 OT (MOR - 37377003 - N. macropterus)

The data restrictions used in selecting the data for analysis were:

Only data from zones 40 and 50 were used, with no limit on median catch,
three or more years in the fishery,
catch rates greater than zero,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths between 70 and 360 m.

With the conditions above there were 9,711 records available for analysis for Jackass Morwong taken by trawl in zones 40 and 50. With no restrictions on years in the fishery and depth there would be 11,203 records. Thus, 86.68% of available records are used and these represent 92.86% of all catches (Table 6.16). This large drop in records is because there were many vessels that only fished for one or two years.

Table 6.16. Number of records used in the CPUE standardization in each year for Jackass Morwong from Otter Trawls only, years in the fishery >2, CE >0, Average Depth >=70 m and <= 360 m, and only zones 40 and 50. The geometric mean (Model 1) and the optimum model (see Figure 6.6) are relative to 1986.

Year	Records	Model1	Model8
1986	364	1.0000	1.0000
1987	313	0.5198	0.6661
1988	404	0.6478	0.9620
1989	339	0.6557	0.7581
1990	405	0.5583	0.6757
1991	291	0.3490	0.4631
1992	284	0.3649	0.4450
1993	245	0.3237	0.3461
1994	311	0.3066	0.3460
1995	291	0.4375	0.3755
1996	336	0.3123	0.3927
1997	475	0.2677	0.3404
1998	266	0.3144	0.3569
1999	383	0.3259	0.3661
2000	390	0.4398	0.4309
2001	888	0.7335	0.4689
2002	857	0.6732	0.3988
2003	661	0.6127	0.3485
2004	686	0.5728	0.4104
2005	720	0.5441	0.4387
2006	801	0.4400	0.3606

Eight statistical models were considered for the Jackass Morwong data from trawl vessels in Zones 40 and 50 (Table 6.17). Model 1 represents the overall geometric mean and Model 8 is the optimum model (Table 6.16, Table 6.18; Figure 6.7).

Table 6.17. The factors involved in each of the eight statistical models trialled with Jackass Morwong from trawlers in Zones 40 and 50. The factor names are as listed in Section 6.2.

Model	**Factors**
model 1	Year
model 2	Year Vessel
model 3	Year Vessel Daynight
model 4	Year Vessel Daynight Month
model 5	Year Vessel Daynight Month DepCat
model 6	Year Vessel Daynight Month DepCat Zone
model 7	Year Vessel Daynight Month DepCat Zone Month*DepCat
model 8	Year Vessel Daynight Month DepCat Zone Month*DepCat Zone*Month

Table 6.18. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	**N**	**Var%**	**df Params**	**df Resids**	**Model SS**	**Resid SS**	**# Param**	**AIC**
Model1	9711	0.052	20	9690	1084	19785	21	6953
Model2	9711	0.1431	71	3939	2987	17882	72	6073
Model3	9711	0.2073	74	9636	4325	16544	75	5324
Model4	9711	0.2551	85	9625	5323	15546	86	4741
Model5	9711	0.3386	99	9611	7066	13804	100	3615
Model6	9711	0.3416	100	9610	7129	13740	101	3572
Model7	9711	0.3904	251	9459	8147	12722	252	3127
Model8	9711	0.403	262	9448	8411	12458	263	2945

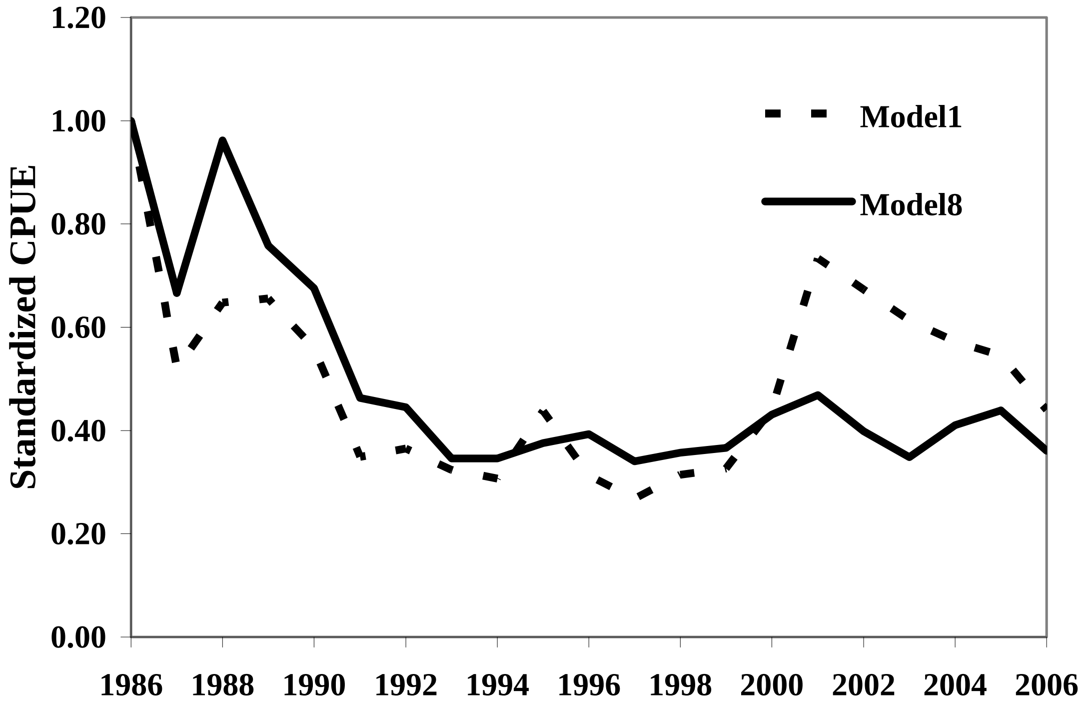

Figure 6.6. The standardized catch per unit of effort per year for Jackass Morwong taken by Otter Trawl vessels in Zones 40 and 50, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (model 8 – solid line) (see Table 6.16 for parameter values).

6.3.6 Flathead Otter Trawl (FLT – 37296001 – Neoplatycephalus richardsoni)

The data restrictions used in selecting the data for analysis were:

Only data from zones 10, 20, and 60 were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 400 m.

There were a total of 265,083 records available for flathead taken by otter trawl. With the restrictions above there are 229,677 records. Thus, 86.6% of available records are used and these represent 90.2% of all catches (Table 6.19).

Table 6.19. Number of records used in the CPUE standardization in each year for trawlers only, years in the fishery >2, CE >0, Average Depth < 400m, and only zones 10, 20, and 30. The geometric mean (Model 1) and the two optimum models (see Figure 6.7) are relative to 1986. Model 7 is the optimum model without the influence of other species in the catch.

Year	Records	Model 1	Model 7
1986	8679	1.0000	1.0000
1987	8051	1.3326	1.3754
1988	9370	1.4950	1.4753
1989	9497	1.4990	1.4182
1990	8142	1.8832	1.7182
1991	8920	1.7499	1.5426
1992	7786	1.5211	1.3079
1993	9844	1.4717	1.2808
1994	11114	1.1262	0.9562
1995	11066	1.1519	0.9911
1996	11774	1.0428	0.8887
1997	11155	1.0840	0.8921
1998	10707	1.1584	0.9454
1999	11189	1.3271	1.1040
2000	13037	1.4410	1.2032
2001	12702	1.3640	1.1658
2002	14032	1.5256	1.3115
2003	15020	1.5576	1.3068
2004	14530	1.5192	1.2345
2005	12296	1.3523	1.0648
2006	10766	1.6511	1.2301

Seven statistical models were considered for the flathead data from trawlers (Table 6.20). Model 1 represents the overall geometric mean and Model 7 is the optimum model (Table 6.21).

Table 6.20. The factors involved in each of the six statistical models trialled with flathead from trawlers. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel Zone
model 4	Year Vessel Zone DepCat
model 5	Year Vessel Zone DepCat Month
model 6	Year Vessel Zone DepCat Month DayNight
model 7	Year Vessel Zone DepCat Month DayNight Zone*Month*DepCat

The statistical outcomes for each model show a steady increase in variability accounted for by the various models (Table 6.21). The optimum model was Model 7 (Table 6.21). The difference between these two optimal models is minor (Figure 6.7; Table 6.19 and Table 6.21).

Table 6.21. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 7, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	231266	0.0211	20	231245	6088	281611	21	45592
Model 2	231266	0.1322	153	231112	38029	249670	154	18016
Model 3	231266	0.1326	155	231110	38138	249561	156	17919
Model 4	229677	0.1581	175	229501	45169	240566	176	10991
Model 5	229677	0.1620	186	229490	46293	239441	187	9936
Model 6	229677	0.1624	189	229487	46400	239334	190	9839
Model 7	229677	0.2026	816	228860	57897	227837	817	-213

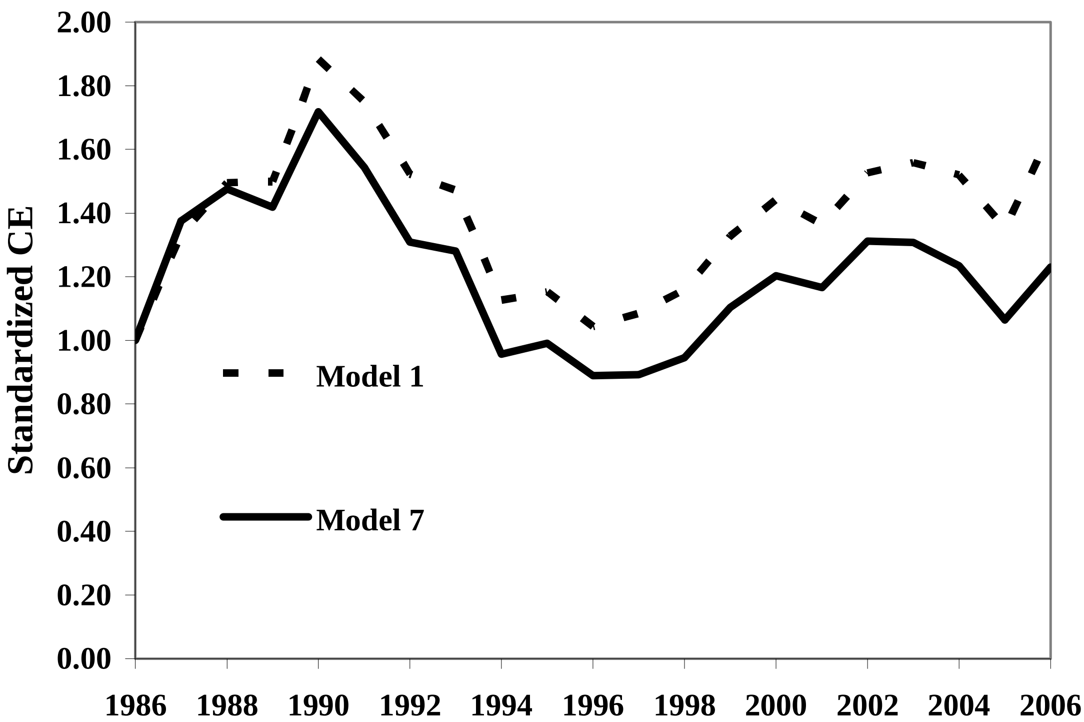

Figure 6.7. The standardized catch per unit of effort per year for flathead taken by trawl relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (model 7 – solid line (see Table 6.19 for parameter values).

6.3.7 Flathead Danish Seine (FLT – 37296001 – Neoplatycephalus richardsoni)

The data restrictions used in selecting the data for analysis were:

Only data from zones 20, and 60 were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for Danish Seine vessels only (i.e. exclude Otter Trawl vessels), and
depths less than 200 m.

There were a total of 138,517 records available for flathead taken by Danish Seine. With the restrictions above there are 109,106 records. Thus, 79.69% of available records are used and these represent 83.2% of all catches (Table 6.22).

Table 6.22. Number of records used in the CPUE standardization in each year for trawlers only, years in the fishery >2, CE >0, Average Depth < 200m, and only zones 20, and 60. The geometric mean (Model 1) and the two optimum models (see Figure 6.8) are relative to 1986. Model 7 is the optimum model without the influence of other species in the catch.

Year	Records	Model 1	Model 7
1986	4467	1.0000	1.0000
1987	5072	1.7847	1.3134
1988	5275	1.8531	1.4796
1989	5140	1.5844	1.2887
1990	4027	0.9758	0.8207
1991	3845	1.3932	1.0533
1992	5311	1.7817	1.1845
1993	4145	0.8122	0.7652
1994	5346	0.7722	0.6311
1995	4416	0.6897	0.6107
1996	6008	0.8083	0.7465
1997	7223	1.3597	0.9652
1998	8543	1.3905	0.7703
1999	6535	2.2417	1.1675
2000	6313	1.5152	0.8367
2001	6618	1.6054	0.8645
2002	6411	1.9822	0.9641
2003	4754	2.1951	1.0341
2004	3569	2.5421	1.1017
2005	3623	2.1771	1.0050
2006	2465	2.1828	0.9879

Seven statistical models were considered for the flathead data from Danish Seine vessels (Table 6.23). Model 1 represents the overall geometric mean and Model 7 is the optimum model (Table 6.24).

Table 6.23. The factors involved in each of the six statistical models trialled with flathead from trawlers. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel Zone
model 4	Year Vessel Zone DepCat
model 5	Year Vessel Zone DepCat Month
model 6	Year Vessel Zone DepCat Month DayNight
model 7	Year Vessel Zone DepCat Month DayNight Zone*Month*DepCat

The statistical outcomes for each model show a steady increase in variability accounted for by the various models (Table 6.24). The optimum model was Model 7 (Table 6.24). The difference between these two optimal models is minor (Figure 6.8; Table 6.22 and Table 6.24).

Table 6.24. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 7, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	110705	0.0582	20	110684	15267	247188	21	88969
Model 2	110705	0.1108	53	110651	29084	233371	54	82667
Model 3	110705	0.2533	54	110650	66476	195979	55	63338
Model 4	109106	0.3794	64	109041	98163	160598	65	42309
Model 5	109106	0.4241	75	109030	109738	149023	76	34169
Model 6	109106	0.4412	78	109027	114162	144599	79	30887
Model 7	109106	0.4661	281	108824	120599	138162	282	26325

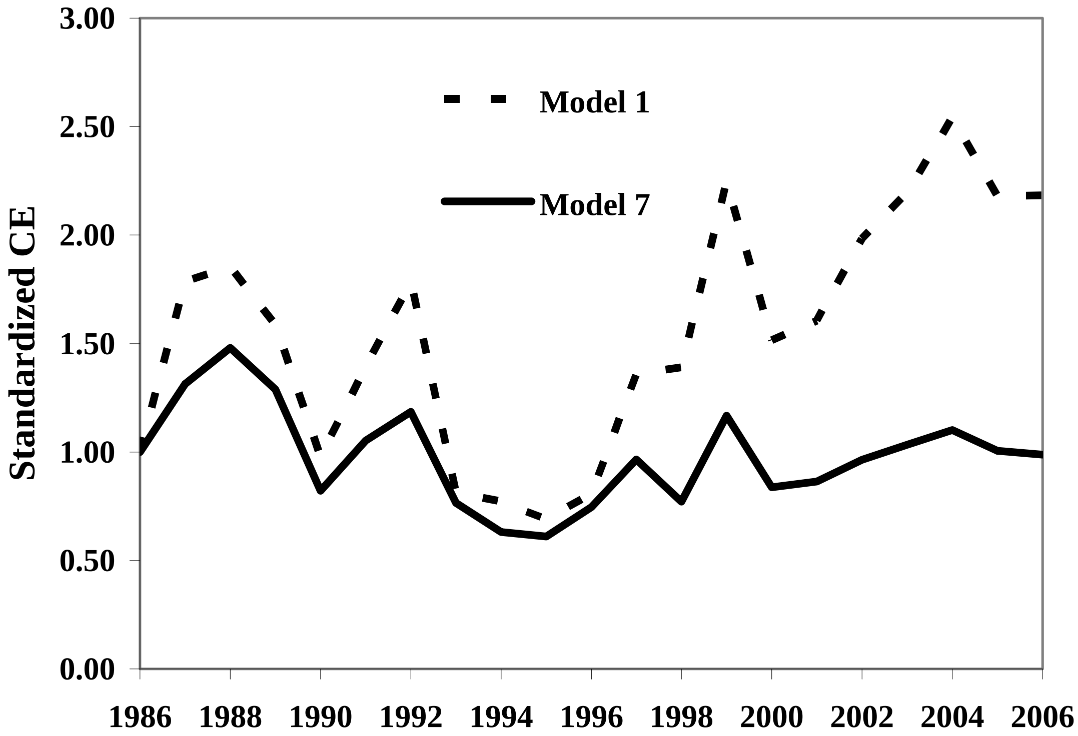

Figure 6.8. The standardized catch per unit of effort per year for flathead taken by trawl relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (model 7 – solid line (see Table 6.22 for parameter values).

6.3.8 RedFish Zone 10 (RED – 37258003 – Centroberyx affinis)

The data restrictions used in selecting the data for analysis were:

Only data from zone 10 were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 400 m.

With no restrictions except zone 10 and trawlers there were 67,425 records available for analysis for Redfish. With the restrictions listed above there were 62,931 records. Thus, 93.3% of available records are used and these represent 95.05% of all catches (Table 6.25).

Table 6.25. Number of records used in the CPUE standardization in each year for Redfish from trawls only, years in the fishery >2, CE >0, Average Depth < 400m, and only zones 10. The geometric mean (Model 1) and the optimum model (see Figure 6.9) are relative to 1986.

Year	Records	Model1	Model6
1986	3877	1.0000	1.0000
1987	3133	0.9155	0.7795
1988	2944	0.9329	0.8258
1989	2154	0.7416	0.6759
1990	1901	0.9586	0.9522
1991	2669	0.9547	0.9781
1992	2627	1.2574	1.3101
1993	3157	1.3248	1.5522
1994	4304	0.9008	1.1073
1995	4406	0.6934	0.7088
1996	3991	0.6793	0.6094
1997	2900	0.8591	0.7068
1998	3040	1.1137	0.8762
1999	2984	0.8389	0.6750
2000	3203	0.6007	0.4505
2001	3135	0.4840	0.4398
2002	3279	0.4588	0.3890
2003	2627	0.4867	0.3776
2004	2593	0.4454	0.3291
2005	2331	0.4416	0.3135
2006	1676	0.4335	0.2993

Six statistical models were considered for the Redfish data from trawl vessels in Zone 10 (Table 6.26). Model 1 represents the overall geometric mean and Model 6 is the optimum model (Table 6.25, Table 6.27; Figure 6.9).

Table 6.26. The factors involved in each of the ten statistical models trialled with Redfish from trawlers in Zone 10. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DepCat
model 4	Year Vessel DepCat Month
model 5	Year Vessel DepCat Month DayNight
model 6	Year Vessel DepCat Month DayNight Month*DepCat

Table 6.27. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model, Model 6, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
Model1	63280	0.0393	20	63259	7302	178687	21	65731
Model2	63280	0.1440	114	63165	26786	159203	115	58613
Model3	62931	0.1986	134	62796	36739	148220	135	54180
Model4	62931	0.2004	145	62785	37073	147886	146	54060
Model5	62931	0.2115	148	62782	39118	145841	149	53190
Model6	62931	0.2334	354	62576	43170	141789	355	51829

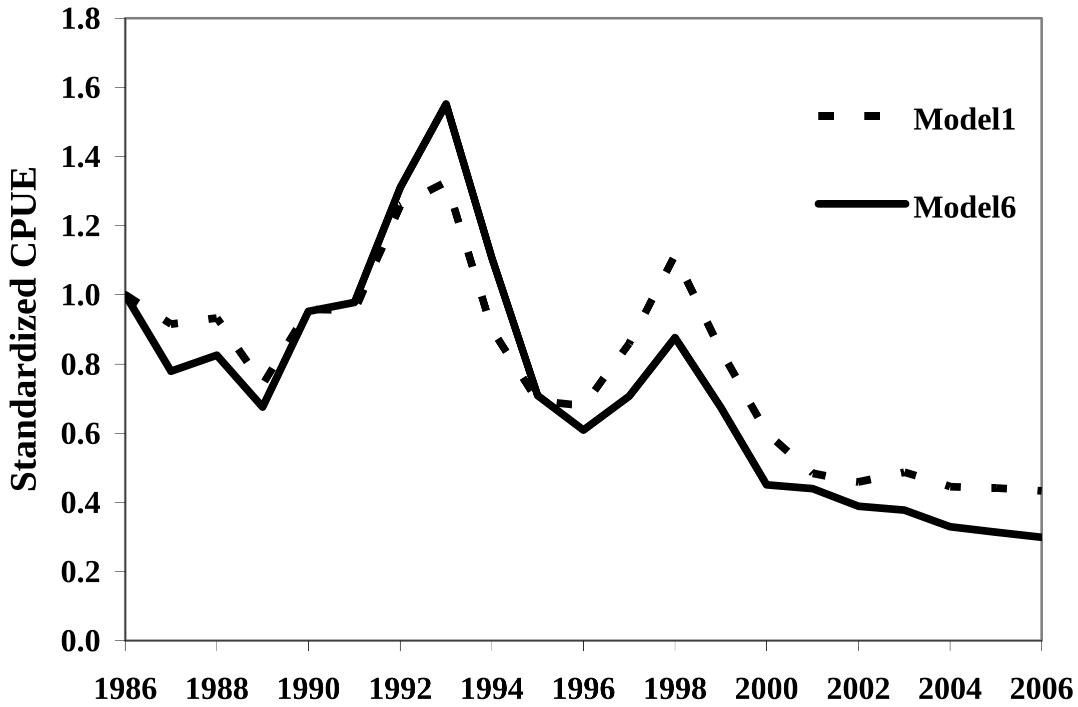

Figure 6.9. The standardized catch per unit of effort per year for Redfish in Zone 10 taken by trawl vessels relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model, model 6 – solid line (see Table 6.23 for parameter values).

6.3.9 RedFish Zone 20 (RED – 37258003 – Centroberyx affinis)

The data restrictions used in selecting the data for analysis were identical to those for zone 10:

Only data from zone 20 were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 400 m.

With no restrictions except zone 20 and trawlers there were 24,840 records available for analysis for Redfish. With the restrictions listed above there were 22,397 records. Thus, 90.2% of available records are used and these represent 94.3% of all catches (Table 6.28).

Table 6.28. Number of records used in the CPUE standardization in each year for Redfish from trawls only, years in the fishery >2, CE >0, Average Depth < 400m, and only zones 20. The geometric mean (Model 1) and the optimum model (see Figure 6.9) are relative to 1986.

Year	Records	Model1	Model6
1986	3877	1.0000	1.0000
1987	3133	1.2974	1.2708
1988	2944	1.7767	1.7019
1989	2154	1.0866	1.0221
1990	1901	1.4054	1.3174
1991	2669	1.8665	1.6526
1992	2627	1.5203	1.3361
1993	3157	1.9306	1.5277
1994	4304	1.7970	1.4410
1995	4406	1.2271	0.9343
1996	3991	1.0026	0.9252
1997	2900	0.9710	0.8020
1998	3040	1.0115	0.8419
1999	2984	0.9886	0.8682
2000	3203	0.5428	0.5367
2001	3135	0.5993	0.5471
2002	3279	0.7054	0.6235
2003	2627	0.4461	0.4160
2004	2593	0.4498	0.4305
2005	2331	0.5815	0.5236
2006	1676	0.5236	0.4746

Six statistical models were considered for the Redfish data from trawl vessels in Zone 10 (Table 6.29). Model 1 represents the overall geometric mean and Model 6 is the optimum model (Table 6.28, Table 6.30; Figure 6.10).

Table 6.29. The factors involved in each of the ten statistical models trialled with Redfish from trawlers in Zone 20. The factor names are as listed in Section 6.2.

Model	**Factors**
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DepCat
model 4	Year Vessel DepCat Month
model 5	Year Vessel DepCat Month DayNight
model 6	Year Vessel DepCat Month DayNight Month*DepCat

Table 6.30. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model, Model 6, is bolded. Model 1 is the base case.

Model	**N**	**Var%**	**df Params**	**df Resids**	**Model SS**	**Resid SS**	**# Param**	**AIC**
Model1	22494	0.0925	20	22473	4965	48705	21	17419
Model2	22494	0.1693	80	22413	9087	44583	81	15550
Model3	22397	0.2210	99	22297	11799	41599	100	14067
Model4	22397	0.2368	110	22286	12642	40756	111	13631
Model5	22397	0.2396	113	22283	12792	40607	114	13555
Model6	22397	0.2589	303	22093	13823	39575	304	13358

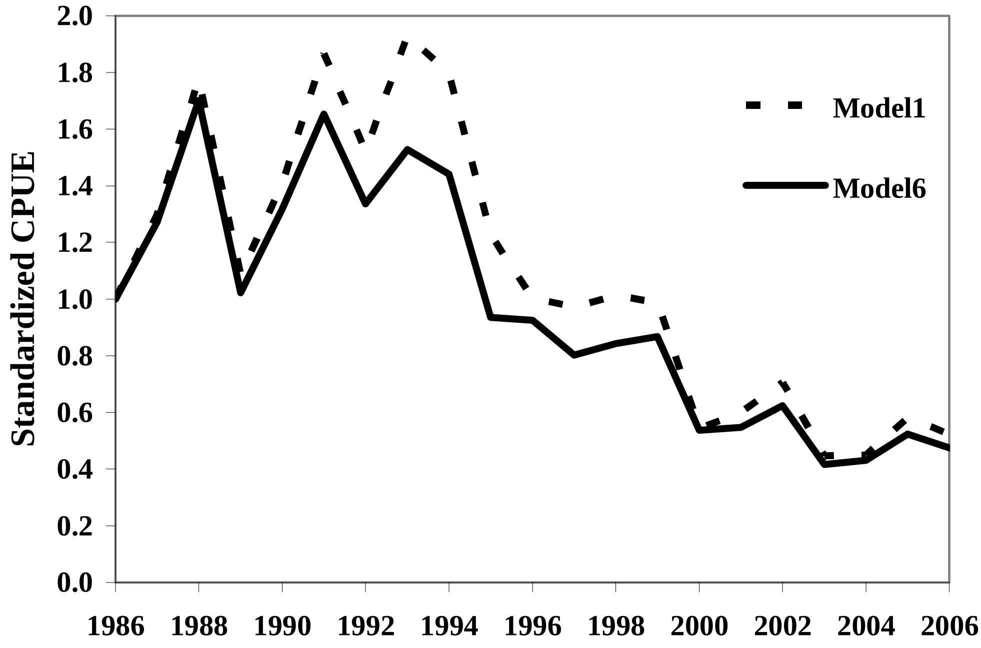

Figure 6.10. The standardized catch per unit of effort per year for Redfish in Zone 20 taken by trawl vessels relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) and the optimal model (model 6 – solid line) (see Table 6.28 for parameter values).

A comparison of the standardized CPUE trends from Zones 10 and 20 indicates that the trends in CPUE are similar in both areas.

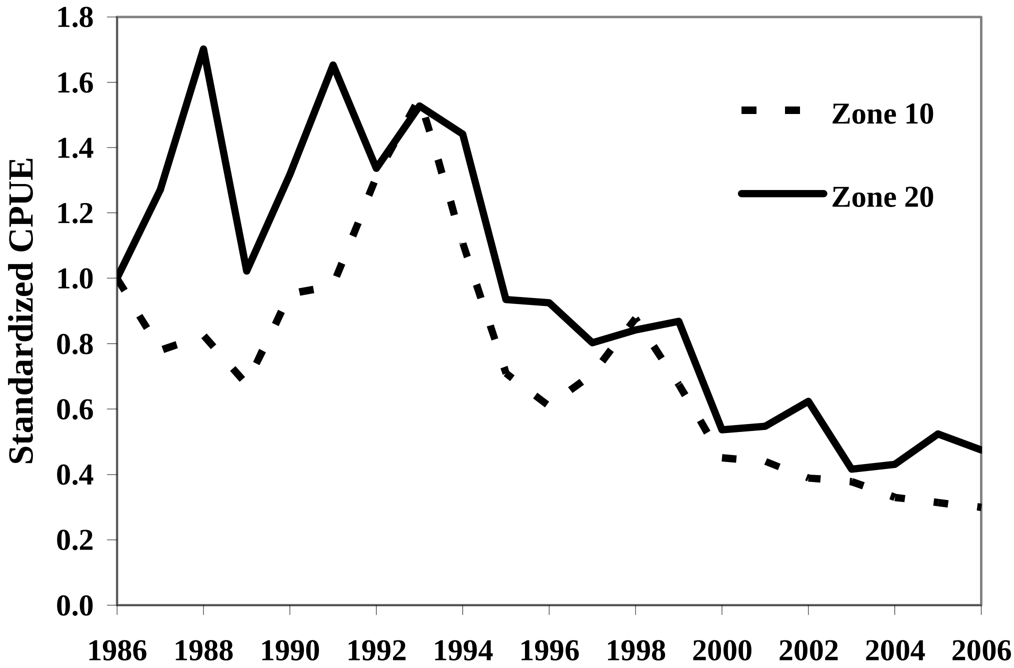

Figure 6.11. A comparison of the optimal statistical models for Redfish taken in zones 10 and 20. Overall, there is little difference between the trends.

6.3.10 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)

The data restrictions used in selecting the data for analysis were similar to those used in 2006, except that no restriction was placed on median or average annual catch:

Only data from zones 10 and 20 combined were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 200 m.

With no restrictions except zones 10 and 20 and trawlers there were 53,328 records available for analysis for Silver Trevally. With the restrictions listed above there were 49,721 records. Thus, 93.2% of available records are used and account for 94.5% of catches (Table 6.31).

Table 6.31. Number of records used in the CPUE standardization in each year for Silver Trevally from trawls only, years in the fishery >2, CE >0, Average Depth < 200m, and only zones 10 and 20. The geometric mean (Model 1) and the optimum model (see Figure 6.9) are relative to 1986.

Year	Records	Model1	Model9
1986	1642	1.0000	1.0000
1987	1175	1.0296	1.1590
1988	1612	1.1567	1.2887
1989	2264	1.4063	1.6750
1990	2198	1.4190	1.8613
1991	2488	1.0592	1.5394
1992	1949	0.8559	0.9585
1993	2409	0.8983	0.9970
1994	3421	0.7732	0.8312
1995	3424	0.8597	0.9671
1996	3208	0.6807	0.9006
1997	2770	0.7461	0.9167
1998	2247	0.6074	0.6836
1999	1812	0.5647	0.6765
2000	1917	0.4088	0.5208
2001	3153	0.5268	0.6422
2002	2489	0.4918	0.6442
2003	2537	0.6365	0.6971
2004	3187	0.7622	0.7846
2005	2203	0.7647	0.6787
2006	1616	0.9296	0.7364

Nine statistical models were considered for the Silver Trevally data from trawl vessels in Zones 10 and 20 (Table 6.32). Model 1 represents the overall geometric mean and Model 9 is the optimum model (Table 6.31, Table 6.33; Figure 6.11).

Table 6.32. The factors involved in each of the ten statistical models trialled with Silver trevally from trawlers in Zones 10 and 20. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year DepCat
model 3	Year DepCat Vessel
model 4	Year DepCat Vessel Month
model 5	Year DepCat Vessel Month Zone
model 6	Year DepCat Vessel Month Zone DayNight
model 7	Year DepCat Vessel Month Zone DayNight Zone*DepCat
model 8	Year DepCat Vessel Month Zone DayNight Zone*DepCat Zone*Month
model 9	Year DepCat Vessel Month Zone DayNight Zone*Month*DepCat

Table 6.33. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 9, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
Model1	50076	0.0379	20	50055	4735	120361	21	43956
Model2	49721	0.1344	30	49690	16690	107477	31	38389
Model3	49721	0.2475	136	49584	30735	93432	137	31638
Model4	49721	0.2558	147	49573	31765	92402	148	31109
Model5	49721	0.2559	148	49572	31773	92393	149	31106
Model6	49721	0.2615	151	49720	32475	91692	152	30734
Model7	49721	0.2628	160	49560	32629	91537	161	30668
Model8	49721	0.2652	171	49549	32933	91234	172	30525
Model9	49721	0.2783	350	49370	34553	89613	351	29991

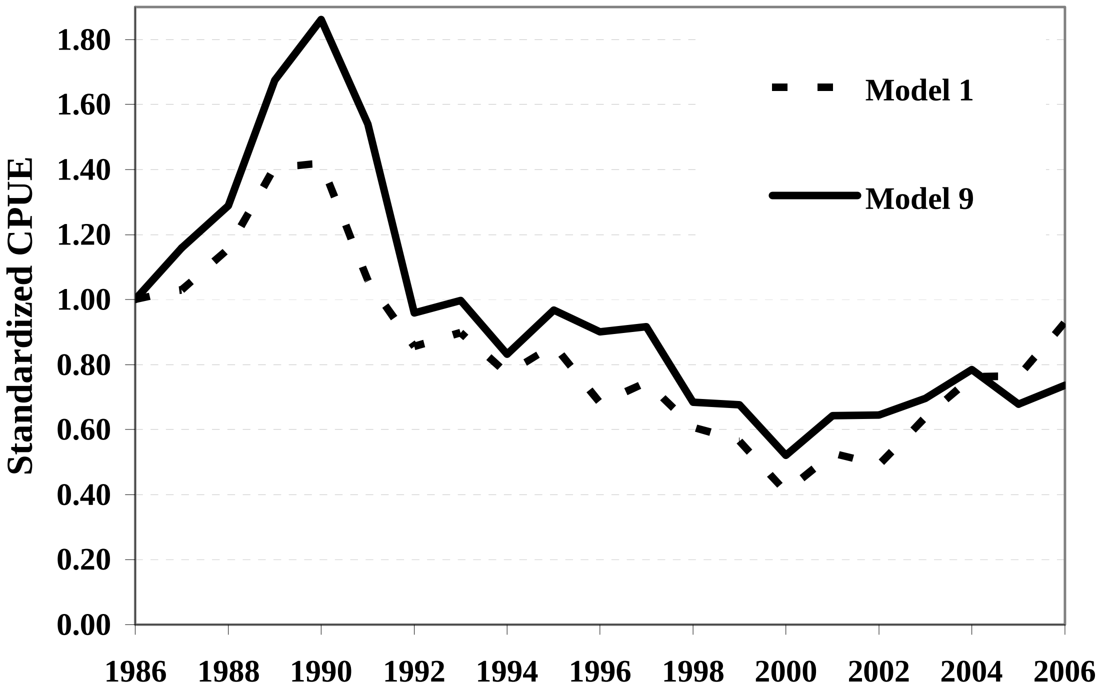

Figure 6.12. The standardized catch per unit of effort per year for Silver Trevally in Zones 10 and 20 taken by trawl vessels relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) and the optimal model (model 9 – solid line) (see Table 6.31 for parameter values).

6.3.11 Royal Red Prawn (PRR – 28714005 - Haliporoides sibogae)

The data restrictions used in selecting the data for analysis were:

Only data from Zone 10 were used,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths between 200 – 700 m.

With no restrictions except Zone 10 and trawlers there were 23,016 records available for analysis for Royal Red Prawns. With the restrictions listed above there were 22,052 records. Thus, 95.8% of available records are used and account for 96.3% of catches (Table 6.34).

Table 6.34. Number of records used in the CPUE standardization in each year for Royal Red Prawn from trawls only, years in the fishery >2, CE >0, Average Depth >= 200m and <=700 m, and only Zones 10. The geometric mean (Model 1) and the optimum model (see Figure 6.9) are relative to 1986.

Year	Records	Model1	Model9
1986	1302	1.0000	1.0000
1987	1668	1.4905	1.2840
1988	1395	1.7579	1.4187
1989	1128	1.6381	1.2148
1990	729	3.3400	2.2210
1991	750	2.8773	2.0848
1992	446	2.4735	1.5537
1993	692	2.3761	1.7000
1994	708	2.6088	1.6074
1995	1090	2.0666	1.3011
1996	1283	2.0972	1.1930
1997	884	1.8276	1.1328
1998	1245	1.3858	1.2188
1999	1593	1.7527	1.2264
2000	1551	1.7616	1.5462
2001	1334	1.2807	1.3228
2002	1754	1.7041	1.6145
2003	871	1.4981	1.6408
2004	575	1.7845	1.7149
2005	594	1.6424	1.5641
2006	460	1.9087	1.8214

Six statistical models were considered for the Royal Red Prawn data from trawl vessels in Zone10 (Table 6.35). Model 1 represents the overall geometric mean and Model 6 is the optimum model (Table 6.34, Table 6.36; Figure 6.13).

Table 6.35. The factors involved in each of the ten statistical models trialled with Royal Red Prawn from trawlers in Zone 10. The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year DepCat
model 3	Year DepCat Vessel
model 4	Year DepCat Vessel Month
model 5	Year DepCat Vessel Month DayNight
model 6	Year DepCat Vessel Month DayNight Month*DepCat

Table 6.36. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 6, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
Model1	22052	0.0393	20	22031	1475	36105	21	10914
Model2	22052	0.2401	72	21979	9023	28556	73	5846
Model3	22052	0.3729	97	21954	14012	23568	98	1662
Model4	22052	0.4111	108	21943	15450	22130	109	296
Model5	22052	0.4133	111	21940	15532	22048	112	220
Model6	22052	0.4387	368	21683	16487	21093	369	-242

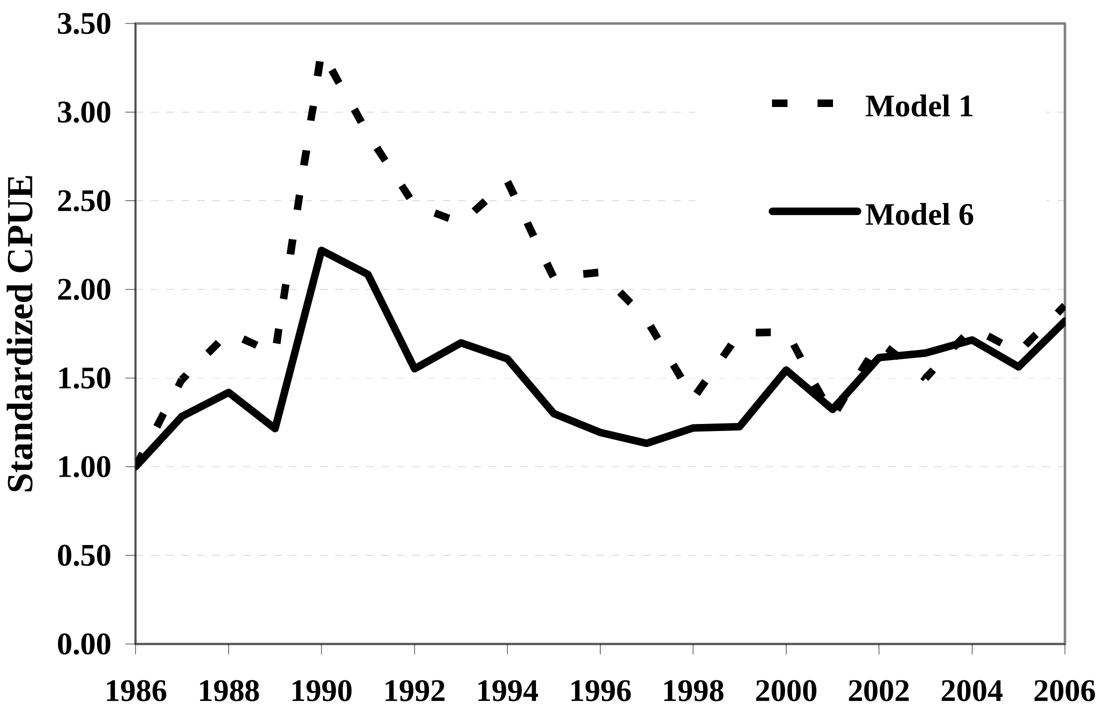

Figure 6.13. The standardized catch per unit of effort per year for Royal Red Prawn in Zone 10 taken by trawl vessels relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) and the optimal model (model 6 – solid line) (see Table 6.34 for parameter values).

6.3.12 Blue Eye, Zones 20, 30 (TBE – 37445001 – Hyperoglyphe antarctica)

Catches from Zone 10 declined greatly from 1997 onwards so only Zones 20 and 30 were considered. Data selection was made using the following criteria:

Data from zones 20 and 30,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 2000 m.

With just the restrictions of zones 20 and 30 and trawlers there were 11,052 records available for analysis for BlueEye taken by trawl. Given the restrictions above these reduce to 10,317 records. Thus, 93.3% of available records are used and these represent 87.8% of all catches (Table 6.37).

Table 6.37. Number of records used in the CPUE standardization in each calendar year for the eastern fishery for Blue Eye, years in the fishery >2, CE >0, and Average Depth < 2000m. The geometric mean (Model 1) and the optimum model (Model 9) are relative to 1986 (see Figure 6.14).

Year	Records	Model 1	Model 9
1986	138	1.0000	1.0000
1987	188	1.0622	0.9939
1988	306	1.5212	1.2854
1989	302	1.4689	1.2648
1990	259	2.3850	1.5528
1991	499	1.0093	0.8363
1992	361	0.8906	0.5754
1993	723	0.8393	0.5058
1994	830	1.0248	0.5692
1995	473	0.6164	0.3969
1996	639	0.6219	0.3193
1997	591	0.5099	0.2938
1998	467	0.4668	0.3345
1999	621	0.4058	0.3394
2000	638	0.2882	0.2237
2001	646	0.2496	0.2168
2002	646	0.3465	0.2227
2003	677	0.2624	0.2142
2004	566	0.3269	0.2154
2005	437	0.3383	0.2176
2006	310	0.4827	0.2412

Nine statistical models were considered for the eastern Blue Eye fishery data (Table 6.38). Model 1 represents the deviations from the overall geometric mean and Model 9 is the optimum model as determined by both variability described and AIC value (Table 6.37; Table 6.39; Figure 6.14).

Table 6.38. The factors involved in each of the nine statistical models trialled with eastern fishery for Blue Eye. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DayNight
4	Year Vessel DayNight Month
5	Year Vessel DayNight Month DepCat
6	Year Vessel DayNight Month DepCat Zone
7	Year Vessel DayNight Month DepCat Zone Month*DepCat
8	Year Vessel DayNight Month DepCat Zone Month*DepCat Zone*Month
9	Year Vessel DayNight Month DepCat Zone Zone*Month*DepCat

Table 6.39. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 9, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
1	10366	0.1414	20	10345	3553	21582	21	7644
2	10366	0.4470	92	10273	11236	13899	93	3226
3	10366	0.4499	95	10270	11310	13825	96	3177
4	10366	0.4551	106	10259	11438	13697	107	3102
5	10317	0.4639	160	10156	11556	13357	161	2986
6	10317	0.4822	161	10155	12013	12900	162	2629
7	10317	0.5167	564	9752	12872	12041	565	2724
8	10317	0.5191	575	9741	12933	11980	576	2694
9	10317	0.5492	792	9524	13681	11232	793	2463

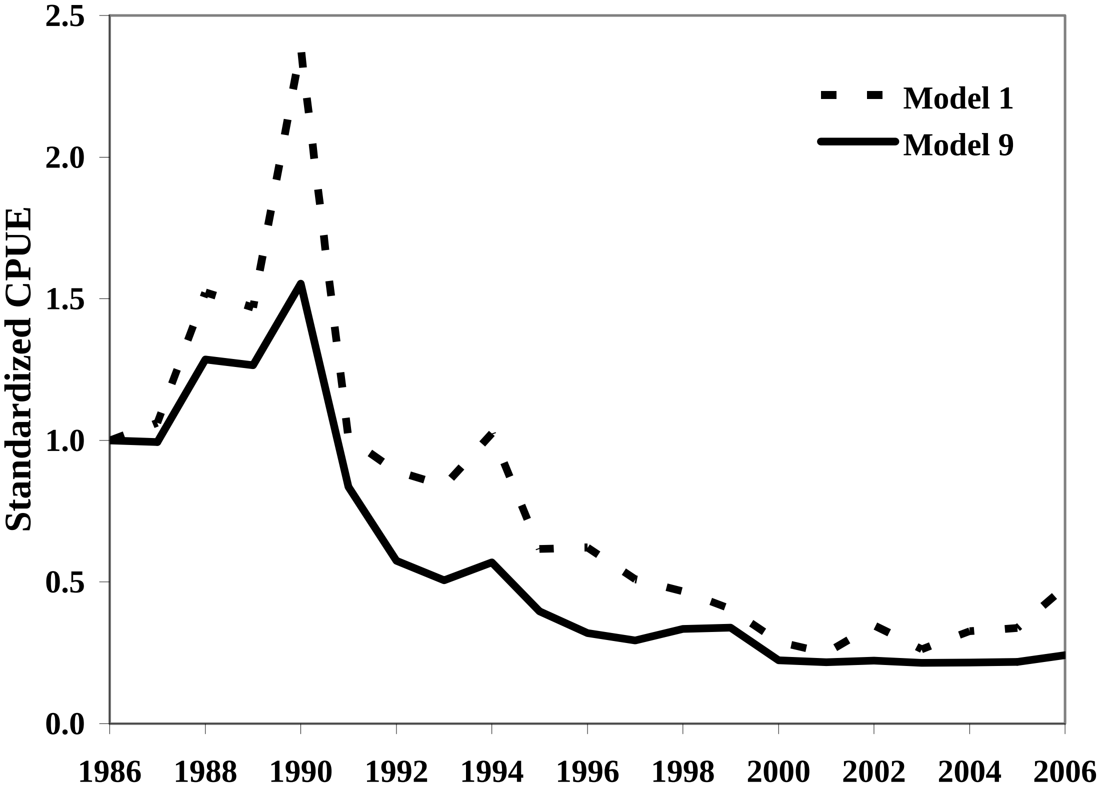

Figure 6.14. The standardized catch per unit of effort per year for the eastern fishery for Blue Eye, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model was Model 9 (solid line; see Table 6.37 for parameter values).

6.3.13 Blue Eye, Zones 40, 50 (TBE – 37445001 – Hyperoglyphe antarctica)

Data selection was made using the following criteria:

Data from zones 40 and 50,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 2000 m.

With just the restrictions of zones 40 and 50 and trawlers there were 10,146 records available for analysis for BlueEye taken by trawl. Given the restrictions above these reduce to 10,002 records. Thus, 96.03% of available records are used and these represent 97.9% of all catches (Table 6.40).

Table 6.40. Number of records used in the CPUE standardization in each calendar year for the western fishery for Blue Eye, years in the fishery >2, CE >0, and Average Depth < 2000m. The geometric mean (Model 1) and the optimum model (Model 6) are relative to 1986 (see Figure 6.15).

Year	Records	Model 1	Model 6	Model 9
1986	138	1.0000	1.0000	1.0000
1987	188	1.0036	0.9866	0.8457
1988	306	3.4248	2.7866	2.9513
1989	302	1.9891	2.4404	2.4505
1990	259	0.9651	2.4624	2.4197
1991	499	1.2022	2.1265	2.2004
1992	361	1.8901	2.7596	2.5287
1993	723	0.6431	1.0999	1.0921
1994	830	0.6547	1.1871	1.1913
1995	473	0.4824	1.0862	1.1260
1996	639	0.5937	1.1030	1.1140
1997	591	0.5009	1.1708	1.1938
1998	467	0.4083	1.3652	1.3799
1999	621	0.4784	1.3915	1.3902
2000	638	0.4085	1.2015	1.2294
2001	646	0.4485	1.1439	1.1585
2002	646	0.3853	0.9551	1.0055
2003	677	0.2576	0.8867	0.8914
2004	566	0.3276	0.7732	0.7892
2005	437	0.2909	0.7156	0.7167
2006	310	0.2820	0.7020	0.7179

Nine statistical models were considered for the western Blue Eye fishery data (Table 6.38). Model 1 represents the deviations from the overall geometric mean and Model 9 is the optimum model as determined by both variability described and AIC value (Table 6.40; Table 6.42; Figure 6.15).

Table 6.41. The factors involved in each of the nine statistical models trialled with western fishery for Blue Eye. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DayNight
4	Year Vessel DayNight Month
5	Year Vessel DayNight Month DepCat
6	Year Vessel DayNight Month DepCat Zone
7	Year Vessel DayNight Month DepCat Zone Month*DepCat
8	Year Vessel DayNight Month DepCat Zone Month*DepCat Zone*Month
9	Year Vessel DayNight Month DepCat Zone Zone*Month*DepCat

Table 6.42. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 6, is bolded. Model 1 is the base case geometric mean catch rate.

Model	**N**	**Var%**	**df Params**	**df Resids**	**Model SS**	**Resid SS**	**# Param**	**AIC**
1	10036	0.1064	20	10015	2147	18044	21	5929
2	10036	0.399	72	9963	8056	12135	73	2052
3	10036	0.4162	75	9960	8404	11787	76	1766
4	10036	0.4208	86	9949	8496	11695	87	1709
5	10002	0.4463	135	9866	8988	11150	136	1359
6	**10002**	**0.4484**	**136**	**9865**	**9030**	**11108**	**137**	**1323**
7	10002	0.4762	484	9517	9589	10548	485	1502
8	10002	0.4793	495	9506	9651	10486	496	1465
9	10002	0.4964	673	9328	9996	10141	674	1486

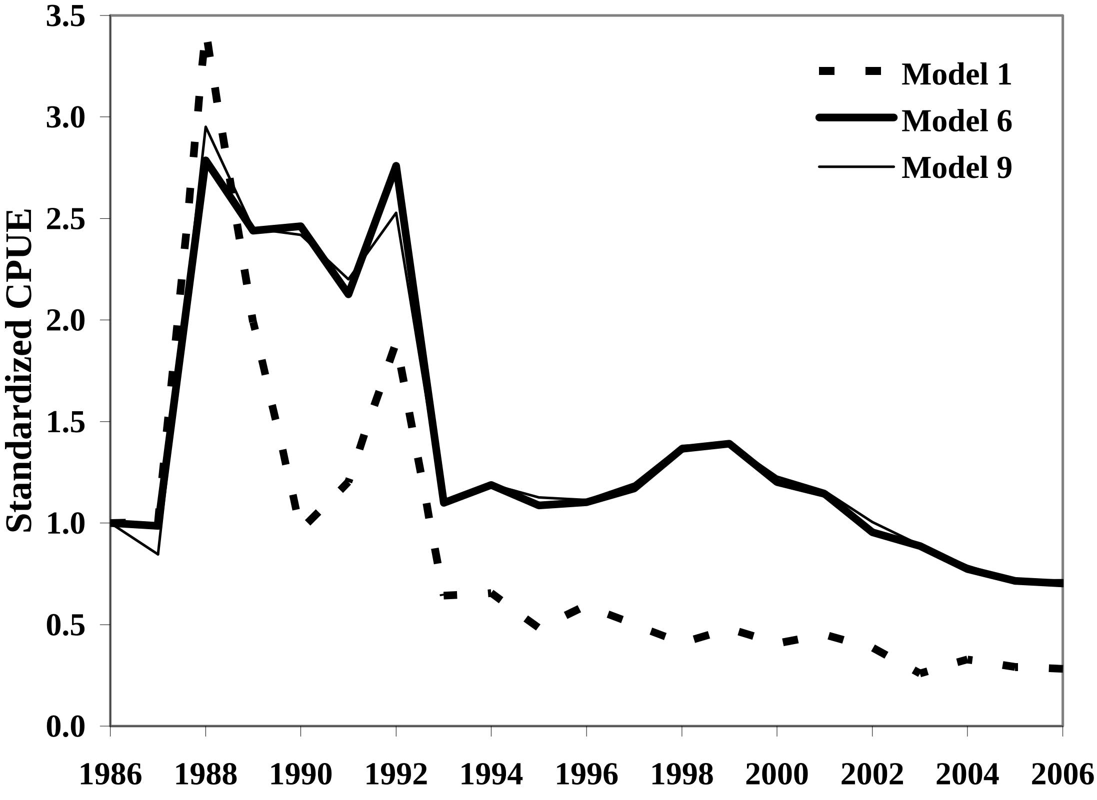

Figure 6.15. The standardized catch per unit of effort per year for the western fishery for Blue Eye, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 6 (solid line; see Table 6.40 for parameter values). Model 9 accounted for the most variation but only differed slightly from Model 6 (Table 6.40 and Table 6.42).

6.3.14 Blue Grenadier Spawning (GRE – 37227001 – Macruronus novaezelandiae)

Data selection was made using the following criteria:

Data from Zone 40 in months June to August,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 2000 m and greater than 0 m.

With just the restrictions of area, trawlers, and years there were 10,578 records available for analysis for Blue grenadier taken by trawl in the spawning fishery. Given the other restrictions above these reduce to 9,416 records. Thus, 89.0% of available records are used and these represent 86.2 % of all catches (Table 6.43). The standardization effectively removes the effects of the factory vessels.

Table 6.43. Number of records used in the CPUE standardization in each calendar year for the spawning fishery for Blue Grenadier, years in the fishery >2, CE >0, and Average Depth > 0m and < 2000m. The geometric mean (Model 1) and the optimum model (Model 4) are relative to 1986 (see Figure 6.17). Model 4 Big is the optimum model when the largest factory boats for 1997, 1999, 2005, and 2006 are treated as single vessel (and are thus included in the analysis). If only differs from Model 4, where these large vessels would be excluded, by very small amounts.

Year	Records	Model 1	Model 4	Model 4 Big
1986	71	1.0000	1.0000	1.0000
1987	154	1.6267	1.1817	1.1872
1988	92	1.3251	2.3373	2.2998
1989	24	0.5015	0.6296	0.6323
1990	132	1.1220	0.6568	0.6456
1991	102	3.2987	2.2650	2.2934
1992	189	1.6294	1.1763	1.1632
1993	142	1.7986	1.7425	1.7256
1994	288	1.1444	1.0005	0.9898
1995	474	0.2298	0.4103	0.4029
1996	352	0.2886	0.5793	0.5720
1997	403	0.1592	0.4547	0.4460
1998	575	0.4271	0.6078	0.5884
1999	857	0.8739	0.4974	0.4685
2000	944	1.0369	0.4952	0.4861
2001	1111	1.5675	0.8029	0.7864
2002	1039	1.1175	0.5726	0.5615
2003	1020	2.2821	0.5500	0.5347
2004	804	0.8010	0.3916	0.3875
2005	316	0.5484	0.8113	0.8843
2006	327	0.5701	1.6912	1.6946

Five statistical models were considered for the spawning Blue Grenadier fishery data (Table 6.44). Model 1 represents the deviations from the overall geometric mean and Model 4 is the optimum model as determined by both variability described and AIC value (Table 6.44; Table 6.45; Figure 6.16).

Table 6.44. The factors involved in each of the five statistical models trialled with the spawning fishery for Blue Grenadier. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DepCat
4	Year Vessel DepCat Weeknum
5	Year Vessel DepCat Weeknum*DepCat

Table 6.45. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 4, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	9416	0.052	20	9395	4721	85857	21		20854
2	9416	0.5255	52	9363	47601	42877	53	57.3362	14380
3	9416	0.5898	100	9315	53502	37076	101	0.1840	13107
4	**9416**	**0.6166**	**113**	**9302**	**55848**	**34730**	**114**	**1.0220**	**12518**
5	9416	0.6465	513	8902	58554	32023	514	0.3518	12554

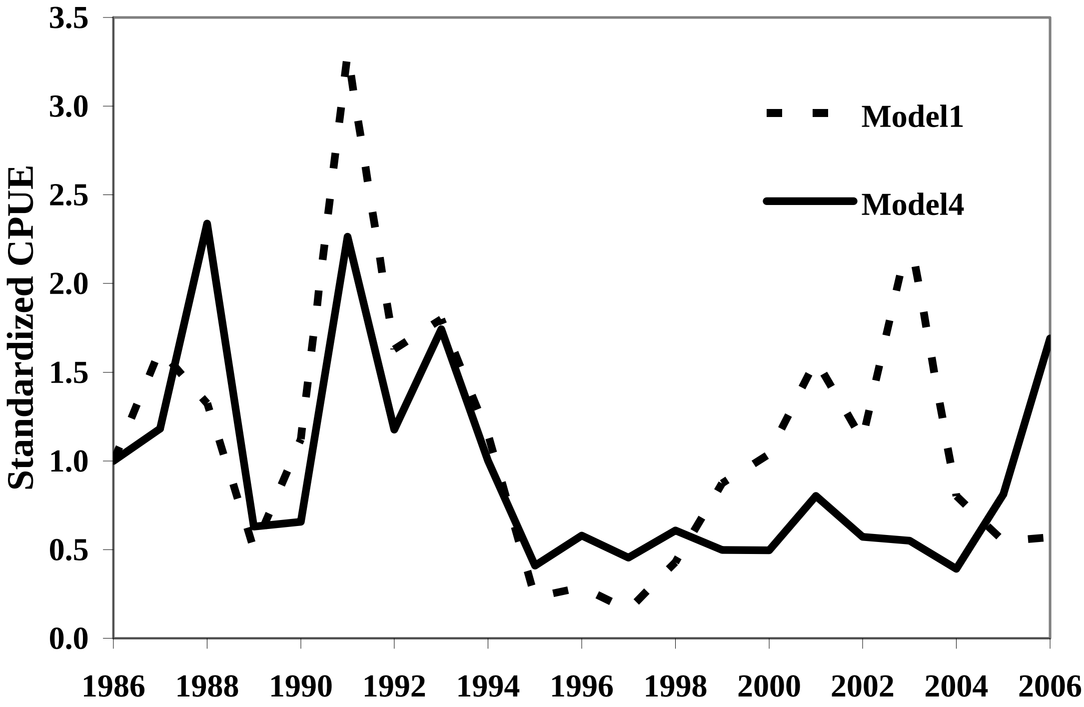

Figure 6.16. The standardized catch per unit of effort per year for the spawning fishery for Blue Grenadier, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 4 (solid line; see Table 6.43 for parameter values; Table 6.44 and Table 6.45).

6.3.15 Blue Grenadier Non-Spawning (GRE – 37227001 – M. novaezelandiae)

Analysis for calendar years.
Data selection was made using the following criteria:

Data from zones 10 to 60 except Zone 40 in months June to August,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than 2000 m and greater than 0 m.

With just the restrictions of area, trawlers, and years there were 113,931 records available for analysis for Blue grenadier taken by trawl in the non-spawning fishery. Given the other restrictions above these reduce to 108,834 records. Thus, 95.5% of available records are used and these represent 96.2 % of all catches (Table 6.46).

Table 6.46. Number of records used in the CPUE standardization in each calendar year for the non-spawning fishery for Blue Grenadier, years in the fishery >2, CE >0, and Average Depth > 0m and < 2000m. The geometric mean (Model 1) and the optimum model (Model 6) are relative to 1986 (see Figure 6.17).

Year	Records	Model 1	Model 6
1986	2911	1.0000	1.0000
1987	3370	0.9705	1.2996
1988	3927	0.9485	1.3789
1989	4289	1.1592	1.4245
1990	3491	1.2087	1.4700
1991	4546	1.2236	1.0301
1992	3582	1.0618	0.8706
1993	4195	0.8553	0.6454
1994	4499	0.7561	0.5787
1995	5087	0.4952	0.3970
1996	5362	0.4108	0.3577
1997	6127	0.3525	0.3737
1998	6605	0.4839	0.6091
1999	8081	0.5829	0.6392
2000	7640	0.4328	0.4551
2001	7192	0.2964	0.2594
2002	6307	0.3399	0.2642
2003	5687	0.2595	0.2181
2004	6358	0.4482	0.3653
2005	5289	0.5175	0.4310
2006	4289	0.7023	0.5673

Six statistical models were considered for the non-spawning Blue Grenadier fishery data (Table 47). Model 1 represents the overall geometric mean and Model 6 is the optimum model as determined by both variability described and AIC value (Table 6.47; Table 6.48; Figure 6.17).

Table 6.47. The factors involved in each of the six statistical models trialled with the non-spawning fishery for Blue Grenadier. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Zone
3	Year Zone Vessel
4	Year Zone Vessel DepCat
5	Year Zone Vessel DepCat Month
6	Year Vessel DepCat Month*Zone

Table 6.48. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 6, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	108834	0.0786	20	108813	23804	278953	21		102479
2	108823	0.1865	28	108794	56472	246262	29	3.3548	88931
3	108823	0.2641	176	108646	79965	222769	177	0.1108	78316
4	108823	0.3418	237	108585	103478	199256	238	0.1170	66300
5	108823	0.3611	248	108574	109317	193417	249	0.0315	63085
6	**108823**	**0.3783**	**322**	**108500**	**114539**	**188195**	**323**	0.0313	**60254**

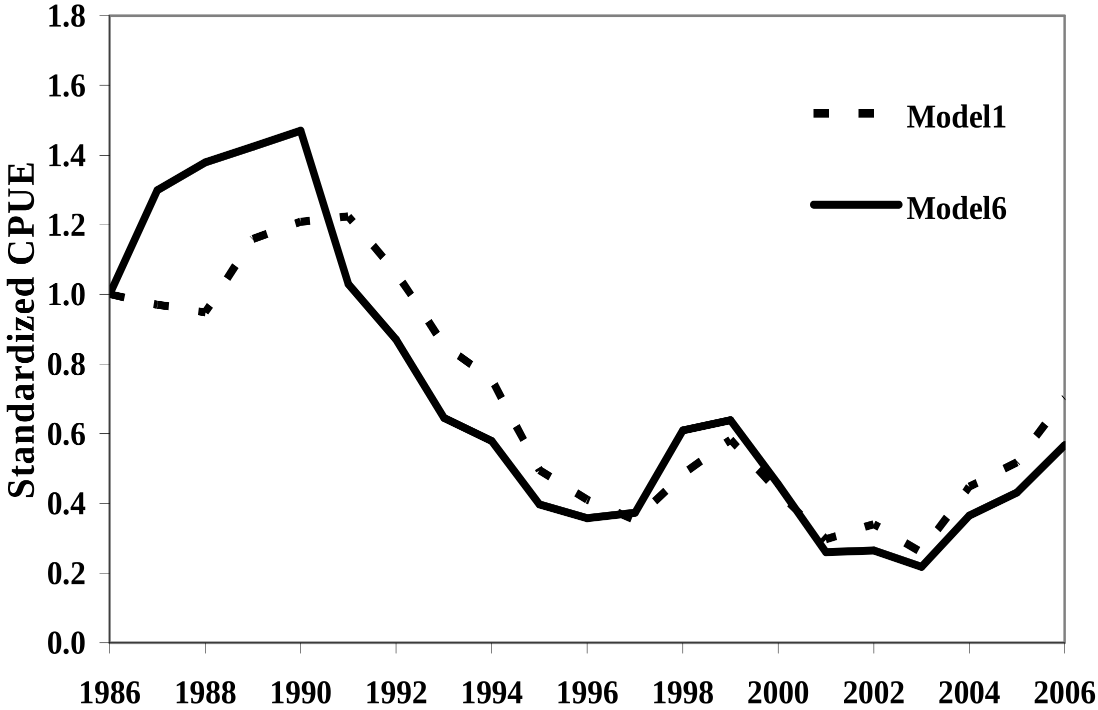

Figure 6.17. The standardized catch per unit of effort per year for the non-spawning fishery for Blue Grenadier, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 6 (solid line; see Table 6.46 for parameter values; Table 6.47 and Table 6.48).

6.3.16 Spotted Warehou (TRS – 37445006 – Seriolella punctata)

Analysis for fishing years – May 1st to April 31st.
Data selection was made using the following criteria:

Data from zones 10 to 50,
three or more years in the fishery,
catch rates greater than zero,
from 1986/1987 onwards until 2005/2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater than 0 m.

With just the restrictions of trawlers, and years there were 100,102 records available for analysis for Spotted Warehou taken by trawl. Given the other restrictions above these reduce to 95,937 records. Thus, 95.6% of available records are used and these represent 97.4 % of all catches (Table 6.49).

Table 6.49. Number of records used in the CPUE standardization in each fishing year for the spotted warehou fishery, years in the fishery >2, CE >0, and Average Depth > 0m, Zones 10 – 50. The geometric mean (Model 1) and the optimum model (Model 9) are relative to 1986/1987 (see Figure 6.18).

Fishing Year	Records	Model 1	Model 9
1986/1987	1840	1.0000	1.0000
1987/1988	1540	0.8599	0.9217
1988/1989	2453	1.0433	1.1951
1989/1990	1834	0.6561	0.9172
1990/1991	2142	0.9048	0.8831
1991/1992	2321	0.6562	0.6899
1992/1993	2813	0.6804	0.6265
1993/1994	4125	0.7421	0.6564
1994/1995	4131	0.8212	0.6516
1995/1996	5638	0.6943	0.6441
1996/1997	6020	0.6009	0.6221
1997/1998	5483	0.6289	0.6153
1998/1999	4989	0.6190	0.5659
1999/2000	5256	0.6414	0.4731
2000/2001	7707	0.5670	0.4554
2001/2002	7599	0.6105	0.4596
2002/2003	8045	0.5220	0.4175
2003/2004	7845	0.5221	0.4873
2004/2005	7659	0.5044	0.4618
2005/2006	6497	0.4734	0.4713

Nine statistical models were considered for the spotted warehou fishery data (Table 6.50). Model 1 represents the deviations from the overall geometric mean and Model 9 is the optimum model as determined by both variability described and AIC value (Table 6.50; Table 6.51; Figure 6.18).

Table 6.50. The factors involved in each of the six statistical models trialled with the fishery for spotted warehou. The factor names are as listed in Section 6.2.

Model	Factors
1	Fyear
2	Fyear vessel
3	Fyear vessel depth
4	Fyear vessel depth month
5	Fyear vessel depth month zone
6	Fyear vessel depth month zone daynight
7	Fyear vessel depth daynight zone*month
8	Fyear vessel daynight zone*month depth*zone
9	Fyear vessel daynight depth*zone*month

Table 6.51. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 9, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**95937**	**0.010**	**19**	**95917**	**3461**	**327349**	**20**		**117787**
2	95937	0.176	158	95778	58179	272631	159	2.309	100517
3	95937	0.189	211	95725	62639	268171	212	0.092	99041
4	95937	0.232	222	95714	76589	254221	223	1.288	93938
5	95937	0.246	226	95710	81249	249561	227	0.065	92171
6	95937	0.247	229	95707	81798	249012	230	0.015	91966
7	95937	0.259	273	95663	85668	245141	274	0.019	90551
8	95937	0.267	415	95521	88455	242355	416	0.016	89738
9	**95937**	**0.298**	**1821**	**94115**	**98458**	**232352**	**1822**	**0.020**	**88506**

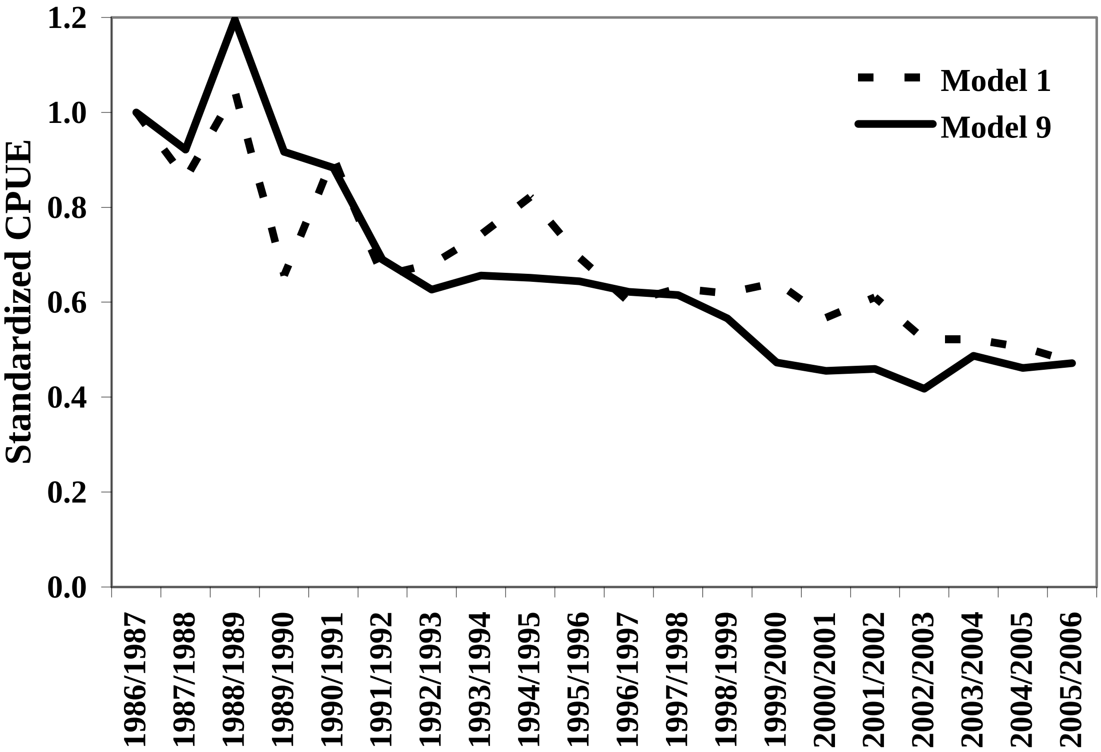

Figure 6.18. The standardized catch per unit of effort per year for the spotted warehou fishery, relative to catch rates in 1986/1987, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 9 (solid line; see Table 6.49 for parameter values; Table 6.50 and Table 6.51).

6.3.17 Blue Warehou Zones 10, 20 & 30 (TRT – 37445005 – Seriolella brama)

Analysis for fishing years – May 1st to April 31st.
Data selection was made using the following criteria:

Data from zones 10, 20, and 30,
three or more years in the fishery,
catch rates greater than zero,
from 1986/1987 onwards until 2005/2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than or equal to 400 m.

With just the restrictions of trawlers, years and zones there were 35,140 records available for analysis for Blue Warehou. Given the other restrictions above these reduce to 33,297 records. Thus, 94.8% of available records are used and these represent 95.0 % of all catches (Table 6.52).

Table 6.52. Number of records used in the CPUE standardization in each fishing year for the blue warehou eastern fishery, years in the fishery >2, CE >0, and Average Depth <= 400m, Zones 10 – 30. The geometric mean (Model 1) and the optimum model (Model 6) are relative to 1986/1987 (see Figure 6.19).

Fishing Year	Records	Model 1	Model 6
1986/1987	490	1.0000	1.0000
1987/1988	414	0.9580	1.1424
1988/1989	1282	1.8465	1.8060
1989/1990	676	1.9276	1.4848
1990/1991	945	1.7194	1.5790
1991/1992	1683	0.9444	0.9990
1992/1993	1716	0.9747	0.6663
1993/1994	2154	0.7699	0.5338
1994/1995	2512	0.6894	0.5267
1995/1996	2800	0.5785	0.4788
1996/1997	3417	0.5467	0.4774
1997/1998	2261	0.4998	0.4704
1998/1999	2404	0.5150	0.4035
1999/2000	1621	0.2049	0.2339
2000/2001	2273	0.2061	0.2115
2001/2002	1454	0.1007	0.1219
2002/2003	1934	0.0842	0.0946
2003/2004	1496	0.1044	0.1161
2004/2005	860	0.0767	0.0821
2005/2006	905	0.0878	0.0905

Six statistical models were considered for the eastern Blue Warehou fishery data (Table 6.53). Model 1 represents the deviations from the overall geometric mean and Model 6 is the optimum model as determined by both variability described and AIC value (Table 6.53; Table 6.54; Figure 6.19).

Table 6.53. The factors involved in each of the six statistical models trialled with the eastern blue warehou fishery. The factor names are as listed in Section 6.2.

Model	Factors
1	Fyear
2	Fyear Vessel
3	Fyear Vessel Zone
4	Fyear Vessel Zone DepCat
5	Fyear Vessel Zone DepCat Month
9	Fyear Vessel Zone DepCat Month Zone*Month*DepCat

Table 6.54. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 6, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**33464**	**0.2398**	**19**	**33444**	**29045**	**92097**	**20**		**33918**
2	33464	0.3349	126	33337	40565	80577	127	120.416	29660
3	33464	0.3372	128	33335	40846	80296	129	0.925	29547
4	33290	0.3504	144	33145	42223	78275	145	13.010	28752
5	33290	0.3603	155	33134	43413	77085	156	1.931	28264
6	**33290**	**0.3934**	**578**	**32711**	**47403**	**73095**	**579**	**4.677**	**27341**

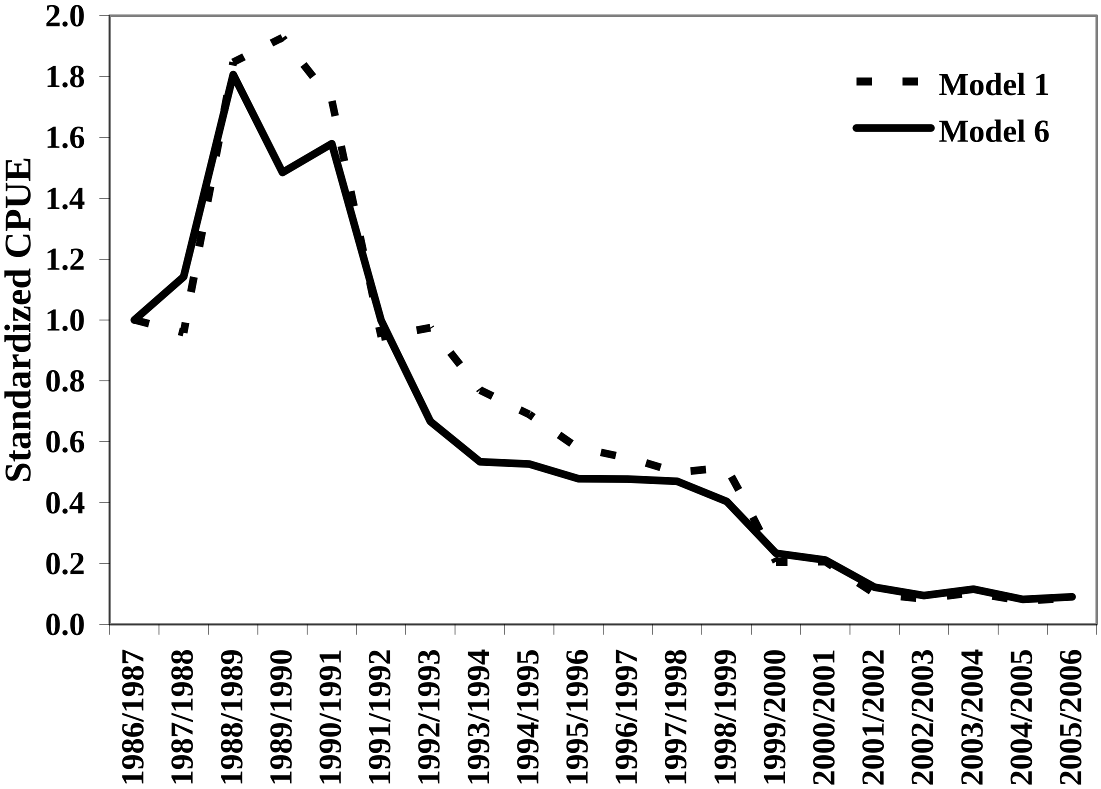

Figure 6.19. The standardized catch per unit of effort per year for the eastern blue warehou fishery, relative to catch rates in 1986/1987, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 6 (solid line; see Table 6.52 for parameter values; Table 6.53 and Table 6.54).

6.3.18 Blue Warehou Zones 40 & 50 (TRT – 37445005 – Seriolella brama)

Analysis for fishing years – May 1st to April 31st.
Data selection was made using the following criteria:

Data from zones 40 and 50,
three or more years in the fishery,
catch rates greater than zero,
from 1986/1987 onwards until 2005/2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than or equal to 400 m.

With just the restrictions of trawlers, years and zones there were 10,310 records available for analysis for Blue Warehou. Given the other restrictions above these reduce to 8,174 records. Thus, 79.3% of available records are used and these represent 85.5% of all catches (Table 6.55).

Table 6.55. Number of records used in the CPUE standardization in each fishing year for the blue warehou western fishery, years in the fishery >2, CE >0, and Average Depth <= 400m, Zones 10 – 30. The geometric mean (Model 1) and the optimum model (Model 5) are relative to 1986/1987 (see Figure 6.20).

Fishing Year	Records	Model 1	Model 5
1986/1987	47	1.0000	1.0000
1987/1988	131	2.8861	0.4701
1988/1989	106	2.9023	0.4159
1989/1990	22	0.2267	0.1043
1990/1991	260	1.5357	0.2877
1991/1992	599	2.8138	0.3682
1992/1993	498	1.5171	0.1599
1993/1994	591	1.4292	0.1396
1994/1995	590	1.1202	0.1232
1995/1996	624	0.7930	0.0930
1996/1997	481	0.4570	0.0564
1997/1998	399	0.8370	0.0920
1998/1999	415	1.3937	0.1053
1999/2000	515	0.6506	0.0533
2000/2001	599	0.5323	0.0521
2001/2002	645	0.4745	0.0522
2002/2003	511	0.5217	0.0582
2003/2004	365	0.4703	0.0574
2004/2005	346	0.5541	0.0926
2005/2006	456	0.7446	0.1065

Six statistical models were considered for the western Blue Warehou fishery data (Table 6.56). Model 1 represents the deviations from the overall geometric mean and Model 5 is the optimum model as determined by both variability described and AIC value (Table 6.56; Table 6.57; Figure 6.19).

Table 6.56. The factors involved in each of the six statistical models trialled with the western blue warehou fishery. The factor names are as listed in Section 6.2.

Model	Factors
1	Fyear
2	Fyear Vessel
3	Fyear Vessel Zone
4	Fyear Vessel Zone DepCat
5	Fyear Vessel Zone DepCat Month
9	Fyear Vessel Zone DepCat Month Zone*Month*DepCat

Table 6.57. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 5, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**8215**	**0.0993**	**19**	**8195**	**2702**	**24525**	**20**		**9025**
2	8215	0.1675	72	8142	4561	22667	73	54.149	8484
3	8215	0.1693	73	8141	4608	22619	74	0.151	8468
4	8174	0.2329	88	8085	6312	20786	89	8.383	7807
5	**8174**	**0.2987**	**99**	**8074**	**8093**	**19004**	**100**	**3.627**	**7096**
6	8174	0.3273	273	7900	8870	18228	274	11.309	7104

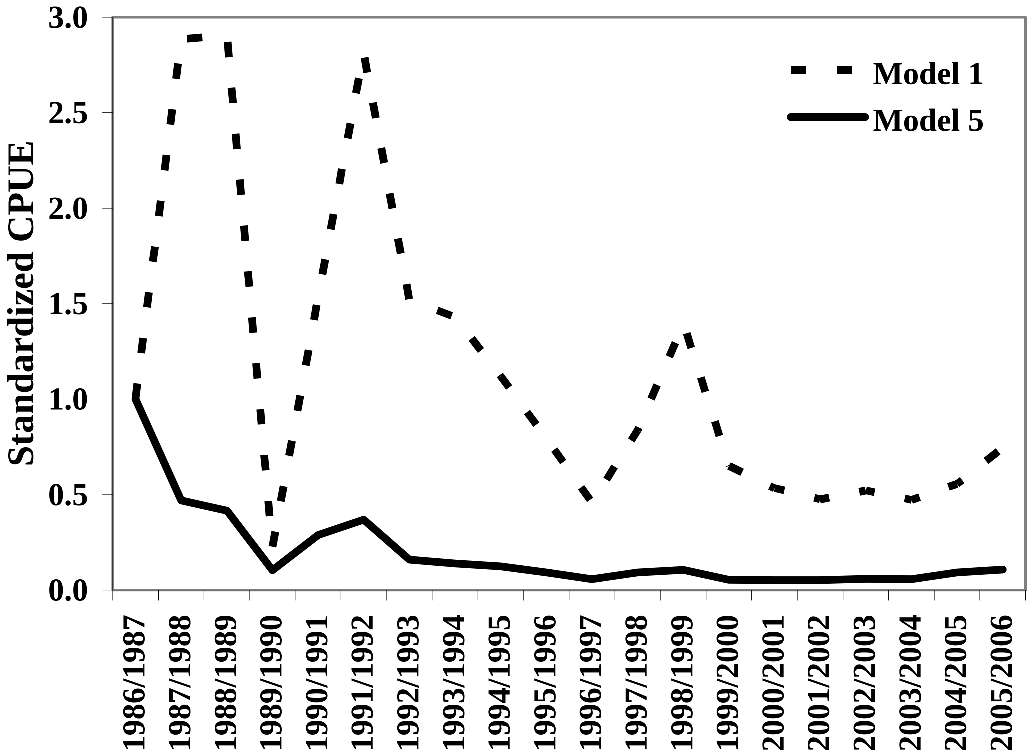

Figure 6.20. The standardized catch per unit of effort per year for the western blue warehou fishery, relative to catch rates in 1986/1987, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 5 (solid line; see Table 6.55 for parameter values; Table 6.56 and Table 6.57).

6.3.19 Pink Ling, Zones 10, 20 & 30 (LIG – 37228002 – Genypterus blacodes)

Data selection was made using the following criteria:

Data from zones 10, 20 and 30,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater than 0 m and less than 1000 m.

With just the restrictions of zones 10, 20 and 30, trawlers, and 1986 - 2006 there were 138,033 records available for analysis for Pink Ling taken by trawl. Given the restrictions above these reduce to 133,545 records. Thus, 96.7% of available records are used and these represent 97.2% of all catches (Table 6.58).

Table 6.58. Number of records used in the CPUE standardization in each calendar year for the eastern fishery for Pink Ling, years in the fishery >2, CE >0, and Depth > 0 m and < 1000m. The geometric mean (Model 1) and the optimum model (Model 8) are relative to 1986 (see Figure 6.21).

Year	Records	Model 1	Model 8
1986	5429	1.0000	1.0000
1987	5326	1.0120	1.0695
1988	4959	1.0090	1.0745
1989	5188	0.9928	0.9570
1990	3960	1.2202	1.2944
1991	4449	1.1145	1.2540
1992	3972	1.0495	1.0674
1993	5141	1.1470	1.0992
1994	6459	1.0383	1.1067
1995	7306	1.0348	1.2717
1996	7306	0.8660	1.0526
1997	8351	0.8536	1.0601
1998	7924	0.8322	1.0091
1999	9068	0.8721	0.9928
2000	8760	0.6198	0.7910
2001	7708	0.5147	0.5960
2002	7002	0.3699	0.4968
2003	7622	0.4376	0.5539
2004	6393	0.4123	0.5249
2005	6394	0.4486	0.5696
2006	4828	0.5468	0.6779

Eight statistical models were considered for the eastern Pink Ling fishery data (Table 6.59). Model 1 represents the deviations from the overall geometric mean and Model 8 is the optimum model as determined by both variability described and AIC value (Table 6.58; Table 6.59; Figure 6.21).

Table 6.59. The factors involved in each of the eight statistical models trialled with eastern fishery for Pink Ling taken by trawlers. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DepCat
4	Year Vessel DepCat Zone
5	Year Vessel DepCat Zone Month
6	Year Vessel DepCat Zone Month DayNight
7	Year Vessel DepCat Zone Month DayNight Zone*Month
8	Year Vessel DepCat Zone Month DayNight DepCat*Zone*Month

Table 6.60. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**133545**	**5.87**	**20**	**133524**	**18383**	**294593**	**21**		**105697**
2	133545	17.25	176	133368	53994	258983	177	0.3042	88804
3	133545	47.84	199	133345	149719	163258	200	1.0169	27228
4	133545	48.61	201	133343	152130	160847	202	0.0164	25245
5	133545	49.20	212	133332	153995	158982	213	0.0041	23710
6	133545	49.45	215	133329	154766	158211	216	0.0062	23067
7	133545	49.73	237	133307	155651	157326	238	0.0049	22362
8	**133545**	**51.94**	**956**	**132588**	**162570**	**150407**	**957**	**0.0160**	**17793**

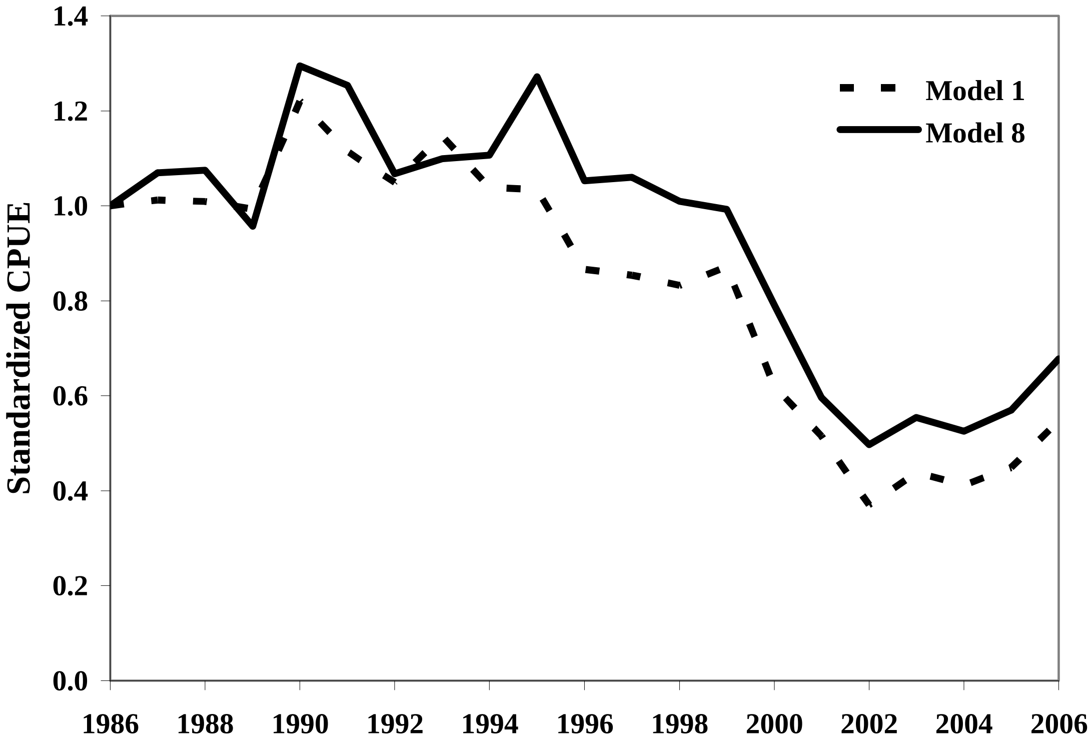

Figure 6.21. The standardized catch per unit of effort per year for the eastern fishery for Pink Ling, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 8 (solid line; see Table 6.58 for parameter values). Model 8 accounted for the most variation but only differed slightly from Model 7 (Table 6.59 and Table 6.60).

6.3.20 Pink Ling, Zones 40 & 50 (LIG – 37228002 – Genypterus blacodes)

Data selection was made using the following criteria:

Data from zones 40 and 50,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater than 0 m and less or equal to 1000 m.

With just the restrictions of zones 40 and 50, trawlers, and 1986 - 2006 there were 63,146 records available for analysis for Pink Ling taken by trawl. Given the restrictions above these reduce to 61,760 records. Thus, 97.8% of available records are used and these represent 98.0% of all catches (Table 6.61).

Table 6.61. Number of records used in the CPUE standardization in each calendar year for the western fishery for Pink Ling, years in the fishery >2, CE >0, and Depth > 0 m and < 1000m. The geometric mean (Model 1) and the optimum model (Model 8) are relative to 1986 (see Figure 6.22).

Year	Records	Model 1	Model 8
1986	1154	1.0000	1.0000
1987	1190	1.5466	1.2715
1988	1049	1.0049	1.0088
1989	1475	1.2653	1.0063
1990	1447	0.9286	0.8900
1991	2060	0.9294	0.9471
1992	1778	0.7121	0.7335
1993	2257	0.9855	0.9953
1994	2108	1.1780	1.1942
1995	3606	1.1024	1.2662
1996	3462	1.1266	1.2947
1997	3790	1.1777	1.3817
1998	3925	1.1517	1.3429
1999	4003	0.9333	1.0633
2000	4872	0.8722	0.9678
2001	5329	0.7909	0.8655
2002	4888	0.7244	0.7630
2003	4128	0.7027	0.7759
2004	4137	0.6349	0.7181
2005	2751	0.5577	0.5946
2006	2351	0.5826	0.6242

Eight statistical models were considered for the western Pink Ling fishery data (Table 6.62). Model 1 represents the deviations from the overall geometric mean and Model 8 is the optimum model as determined by both variability described and AIC value (Table 6.61; Table 6.63; Figure 6.22).

Table 6.62. The factors involved in each of the eight statistical models trialled with western fishery for Pink Ling taken by trawlers. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DepCat
4	Year Vessel DepCat Zone
5	Year Vessel DepCat Zone Month
6	Year Vessel DepCat Zone Month DayNight
7	Year Vessel DepCat Zone Month DayNight Zone*Month
8	Year Vessel DepCat Zone Month DayNight DepCat*Zone*Month

Table 6.63. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**61760**	**5.33**	**20**	**61739**	**3788**	**67227**	**21**		**5280**
2	61760	12.27	100	61659	8715	62300	101	0.6921	740
3	61760	26.68	124	61635	18945	52069	125	0.1821	-10292
4	61760	27.17	125	61634	19295	51719	126	0.0238	-10706
5	61760	29.54	136	61623	20974	50040	137	0.0254	-12722
6	61760	29.61	139	61620	21025	49990	140	0.0018	-12778
7	61760	30.90	150	61609	21943	49071	151	0.0137	-13902
8	**61760**	**34.79**	**647**	**61112**	**24708**	**46307**	**648**	**0.0153**	**-16489**

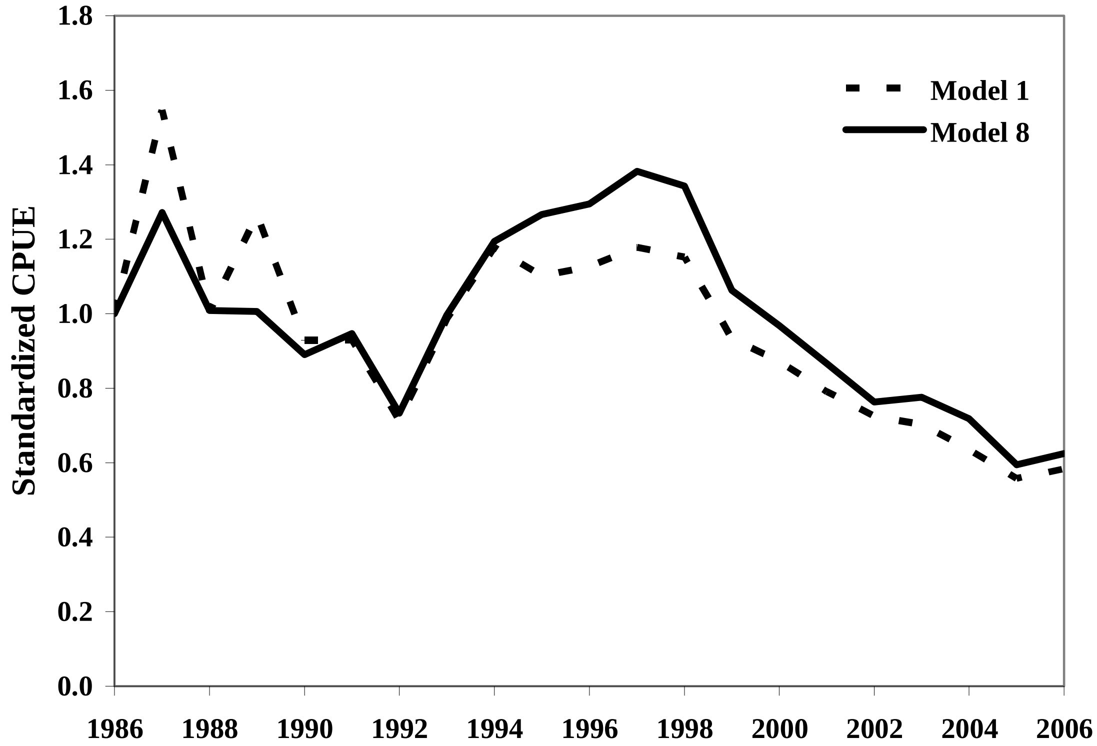

Figure 6.22. The standardized catch per unit of effort per year for the western fishery for Pink Ling, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 8 (solid line; see Table 6.61 for parameter values). Model 8 accounted for the most variation but only differed slightly from Model 7 (Table 6.62 and Table 6.63).

6.3.21 Ocean Perch, Zones 10 & 20 (REG – 37287001 – Helicolenus percoides)

Data selection was made using the following criteria:

Data from zones 10 and 20,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater or equal to 200 m and less than or equal to 700 m.

With just the restrictions of zones 10 and 20, trawlers, and 1986 - 2006 there were 68,794 records available for analysis for offshore Ocean Perch taken by trawl. Given the restrictions above these reduce to 66,577 records. Thus, 96.8% of available records are used and these represent 97.3% of all catches (Table 6.64).

Table 6.64. Number of records used in the CPUE standardization in each calendar year for the eastern fishery for Offshore Ocean Perch, years in the fishery >2, CE >0, and Depth >= 200 m and <= 700 m. The geometric mean (Model 1) and the optimum model (Model 8) are relative to 1986 (see Figure 6.23).

Year	Records	Model 1	Model 8
1986	3072	1.0000	1.0000
1987	3101	0.7393	0.9500
1988	2803	0.8672	1.0418
1989	3049	0.8768	1.0000
1990	1991	0.9932	1.3215
1991	2188	1.1033	1.3465
1992	2021	0.9642	1.1021
1993	2922	1.0687	1.1516
1994	3045	0.9671	1.0730
1995	3162	0.8674	0.9869
1996	3448	0.8075	0.9001
1997	3680	0.8141	0.9453
1998	3859	0.7767	0.8297
1999	4422	0.8052	0.9533
2000	4173	0.6241	0.7236
2001	4061	0.6949	0.7937
2002	3506	0.6141	0.7704
2003	3889	0.6289	0.8200
2004	3063	0.6572	0.7943
2005	2901	0.7764	0.9098
2006	2221	0.6701	0.7968

Eight statistical models were considered for the offshore Ocean Perch fishery data (Table 6.65). Model 1 represents the deviations from the overall geometric mean and Model 8 is the optimum model as determined by both variability described and AIC value (Table 6.64; Table 6.66; Figure 6.23).

Table 6.65. The factors involved in each of the eight statistical models trialled with eastern fishery for offshore Ocean perch taken by trawlers. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DepCat
4	Year Vessel DepCat Zone
5	Year Vessel DepCat Zone Month
6	Year Vessel DepCat Zone Month DayNight
7	Year Vessel DepCat Zone Month DayNight Zone*Month
8	Year Vessel DepCat Zone Month DayNight DepCat*Zone*Month

Table 6.66. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The deviance is the sum of the squared residual difference between sequential models. The optimum model – Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	Deviance	AIC
1	**66577**	**2.30**	**20**	**66556**	**1981**	**84284**	**21**		**15743**
2	66577	14.09	143	66433	12155	74110	144	0.0854	7424
3	66577	24.31	163	66413	20971	65295	164	0.1007	-967
4	66577	24.32	164	66412	20979	65286	165	0.0002	-974
5	66577	26.20	175	66401	22601	63664	176	0.0826	-2627
6	66577	26.39	178	66398	22767	63498	179	0.0002	-2794
7	66577	28.05	189	66387	24201	62064	190	0.0379	-4293
8	**66577**	**30.18**	**646**	**65930**	**26032**	**60234**	**647**	**0.0075**	**-5372**

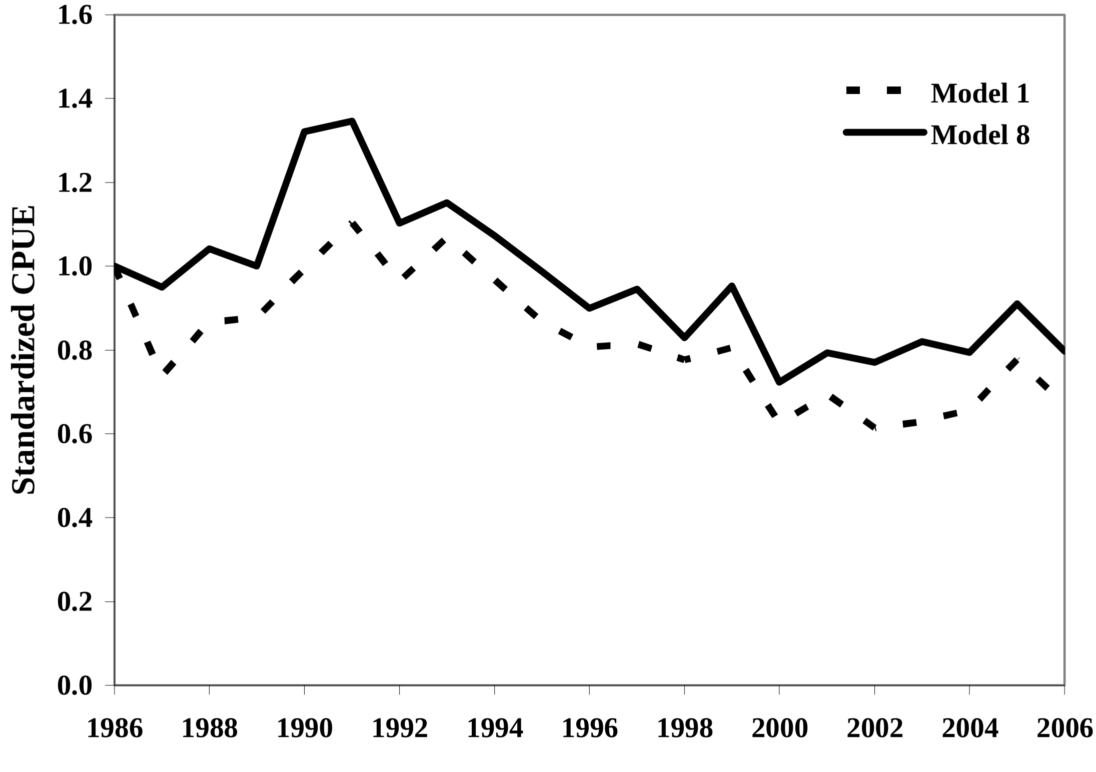

Figure 6.23. The standardized catch per unit of effort per year for the eastern fishery for offshore Ocean Perch, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 8 (solid line; see Table 6.64 for parameter values). Model 8 accounted for the most variation but only differed slightly from Model 7 (Table 6.65 and Table 6.66).

6.3.22 Western Gemfish (GEM – 37439002 – Rexea solandri)

Data selection was made using the following criteria:

Data from zones 40 and 50,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater or equal to 160 m and less than or equal to 600 m.

With just the restrictions of zones 40 and 50, trawlers, and 1986 - 2006 there were 26,327 records available for analysis for western Gemfish taken by trawl. Given the restrictions above these reduce to 25,161 records. Thus, 95.6% of available records are used and these represent 96.0% of all catches (Table 6.67).

Table 6.67. Number of records used in the CPUE standardization for Western Gemfish in each year, years in the fishery >2, CE >0, Average Depth => 160m and <= 600, and only Zones 40 and 50. The geometric mean and the optimum model 8 (see Figure 6.24) are relative to 1986.

Year	Records Used	Model 1	Model 8
1986	1371	1.0000	1.0000
1987	1047	1.1414	1.0593
1988	1208	0.9214	1.0179
1989	1068	0.8033	0.8492
1990	991	0.5576	0.6319
1991	1504	0.7094	0.6002
1992	707	0.5672	0.4178
1993	717	0.5572	0.3938
1994	832	0.5542	0.4291
1995	962	0.4205	0.3928
1996	1176	0.4592	0.4272
1997	1389	0.4529	0.3700
1998	1258	0.4509	0.4152
1999	1691	0.4364	0.4024
2000	1903	0.4373	0.4152
2001	1694	0.4197	0.3419
2002	1418	0.2432	0.2590
2003	1072	0.3813	0.3121
2004	1212	0.2725	0.3188
2005	1069	0.3597	0.3160
2006	872	0.3049	0.2660

Eight statistical models were considered for the data from Western Gemfish (Table 6.68). Model 1 represents the geometric mean catch rates and Model 8 is the optimum model. (Table 6.67; Table 6.69; Figure 6.24).

Table 6.68. The structure of the eight statistical models trialled with Western Gemfish. The factor names are as listed in Section 6.2.

Model	**Factors**
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DayNight
model 4	Year Vessel DayNight Month
model 5	Year Vessel DayNight Month DepCat
model 6	Year Vessel DayNight Month DepCat Zone
model 7	Year Vessel DayNight Month DepCat Zone DepCat*Month
model 8	Year Vessel DayNight Month DepCat Zone DepCat* Zone*Month

Table 6.69. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case.

Model	**N**	**Var%**	**df Params**	**df Resids**	**ModelSS**	**Resid SS**	**# Param**	**AIC**
Model 1	**25161**	**0.0717**	**20**	**25140**	**4056**	**52521**	**21**	**18558**
Model 2	25161	0.2709	79	25081	15324	41253	80	12600
Model 3	25161	0.2764	82	25078	15636	40941	83	12415
Model 4	25161	0.2932	93	25067	16590	39987	94	11844
Model 5	25161	0.4459	111	25049	25226	31351	112	5758
Model 6	25161	0.4462	112	25048	25245	31332	113	5745
Model 7	25161	0.4611	303	24857	26093	30484	304	5437
Model 8	**25161**	**0.4698**	**458**	**24702**	**26581**	**29996**	**459**	**5341**

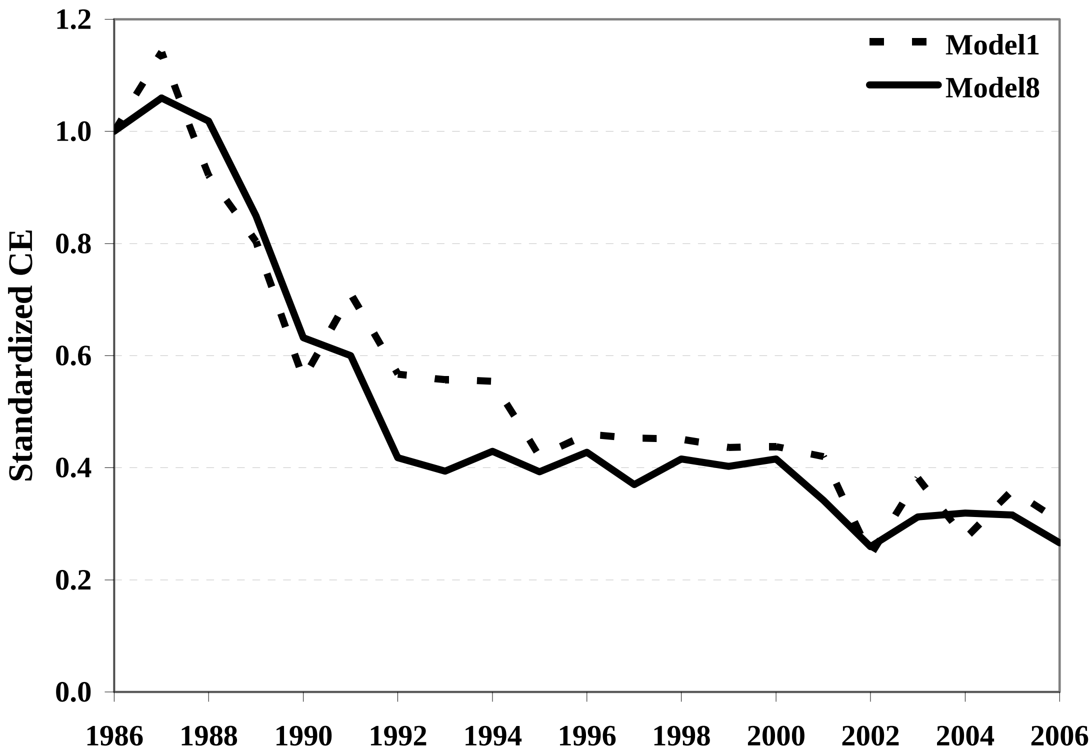

Figure 6.24. The standardized catch per unit of effort per year for Western Gemfish relative to catch rates in 1986, as represented by the geometric mean (model 1 - dashes) the optimal model (model 8 – solid line; see Table 6.67 for parameter values). Model descriptions in Table 6.68.

6.3.23 Western Gemfish and GAB (GEM – 37439002 – Rexea solandri)

Data selection was made using the following criteria:

Data from zones 40 and 50 and 80,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths greater than 0 and less than or equal to 600 m.

This analysis included western gemfish catches from both within the SEF and in the Great Australian Bight fishery, which shares the same stock of western gemfish. With just the restrictions of zones 40 and 50 and 80, trawlers, and 1986 - 2006 there were 29,998 records available for analysis for western Gemfish taken by trawl. Given the restrictions above these reduce to 26.752 records. Thus, 89.2% of available records are used and these represent 89.0% of all catches (Table 6.70).

Table 6.70. Number of records used in the CPUE standardization for Western Gemfish in each year, years in the fishery >2, CE >0, Average Depth => 160m and <= 600, and only Zones 40 and 50. The geometric mean and the optimum model 8 (see Figure 6.25) are relative to 1986.

Year	Records Used	Model 1	Model 8
1986	1371	1.0000	1.0000
1987	1067	1.1374	1.0667
1988	1344	0.9086	0.9923
1989	1128	0.7309	0.8250
1990	1003	0.5514	0.6430
1991	1537	0.7228	0.6179
1992	722	0.5806	0.4288
1993	717	0.5573	0.4009
1994	832	0.5543	0.4353
1995	964	0.4214	0.3988
1996	1238	0.4260	0.4286
1997	1619	0.4167	0.3944
1998	1450	0.4160	0.4170
1999	1950	0.4337	0.4109
2000	1947	0.4331	0.4245
2001	1815	0.4155	0.3532
2002	1476	0.2464	0.2742
2003	1178	0.3398	0.3193
2004	1293	0.2764	0.3325
2005	1142	0.3763	0.3340
2006	959	0.3203	0.2997

Eight statistical models were considered for the data from Western Gemfish (Table 6.71). Model 1 represents the geometric mean catch rates and Model 8 is the optimum model. (Table 6.70; Table 6.72; Figure 6.25).

Table 6.71. The structure of the eight statistical models trialled with Western Gemfish (including GAB). The factor names are as listed in Section 6.2.

Model	Factors
model 1	Year
model 2	Year Vessel
model 3	Year Vessel DayNight
model 4	Year Vessel DayNight Month
model 5	Year Vessel DayNight Month DepCat
model 6	Year Vessel DayNight Month DepCat Zone
model 7	Year Vessel DayNight Month DepCat Zone DepCat*Month
model 8	Year Vessel DayNight Month DepCat Zone DepCat* Zone*Month

Table 6.72. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Params is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model, Model 8, is bolded. Model 1 is the base case.

Model	N	Var%	df Params	df Resids	ModelSS	Resid SS	# Param	AIC
Model 1	**26827**	**0.0686**	**20**	**26806**	**4210**	**57182**	**21**	**20345**
Model 2	26827	0.2529	79	26826	15527	45865	80	14547
Model 3	26827	0.2618	82	26744	16072	45319	83	14232
Model 4	26827	0.2772	93	26733	17016	44376	94	13690
Model 5	26752	0.4423	115	26636	27119	34193	116	6797
Model 6	26752	0.4433	117	26634	27178	34133	118	6754
Model 7	26752	0.4593	331	26420	28161	33150	332	6401
Model 8	**26752**	**0.4806**	**693**	**26058**	**29464**	**31847**	**694**	**6052**

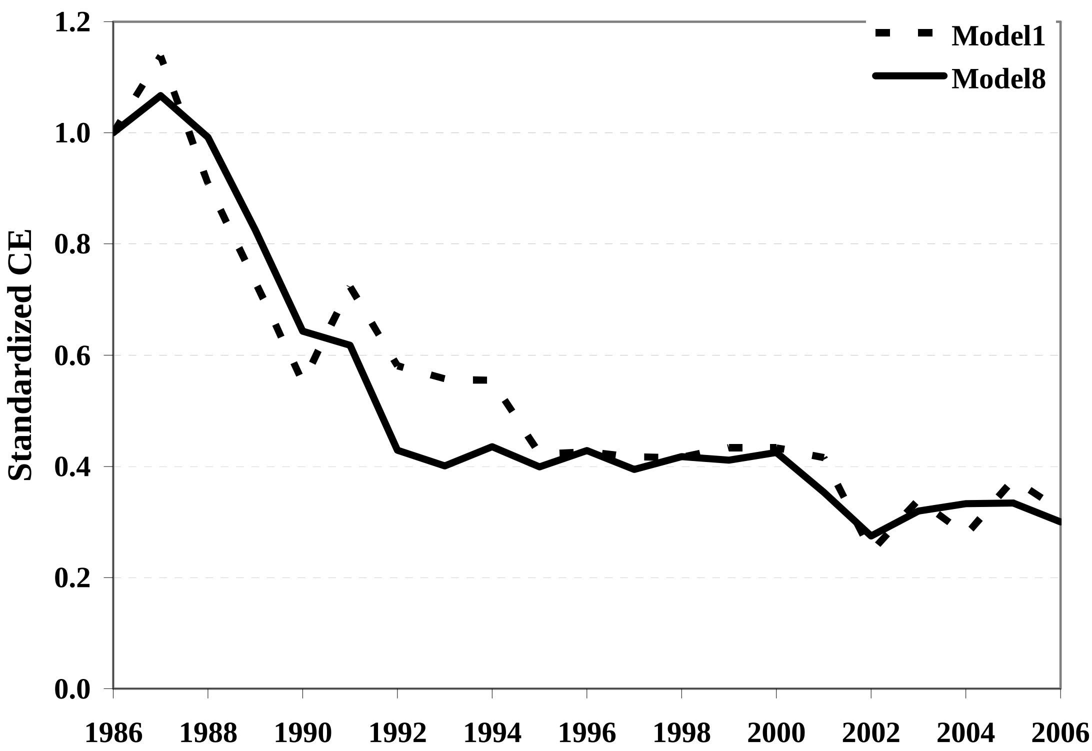

Figure 6.25. The standardized catch per unit of effort per year for Western Gemfish (including GAB) relative to catch rates in 1986, as represented by the geometric mean (model 1 - dashes) the optimal model (model 8 – solid line; see Table 6.67 for parameter values). Model descriptions in Table 6.68.

6.3.24 Total Ocean Perch, Zones 10 & 20 (REG – 37287001 – Helicolenus percoides)

Data selection was made using the following criteria:

Data from zones 10 and 20,
three or more years in the fishery,
catch rates greater than zero,
from 1986 onwards until 2006,
for trawl vessels only (i.e. exclude Danish Seine vessels), and
depths less than or equal to 700 m (combines Offshore and Inshore populations).

With just the restrictions of zones 10 and 20, trawlers, and 1986 - 2006 there were 83,698 records available for analysis for offshore Ocean Perch taken by trawl. Given the restrictions above these reduce to 80,365 records. Thus, 90.0% of available records are used and these represent 96.3% of all catches (Table 6.73).

Table 6.73. Number of records used in the CPUE standardization in each calendar year for the eastern fishery for Offshore Ocean Perch, years in the fishery >2, CE >0, and Depth <= 700 m. The geometric mean (Model 1) and the optimum model (Model 8) are relative to 1986 (see Figure 6.26).

Year	**Records**	**Model 1**	**Model 8**
1986	3325	1.0000	1.0000
1987	3464	0.7469	0.9588
1988	3298	0.8697	1.0708
1989	3489	0.8911	1.0308
1990	2426	0.9613	1.3200
1991	2738	1.0492	1.3696
1992	2290	0.9903	1.1531
1993	3377	1.0865	1.2250
1994	3595	0.9829	1.1310
1995	3749	0.8867	1.0378
1996	4090	0.8107	0.9317
1997	4171	0.8203	0.9474
1998	4492	0.7618	0.8325
1999	5106	0.7731	0.9383
2000	5465	0.5849	0.7699
2001	5096	0.6345	0.8199
2002	4874	0.4783	0.7368
2003	4913	0.5143	0.7575
2004	3995	0.5157	0.7323
2005	3669	0.6501	0.8422
2006	2743	0.5490	0.7252

Eight statistical models were considered for the total Ocean Perch fishery data (Table 6.74). Model 1 represents the deviations from the overall geometric mean and Model 8 is the optimum model as determined by both variability described and AIC value (Table 6.73; Table 6.75; Figure 6.26).

Table 6.74. The factors involved in each of the eight statistical models trialled with eastern fishery for all or or total Ocean perch taken by trawlers. The factor names are as listed in Section 6.2.

Model	Factors
1	Year
2	Year Vessel
3	Year Vessel DepCat
4	Year Vessel DepCat Zone
5	Year Vessel DepCat Zone Month
6	Year Vessel DepCat Zone Month DayNight
7	Year Vessel DepCat Zone Month DayNight Zone*Month
8	Year Vessel DepCat Zone Month DayNight DepCat*Zone*Month

Table 6.75. Outcomes for each statistical model. N is the total number of observations used, Var% is the percent variation in the data accounted for by the model, df Param is the degrees of freedom associated with the model, df Resids are the degrees of freedom associated with the rest of the data, Model SS is the sum of squared residuals for the model, Resid SS is the residual sum of squared not accounted for by the model, # Param is the number of parameters and AIC is Akaike's Information Criterion as defined in the General Methods. The optimum model – Model 8, is bolded. Model 1 is the base case geometric mean catch rate.

Model	N	Var%	df Params	df Resids	Model SS	Resid SS	# Param	AIC
1	80657	4.39	20	80636	5050	110127	21	25161
2	80657	16.20	143	80513	18665	96512	144	14763
3	80365	28.08	171	80193	32221	82507	172	2458
4	80365	28.14	172	80192	32283	82445	173	2400
5	80365	29.48	183	80181	33827	80901	184	902
6	80365	29.68	186	80178	34045	80682	187	690
7	80365	30.80	197	80167	35331	79397	198	-578
8	80365	33.27	810	79554	38173	76555	811	-2281

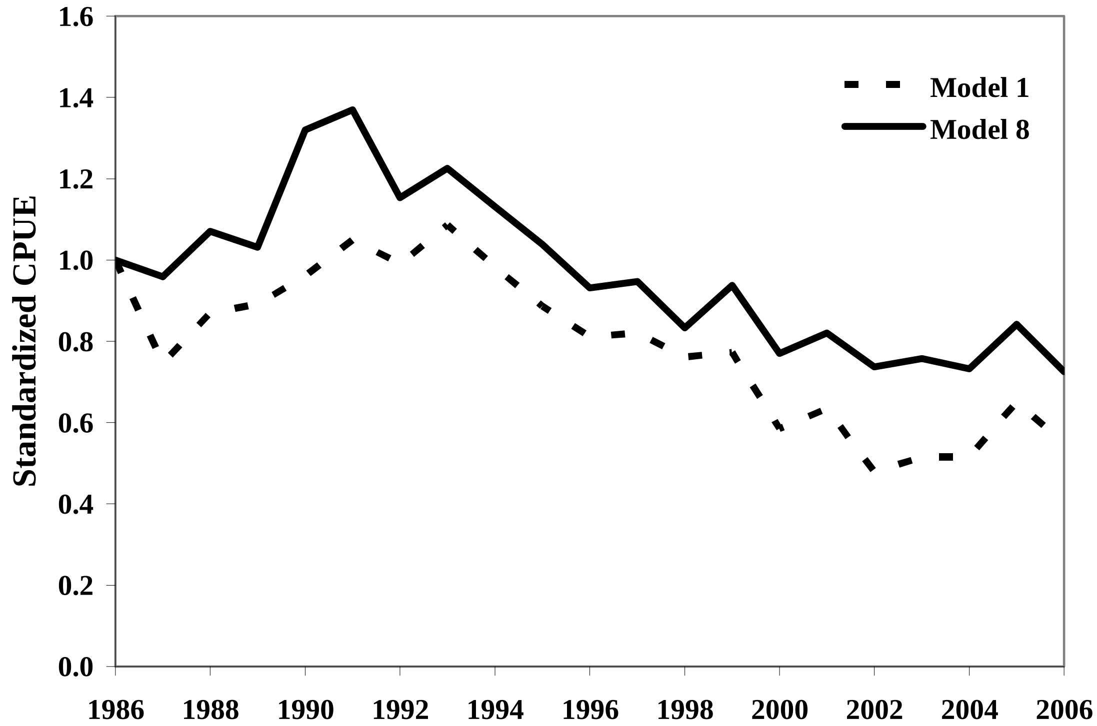

Figure 6.26. The standardized catch per unit of effort per year for the eastern fishery for all or Total Ocean Perch, relative to catch rates in 1986, as represented by the geometric mean (model 1 - dots) the optimal model (as selected using the AIC) was Model 8 (solid line; see Table 6.73 for parameter values). Model 8 accounted for the most variation but only differed slightly from Model 7 (Table 6.74 and Table 6.75).

6.4 References

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7. Updated Stock Assessment of Blue Grenadier (*Macruronus novaezelandiae)* Based on Data up to 2006: July 2007[1]

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7.1 Summary

The 2007 assessment of blue grenadier *Macruronus novaezelandiae* uses the age-structured integrated assessment method developed by Punt *et al.* (2001). The assessment has been updated by the inclusion of data from the 2006 calendar year. In addition, age reading error and new biological parameters relating to the proportion spawning and the length at maturity, first introduced in August 2006, have been used. Estimates of spawning biomass from acoustic surveys from 2003-2006 (method of Cordue (2000); 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included. This corresponds to the 'Low' model of Tuck and Punt (2006).

Results conclude that the female spawning biomass in 2006 is around 47% of the reference biomass and the depletion in 2008, used for the harvest control rules, will be approximately 44%. This compares with 40% for the 2005 depletion and 36% for the 2007 depletion in the 2006 assessment. These increases relative to the reference biomass are in part due to recent estimated biomasses being shifted upward through the increased level of the 2006 acoustic estimate and the increased cpue in both sub-fisheries. The Recommended Biological Catches (RBCs) for 2008 are between 3,275 t and 4,687 t (landed catch and discards), depending on the harvest control rule that is applied. The long-term RBCs are around between 5,000 and 6,000 t. In comparison, the RBCs for 2007 from the 2006 assessment were between 2,000 t and 3,300 t, with long-term RBCs of around 5,500 t.

The recruitment of 2004 is estimated to be about twice that expected from the stock-recruitment relationship. While a positive sign for the stock and fishery following several years of poor recruitment, this recruitment is not estimated to be as large as the recruitments of the mid-1990s.

[1] Paper presented to the Slope Resource Assessment Group on 23 and 24 July, 2007.

7.2 Introduction

An integrated analysis model has been applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by inclusion of the 2006 calendar year data (catch and discard at age; updated catch rate series; landings and discard catch weight) and additional information from acoustic surveys of spawning biomass (series from 2003-2006). The same assessment model that has been used in previous years (e.g. Punt *et al.*, 2001; Tuck and Punt, 2006) was used this year. This document presents (a) diagnostic plots and (b) recommended biological catches (RBCs) from an application of the Tier 1 harvest control rules.

The model considered here includes age-reading error, updated biological parameters for the proportion spawning and length at maturity (for males and females) and an assumption of 2-times turnover on the spawning ground. The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The acoustic estimates are assumed to pertain to total (male and female) spawning biomass. In Tuck and Punt (2006) two models were considered, differing according to the target strength used to produce the absolute estimates of spawning biomass from the acoustic surveys and assumptions about the egg survey estimates. The ‘High’ model assumes the target strength of Macauley (2004) and doubles the egg survey estimates. The survey estimates of absolute abundance used when fitting this model are higher than those used when fitting the ‘Low’ model which uses the Cordue (2000) target strength and the base-case egg survey estimates of spawning biomass. Following the recommendations of Ryan *et al.* (2007), here we only consider the ‘Low’ model, with the spawning biomass estimates resulting from the target strength estimates of Kloser *et al.* (2007).

7.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Data support the hypothesis of a single breeding population in Australian waters. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years and an age at maturity of 4-5 years. Spawning occurs off western Tasmania between late May and early September. Adults migrate to the spawning area from throughout southeastern Australia, with large fish arriving earlier in the spawning season.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2006 was 3,730 tonnes, and in 2005 it was 5000 t (with a voluntary industry reduction to 4200 t), down from 7000 t in 2004, 9000 t in 2003 and 10000 t which it had been since 1994. There are two defined sub-fisheries: the spawning and non-spawning fisheries. The non-spawning fishery catches have been relatively consistent over the last few years (at just under 2000t), whereas the spawning fishery catches showed a marked increase during the mid-1990s before decreasing from 2003. The spawning and non-spawning fishery catches are currently at similar levels.

7.4 Data

The model has been updated by the inclusion of the 2006 catch- and discard-at-age from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2007), the total mass landed and discarded, mean length- and weight-at-age; updated acoustic estimates of spawning biomass (Ryan *et al.*, 2007) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman *et al.*, 1999). Data were formulated by calendar year (i.e. 1 Jan to 31 Dec).

7.4.1 Catch

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery since 1986; 1.2 for the spawning fishery from 1986 up to and including 1996). These figures were then scaled up to the SEF2 data. As SEF2 data were only available from 1993, for years prior to this the average scaling factor from 1993 to 1998 was used to scale the data. The landings data are provided in Table 7.1.

Table 7.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted to account for reporting of headed and gutted catches, and scaled up to the SEF2 data (see text). The annual TAC is also shown. *Note that a voluntary industry reduction to 4,200 t was implemented in 2005.

Year	Landings		Discards		TAC
	Spawning	Non-spawning	Spawning	Non-spawning	
1979	245	245			
1980	410	410			
1981	225	225			
1982	390	390			
1983	450	450			
1984	675	675			
1985	600	600			
1986	321	1840			
1987	1020	2214			
1988	416	2279			
1989	47	2817			
1990	743	2605			
1991	1158	4193			
1992	931	2669			
1993	990	2359			
1994	1194	1916			10000
1995	1196	1558		80	10000
1996	1465	1505		975	10000
1997	2952	1581		3716	10000
1998	3267	2469		1329	10000
1999	6087	3214		123	10000
2000	6056	2592		69	10000
2001	7627	1498		10	10000
2002	7431	1731		2	10000
2003	7573	899		4	9000
2004	4801	1663		21	7000
2005	2694	1566		431	5000*
2006	1949	1761		175	3730

7.4.2 Catch rates

Haddon (2007) provides the updated catch rate series for blue grenadier (Table 7.2, Figure 7.1). Models 6 and 4 of Haddon (2007) were recommended to be used for the non-spawning and spawning fisheries respectively in the assessment models. The series show recent increases in cpue for both sub-fisheries.

Table 7.2. Standardised CPUE (Haddon, 2007) for the spawning and non-spawning sub-fisheries by calendar year.

Year	Spawning		Non-spawning	
	CPUE	Records	CPUE	Records
1986	1.00	71	1.00	2911
1987	1.18	154	1.30	3370
1988	2.34	92	1.38	3927
1989	0.63	24	1.42	4289
1990	0.66	132	1.47	3491
1991	2.27	102	1.03	4546
1992	1.18	189	0.87	3582
1993	1.74	142	0.65	4195
1994	1.00	288	0.58	4499
1995	0.41	474	0.40	5087
1996	0.58	352	0.36	5362
1997	0.45	403	0.37	6127
1998	0.61	575	0.61	6605
1999	0.50	857	0.64	8081
2000	0.50	944	0.46	7640
2001	0.80	1111	0.26	7192
2002	0.57	1039	0.26	6307
2003	0.55	1020	0.22	5687
2004	0.39	804	0.37	6358
2005	0.81	316	0.43	5289
2006	1.69	327	0.57	4289

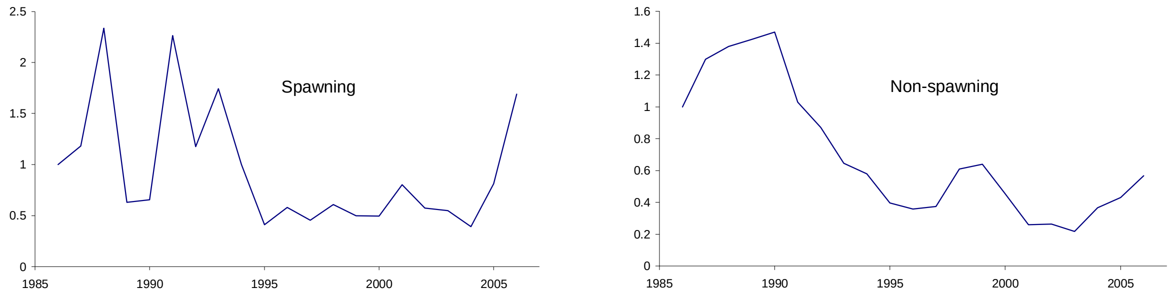

Figure 7.1. The calendar year catch-rate indices for the spawning and non-spawning blue grenadier fisheries (Haddon, 2007).

7.4.3 Catch-at-age

Although length frequency information is collected at several ports around Australia, traditionally only the data collected in Portland and Beachport (for 2002 to 2004) have been used when constructing a length-frequency distribution for the non-spawning fishery. This was done because BGAG had agreed to only use Portland data - earlier investigations by BGAG members indicated that the data from all ports showed the same trend. However, 2005 and 2006 length frequencies show differences in length frequency among ports. As such, a consistent method for catch-weighting length frequencies across ports was used to produce the length frequencies used in this assessment. A comparison of the port catch-weighted length frequencies against the previous single port length frequencies led to negligible differences (not shown). Figure 7.2 shows recent year non-spawning length frequencies. The age-compositions over all years are shown in Figure 7.8 to Figure 7.10.

Spawning sub-fishery length frequencies were obtained from AFMA on-board observations. To obtain the overall length-frequency, length records were catch-weighted by the weight of catch from the haul and the sample weight of the fish (Figure 7.3).

The catch-at-age for 2006 for each of the two sub-fisheries is shown in Figure 7.4. As expected, the non-spawning age composition shows the presence of a recent year-class progressing into the available biomass. This year-class has now entered the spawning fishery also.

7.4.4 Age-reading error

Standard deviations for aging error have been estimated, producing the age-reading error matrix of Table 7.4.

7.4.5 Acoustic survey estimates

Estimates of spawning biomass for years 2003-2006 are provided in Ryan *et al.* (2007). Two models of target strength were used in the assessments of Tuck and Punt (2006), namely Macauley (2004) and Cordue (2000). However, following the recommendations of Ryan *et al.* (2007) only estimates based on their results are presented here. Table 7.3 shows the spawning biomass estimates with their corresponding c.v. It is assumed that the spawning ground experiences a turnover rate equal to 2 (ie, for the model applied here the spawning biomass estimates are doubled).

Table 7.3. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2006 (Ryan *et al.*, 2007).

Model	Name	2003	2004	2005	2006
Ryan *et al.* (2007)	Low	24,690	16,295	18,852	42,882
c.v. used in assessment model		0.3	0.46	0.3	0.3

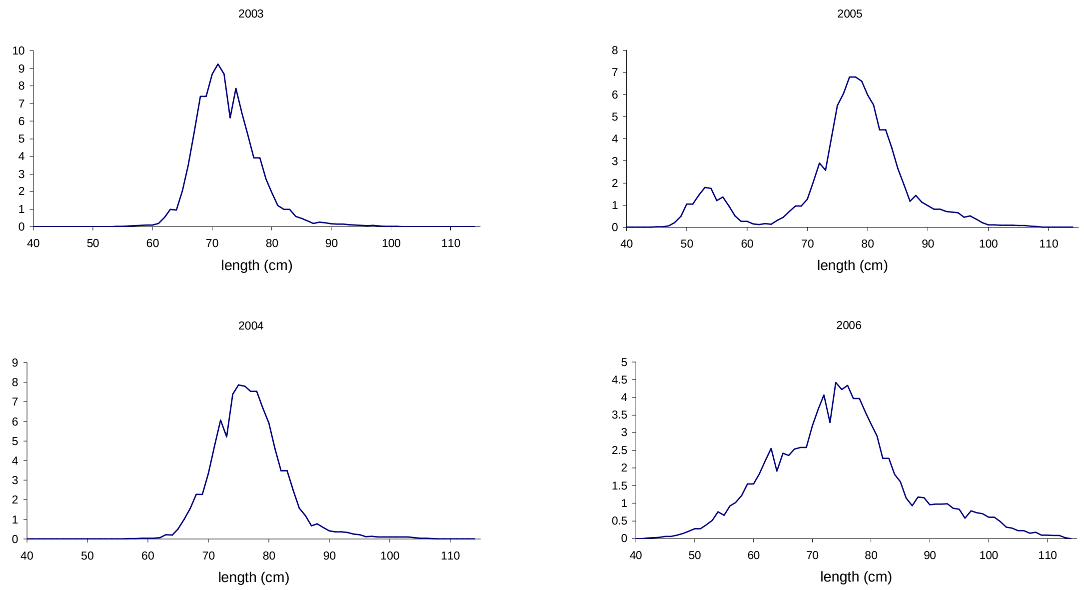

Figure 7.2. The port-based catch-weighted length frequencies for the non-spawning blue grenadier fishery over years 2003-2006.

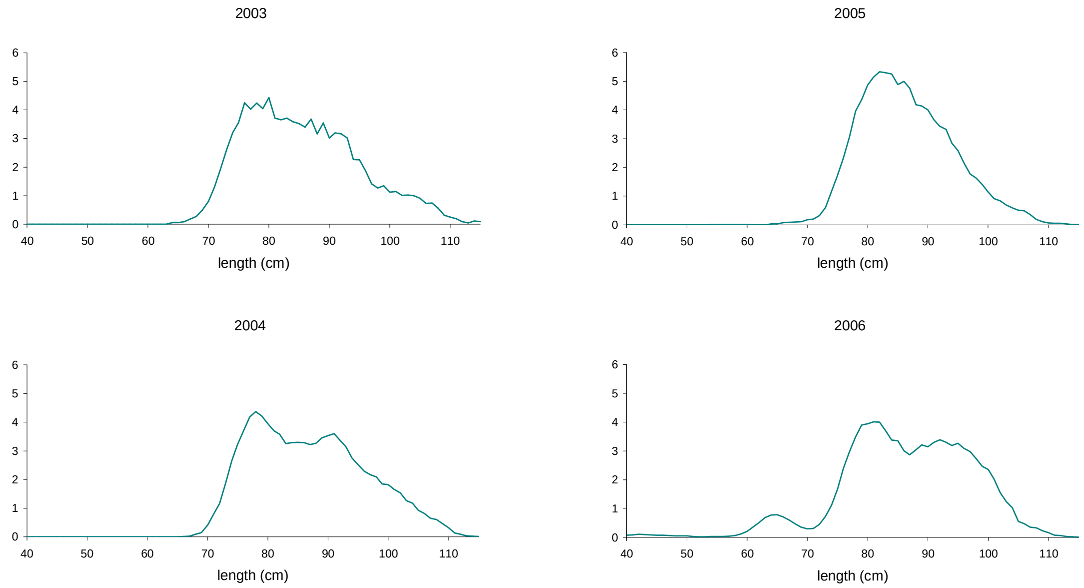

Figure 7.3. The catch-weighted length frequency for blue grenadier of the spawning sub-fishery in years 2003-2006.

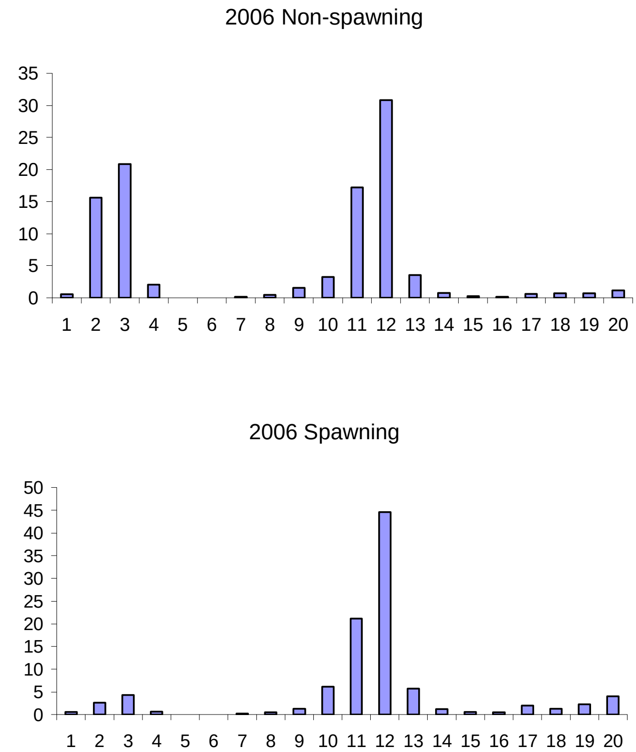

Figure 7.4. The observed proportion caught–at-age data for the non-spawning (top) and spawning (bottom) sub-fisheries in 2006.

7.4.6 Egg survey estimates

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman *et al.*, 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

Table 7.4. The age-reading error matrix, shown as the percentage of times an animal with true age given by the column header is aged to be of the age given by the rows. Source: A.E. Punt and Central Aging Facility (CAF, PIRVic, Queenscliff, Victoria).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	89.3	11.5	0	0	0	0	0	0	0	0	0	0	0	0	0
2	10.7	77.1	12.2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	11.5	75.5	13.1	0.1	0	0	0	0	0	0	0	0	0	0
4	0	0	12.2	73.8	13.9	0.1	0	0	0	0	0	0	0	0	0
5	0	0	0	13.1	72.0	14.9	0.1	0	0	0	0	0	0	0	0
6	0	0	0	0	13.9	70	15.9	0.2	0	0	0	0	0	0	0
7	0	0	0	0	0.1	14.9	68.0	16.8	0.3	0	0	0	0	0	0
8	0	0	0	0	0	0.1	15.9	65.9	17.8	0.5	0	0	0	0	0
9	0	0	0	0	0	0	0.1	16.8	63.7	18.8	0.7	0	0	0	0
10	0	0	0	0	0	0	0	0.2	17.8	61.5	19.8	0.9	0	0	0
11	0	0	0	0	0	0	0	0	0.3	18.8	59.1	20.7	1.3	0	0
12	0	0	0	0	0	0	0	0	0	0.5	19.8	56.8	21.5	1.7	0
13	0	0	0	0	0		0	0	0	0	0.7	20.7	54.4	22.3	2.2
14	0	0	0	0	0	0	0	0	0	0	0	0.9	21.5	51.9	23.0
15	0	0	0	0	0	0	0	0	0	0	0	0	1.3	24.0	74.8

7.4.7 Parameters of breeding biology

The assessment models prior to 2006, including base-case models, have assumed that the proportion of females that spawn is 0.77 and that the length at maturity is 70cm (Punt *et al.,* 2001). These values were taken from research on hoki in New Zealand (Livingston *et al.*, 1997). Recent studies have provided more up-to-date values for these parameters that are specific to the Australian stock of blue grenadier (S. Russell and D. Smith, pers. comm.), namely 0.84 for the proportion of females that is on the spawning grounds, and lengths at 50% maturity of 63.7cm for females and 56.8cm for males. As no information was available on the proportion of non-spawning male blue grenadier, it was assumed that this proportion was the same as that for females. In the results that follow (as was the case in Tuck and Punt (2006)), the updated parameters have been used.

7.5 Analytic approach

7.5.1 The population dynamics model

The population and likelihood models applied in 2007 are the same as those used in the 2006 assessment and are based upon the integrated analysis model developed for blue grenadier in the South East Fishery by Punt *et al.* (2001; Appendix; see also Tuck and Punt, 2006). The 2007 model is updated and extended by including the following data:

- the total mass landed and discarded during 2006; the catch- and discard-at-age during 2006 and the estimated mean length and weight of each age-class present during 2006,
- revised standardised CPUE series,
- an updated age-reading error matrix,
- an acoustic estimate of the 2006 spawning biomass off western Tasmania.

Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania, and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year. The model is sex dis-aggregated. However male and female fish are assumed to grow at the same rate.

Parameter uncertainty is examined through the use of sensitivity tests and by applying the Markov Chain Monte Carlo (MCMC) algorithm (Hastings, 1970; Gelman *et al.*, 1995).

7.5.2 The objective function

The negative of the logarithm of the likelihood function includes five components. These relate to minimizing the sizes of the recruitment residuals, fitting the observed catches and discards by fleet, fitting the observed age-compositions by fleet, fitting the catch rate information, and fitting the estimates of spawner biomass from the egg and acoustic surveys. The Appendix (Section 7.10) has details of the likelihood formulations (see also Punt *et al*. (2001)).

7.5.3 Parameter estimation

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 7.5. The model has 115 estimated parameters: 2 catchability coefficients; 1 female natural mortality, 1 B_0, 29 annual fishing mortality rates for each of the two sub-fisheries; recruitment residuals for 27 years and 19 age classes in the first year; 2 selectivity parameters for the spawning sub-fishery and 3 for the non-spawning; and 2 parameters for the probability of discarding-at-length function.

The values for the parameters that maximize the objective function are determined using the AD Model Builder package[2]. This assessment quantifies the uncertainty of the estimates of the model parameters and of the other quantities of interest using Bayesian methods. The Markov Chain Monte Carlo (MCMC) algorithm (Hastings, 1970; Gelman *et al.*, 1995) was used to sample 2000 equally likely parameter vectors from the joint posterior density function. The samples on which inference is based were generated by running 2,000,000 cycles of the MCMC algorithm, discarding the first 1,000,000 as a burn-in period and retaining every 500th parameter vector thereafter.

Table 7.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
N	Weight for the catch- and discard-at-age data	50
σ_r	c.v. for the recruitment residuals	1.0
σ_c	c.v. for the landings data	0.05
σ_d	c.v. for the discard data	0.3
σ_q	c.v. for the CPUE data	0.3
h	“steepness” of the Beverton-Holt stock-recruit curve	0.9
x	age of plus group	15 years
μ	fraction of mature population that spawn each year	0.84
l_∞	von Bertalanffy parameter (maximum length)	102.76 cm
κ	von Bertalanffy parameter (growth rate)	0.16 y^{-1}
t_0	von Bertalanffy parameter	-2.209 y
aa	allometric length-weight equations	0.00375 g^{-1}.cm
bb	allometric length-weight equations	3.013
l_m	length at maturity (knife-edged) (M, F)	63.7, 56.8cm

[2] Copyright 1991, 1992 Otter Software Ltd.

7.6 Results and discussion

7.6.1 Stock assessment

Figure 7.5 shows the observed and predicted fits to the landings and discards from each sub-fishery. The model is forced to fit the recorded landings because of the low c.v. that is assumed for these data (σ_c = 0.05, Table 7.5). The model is able to fit the recent drop in the mass of discards and the recent increase; however the large discard measured in 1997 is not well estimated despite the ability of the model to allow for density-dependant discarding.

The estimated natural mortality figure for females is approximately 0.165 and consequently that for males is 0.2 (as male natural mortality is assumed to be 1.2 times that of females). This compares with 0.18 and 0.21 in Tuck and Punt (2006), 0.2 and 0.24 in Tuck (2006), Tuck and Koopman (2005) and Tuck *et al*. (2004). The reduction in natural mortality needs further exploration but is co-incident with the introduction of the new breeding parameters and age-reading error in 2006.

For the winter spawning sub-fishery, Figure 7.6 shows that the model is not able to fit the early large fluctuations in the CPUE, nor the large increases in CPUE in years 2005 and 2006, but it is able to achieve a reasonable fit to the CPUE in intermediate years. The fit to the CPUE for the non-spawning sub-fishery is reasonably good, although the increase in the CPUE after 1998 is not as well estimated; nor is the drop in CPUE for 2000. However, the modelled CPUE has begun increasing in line with the observed increases in 2005 and 2006. In general though, it appears the model is 1 to 2 years out of phase with the observed non-spawning catch rates. Attempts to provide better fits to the non-spawning fishery catch rates have not been fruitful (such as forcing fits to the catch rate by lowering the cv). This issue will be explored further as a high priority. Changes to the form of the selectivity function may prove successful and conversion of the model to SS2 may assist this exploration.

The estimated vulnerability of fish of a given length class to being caught (but not necessarily landed) by either sub-fishery is shown in Figure 7.7. The probability that a fish will be discarded once it has been caught is also shown.

The fits to the catch-at-age and the discard-at-age data for both sub-fisheries are reasonably good (Figure 7.8 to Figure 7.10). Figure 7.11 shows the estimated annual recruitment multipliers, and illustrates a long period of poor recruitment following the strong recruitments of 1994 and 1995. An increase in recruitment has been estimated for years 2003 and 2004. These recent recruitment events are approximately equal to (a value of 1.0 in 2003) or twice (in 2004) that predicted by the stock recruitment relationship. The recruitments do not appear to be as strong as those of the mid-1990s.

Table 7.6 shows the results against various quantities of interest for the base case models. The quantities of interest shown are the estimated pristine female spawning biomass (B_0); the reference biomass (B_{ref}) which is the average female spawning biomass over 1979–1988; the spawning biomass in 1979 ($\tilde{B}_{79}$) and in 2006 ($\tilde{B}_{2006}$) and its size in 2006 relative to the reference level (depletion, $\tilde{B}_y / B_{ref}$); the estimated fishing mortality rate for the spawning (F^1_{curr}) and non-spawning (F^2_{curr}) sub-fisheries for 2006 (=*curr*); the estimated recruitment residual for the strong 1994 cohort, and the more recent 2004 cohort, and the negative log likelihood (-ln L) value from the model. Also shown are the base-case results for previous years' assessments. Note that the final year of biomass estimation (*curr*) is one year less than the year the assessment is produced.

The assessment of 2007 concludes that the reference female biomass is approximately 50,600 t and that current female spawner biomass (in the middle of 2006) is approximately 47% of the reference biomass. Figure 7.12 shows the spawning biomass trajectory with the egg survey estimates (left; female spawning biomass only) and the acoustic estimates (right; total spawning biomass). Intervals on survey estimates are 2 standard deviations. Figure 7.14 shows the female spawning biomass trajectory relative to the reference biomass for each model.

Table 7.6. Estimated values for several parameters of interest. The base case model is shown as well as sensitivity tests. Results are shown for base-case runs in the previous 3 years for comparison with the 2005 assessment. ‘Curr’ refers to the current or final year of the estimation. The High Model uses the higher acoustic survey estimates of total spawning biomass with the egg survey estimates of female spawning biomass doubled. The Low model uses the lower acoustic estimates of total spawning biomass with the base-case egg survey estimates. Both of these models assume 2 times turnover.

Specification	B_0	B_{ref}	$\tilde{B}_{79}$	$\tilde{B}_{curr}$	$\tilde{B}_{curr} / B_{ref}$	F^1_{curr}	F^2_{curr}	R_{94}	R_{03}	-ln L
Previous assessment results										
Base-case, *curr*=2002	33026	52605	51685	31241	59.39%	0.175	0.027	6.0	-	352.42
Base-case, *curr*=2003	26877	42082	41441	18066	42.93%	0.278	0.026	6.2	-	362.06
Base-case, *curr*=2004	30241	48612	47311	21283	43.78%	0.139	0.036	6.9	0.71	396.00
2006 assessment, *curr*=2005										
Low Model	27467	49293	47396	18065	36.65%	0.085	0.067	11.4	1.7	372.67
High Model	63917	148749	155947	62203	41.82%	0.027	0.020	10.1	1.8	378.56
2007 assessment, *curr*=2006										
Low Model	30340	50644	44701	23867	47.13%	0.050	0.055	11.6	2.1	466.49

7.6.2 Retrospective analysis

Figure 7.14 and Figure 7.15 show the female spawning biomass, total spawning biomass and recruitment multipliers for each of the assessments from 2004 to 2007. This shows how the 2007 spawning biomass trajectories have increased in recent years compared to previous assessments. This is due to the increase in observed catch rate and the large 2006 acoustic estimate. The 2006 and 2007 assessments look somewhat different to the others due to the inclusion of new breeding parameters and age-reading error (see Tuck (2006)).

7.6.3 Transition from the 2006 to the 2007 assessment

To explore the changes observed in Figure 7.14 and Figure 7.15 following the inclusion of the 2006 calendar year data, a sequential analysis was conducted to determine the influence of each of the input sources. Figure 7.16 to Figure 7.19 show the SSB, recruitment deviations and catch rate for each sub-fishery as each data source (listed and labelled below) is added and an assessment conducted. Note the age data below refers to the catch-at-age, discard-at-age, mean length-at-age and age-reading error data. The various data sources are:

1. The 2006 assessment data with the addition of the 2006 catches (**2006 C**)
2. Option 1 with the updated catch rate series of 2007 (**C + Cpue**)
3. Option 1 with the updated acoustic estimates of Ryan *et al*. (2007) (**C + Ac**)
4. Option 1 with the addition of the age data (**C + Age Data**)
5. Option 3 with the updated acoustic estimates of Ryan *et al*. (2007) (**C + Cpue + Ac**)
6. Option 3 with the addition of the age data (**C + Cpue + Age Data**)
7. The 2007 assessment result (**2007**)

Note that the 2007 assessment result is equivalent to (**C + Cpue + AgeData + Acoustic + D**), where D is the discard mass. A sensitivity to the discard mass was not shown as it did not produce significantly different plots whether included or not.

Figure 7.16 shows that as each data source is added the most recent year female spawning biomass increases from the 2006 assessment values through to the 2007 assessment values. Not surprisingly, the inclusion of the cpue and acoustic data produces a substantial shift in the trajectory. The age data appear to shift the early years down, whereas the cpue and acoustic data shift those years up (in comparison to the 2006 trajectory). As a consequence the 2007 trajectory begins at a similar point to the 2006 assessment.

Figure 7.17 shows the estimated annual recruitment multipliers as each of the data sources are included in the as sessment. There is not much difference in the trajectories since the 1980s, apart from the magnitude of the most recent recruitment being greater with the inclusion of cpue and acoustic data.

Figure 7.17 and Figure 7.19 show the estimated annual catch rates for each of the sub-fisheries as each of the data sources re included. Once the updated catch rate series (**Cpue**) from 2007 (Haddon, 2007) is included, the fit is plotted against this series (bottom figure), as opposed to the 2006 series (top). Note that the fit to the spawning catch rate series is poorer than in 2006. This appears to have been influenced by a relative change in the 2007 catch series through the mid-1990s compared to the 2006 series (see Figure 7.20), in addition to the model's inability to fit to the most recent large catch rates. As mentioned in previous assessments, the fit to the non-spawning fishery catch rate is poor and needs further exploration.

7.6.4 Harvest control rule application

The steps involved in computing the Recommended Biological Catch for 2007 using the Tier 1 rules are:

1. Determine the relationship between exploitation rate and spawning biomass, where the relative exploitation rates among the fleets are based on the exploitation rates estimated for 2007.
2. Find the exploitation rates so that spawning biomass is a pre-specified fraction of that in an unfished state.
3. Determine the depletion of the spawning biomass in the middle of 2008.
4. Determine the correction factor (if needed), and multiply the exploitation rates calculated at step 2 by this correction factor.
5. Multiply the numbers-at-age in the middle of 2008 by the exploitation rates calculated at step 4.

Three variants of the Tier 1 rules are applied depending on specifications for the target spawning biomass and the depletion at which the exploitation rate begins to be reduced to zero (all variants set the exploitation rate to zero if the stock is assessed to be depleted to be 20% of B_{ref}):

a) 20-48-48; a target stock size of 48% of B_{ref}, with the exploitation rate dropping off once the stock drops below the target level.
b) 20-40-48; a target stock size of 48% of B_{ref}, with the exploitation rate dropping off once the stock drops below 0.4 B_{ref}.
c) 20-40-40; a target stock size of 40% of B_{ref}, with the exploitation rate dropping off once the stock drops below the target level.

The mid-year depletion in 2008 must be calculated to apply the Tier 1 harvest control rule. The 2008 depletion is shown in Table 7.7 and is calculated by assuming a 2007 catch of 3,730 t. The ensuing landed and total Recommended Biological Catches (RBC) for 2008 are given in Table 7.7.

The time series of landed RBCs under each Tier 1 rule is given in Table 7.8 and Figure 7.21. Note that the final depletions are not exactly 40% and 48% of B_{ref} even when the catches are those for the model concerned (i.e. RBCs determined from the Low Acoustic model projected forward when reality is assumed to be the Low Acoustic model). This occurs presumably because density-dependence in the stock recruitment model is a function of depletion relative to B_0 and not relative to B_{ref}. As a result the depletion in terms of B_0 is higher than in terms of B_{ref}. The annual depletion level under the current catch of 3,730t are also shown in this table.

From Table 7.8, the long-term RBCs are approximately 4,880t for a target depletion of 48% of the reference biomass and 5,470t for 40% (note these values are approximate as they have not stabilised over the 20 year projection horizon considered in Table 7.8).

Table 7.7. The estimated 2008 mid-year depletion and RBCs (landed and total; tonnes) for three Tier 1 harvest control rules with target biomass depletions of either 48% or 40%.

Tier rule	2008 Depletion	Landed RBC	Total RBC (landed+discard)
20:40:40	0.44	4,368	4,687
20:48:48	0.45	3,054	3,275
20:40:48	0.45	3,418	3,666

Table 7.8. The time series of landed RBCs and corresponding depletions relative to Bref for each Tier 1 rule. Also shown is the annual depletion if the current landed catch of 3,730 t is maintained over all projected years.

	Landed RBC			Depletion			
	20:40:40	20:48:48	20:40:48	20:40:40	20:48:48	20:40:48	Ccurr=3,730
2007	3729	3729	3729	0.44	0.44	0.44	0.44
2008	4368	3054	3418	0.44	0.45	0.45	0.45
2009	3886	2471	3285	0.38	0.40	0.39	0.38
2010	4056	2809	3556	0.38	0.41	0.40	0.39
2011	4305	3180	3749	0.39	0.43	0.41	0.40
2012	4647	3599	3937	0.39	0.44	0.42	0.42
2013	4970	3997	4137	0.40	0.46	0.43	0.44
2014	5098	4305	4288	0.40	0.47	0.44	0.46
2015	5181	4528	4405	0.41	0.48	0.45	0.48
2016	5243	4660	4497	0.41	0.48	0.46	0.49
2017	5292	4706	4572	0.42	0.49	0.47	0.51
2018	5331	4742	4633	0.42	0.49	0.48	0.53
2019	5363	4772	4683	0.42	0.50	0.48	0.55
2020	5388	4796	4724	0.42	0.50	0.49	0.56
2021	5409	4816	4757	0.43	0.50	0.49	0.57
2022	5425	4832	4784	0.43	0.50	0.50	0.58
2023	5439	4845	4807	0.43	0.51	0.50	0.60
2024	5450	4856	4825	0.43	0.51	0.50	0.61
2025	5458	4865	4839	0.43	0.51	0.50	0.61
2026	5465	4872	4851	0.43	0.51	0.51	0.62

7.7 Acknowledgements

Many thanks are due to Sandy Morison, Gavin Fay, Rick Methot and all of the SS2-WG for their assistance with general model discussions and SS2 model development. Malcolm Haddon is thanked for providing catch rate indices, Mike Fuller and Neil Klaer for their advice on data matters. The Central Aging Facility and the AFMA observer section are thanked for providing the aging data and spawning length frequency data respectively.

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7.9 Figures

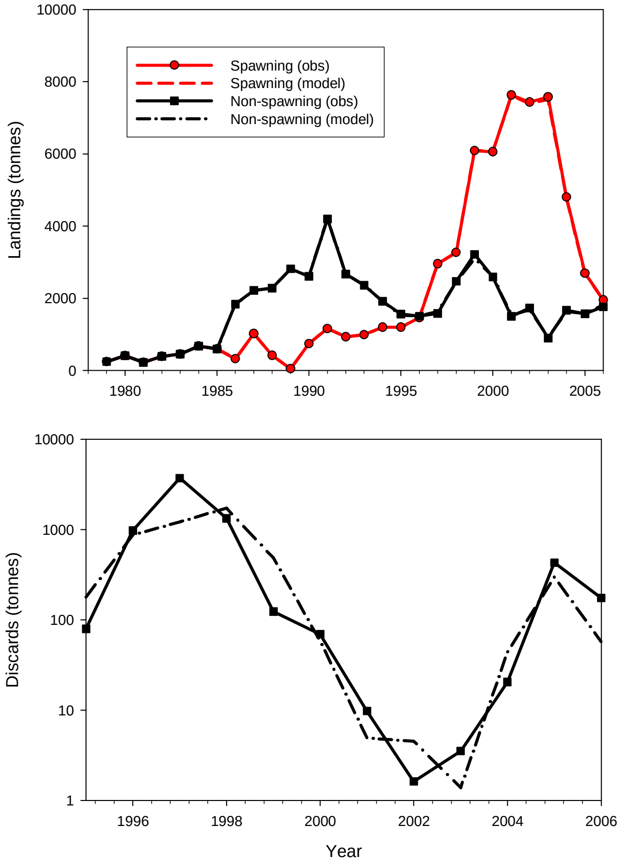


Figure 7.5. Top plot: Annual estimated landings of blue grenadier (obs; scaled to account for headed and gutted fish and to sef2) and estimated by the Low base case model (model). Bottom plot: Discards estimated from the ISMP (solid line) and Low model estimated values (dashed line). Note that the lines for the modelled spawning and non-spawning (model) landings overlay those of the observed (obs) lines for each sub-fishery.

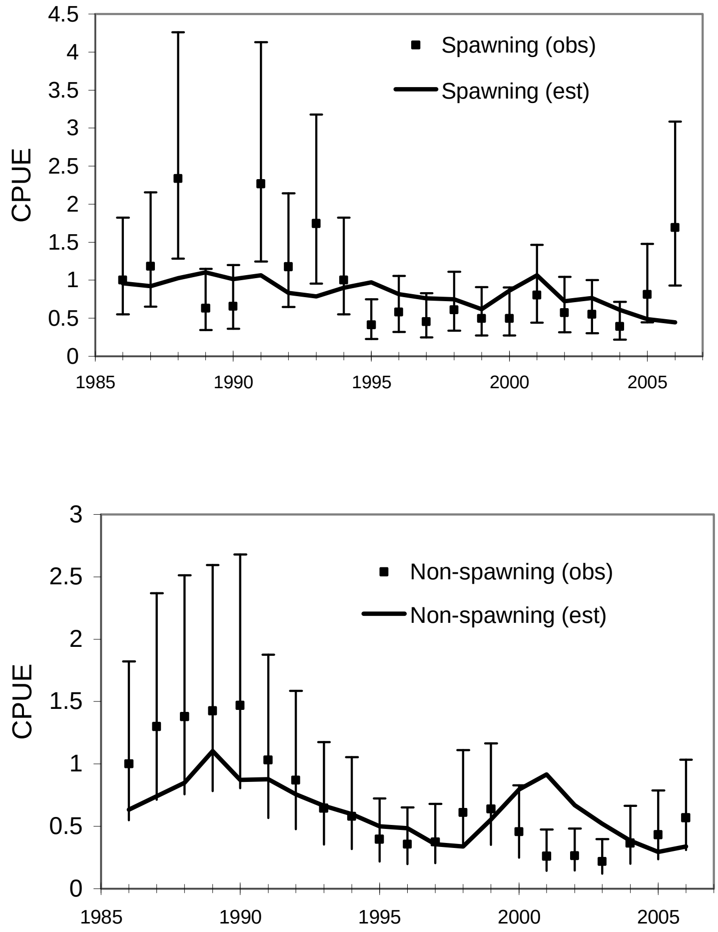


Figure 7.6. Catch-per-unit-effort (CPUE) calculated using a GLM to standardise CPUE from log-books (obs) and the High and Low model estimated CPUE for the spawning fishery (top) and the non-spawning fishery (bottom).

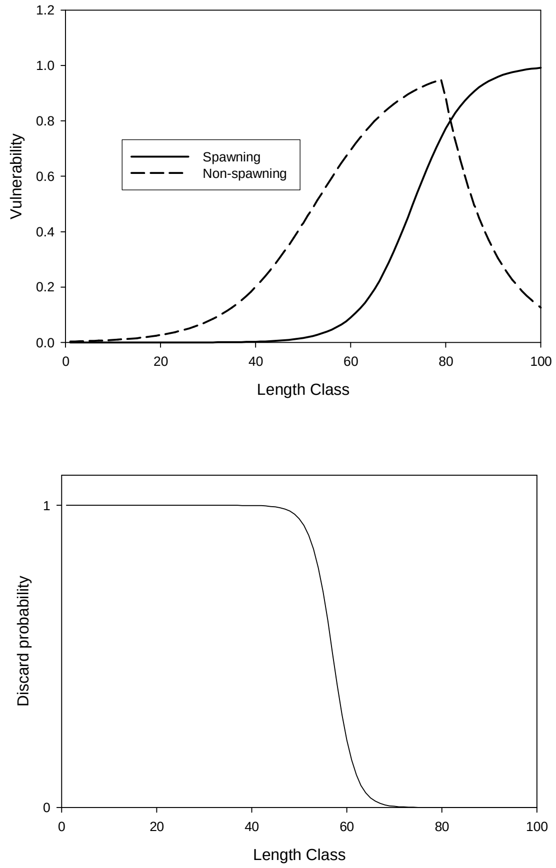


Figure 7.7. Vulnerability of blue grenadier to being caught (but not necessarily landed) by the two sub-fisheries (top) and the probability of being discarded if caught (bottom) as a function of length class for the Low model.

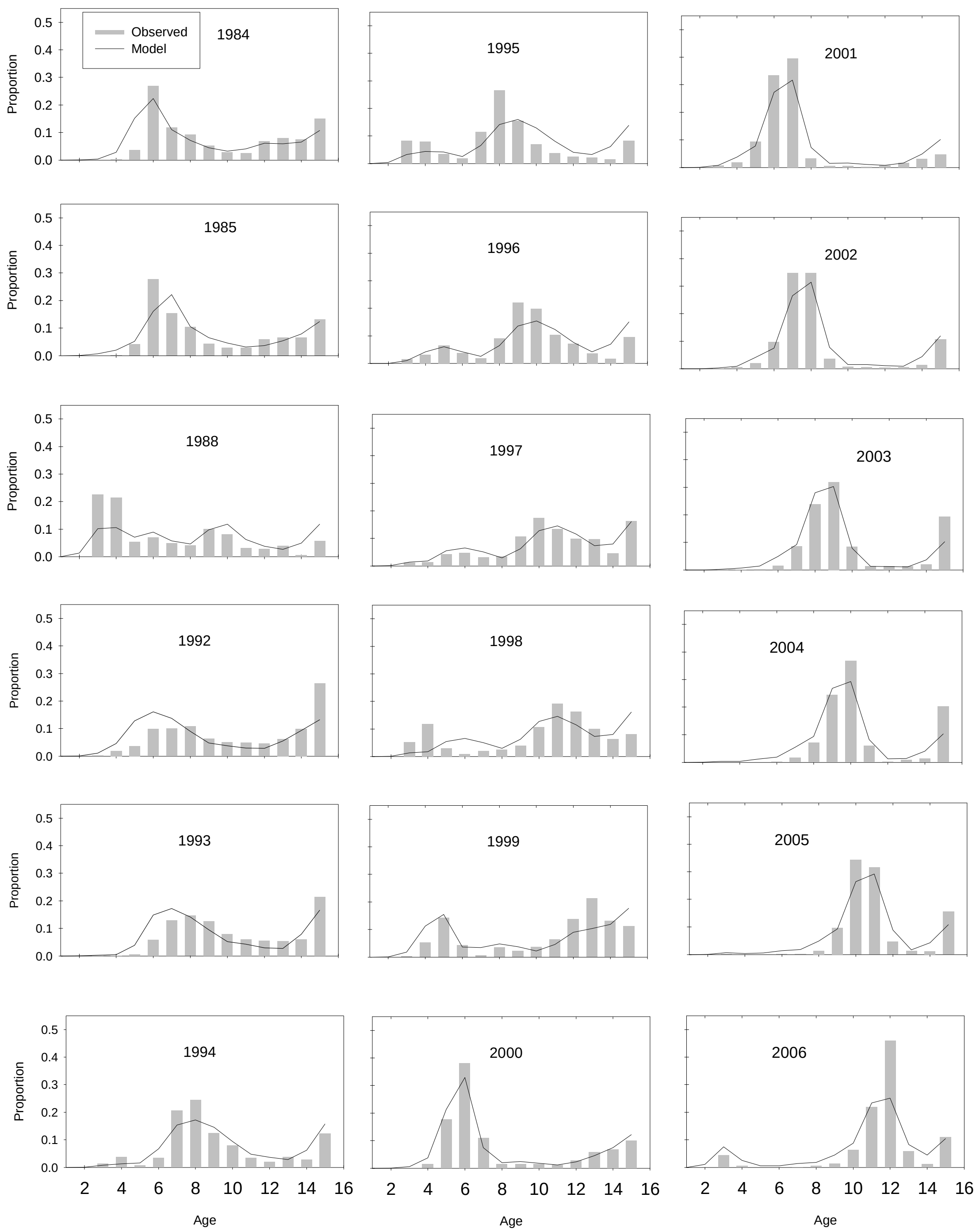


Figure 7.8. Observed (bars) and model estimated (lines) proportion caught at age for the spawning sub-fishery and Low model.

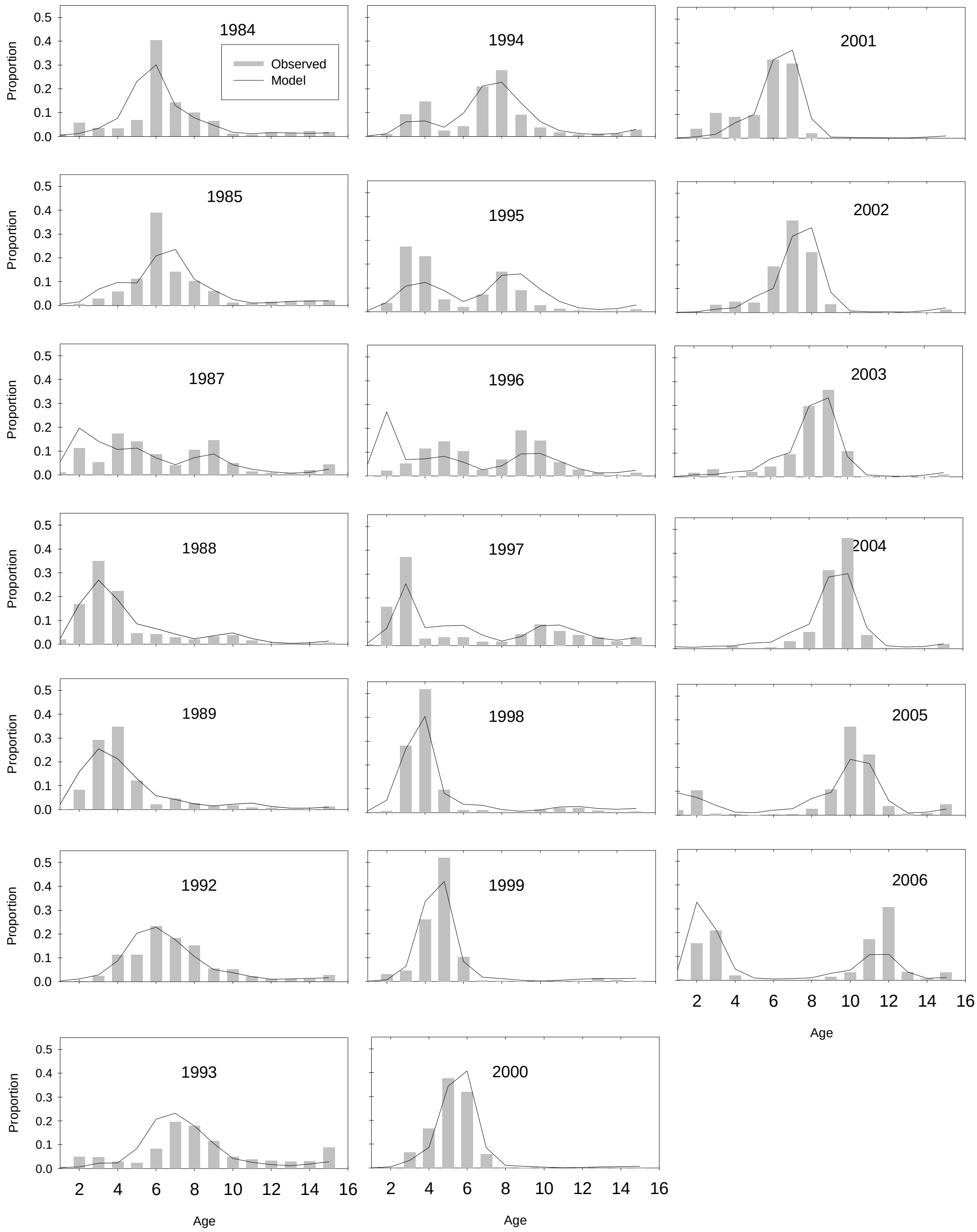


Figure 7.9. Observed (bars) and model estimated (lines) proportion caught at age for the non-spawning sub-fishery and Low model.

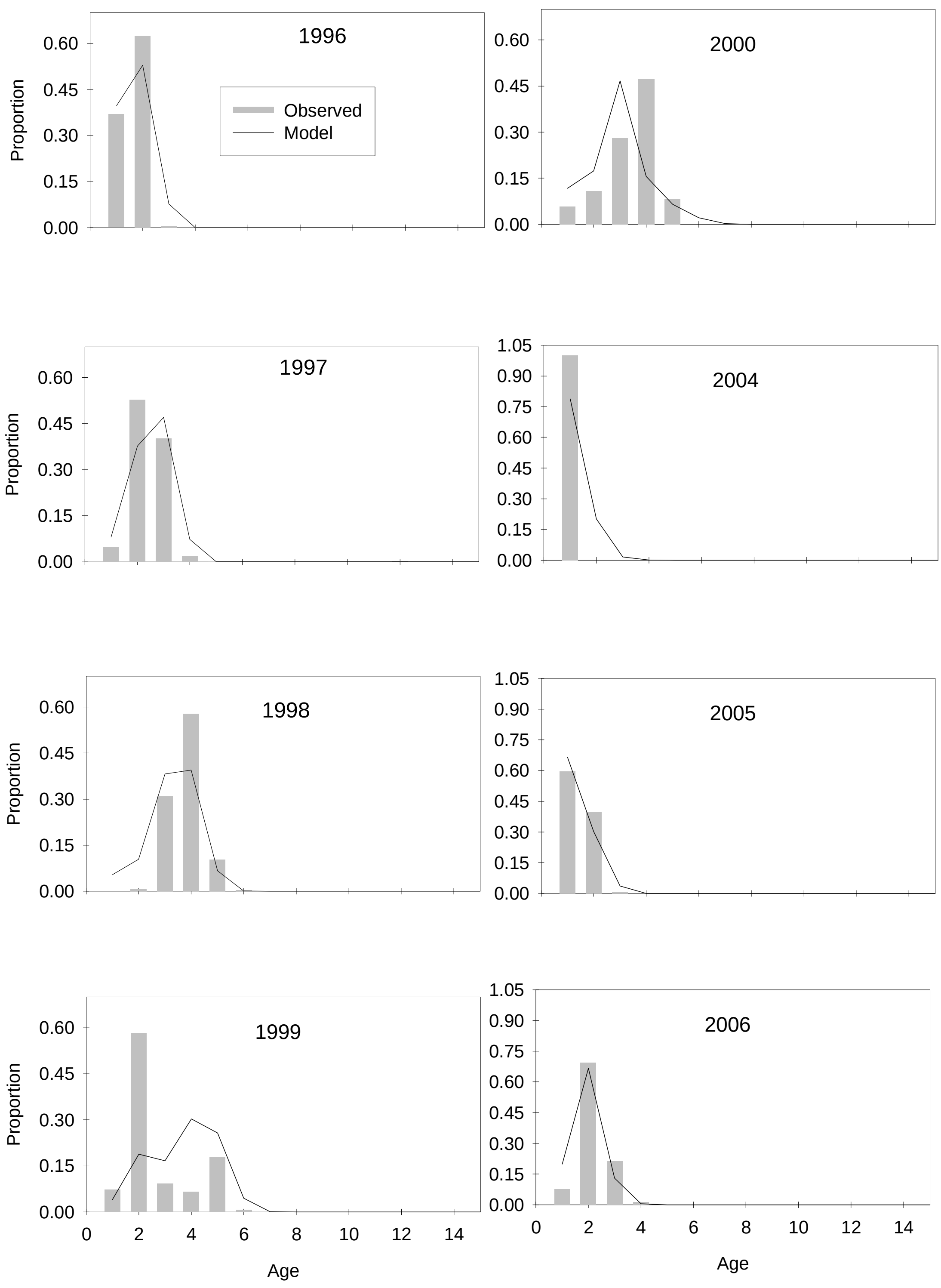
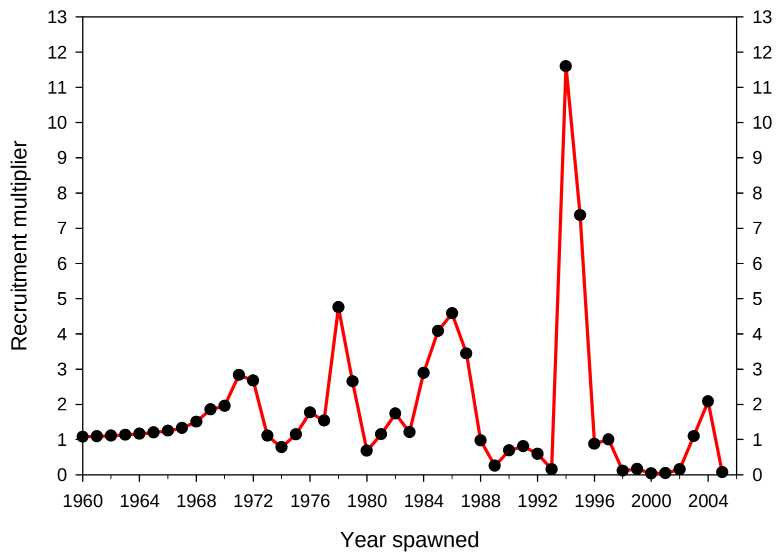


Figure 7.10. Observed (bars) and model estimated (lines) proportion discarded-at-age for the non-spawning sub-fishery and Low model.



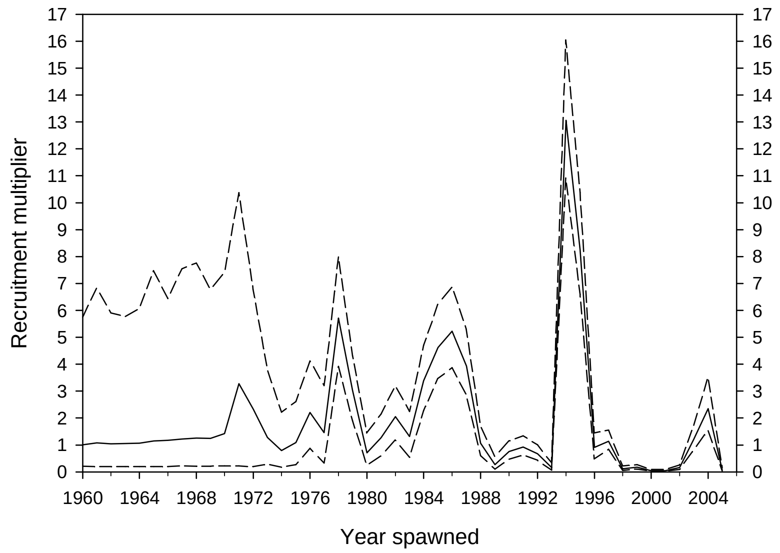


Figure 7.11. Top: Estimated recruitment multipliers (the amount by which the recruitment deviated from that predicted by the stock-recruit relationship) versus year of spawning from Low model. Bottom: The median (solid line), upper and lower 95% bounds (dashed lines) on the recruitment multipliers for the Low model.

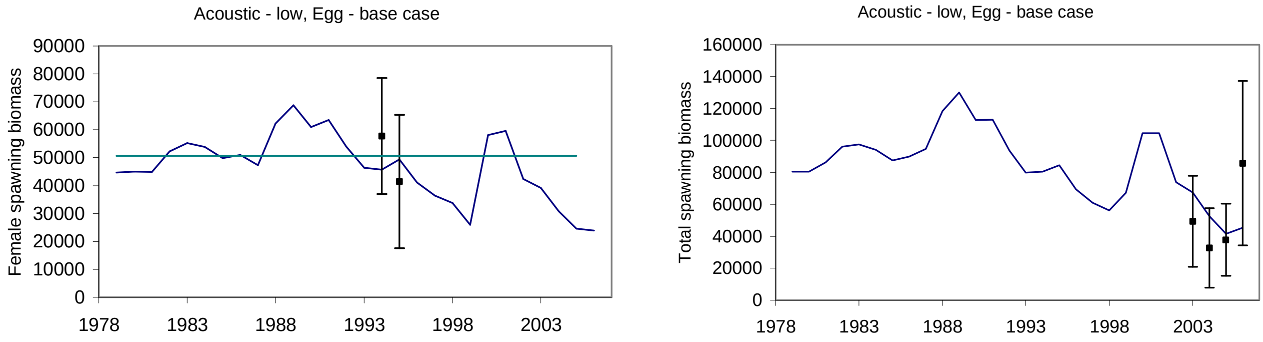


Figure 7.12. The time-trajectory of female spawning biomass (left) and total spawning biomass (right) for the Low model. The vertical lines show the estimates of spawning biomass derived from surveys of egg abundance in 1994 and 1995 and acoustic surveys from 2003 to 2006. The horizontal line shows B_{ref}, which is defined as the average female spawning biomass over 1979–1988.

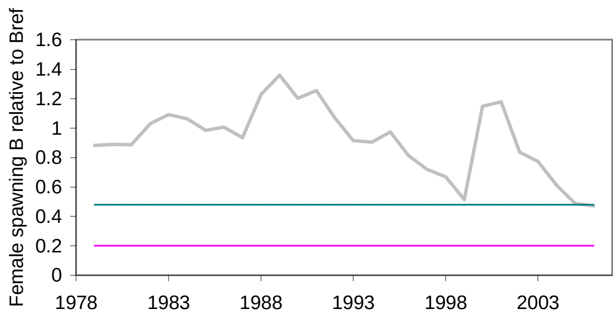
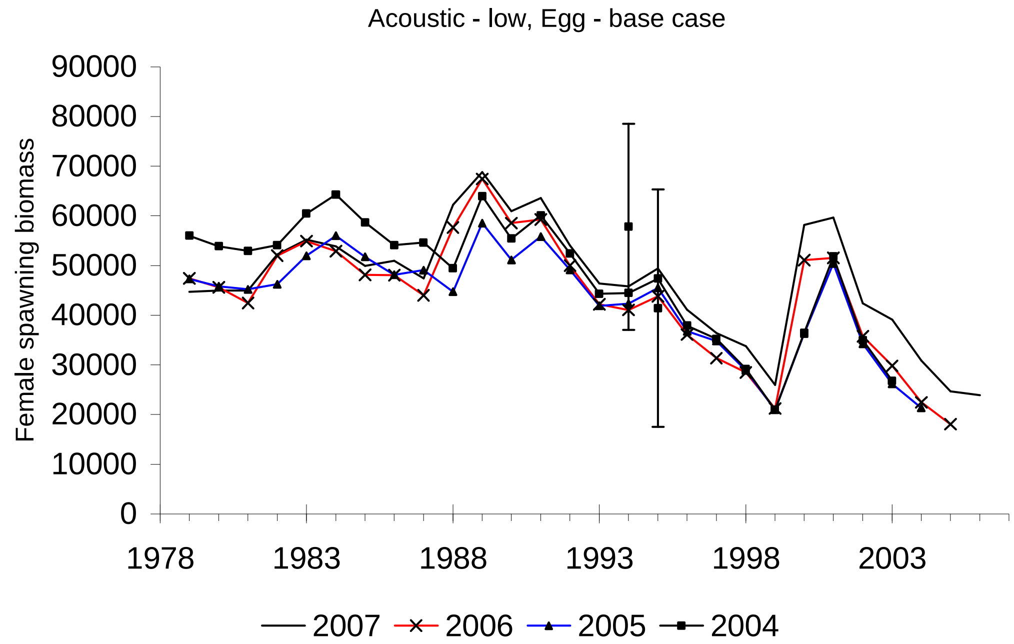


Figure 7.13. The trajectory of female spawning biomass relative to the reference biomass, Br_{ef} for the Low model. The horizontal lines show the 0.48 and 0.20 levels.



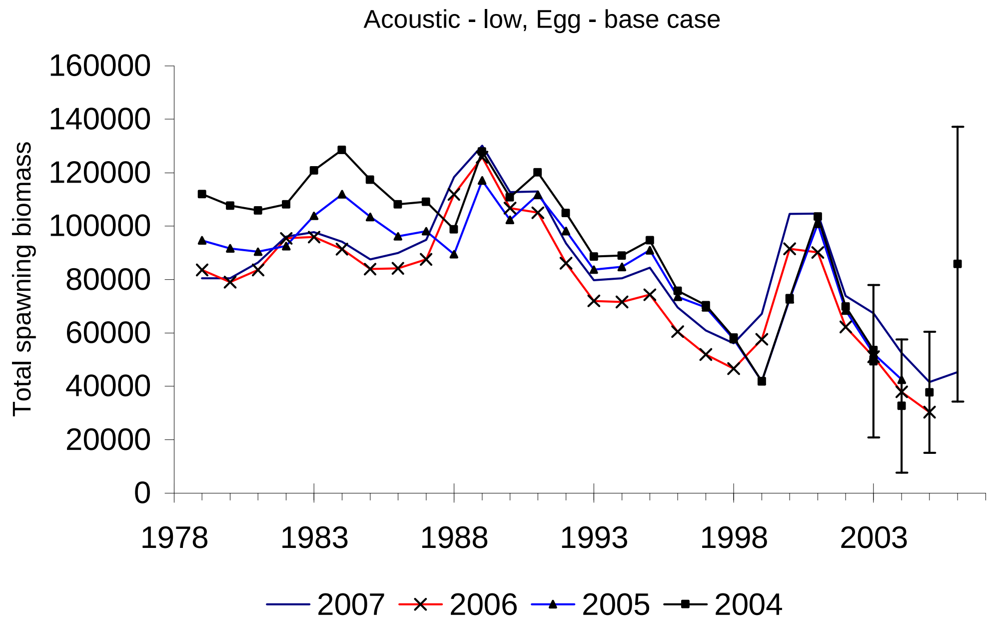


Figure 7.14. The female spawning biomass (top) in relation to the egg survey estimates of biomass and the total spawning biomass (bottom) in relation to the acoustic estimates for each of the assessments from 2003 to 2007.

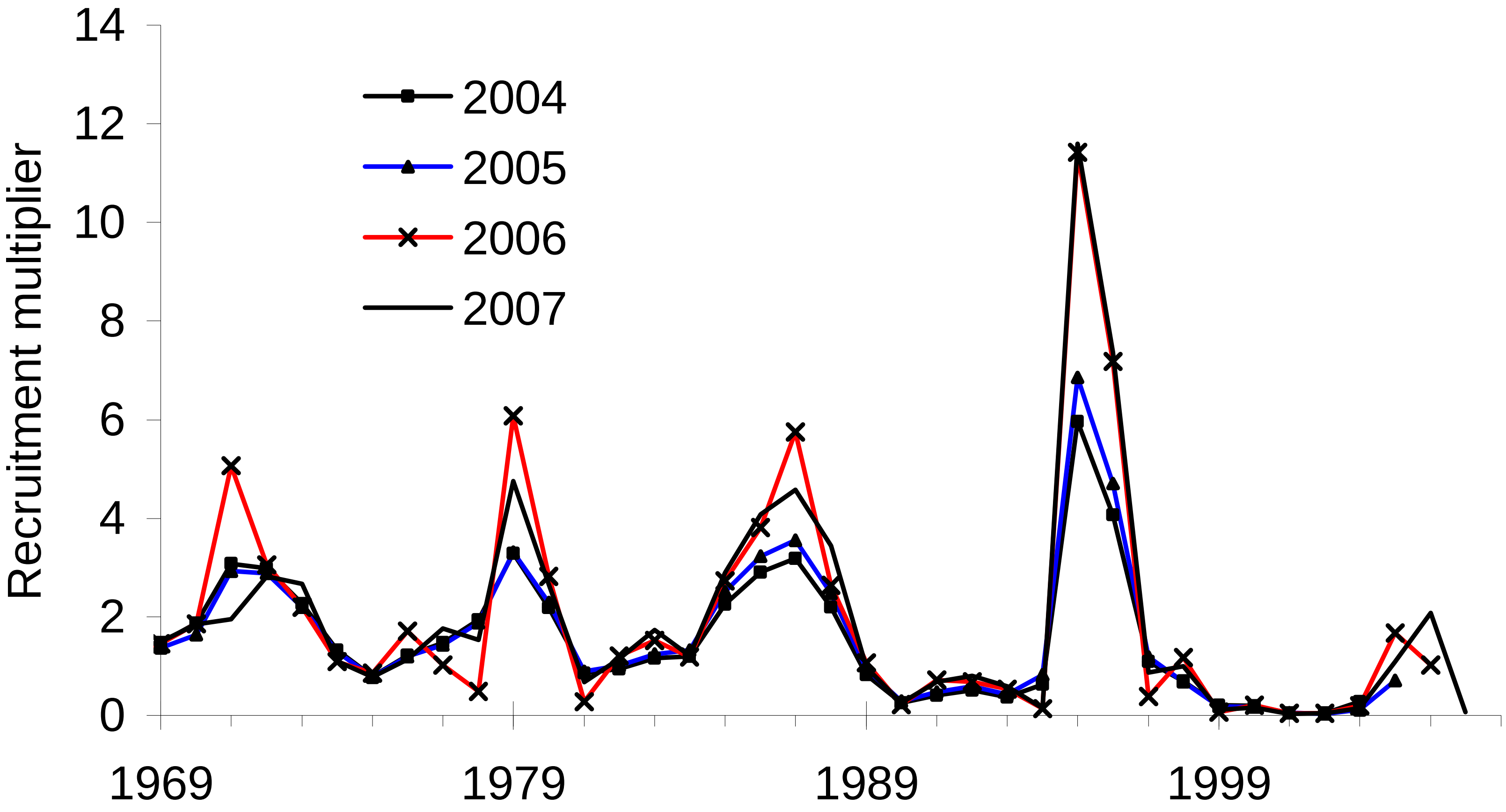


Figure 7.15. The estimated annual recruitment multipliers for each of the assessments of blue grenadier from 2003 to 2007.

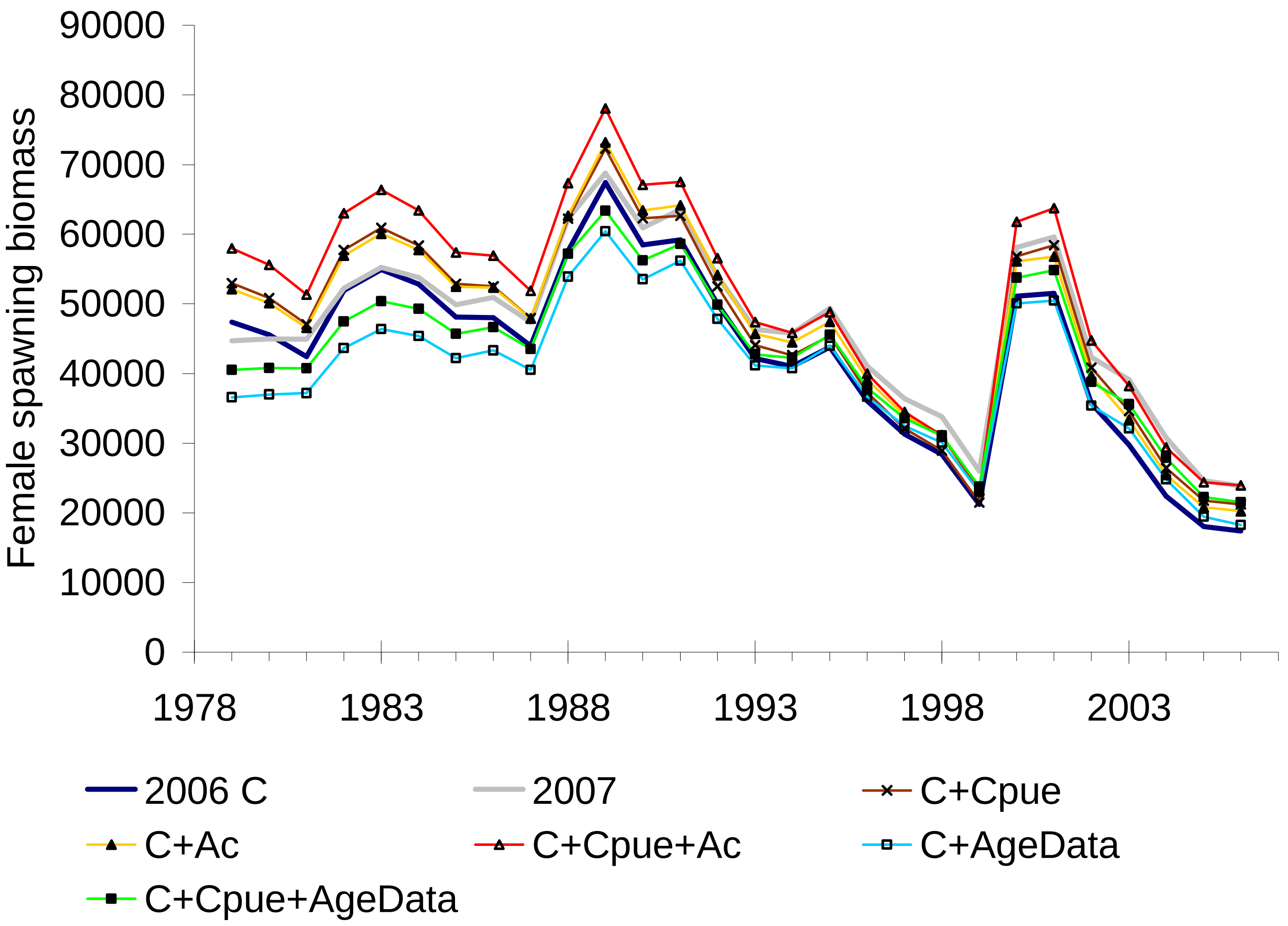


Figure 7.16. The female spawning biomass as a function of the data sources provided to the assessment. C = landed catches for 2006 included, Ac = updated acoustic estimates included, Cpue = 2007 cpue series included, AgeData = updated age data are included.

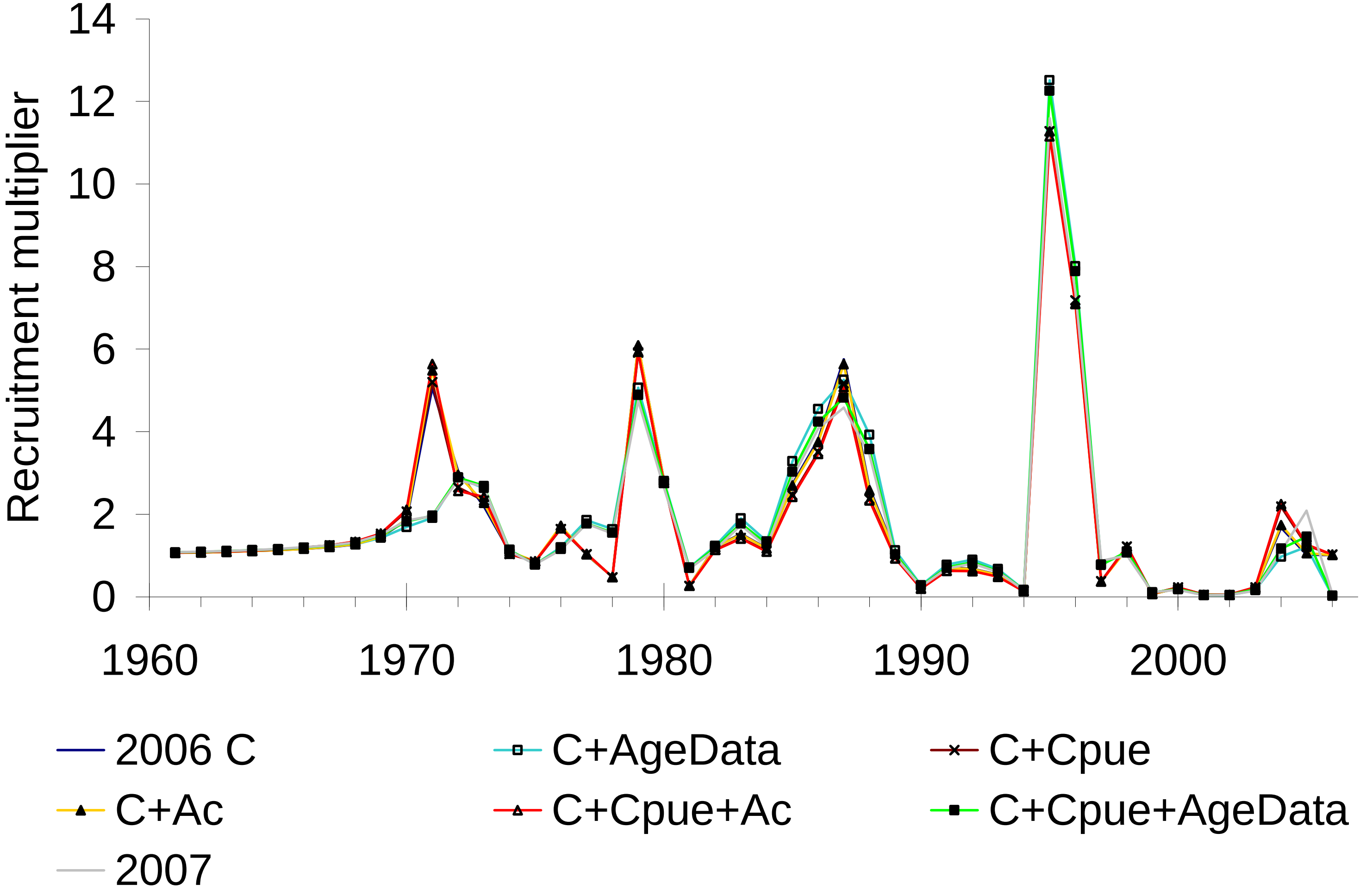
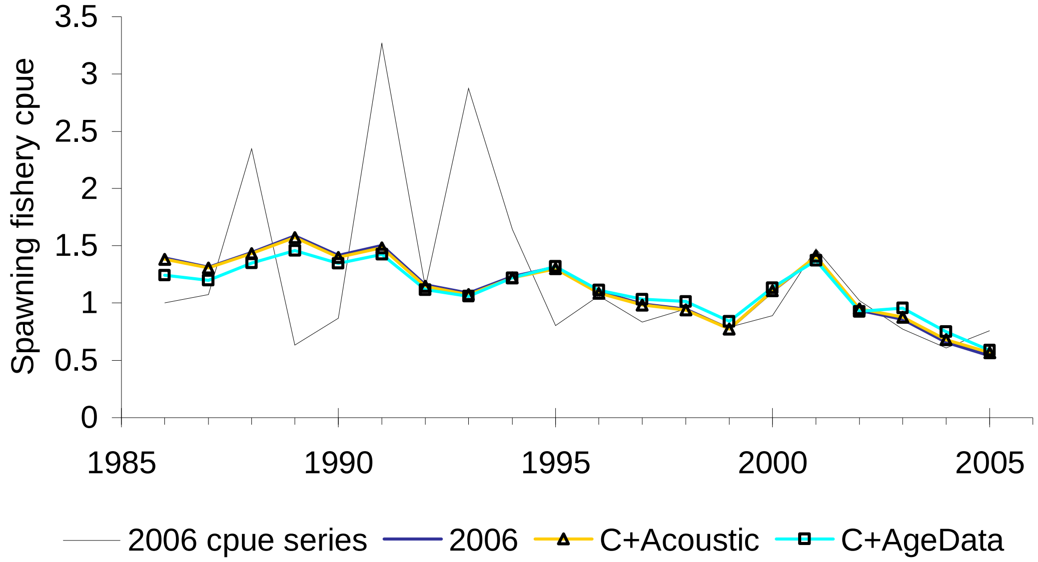


Figure 7.17. The recruitment multipliers as a function of the data sources provided to the assessment. C = landed catches for 2006 included, Ac = updated acoustic estimates included, Cpue = 2007 cpue series included, AgeData = updated age data are included.



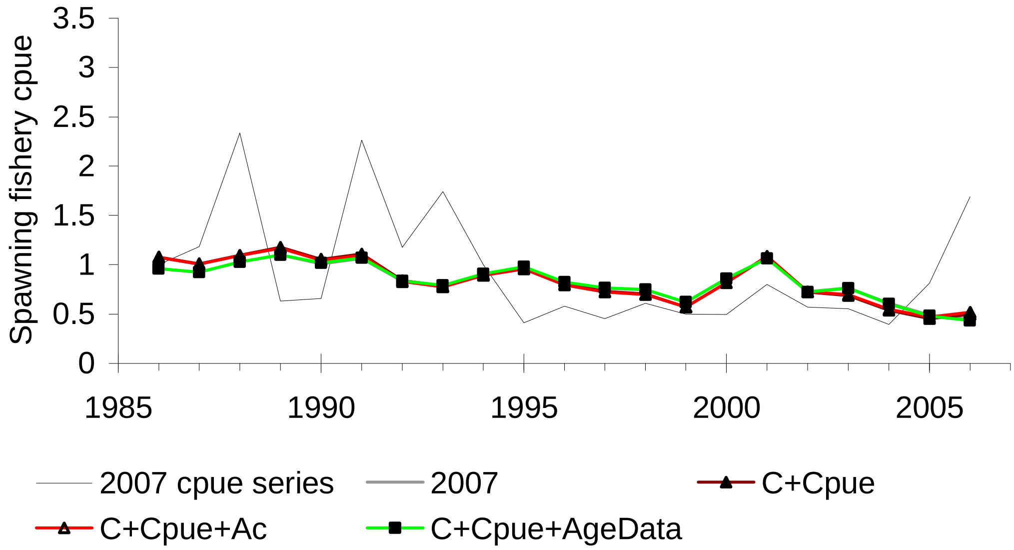
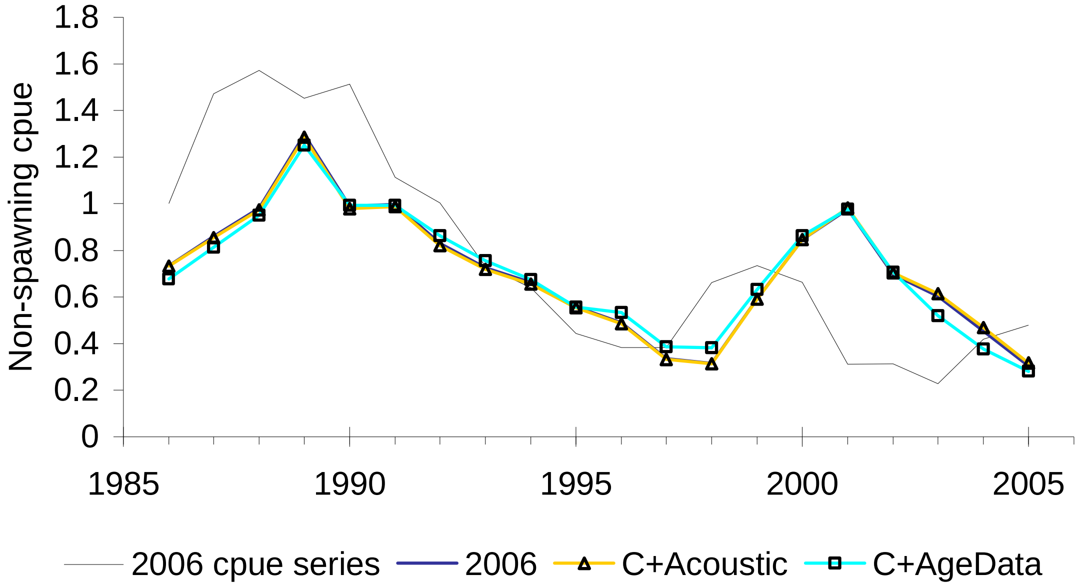


Figure 7.18. The modelled spawning fishery catch rate as a function of the data sources provided to the assessment. Top: Spawning cpue series of 2006 is applied. Bottom: Spawning cpue series of 2007 is applied. C = landed catches for 2006 included, Ac = updated acoustic estimates included, Cpue = 2007 cpue series included, AgeData = updated age data are included.



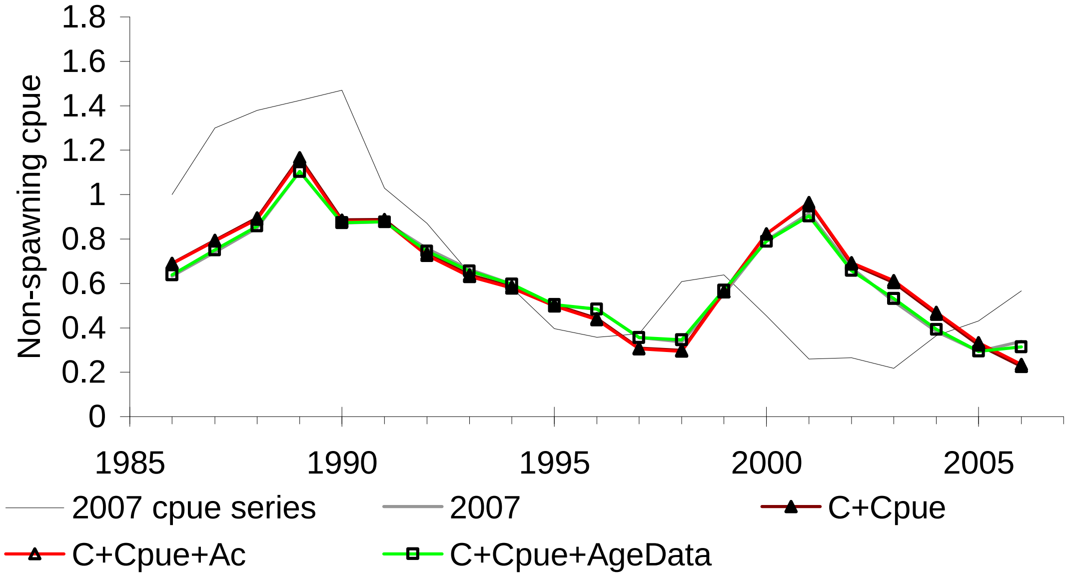
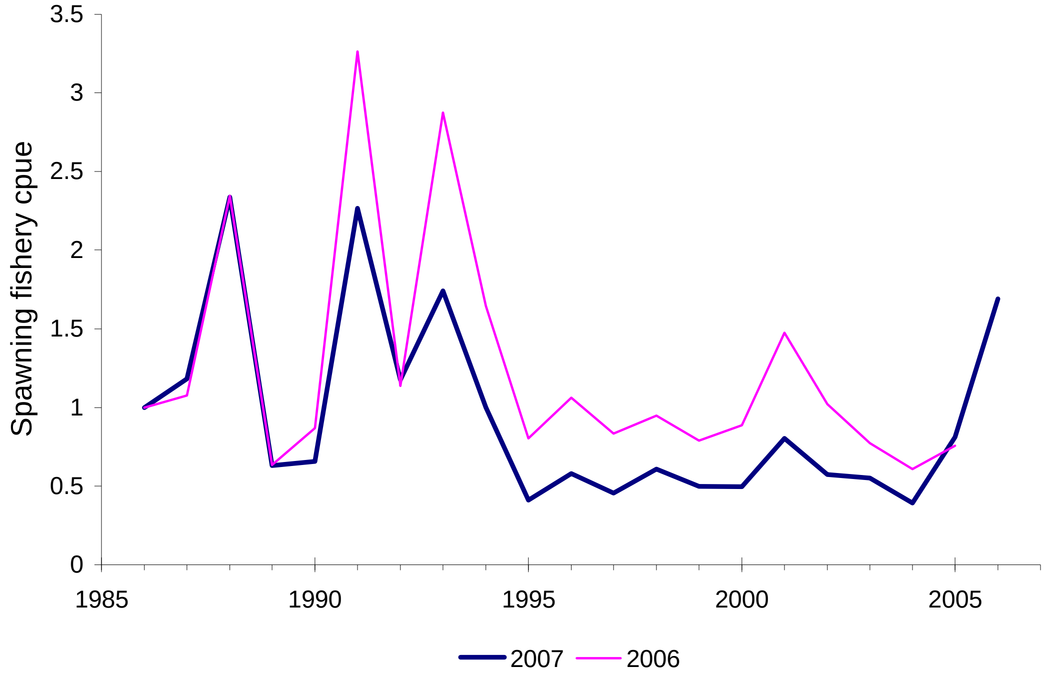


Figure 7.19. The modelled non-spawning fishery catch rate as a function of the data sources provided to the assessment. Top: Non-spawning cpue series of 2006 is applied. Bottom: Non-spawning cpue series of 2007 is applied. C = landed catches for 2006 included, Ac = updated acoustic estimates included, Cpue = 2007 cpue series included, AgeData = updated age data are included.



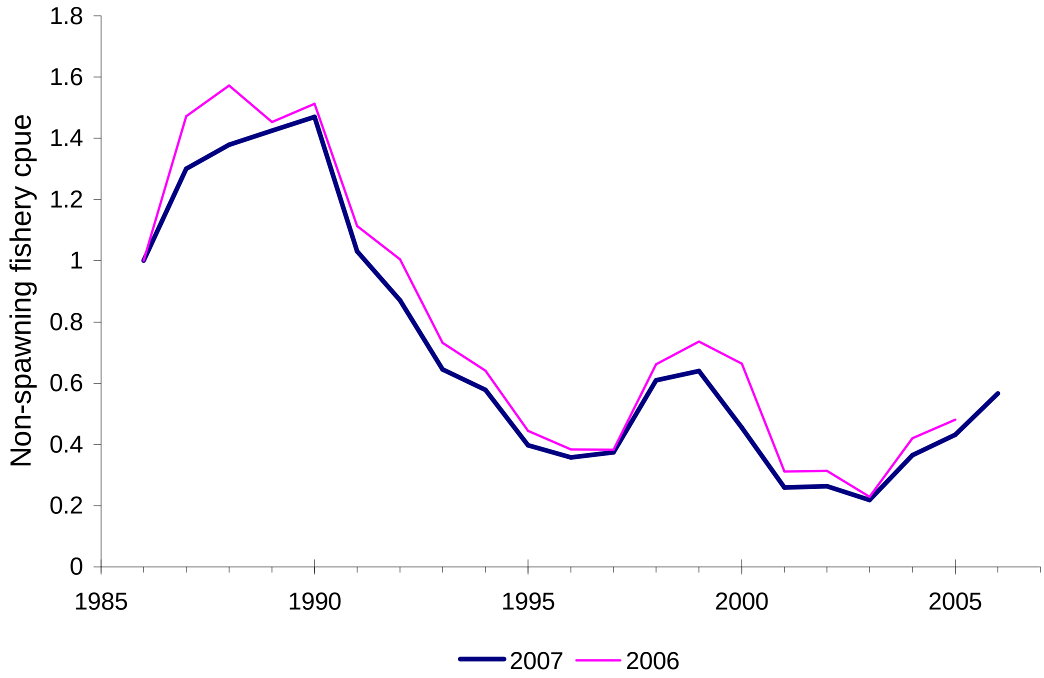
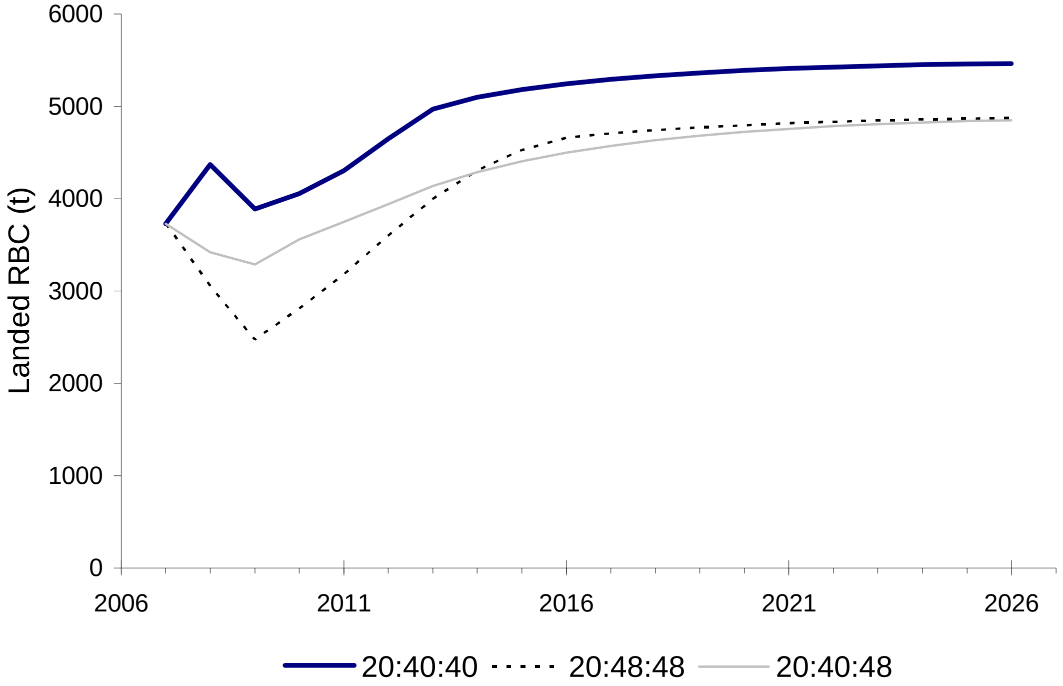


Figure 7.20. A comparison of the spawning (top) and non-spawning (bottom) standardised catch rates from 2006 and 2007.



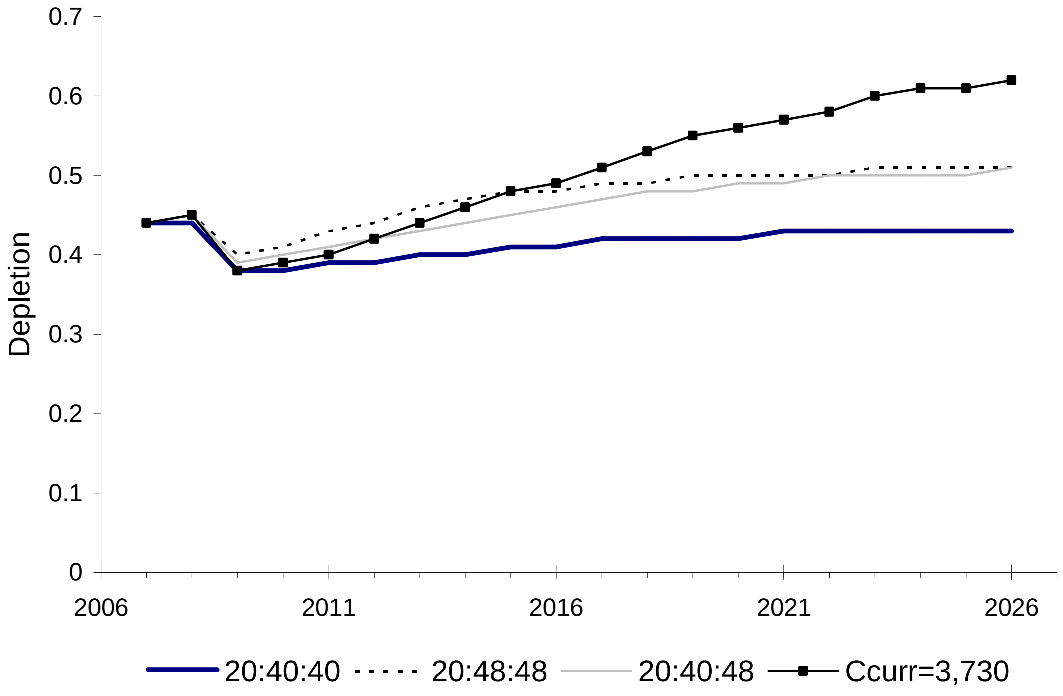


Figure 7.21. The trajectories of the landed RBC (top) and the corresponding depletion level (bottom) according to the 3 potential harvest control rules applied in the SESSF. The depletion figure also shows the depletion if a constant catch equal to the current catch of 3,730t is applied over all projected years.

7.10 Appendix: The population dynamics model and likelihood model

The equations presented in this appendix have been adapted from those in Punt *et al.* (2001).

7.10.1 Basic dynamics

The dynamics of animals of sex *s* aged 1 and above are governed by the equation:

$$N^s_{y+1,a} = \begin{cases} N^s_{y+1,1} & \text{if } a = 1 \\ N^s_{y,a-1} e^{-Z^s_{y,a-1}} & \text{if } 1 < a < x \\ N^s_{y,x}\, e^{-Z^s_{y,x}} + N^s_{y,x-1}\, e^{-Z^s_{y,x-1}} & \text{if } a = x \end{cases} \qquad \text{(A.1)}$$

where $N^s_{y,a}$ is the number of fish of sex *s* and age *a* at the start of year *y* (where *y* runs from 1 to *t*),

$Z^s_{y,a}$ is the total mortality on fish of sex *s* and age *a* during year *y*:

$$Z^s_{y,a} = M^s + S^1_a F^1_y + S^2_a F^2_y \qquad \text{(A.2)}$$

M^s is the (age-independent) rate of natural mortality for animals of sex *s*,

$S^f_{y,a}$ is the vulnerability by sub-fishery *f* (*f*=1 for the 'spawning' sub-fishery, and *f*=2 for the 'non-spawning' sub-fishery) on fish of age *a* during year *y*,

F^f_y is the fully-selected fishing mortality by sub-fishery *f* during year *y*, and

x is the maximum age-class (taken to be a plus-group).

The number of 1-year-olds of sex *s* at the start of year *y*+1 is related to the spawner biomass of females in the middle of the preceding year according to the equation:

$$N^s_{y+1,1} = \left[0.5\,\tilde{B}_y / (\alpha + \beta\,\tilde{B}_y)\right] e^{\varepsilon_y} \qquad \text{(A.3)}$$

where $\tilde{B}_y$ is the spawner biomass of females in the middle of year *y*:

$$\tilde{B}_y = \mu \sum_{a=1}^{x} f_{y,a}\, w_{y,a}\, N^{\mathrm{f}}_{y,a}\, e^{-Z^{\mathrm{f}}_{y,a}/2} \tag{A.4}$$

is the proportion of mature females that spawn each year,

$f_{y,a}$ is the proportion of females of age *a* that are mature during year *y*:

$$f_{y,a} = \begin{cases} 1 & \text{if } L_{y,a} \geq 70\,\text{cm} \\ 0 & \text{otherwise} \end{cases}$$

$w_{y,a}$ is the mass of a fish of age *a* in the middle of the year *y*,

$L_{y,a}$ is the mean length of a fish of age *a* during year *y* (given either by the empirical mean length-at-age each year, or from the fit of a von Bertalanffy growth curve),

α, β are the parameters of the stock-recruitment relationship, and

ε_y is the recruitment residual for year *y* (for ease of presentation, $\exp(\varepsilon_y)$ will be referred to as the recruitment anomaly for year *y*).

The values for α and β are determined from the steepness of the stock-recruitment relationship (*h*) and the virgin biomass (B_0) using the equations of Francis (1992). The assumption that maturity is knife-edged at 70 cm is very crude and a research project has been proposed to provide a more realistic picture of maturity as a function of length. In principle, the probability of being mature-at-length could have been assumed to be the same as vulnerability to the ‘spawning’ sub-fishery. This assumption has been made for assessments of blue grenadier in New Zealand (e.g. McAllister *et al*., 1994). However, it may be substantially in error for blue grenadier in Australia because it is known that fish of different sizes arrive on the spawning grounds at different times, and that some immature fish are caught during the ‘spawning’ sub-fishery.

The specifications for the numbers-at-age at the start of 1979 are based on the assumption that the stock would have been close to its unexploited equilibrium size at that time:

$$N^{s}_{1979,a} = 0.5 \begin{cases} R_0\, e^{-(a-1)M^s}\, e^{\varepsilon_a} & \text{if } a < x \\ R_0\, e^{-(x-1)M^s} / (1 - e^{-M^s}) & \text{if } a = x \end{cases} \tag{A.5}$$

where R_0 is the expected number of 1-year-olds at unexploited equilibrium (the sex ratio at age 1 is taken to be 1:1), and

ε_a is the recruitment residual for age a.

The equation for the plus-group does not include a contribution by a recruitment residual because this group comprises several age-classes, which will largely damp out the impact of inter-annual variation in year-class strength.

7.10.2 Vulnerability

The vulnerability of the gear is governed by a logistic curve that permits the probability of capture to drop off with length:

$$S^f_{y,a} = \begin{cases} (1+e^{-\ell n19(L_{y,a}-L^f_{50})/(L^f_{95}-L^f_{50})})^{-1} & \text{if } L_{y,a} \le L^f_{95} \\ (1+e^{-\ell n19(L_{y,a}-L^f_{50})/(L^f_{95}-L^f_{50})})^{-1} e^{-\lambda^f (L_{y,a}-L^f_{95})} & \text{otherwise} \end{cases} \tag{A.6}$$

where L^f_{50} is the length-at-50%-vulnerability for sub-fishery *f*,

L^f_{95} is the length-at-95%-vulnerability for sub-fishery *f*, and

λ^f is the "vulnerability slope" for sub-fishery *f*.

The vulnerability pattern for the 'spawning' sub-fishery is assumed to be asymptotic (i.e. $\lambda = 0$ for the 'spawning' sub-fishery).

7.10.3 Catches

The catch (in number) of fish of age *a* by sub-fishery *f* during year *y*, $\hat{C}^f_{y,a}$, and the number of fish of age *a* discarded by sub-fishery *f*, during year *y*, $\hat{D}^f_{y,a}$, are given by the equations:

$$\hat{C}^f_{y,a} = \sum_s \frac{(1-P_{y,a})S^f_{y,a}F^f_y}{Z^s_{y,a}} N^s_{y,a}(1-e^{-Z^s_{y,a}}) \tag{A.7a}$$

$$\tilde{D}^f_{y,a} = \sum_s \frac{P_{y,a}S^f_{y,a}F^f_y}{Z^s_{y,a}} N^s_{y,a}(1-e^{-Z^s_{y,a}}) \tag{A.7b}$$

where $P_{y,a}$ is the probability of discarding a fish of age *a* during year *y*:

$$P_{y,a} = \frac{\gamma(\sum_s N^s_{y,1})^\phi / \max_{y'}(\sum_{s'} N^{s'}_{y',1})^\phi}{1+e^{-(L_a-L^D_{50})/\delta}} \tag{A.8}$$

γ is the maximum possible discard rate for the largest year-class,

L^D_{50} is the length at which discarding is half the maximum possible rate,

δ is the parameter that determines the width of the relationship between length and the discard probability, and

ϕ is the parameter that controls the extent of density-dependent discarding.

The rate of discarding is therefore assumed to be related only to the size of the year-class at birth; the impact of density-dependence on the rate of discarding is assumed to be constant during the whole of an animal's life. The first assumption will be violated to some extent because *inter alia* the rate of discarding will depend on the abundance of other year-classes in the population (through high-grading). Violation of the second assumption is probably inconsequential because for older ages the form of the denominator of Equation (A.8) will mean that $P_{y,a} \approx 0$.

The model estimates of the catch (in mass) by sub-fishery *f* during year *y*, $\hat{C}_y^f$, and of the mass of fish discarded by sub-fishery *f* during year *y*, $\hat{D}_y^f$, are given by the equations:

$$\hat{C}_y^f = \sum_{a=1}^{x} w_{y,a}\, \hat{C}_{y,a}^f \tag{A.9a}$$

$$\hat{D}_y^f = \sum_{a=1}^{x} w_{y,a}\, \hat{D}_{y,a}^f \tag{A.9b}$$

Equations (A.9a) and (A.9b) imply that the (expected) mass of a fish of age *a* that is discarded is the same as the (expected) mass of a fish of age *a* that is retained.

7.10.4 The likelihood function

The negative of the logarithm of the likelihood function includes five contributions. These relate to minimising the sizes of recruitment residuals, fitting the observed catches / discards by fleet, fitting the observed catch / discard age-compositions, fitting the catch rate information, and fitting the estimates of spawner biomass from the egg-production method.

$$L = \sum_{i=1}^{5} L_i \tag{A.10}$$

The contribution of the recruitment residuals to the negative of the logarithm of the likelihood function is based on the assumption that the inter-annual fluctuations in year-class strength are independent and log-normally distributed with a CV of σ_r [3]:

$$L_1 = \frac{1}{2\sigma_r^2}\left(\sum_{a=1}^{x-1} \varepsilon_a^2 + \sum_{y=1}^{t-1} \varepsilon_y^2 \right) \tag{A.11}$$

[3] The summation in Equation (A.11) runs to *x*-1 and *t*-1 because the plus-group (age *x*) is not impacted by variability in year-class strength, and because the model is not used to predict the number of 1-year-olds for year *t*+1.

The contribution of the observed catch (in mass) information to the negative of the logarithm of the likelihood function is based on the assumption that the errors in measuring the catch in mass are log-normally distributed with a CV of σ_c:

$$L_2 = \tfrac{1}{2\sigma_c^2}\sum_f \sum_{y=1}^{t} (\ell n C_y^{f,\text{obs}} - \ell n \hat{C}_y^f)^2 \tag{A.12}$$

where $C_y^{f,\text{obs}}$ is the observed catch (in mass) by sub-fishery *f* during year *y*.

The contribution of the observed mass of discards to the negative of the logarithm of the likelihood function follows Equation (A.12) except that $\hat{C}_y^f$ is replaced by $\hat{D}_y^f$, $C_y^{f,obs}$ is replaced by the observed mass of discards by sub-fishery *f* during year *y*, and the summations over year are restricted to those years for which estimates of discards are available.

The contribution of the age composition information to the negative of the logarithm of the likelihood function is based on the assumption that the age-structure information is determined from a random sample of *N* animals from the catch:

$$L_3 = -\sum_f \sum_y \sum_{a=1}^{15+} N \rho_{y,a}^{f,\text{obs}} \, \ell n(\hat{\rho}_{y,a}^f) \tag{A.13}$$

where $\rho_{y,a}^{f,\text{obs}}$ is the observed proportion which fish of age *a* made up of the catch during year *y* by sub-fishery *f*,

$\hat{\rho}_{y,a}^f$ is the model-estimate of the proportion which fish of age *a* made up of the catch during year *y* by sub-fishery *f*:

$$\hat{\rho}_{y,a}^f = \sum_{a''} \chi_{a,a''} \hat{C}_{y,a''}^f / \sum_{a'=1}^{x} \hat{C}_{y,a'}^f \tag{A.14}$$

$\chi_{a,a'}$ is the probability that an animal of age *a*' will be found to be age *a* (the age-reading error matrix).

Note that all animals aged 15 and older are treated as a single "age-class" when fitting to the catch proportion-at-age information. This prevents data for older fish (for which there is relatively little data) having a disproportionate influence on the results. The summations over year include only those years for which age-composition data are available. The contribution of the age-composition of the discards follows Equations (A.13) and (A.14), except that $\hat{\rho}_{y,a}^f$ is replaced by the model-estimate of the proportion which fish of age *a* made up of the discards during year *y* by sub-fishery *f*, and $\rho_{y,a}^{f,obs}$ is replaced by the observed proportion which fish of age a made up of the discards during year *y* by sub-fishery *f*.

The contribution of the catch rate data to the negative of the logarithm of the likelihood function is based on the assumption that fluctuations in catchability are log-normally distributed with a CV of σ_q:

$$L_4 = \tfrac{1}{2\sigma_q^2}\sum_f \sum_y (\ell\text{n} I_y^f - \ell\text{n}(q^f B_y^f))^2 \tag{A.15}$$

where q^f is the catchability coefficient for sub-fishery *f*,

I_y^f is the catch-rate index for sub-fishery *f* and year *y*, and

B_y^f is the mid-season (available) biomass for sub-fishery *f* and year *y*:

$$B_y^f = \sum_s \sum_a w_{y,a}\,(1-P_{y,a})\,S_a^f\,N_{y,a}^s\,e^{-Z_{y,a}^s/2} \tag{A.16}$$

The summation over year includes only those years for which catch rate data are available.

The contribution of the egg-production or acoustic estimates to the negative of the logarithm of the likelihood function is given by:

$$L_5 = \sum_{y=1994/5} (\widetilde{B}_y - B_y^{obs})^2 / (2\sigma_y^2) \tag{A.17}$$

where B_y^{obs} is the estimate of female spawner biomass for year *y* based on egg-production or acoustic methods, and

σ_y is the standard error of B_y^{obs}.

8. Updated Stock Assessment of Blue Grenadier (*Macruronus novaezelandiae)* Based on Data up to 2006: Summary of Sensitivity Tests. August 2007[4]

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8.1 Summary

The 2007 assessment of blue grenadier *Macruronus novaezelandiae* uses the age-structured integrated assessment method developed by Punt *et al.* (2001). The assessment has been updated by the inclusion of data from the 2006 calendar year. In addition, age reading error and new biological parameters relating to the proportion spawning and the length at maturity, first introduced in August 2006, have been used. Estimates of spawning biomass from acoustic surveys from 2003-2006 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 are included.

This paper follows that of Tuck *et al.* (2007) where results only from the Low model were presented. The Low model uses the acoustic estimates of spawning biomass from Ryan *et al.* (2007), whereas the High model uses acoustic biomass estimates that are much larger in magnitude and are derived from using the target strengths suggested by Macauley (2004). Several other sensitivity tests are presented in this paper.

Results conclude that the female spawning biomass in 2006 is around 50% of the reference biomass across most sensitivity models. This is an increase (i.e. a greater percentage of fish remain) over the assessment presented in 2006 and is in part due to recent estimated biomasses being shifted upward through the increased level of the 2006 acoustic estimate and the increased cpue in both sub-fisheries.

The Recommended Biological Catches (RBCs) for 2008 are around 4,600 t (landed catch and discards) and 3,600 t for the 20:40:40 and 20:40:48 harvest control rules respectively. The High model RBCs are substantially larger than this (and greater than 150% of the 2007 TAC). The long-term annual RBCs are much more dependent on model assumptions and vary between 4,500 t and 9,500 t. The long term RBCs for the High model are up to 18,500 t.

[4] Paper presented to the Slope Resource Assessment Group on 21 and 22 August, 2007.

8.2 Introduction

An integrated analysis model has been applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by inclusion of the 2006 calendar year data (catch and discard at age; updated catch rate series; landings and discard catch weight) and additional information from acoustic surveys of spawning biomass (series from 2003-2006). The same assessment model that has been used in previous years (e.g. Punt *et al.,* 2001; Tuck and Punt, 2006) was used this year. The main purpose of this document is to provide an exploration over several changes to the model structure, either through changes to input data or parameterisations. The document presents (a) diagnostic plots and (b) recommended biological catches (RBCs) from an application of the Tier 1 harvest control rules for the base-case and each sensitivity test.

Each of the models considered here includes age-reading error, updated biological parameters for the proportion spawning and length at maturity (for males and females) and an assumption of 2-times turnover on the spawning ground. The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The acoustic estimates are assumed to pertain to total (male and female) spawning biomass.

A list of the various sensitivities considered in this paper is shown below, with its reference name in bold:

1. Low acoustic estimates, base-case egg survey estimates (**Low**)
2. High acoustic estimates, double egg survey estimates (**High**)
3. Cpue including a dummy Pink Ling factor (**Ling**)
4. Inclusion of GAB catches in the non-spawning fishery (**GAB**)
5. Fixed natural mortality of M=0.2 (***M*=0.20**)

These models and their results are discussed in more detail in the sections that follow.

8.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Data support the hypothesis of a single breeding population in Australian waters, however spawning fish have recently been caught off the east coast of Australia. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years and an age at maturity of 4-5 years. Spawning occurs off western Tasmania between late May and early September. Adults migrate to the spawning area from throughout southeastern Australia, with large fish arriving earlier in the spawning season.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2006 was 3,730 tonnes, and in 2005 it was 5000 t (with a voluntary industry reduction to 4200 t), down from 7000 t in 2004, 9000 t in 2003 and 10000 t which it had been since 1994. There are two defined sub-fisheries: the spawning and non-spawning fisheries. The non-spawning fishery catches have been relatively consistent over the last few years (at just under 2000t), whereas the spawning fishery catches showed a marked increase during the mid-1990s before decreasing from 2003. The spawning and non-spawning fishery catches are currently at similar levels.

8.4 Data

The model has been updated by the inclusion of the 2006 catch- and discard-at-age from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2007), the total mass landed and discarded, mean length- and weight-at-age; updated acoustic estimates of spawning biomass (Ryan *et al*., 2007) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman *et al.*, 1999). Data were formulated by calendar year (i.e. 1 Jan to 31 Dec).

8.4.1 Catch

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery since 1986; 1.2 for the spawning fishery from 1986 up to and including 1996). These figures were then scaled up to the SEF2 data. As SEF2 data were only available from 1993, for years prior to this the average scaling factor from 1993 to 1998 was used to scale the data. The landings data are provided in Table 8.1 and displayed in Figure 8.1. Catches from the GAB are generally not included in the catch data for the blue grenadier assessment. However, as these catches have increased over the last 3 years, the model's sensitivity to including these data is considered (in the model referred to here as **GAB**).

Table 8.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted to account for reporting of headed and gutted catches, and scaled up to the SEF2 data (see text). Great Australian Bight (GAB) catches were provided by M. Koopman. The annual TAC is also shown. *Note that a voluntary industry reduction to 4,200 t was implemented in 2005.

Year	Landings			Discards		TAC
	Spawning	Non-spawning	GAB	Spawning	Non-spawning	
1979	245	245				
1980	410	410				
1981	225	225				
1982	390	390				
1983	450	450				
1984	675	675				
1985	600	600				
1986	321	1840				
1987	1020	2214				
1988	416	2279	40			
1989	47	2817	22			
1990	743	2605	20			
1991	1158	4193	1			
1992	931	2669	4			
1993	990	2359	2			
1994	1194	1916	1			10000
1995	1196	1558	2		80	10000
1996	1465	1505	26		975	10000
1997	2952	1581	20		3716	10000
1998	3267	2469	27		1329	10000
1999	6087	3214	45		123	10000
2000	6056	2592	7		69	10000
2001	7627	1498	28		10	10000
2002	7431	1731	0		2	10000
2003	7573	899	16		4	9000
2004	4801	1663	147		21	7000
2005	2694	1566	288		431	5000*
2006	1949	1761	100		175	3730

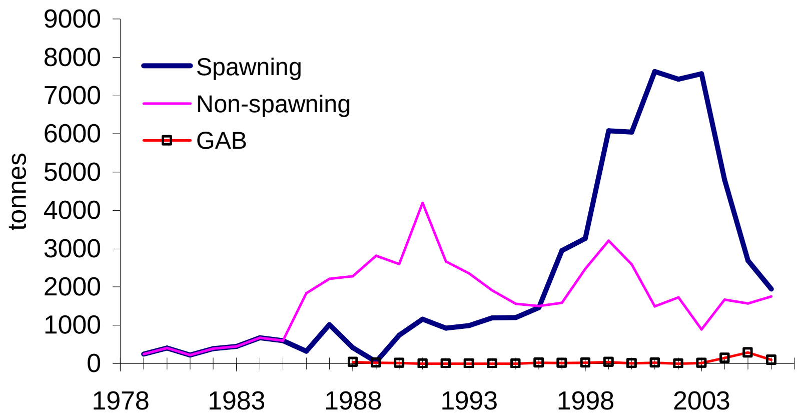

Figure 8.1.The estimated annual landings of blue grenadier from each of the sub-fisheries and the GAB.

8.4.2 Catch-rates

Haddon (2007) provides the updated catch-rate series for blue grenadier (Table 8.2, Figure 8.2). Models 6 and 4 of Haddon (2007) were recommended to be used for the non-spawning and spawning fisheries respectively in the assessment models. The series show recent increases in cpue for both sub-fisheries.

As the cpue series for the spawning fishery changed considerably from 2006 to 2007, an investigation into the reasons for this change was conducted by Haddon (2007b). It appears that the inclusion or otherwise of a dummy pink ling factor in the standardisation accounts for a large proportion of the change. This factor was removed from the 2007 series (Haddon, 2007a), following instruction not to include dummy variables relating to co-occurring catches in the standardizations (CPUE Workshop, March 2007). However, here a sensitivity is conducted by using the spawning fishery cpue time-series with the pink ling factor included (akin to the 2006 statistical model). In the summary figures that follow, this model is referred to as **Ling**.

8.4.3 Catch-at-age

The catch-at-age data for the sensitivity tests of this document have not changed from that presented in Tuck *et al.* (Chpt 7). Figure 4.4 of Tuck *et al.* (Chpt 7) shows the age composition data and the fit of the Low model. As expected, the non-spawning age composition shows the presence of a recent year-class progressing into the available biomass. This year-class has now entered the spawning fishery also. Figure 8.7 shows the observed catch-at-age for the spawning fishery.

Table 8.2. Standardised CPUE (Haddon, 2007a; 2007b) for the spawning and non-spawning sub-fisheries by calendar year.

Year	Spawning			Non-spawning	
	CPUE	Records	CPUE +Ling	CPUE	Records
1986	1.00	71	1.00	1.00	2911
1987	1.18	154	1.11	1.30	3370
1988	2.34	92	2.52	1.38	3927
1989	0.63	24	0.72	1.42	4289
1990	0.66	132	0.93	1.47	3491
1991	2.27	102	3.07	1.03	4546
1992	1.18	189	1.43	0.87	3582
1993	1.74	142	2.41	0.65	4195
1994	1.00	288	1.28	0.58	4499
1995	0.41	474	0.68	0.40	5087
1996	0.58	352	1.02	0.36	5362
1997	0.45	403	0.79	0.37	6127
1998	0.61	575	0.84	0.61	6605
1999	0.50	857	0.74	0.64	8081
2000	0.50	944	0.78	0.46	7640
2001	0.80	1111	1.26	0.26	7192
2002	0.57	1039	0.84	0.26	6307
2003	0.55	1020	0.70	0.22	5687
2004	0.39	804	0.58	0.37	6358
2005	0.81	316	1.05	0.43	5289
2006	1.69	327	1.97	0.57	4289

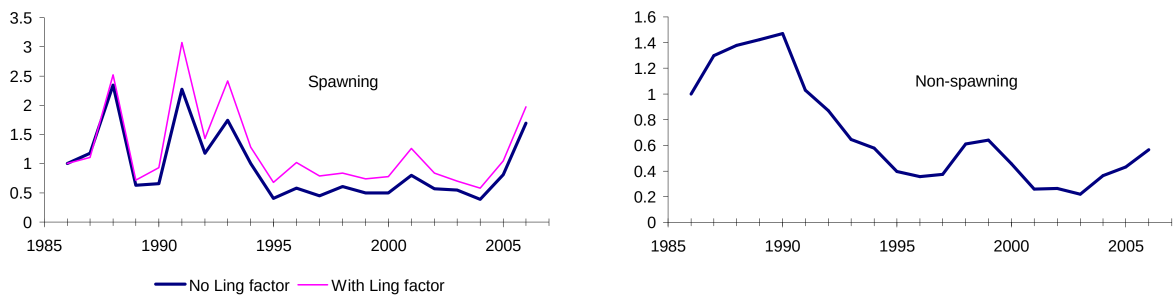

Figure 8.2 The calendar year catch-rate indices for the spawning and non-spawning blue grenadier fisheries (Haddon, 2007a; 2007b). The cpue series without the ling factor has been used as the base-case series in 2007.

8.4.4 Acoustic survey estimates

Estimates of spawning biomass for years 2003-2006 are provided in Ryan *et al.* (2007). Two models of target strength were used in the assessments of Tuck and Punt (2006), namely Macauley (2004) and Cordue (2000). The model of Macauley (2004) produces markedly higher estimates of biomass (with a lower estimate of target strength) than that of Cordue (2000) or the most recent update from Ryan *et al.* (2007) (with a correspondingly higher estimate of target strength). Table 8.3 shows the spawning biomass estimates with their corresponding c.v.

Table 8.3. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2006 (Ryan *et al.*, 2007).

Model	Name	2003	2004	2005	2006
Ryan *et al.* (2007)	**Low**	24,690	16,295	18,852	42,882
Macauley (2004)	**High**	131,991	87,852	116,390	210,000
c.v. used in assessment model		0.3	0.46	0.3	0.3

The **Low** model and its results have been presented in Tuck *et al.* (Chpt 7). The **High** and **Low** models differ according to the target strength used to produce the absolute estimates of spawning biomass from the acoustic surveys and assumptions about the egg survey estimates. The **High** model assumes the target strength of Macauley (2004) and doubles the egg survey estimates. The survey estimates of absolute abundance used when fitting this model are higher than those used when fitting the **Low** model which uses the Ryan *et al.* (2007) target strength and the base-case egg survey estimates of spawning biomass. It is assumed that the spawning ground experiences a turnover rate equal to 2 (i.e., for the model applied here the spawning biomass estimates are doubled).

8.4.5 Age-reading error

Standard deviations for aging error have been estimated, producing the age-reading error matrix of Table 8.4.

8.4.6 Egg survey estimates

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman *et al.*, 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

8.4.7 Natural mortality

Natural mortality has generally been estimated to be around 0.20 for female blue grenadier (with males 1.2 times greater). However, the most recent assessments have shown a decrease in M. A retrospective investigation of natural mortality is presented and results are shown when M is fixed at 0.2. This model is referred to as ***M*=0.2** in the text and figures.

Table 8.4. The age-reading error matrix, shown as the percentage of times an animal with true age given by the column header is aged to be of the age given by the rows. Source: A.E. Punt and Central Aging Facility (CAF, PIRVic, Queenscliff, Victoria).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	89.3	11.5	0	0	0	0	0	0	0	0	0	0	0	0	0
2	10.7	77.1	12.2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	11.5	75.5	13.1	0.1	0	0	0	0	0	0	0	0	0	0
4	0	0	12.2	73.8	13.9	0.1	0	0	0	0	0	0	0	0	0
5	0	0	0	13.1	72.0	14.9	0.1	0	0	0	0	0	0	0	0
6	0	0	0	0	13.9	70	15.9	0.2	0	0	0	0	0	0	0
7	0	0	0	0	0.1	14.9	68.0	16.8	0.3	0	0	0	0	0	0
8	0	0	0	0	0	0.1	15.9	65.9	17.8	0.5	0	0	0	0	0
9	0	0	0	0	0	0	0.1	16.8	63.7	18.8	0.7	0	0	0	0
10	0	0	0	0	0	0	0	0.2	17.8	61.5	19.8	0.9	0	0	0
11	0	0	0	0	0	0	0	0	0.3	18.8	59.1	20.7	1.3	0	0
12	0	0	0	0	0	0	0	0	0	0.5	19.8	56.8	21.5	1.7	0
13	0	0	0	0	0	0	0	0	0	0	0.7	20.7	54.4	22.3	2.2
14	0	0	0	0	0	0	0	0	0	0	0	0.9	21.5	51.9	23.0
15	0	0	0	0	0	0	0	0	0	0	0	0	1.3	24.0	74.8

8.5 Analytic approach

8.5.1 The population dynamics model

The population and likelihood models applied in 2007 are the same as those used in the 2006 assessment and are based upon the integrated analysis model developed for blue grenadier in the South East Fishery by Punt *et al.* (2001; Appendix; see also Tuck and Punt, 2006). The 2007 model is updated and extended by including the following data:

- the total mass landed and discarded during 2006; the catch- and discard-at-age during 2006 and the estimated mean length and weight of each age-class present during 2006,
- revised standardised CPUE series,
- an updated age-reading error matrix,
- an acoustic estimate of the 2006 spawning biomass off western Tasmania.

Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania, and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year. The model is sex dis-aggregated. However male and female fish are assumed to grow at the same rate.

Parameter uncertainty is examined through the use of sensitivity tests and by applying the Markov Chain Monte Carlo (MCMC) algorithm (Hastings, 1970; Gelman *et al.*, 1995).

8.5.2 The objective function

The negative of the logarithm of the likelihood function includes five components. These relate to minimizing the sizes of the recruitment residuals, fitting the observed catches and discards by fleet, fitting the observed age-compositions by fleet, fitting the catch rate information, and fitting the estimates of spawner biomass from the egg and acoustic surveys. See the Appendix of Tuck *et al.* (Chpt 7) or Punt *et al.* (2001) for details of the likelihood formulations.

8.5.3 Parameter estimation

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 8.5. The model has 115 estimated parameters: 2 catchability coefficients; 1 female natural mortality, 1 B_0, 29 annual fishing mortality rates for each of the two sub-fisheries; recruitment residuals for 27 years and 19 age classes in the first year; 2 selectivity parameters for the spawning sub-fishery and 3 for the non-spawning; and 2 parameters for the probability of discarding-at-length function.

The values for the parameters that maximize the objective function are determined using the AD Model Builder package[5]. This assessment quantifies the uncertainty of the estimates of the model parameters and of the other quantities of interest using Bayesian methods. The Markov Chain Monte Carlo (MCMC) algorithm (Hastings, 1970; Gelman *et al.*, 1995) was used to sample 2000 equally likely parameter vectors from the joint posterior density function. The samples on which inference is based were generated by running 2,000,000 cycles of the MCMC algorithm, discarding the first 1,000,000 as a burn-in period and retaining every 500th parameter vector thereafter.

Table 8.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
N	Weight for the catch- and discard-at-age data	50
σ_r	c.v. for the recruitment residuals	1.0
σ_c	c.v. for the landings data	0.05
σ_d	c.v. for the discard data	0.3
σ_q	c.v. for the CPUE data	0.3
h	"steepness" of the Beverton-Holt stock-recruit curve	0.9
x	age of plus group	15 years
μ	fraction of mature population that spawn each year	0.84
l_∞	von Bertalanffy parameter (maximum length)	102.76 cm
κ	von Bertalanffy parameter (growth rate)	0.16 y^{-1}
t_0	von Bertalanffy parameter	-2.209 y
aa	allometric length-weight equations	0.00375 g^{-1}.cm
bb	allometric length-weight equations	3.013
l_m	length at maturity (knife-edged) (M, F)	63.7, 56.8cm

8.6 Results and discussion

8.6.1 Low and High models

The fits to the Low model parameterisation were provided in Tuck *et al.* (Chpt 7). This document also included retrospective analysis and an extensive exploration of the changes when moving from the 2006 to 2007 assessments. These analyses are not repeated here, and many of the typical diagnostic plots are also not shown. However, basic plots of key indicators such as spawning biomass, recruitment and fits to the cpue are shown (where relevant).

Figure 8.3 shows the time series of female spawning biomass and total spawning biomass for the Low model and the other sensitivity models. Figure 8.4 shows the biomass trajectories for the High model. As seen in Tuck and Punt (2006), the High

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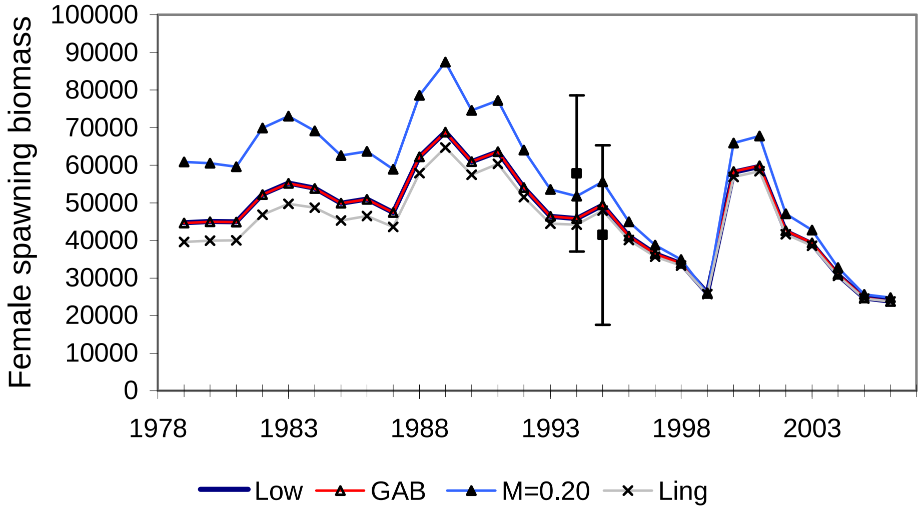
model produces much larger estimates of spawning biomass than the Low model. The fits to the acoustic survey estimates are reasonable for all sensitivity runs, with the exception that fits to the final year (2006) are generally poor, and especially so for the High model. This model is unable to increase the spawning biomass in the final year to match the large acoustic estimate of 2006.

Figure 8.5 shows the model estimated recruitment for each of the sensitivity models. In general there is little difference between the models, with a consistent trend in recruitment shown.



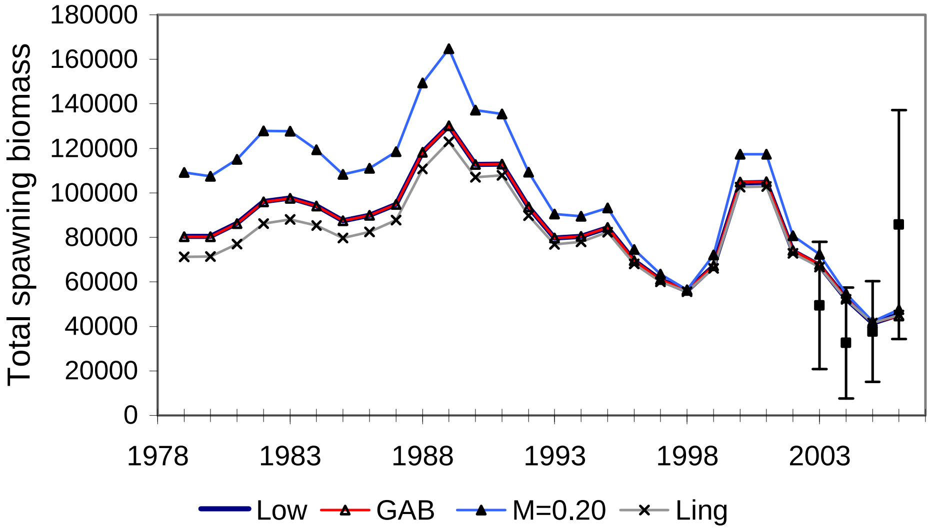
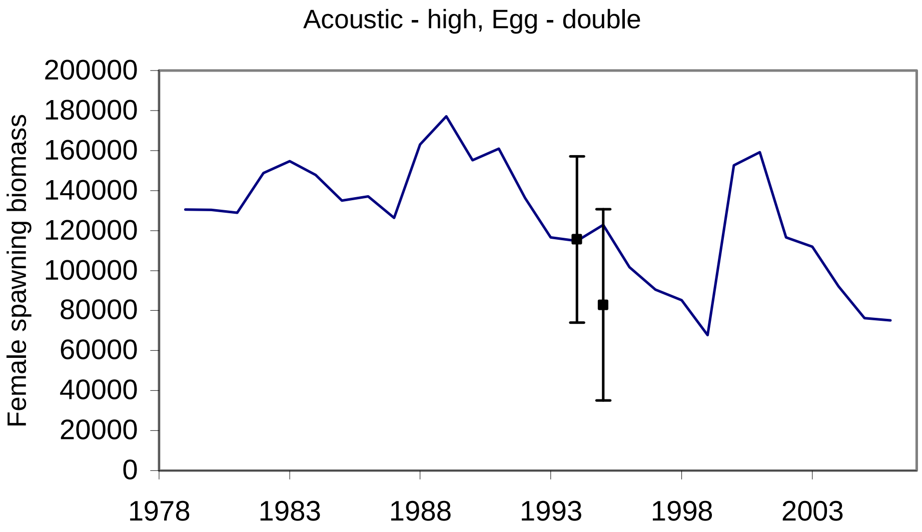


Figure 8.3. The time-trajectory of female spawning biomass (top) and total spawning biomass (bottom) for the **Low**, **GAB**, ***M*=0.2** and **Ling** models. The vertical lines show the estimates of spawning biomass derived from surveys of egg abundance in 1994 and 1995 and acoustic surveys from 2003 to 2006.



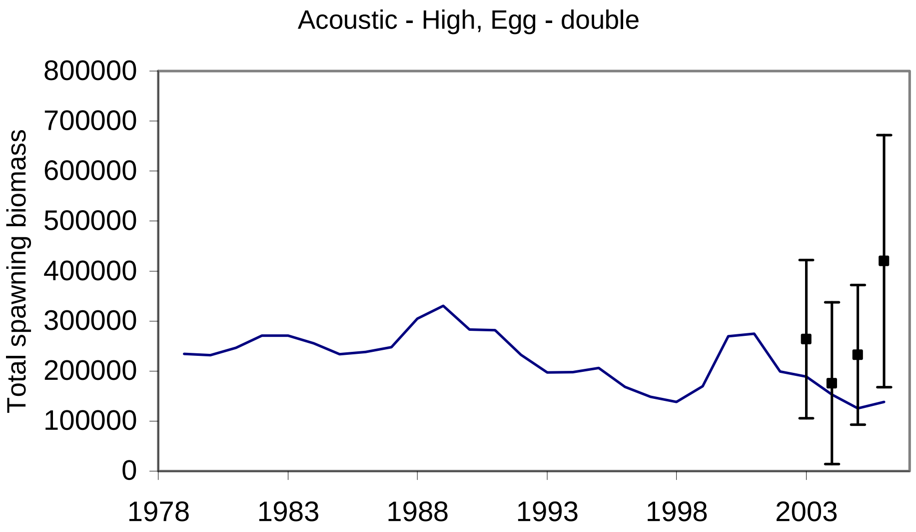


Figure 8.4. The time-trajectory of female spawning biomass (top) and total spawning biomass (bottom) for the High model. The vertical lines show the estimates of spawning biomass derived from surveys of egg abundance in 1994 and 1995 and acoustic surveys from 2003 to 2006.

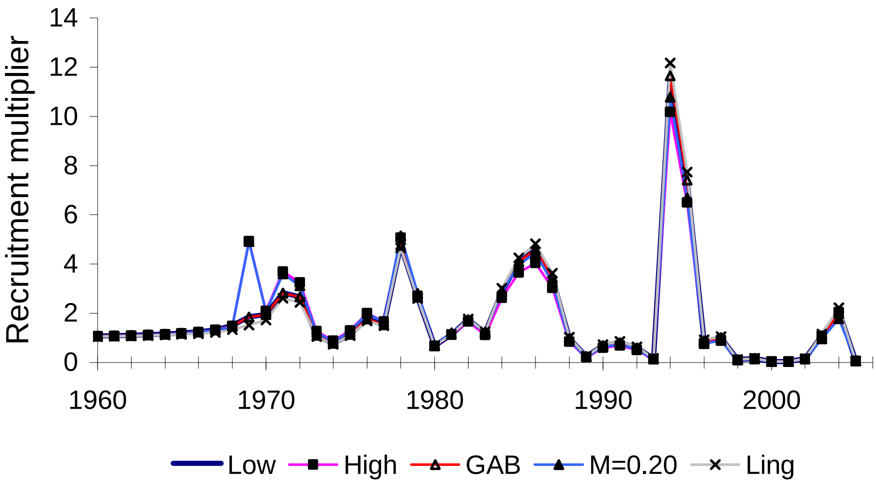


Figure 8.5. Estimated recruitment multipliers (the amount by which the recruitment deviated from that predicted by the stock-recruit relationship) versus year of spawning for each of the sensitivity models.

8.6.2 Natural mortality

Recent models have indicated that the preferred estimated value for natural mortality, *M*, has been decreasing with each annual assessment. Table 8.6 shows estimates of *M* from 2004 to 2007. The decrease in *M* corresponds to a change in the way the age-length keys have been applied when determining the age-composition for each fleet. Following recommendation from the RAG (Slope RAG, July 2006), a single age-length key has been applied (since August 2006), whereas previous assessments had used fleet specific age-length keys (i.e. an age length key for each of the spawning and on-spawning fishery was applied). The affect of this has been to increase the number of old fish in the spawning age compositions of the most recent years (Figure 8.6). The model attempts to fit this by decreasing natural mortality, thereby allowing more fish to survive to older ages (the plus group).

A model was run where the natural mortality was fixed at *M*=0.2. Figure 8.7 clearly shows that with a larger value of natural mortality than the base case model (i.e. the **Low** model, with *M*=0.165) the fit to the older age classes is poorer. The log-likelihood with *M* fixed at 0.20 is also larger, implying a worse fit (namely 470.1, compared to 466.5). Results in the figures with natural mortality fixed are referred to as ***M*=0.2.**

Table 8.6. A retrospective view of the estimated natural mortality, M, over successive assessments.

	Natural mortality, *M*	
Date	Low Model	High Model
July 2007	0.165	0.188
Aug 2006	0.176	0.212
July 2006	0.196	0.233
Aug 2005	0.198	0.216
Aug 2004	0.200 Base-case model	
Aug 2003	0.200 Base-case model	

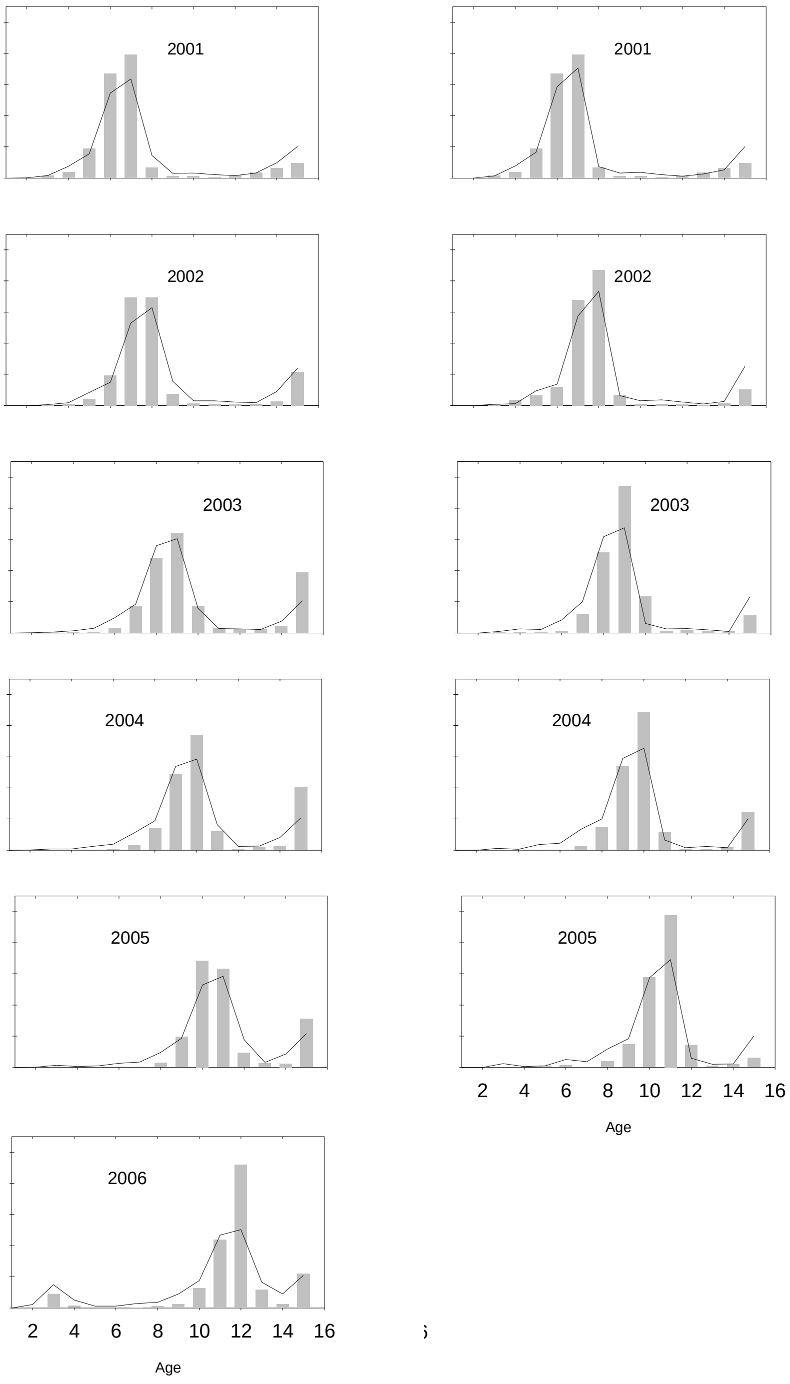


Figure 8.6. Observed (bars) and model estimated (lines) proportion caught at age for the spawning sub-fishery when a single ALK is used (left) and when separate ALK ‘s for each sub-fishery are used. Using a single ALK has increased the proportion of older aged fish.

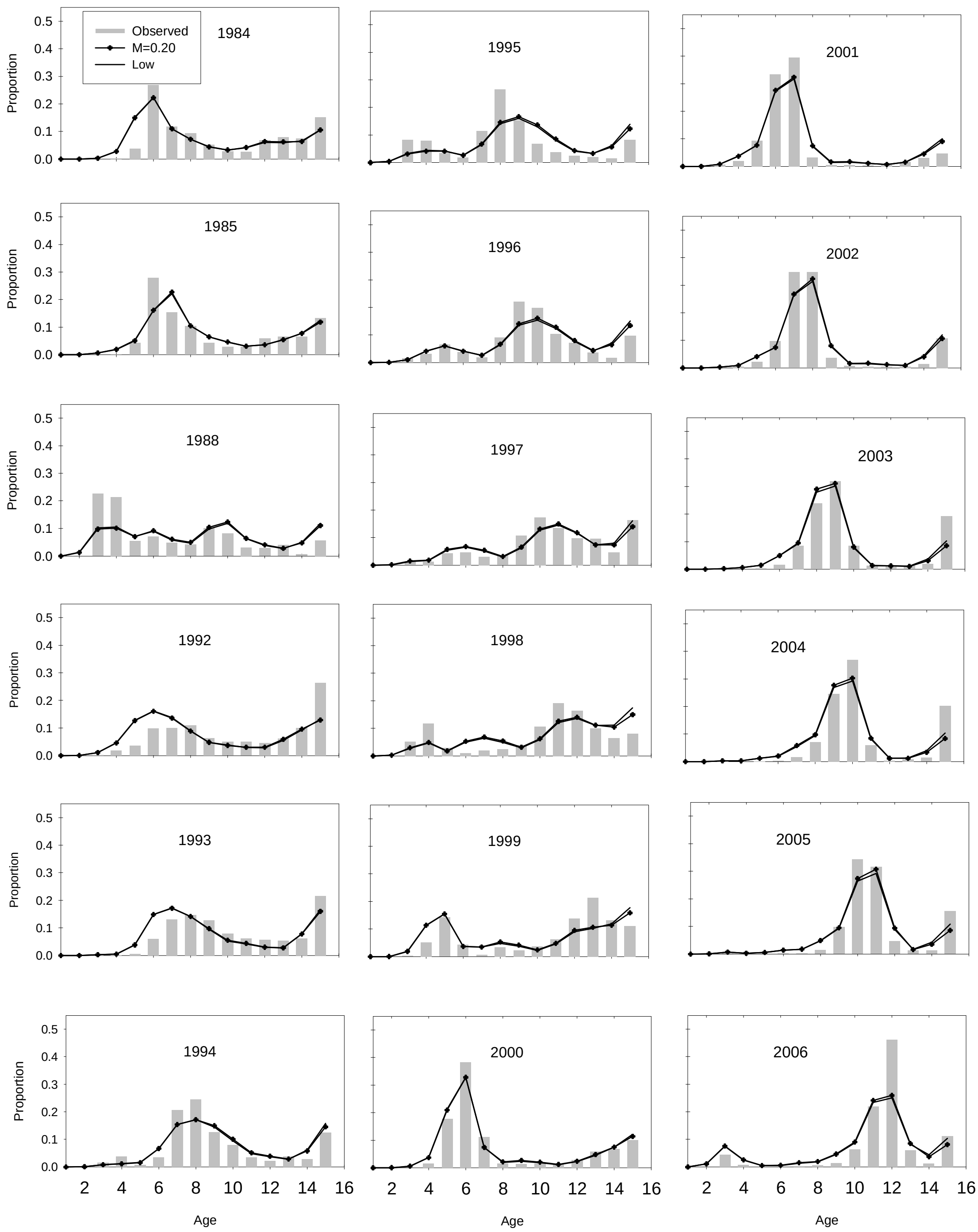


Figure 8.7. Observed (bars) and model estimated (lines) proportion caught at age for the spawning sub-fishery when natural mortality is estimated (M=0.165; Low model; line) or is fixed at 0.2 (M=0.2 model; symbol).

8.6.3 GAB catches

The GAB catches are shown in Figure 8.1 and, while they have increased recently, are still small compared to the catches in the east. Not surprisingly, the model (**GAB**) with these catches included produces biomass and recruitment trends that tend to overlap that of the Low model (Figure 8.3 and Figure 8.5).

8.6.4 Ling catch rate factor

The catch-rate series for 2007 (Haddon, 2007a) did not include a dummy pink ling catch factor that had been included in the GLM standardisation in 2006. The result being that the spawning fishery index is lower through the middle years of the fishery than in 2006. When this factor is included (Haddon, 2007b), the series more closely resembles that of 2006. Figure 8.8 shows plots of the 2007 catch-rate series for the spawning fishery without (top: **Low** model) and with (bottom: **Ling** model) the pink ling factor. Clearly fits to the series without the ling factor are poorer than when it is included, with the model generally over estimating catch-rates from 1995 to 2004 (for both series). This may also be influenced by the model's desire to increase catch rates in order to fit to the much larger values seen in 2005 and 2006.

Spawning biomass trajectories and estimated recruitment multipliers for the **Ling** model are shown in Figure 8.3 and Figure 8.5. While the recruitment time-series is similar to the other models, the magnitude of the initial spawning biomass is lower, but then gradually follows essentially the same trajectory (in trend and biomass).

8.6.5 Assessment summary

Table 8.7 shows the results against various quantities of interest for the base case models. The quantities of interest shown are the estimated pristine female spawning biomass (B_0); the reference biomass (B_{ref}) which is the average female spawning biomass over 1979–1988; the spawning biomass in 1979 ($\tilde{B}_{79}$) and in 2006 ($\tilde{B}_{2006}$) and its size in 2006 relative to the reference level (depletion, $\tilde{B}_y / B_{ref}$); the estimated fishing mortality rate for the spawning (F^1_{curr}) and non-spawning (F^2_{curr}) sub-fisheries for 2006 (=*curr*); the estimated recruitment residual for the strong 1994 cohort, and the more recent 2004 cohort, and the negative log likelihood (-ln L) value from the model. Note that the final year of biomass estimation (*curr*) is one year less than the year the assessment is produced.

The sensitivity tests conclude that the reference female biomass is (a) approximately 50,000 t for the **Low**, **Ling** and **GAB** models, (b) 140,000 t for the **High** model and (c) 66,000 t for the ***M*=0.2** analysis.. The current female spawner biomass (in the middle of 2006) is around 24,000 t for all models except the **High** model (75,000 t) and this is approximately 50% of the reference biomass (except for the ***M*=0.2** model, which is 37%).

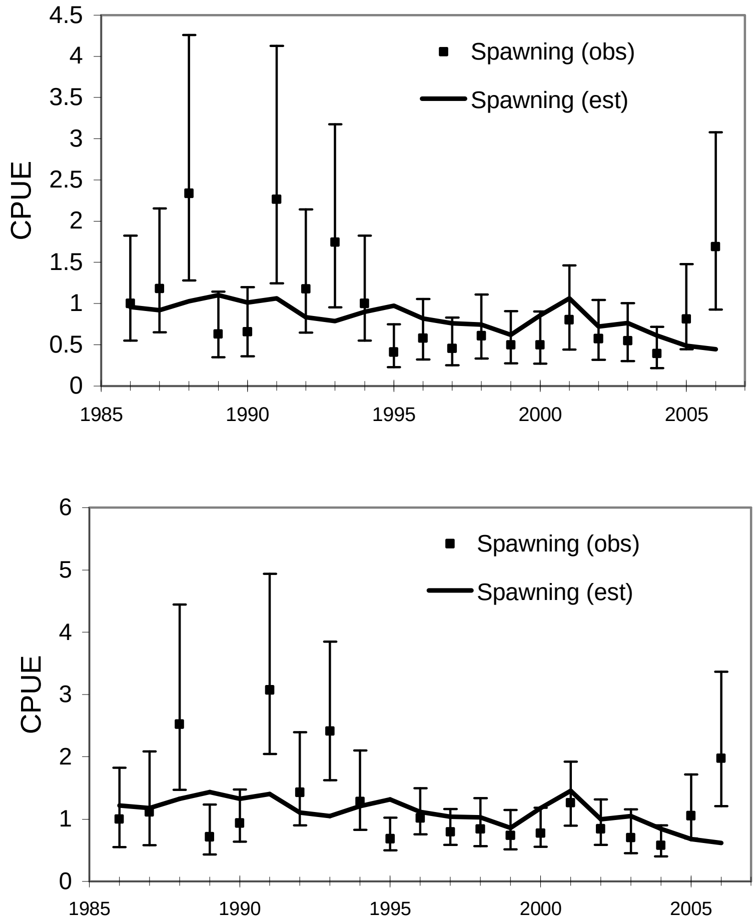


Figure 8.8. The model fit to the spawning catch-rate series. Top: without the pink ling factor in the GLM. Bottom: With the pink ling factor in the GLM.

Table 8.7. Estimated values for several parameters of interest. 'Curr' refers to the current or final year of the estimation, i.e. 2006. The "alternative acoustic cv's" sensitivity uses cv's for each year's acoustic survey of 2003 (cv=0.34), 2004 (0.55), 2005 (0.33) and 2006 (0.41).

Specification	B_0	B_{ref}	$\tilde{B}_{79}$	$\tilde{B}_{curr}$	$\tilde{B}_{curr} / B_{ref}$	F^1_{curr}	F^2_{curr}	R_{94}	R_{04}	-ln L
Low	30340	50644	44701	23867	47.13%	0.050	0.055	11.6	2.1	466.49
High	69677	140254	130565	75166	53.59%	0.016	0.019	10.2	2.0	466.40
GAB	30334	50591	44630	23710	46.87%	0.050	0.059	11.7	2.0	465.90
Ling	29113	45784	39572	23750	51.88%	0.050	0.056	12.2	2.2	457.92
M=0.20	32832	65658	60884	24780	37.74%	0.057	0.045	10.8	1.8	470.07
Alternative acoustic cv's (Ryan *et al*. 2007)	30672	51446	45448	24291	47.22%	0.049	0.054	11.6	2.1	465.47

8.6.6 Harvest control rule application

The steps involved in computing the Recommended Biological Catch for 2007 using the Tier 1 rules are:

1. Determine the relationship between exploitation rate and spawning biomass, where the relative exploitation rates among the fleets are based on the exploitation rates estimated for 2007.
2. Find the exploitation rates so that spawning biomass is a pre-specified fraction of that in an unfished state.
3. Determine the depletion of the spawning biomass in the middle of 2008.
4. Determine the correction factor (if needed), and multiply the exploitation rates calculated at step 2 by this correction factor.
5. Multiply the numbers-at-age in the middle of 2008 by the exploitation rates calculated at step 4.

Three variants of the Tier 1 rules are applied depending on specifications for the target spawning biomass and the depletion at which the exploitation rate begins to be reduced to zero (all variants set the exploitation rate to zero if the stock is assessed to be depleted to be 20% of B_{ref}):

a) 20-40-48; a target stock size of 48% of B_{ref}, with the exploitation rate dropping off once the stock drops below 0.4 B_{ref}.
b) 20-40-40; a target stock size of 40% of B_{ref}, with the exploitation rate dropping off once the stock drops below the target level.

The mid-year depletion in 2008 must be calculated to apply the Tier 1 harvest control rule. The 2008 depletion for each model is shown in Table 8.8 and is calculated by assuming a 2007 catch of 3,730 t. The ensuing landed and total Recommended Biological Catches (RBC) for 2008 and long-term are also shown.

The time series of landed RBCs under each Tier 1 rule is given in Table 8.9 for the **Low** and **High** models and in Figure 8.9 for all models. Note that the final depletions are not exactly 40% and 48% of B_{ref} . This occurs presumably because density-dependence in the stock recruitment model is a function of depletion relative to B_0 and not relative to B_{ref}. As a result the depletion in terms of B_0 is higher than in terms of B_{ref}. The annual depletion level under the current catch of 3,730t are also shown in Table 8.9.

Figure 8.10 shows the projected depletion under the **Low** model and its RBCs, and also if the RBCs from the **High** model are applied under the **Low** model parameterisation. The catches from the **High** model have been adjusted so that the initial RBCs are not more the 50% of the previous RBC (see Table 8.9). This clearly shows that the large RBCs of the **High** model are not sustainable if the **Low** model parameterisation is true.

Table 8.8. The estimated 2008 mid-year depletion and RBCs (landed and total; tonnes) for two Tier 1 harvest control rules with target biomass depletions of either 48% or 40%. Note that the long-term RBC's are the final projected RBC in year 2026, at which point the RBC may not have stabilised to the target biomass (but is typically close).

20:40:40 harvest strategy		2008 RBC (t)		Long term RBC (t)	
Model	SB_{2008}/SB_0	Landed	Total (land + discard)	Landed	Total (land + discard)
Low	0.44	4,368	4,687	5,465	5,836
High	0.51	14,715	15,928	17,160	18,559
GAB	0.44	4,217	4,535	5,421	5,792
Ling	0.49	4,255	4,530	4,770	5,087
M=0.20	0.35	4,324	4,758	8,831	9,512

20:40:48 harvest strategy		2008 RBC (t)		Long term RBC (t)	
Model	SB_{2008}/SB_0	Landed	Total (land + discard)	Landed	Total (land + discard)
Low	0.45	3,418	3,666	4,851	5,143
High	0.51	11,539	12,485	15,244	16,348
GAB	0.44	3,301	3,548	4,808	5,101
Ling	0.50	3,329	3,542	4,240	4,490
M=0.20	0.35	3,430	3,772	7,860	8,392

Table 8.9. The time series of landed RBCs and corresponding depletions relative to Bref for each Tier 1 rule for the Low model (top) and High model (bottom). Also shown is the annual depletion if the current landed catch of 3,730 t is maintained over all projected years. Shaded cells are more than 50% higher than the previous year's RBC (assuming that RBCs from 2008 onward cannot be greater than 1.5 times the previous year, i.e. RBC(2008)=5,595; RBC(2009)=8,393; RBC(2010)=12,589).

Low	Landed RBC		Depletion		
	20:40:40	20:40:48	20:40:40	20:40:48	Ccurr=3,730
2007	3729	3729	0.44	0.44	0.44
2008	4368	3418	0.44	0.45	0.45
2009	3886	3285	0.38	0.39	0.38
2010	4056	3556	0.38	0.40	0.39
2011	4305	3749	0.39	0.41	0.40
2012	4647	3937	0.39	0.42	0.42
2013	4970	4137	0.40	0.43	0.44
2014	5098	4288	0.40	0.44	0.46
2015	5181	4405	0.41	0.45	0.48
2016	5243	4497	0.41	0.46	0.49
2017	5292	4572	0.42	0.47	0.51
2018	5331	4633	0.42	0.48	0.53
2019	5363	4683	0.42	0.48	0.55
2020	5388	4724	0.42	0.49	0.56
2021	5409	4757	0.43	0.49	0.57
2022	5425	4784	0.43	0.50	0.58
2023	5439	4807	0.43	0.50	0.60
2024	5450	4825	0.43	0.50	0.61
2025	5458	4839	0.43	0.50	0.61
2026	5465	4851	0.43	0.51	0.62

High	Landed RBC		Depletion	
	20:40:40	20:40:48	20:40:40	20:40:48
2007	3730	3730	0.51	0.51
2008	14715	11539	0.50	0.51
2009	14272	11439	0.41	0.43
2010	14367	11742	0.41	0.43
2011	14607	12126	0.41	0.44
2012	15217	12797	0.41	0.45
2013	15751	13393	0.41	0.46
2014	16116	13828	0.42	0.47
2015	16374	14152	0.42	0.47
2016	16564	14400	0.42	0.48
2017	16708	14595	0.43	0.49
2018	16820	14748	0.43	0.49
2019	16907	14870	0.43	0.50
2020	16974	14967	0.43	0.50
2021	17027	15044	0.43	0.51
2022	17068	15105	0.44	0.51
2023	17100	15153	0.44	0.51
2024	17125	15191	0.44	0.51
2025	17145	15220	0.44	0.51
2026	17160	15244	0.44	0.51

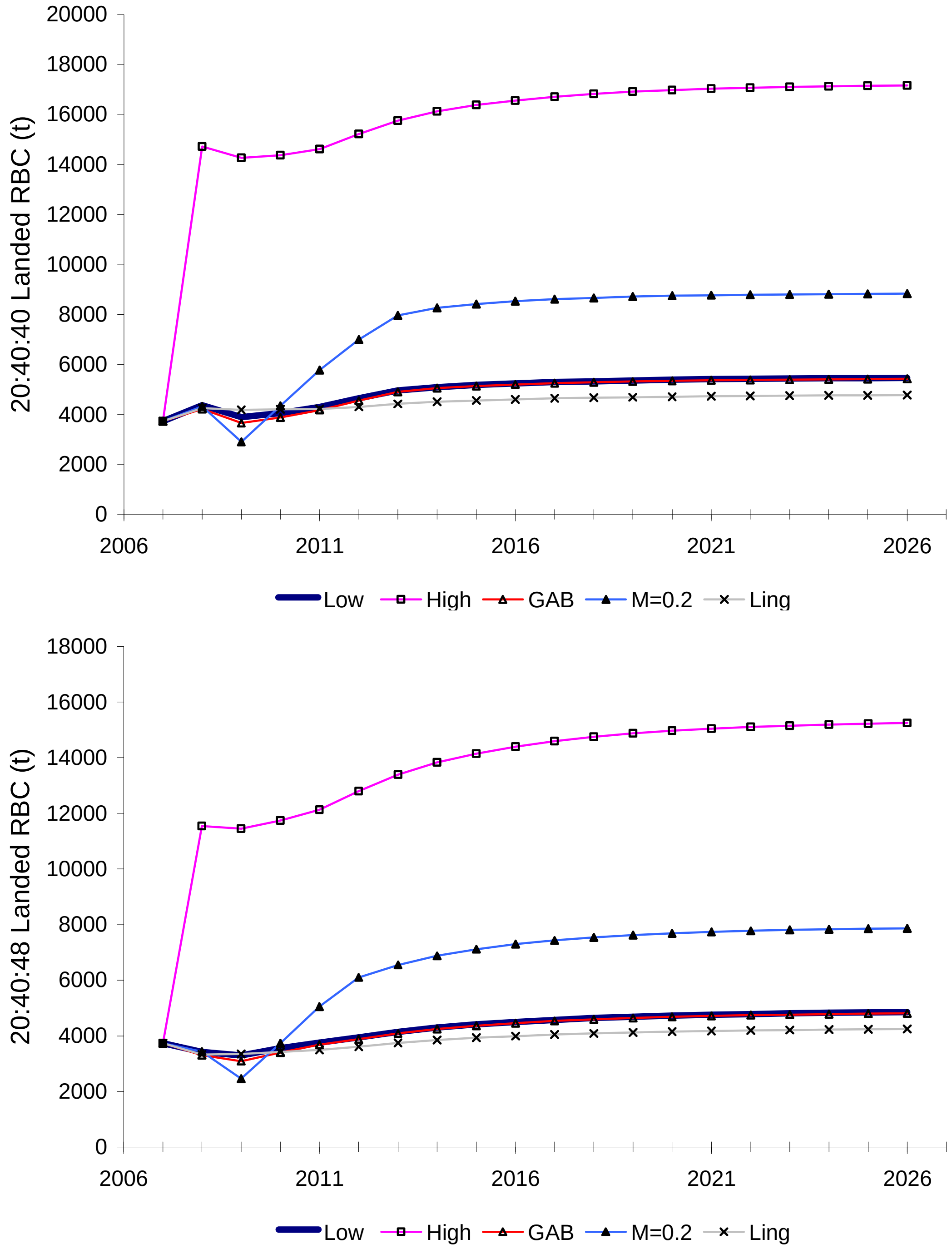


Figure 8.9. The time-series of landed RBC's for blue grenadier for each of 5 sensitivity models. Note that the High model RBC's are the raw values and have not been adjusted for the 50% maximum increase rule.

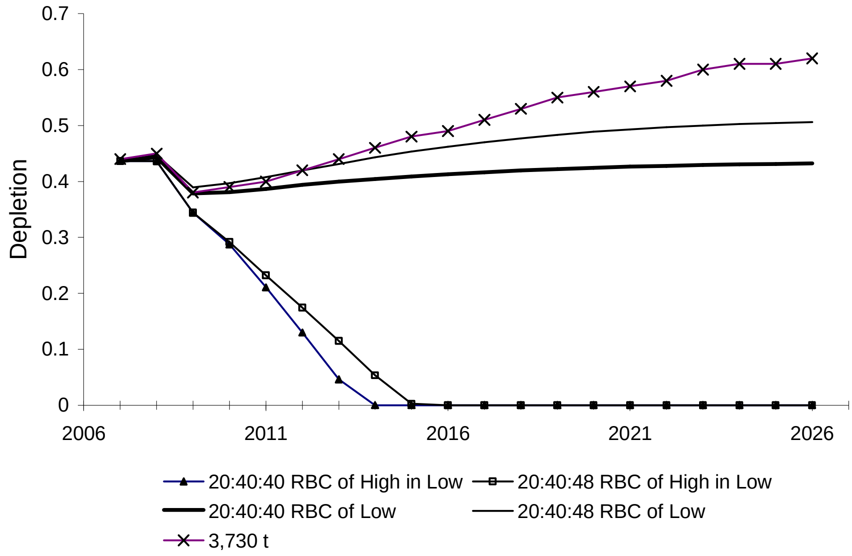


Figure 8.10. The time-series of depletion when (a) the current catch (3,730 t), (b) RBCs from the Low model and (c) the RBCs from the High model are projected under the Low model parameterisation.

8.7 Acknowledgements

Many thanks are due to Sandy Morison, Gavin Fay, Rick Methot and all of the SS2-WG for their assistance with general model discussions and SS2 model development. Malcolm Haddon is thanked for providing catch rate indices, Mike Fuller and Neil Klaer for their advice on data matters. The Central Aging Facility and the AFMA observer section are thanked for providing the aging data and spawning length frequency data respectively.

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9. Updated Stock Assessment of Pink Ling (*Genypterus blacodes*) in the South East Fishery, August 2007

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9.1 Summary

The 2007 stock assessment of Pink Ling (*Genypterus blacodes*) has been updated following a review in December 2006 and advice from the July Slope RAG meeting. The 2007 Pink Ling assessment model has been run in version 2 of Stock Synthesis 2 (SS2). It assumes separate stocks in the east and west of the fishery. The data had been updated to include 2007 data. This updated assessment includes estimates of female and male growth parameters and of natural mortality. The non-trawl catch rate data is being re-evaluated and was not used in 2007.

The new reference case estimates the spawning biomass at the start of 2007 at 28% of the virgin spawning biomass in the east and 52% in the west. The 2006 assessment projected the spawning biomass in 2007 to be 11% in the east and 33% in the west.

The RBC for 2008 using the 20:40:48 Tier 1 rule is 688 tonnes (68t from the east and 620t from the west). With a 20:40:48 rule, the RBC is 858 tonnes (84 in the east and 774 tonnes in the west). Projections suggest a long term sustainable yield of almost 1450 tonnes under the 20:40:48 rule and almost 1600 tonnes under the 20:40:40 rule.

9.2 Method

9.2.1 Previous Assessments

In 2005, the base case Pink Ling assessment model (Klaer 2003a, 2003b) was run with updated 2003 and 2004 data (Taylor, 2005). This model was developed in Coleraine (Hilborn, 2000), a generalised age structured stock assessment model. It assumed the fishery was a single stock and used unstandardised trawl catch-rates. An alternative run used standardised catch-rates from the trawl fishery. This was then run in SS2 (Taylor, 2006a) and 2005 data added and run as east and west fisheries (Taylor, 2006b, 2007).

9.2.2 Data

Catch: From 1986 for trawl fleet and 1997 for the non-trawl fleet, most of the catch is reported to the Commonwealth. When available, the total annual landings from SEF2 and SAN2 are used for the estimated total catch and SEF1 and GN01 are used to estimate the relative catch taken by zone and gear type. The estimated catches reported by zone are listed in Table 2 and shown in Figure 9.14.

Before 1986 (and 1997 for the non-trawl fishery), catches were reported to the states and data from these sources have been included this year. These are shown in Table 1. The total catches were based on Peace (1995), PIRVic Catch and Effort data, Wayte and Smith (2003) and Klaer (2003b). The 2007 projected catch was set equal to the quota (1200 tonnes), with the same gear type and east/west split as in 2006. The catches by gear type that were used in the assessment are listed in Table 1 and shown in Figure 9.1.

Catch-rate: The standardised otter trawl catch-rate was taken from Haddon (2007). It is similar to that used in 2006, with the trend in the east continuing to rise, and a slight rise in the west in 2006. The trawl catch rates are shown in Figure 9.4.

The non-trawl (autolongline) catch rate data is still being evaluated and was not used in this assessment. There was only one vessel using autolongline until 2002 and it is unlikely there will be meaningful catch rates before then.

The catch rates from three Kapala surveys were also used in the east.

Age and length frequency data: The length frequency data were taken from the port samples (Figure 9.6). In the east, Sydney Fish Market trawl length frequency data from 1986-90 and from two Kapala surveys were also used. Samples less than 80 were dropped. A maximum effective sample size of 200 was used.

Maturity: The maturity ogive was set at a 72cm infection point (Wayte and Smith, 2003) and a slope of -3 was assigned to approximate the knife-edge selection of previous assessments.

9.2.3 The 2007 Assessment

The 2007 assessment was run within the age-length model Stock Synthesis 2 (Methot, 2006). The data is fitted by maximum likelihood, and the RBC is estimated within the model. Unlike the 2006 assessment, this assessment estimated growth separately for males and females, and estimated natural mortality. It modelled length in 5 cm intervals. The current assessment estimates recruitment from 1983 (east) and 1982 (west).

Fixed parameters: As in previous assessments (Taylor, 2006, 2005; Klaer, 2003a, 2003b), recruitment steepness (0.75) and the weight at length coefficients and maturity at age (Figure 9.3) were fixed. The values used are given in Table 3. In 2007, natural mortality was estimated.

Selectivity: Selectivity at length for each gear type in each of the east and west was estimated in the model (Figure 9.2). The trawl selectivity (fishing fleet and Kapala) used a fully estimated double normal function (instead of the double logistic function used in 2006) while the non-trawl selectivity used a logistic curve. The selectivity function also includes an availability component, so can be different in the west to the east. In assessments prior to 2006, the selectivities were age based and fixed.

9.3 Results and Discussion

The catch in 2006 was 1201 tonnes (Table 1). It followed catches of 1600, 1607, 1608 and 1372 tonnes in the previous 4 years, and has decreased due to a reduction in quota. The trawl catch has remained stable at 726-756 tonnes over the past 3 years (Table 1). There was a transfer of quota to the non-trawl catch in 2004, but there has been a reduction in catch since then (475 tonnes in 2006, down from 851 tonnes in 2004). Catches have reduced in both the east and the west since 2004, the reduction being greater in the west (Figure 9.1). A catch of 1200 tonnes (based on the quota) in proportion to catches by gear type and zone was used for an estimate of the 2007 catch.

The catch-rates, and the fits to them, are shown in Figure 9.4. Both trawl cpue series show a decline since 1997-8 although the decline appears to have stabilised in recent years in the eastern trawl fishery and is stable in 2006 in the west.

9.3.1 Reference case

The fishery was modelled on a reference case (Table 3). The assumptions or data were then tested by varying the parameters or data in turn from the reference values. The summary of the outcomes of these sensitivity tests is listed in Table 5. Outputs from the reference case are shown in Figure 9.1 - Figure 9.12.

East: For the reference case in the east, the estimated value of the virgin female spawning stock biomass (SSB) is 6,926t and the 2006 SSB is 2,203t. The SSB level at the end of 2006 as a proportion of virgin biomass is 28% (32% in 2005 and projected to be 24% in 2007 under the current quota). The RBC for 2008 is 68 tonnes under the 20:48:48 rule and 84 tonnes under the 20:40:48 rule.

The recruit deviations were only estimated for the period 1983-2004. Before 1983, they had low values and a large variance and gave a larger than expected stock decline.

Separate growth estimates for males and females gave a 20 cm difference in size of larger fish in the east (Table 3b, Figure 9.5a). Eastern females are larger than those in the west and eastern makes are slightly smaller.

Male mortality was modelled separately but gave no significant difference, so a single estimate was made of mortality. In the east this was 0.238, similar to 0.23 in the west. These were higher than 0.2 used in previous assessments and 0.18 used in New Zealand.

The length data (Figure 9.6a) overall fits well. The poorer fits in 1991 and 1997 may be due to smaller sample sizes. In 2004, the model underestimates the smaller sizes and in 2005 it overestimates them. The age data generally fits well. (The age data was not used for fitting directly but was included to compare with the predicted ages structure).

The cpue generally fits the data until 2000 (with the exceptions of 1990-91). The eastern assessment does not predict the recent stabilisation and increase of trawl cpue. In the 2006 assessment, the model had been tested for excluding the 2005 length data. This gave a much better fit to recent cpue data. When the 2005 and 2006 length data were not used in the 2007 model, there is a much better fit to the cpue, and a predicted increase in the past 2 years. A comparison of the cpue, length and age fits, and recruitment, is shown in Figure 9.13. The cpue data appears to require an increase in smaller sizes (and recruitment in 2003) while the 2005 length data has fewer small animals and more larger animals.

West: In the west, the estimated value of the virgin SSB is 7,037t and the 2006 SSB is 4,109t. The SSB level at the end of 2006 as a proportion of virgin is 58% (66% in 2005 and projected to be 52% in 2007 under the current quota). The RBC for 2008 is 620 tonnes under the 20:48:48 rule and 774 tonnes under the 20:40:48 rule.

Growth estimates show females growing 10 cm larger than males (Table 3b, Figure 9.5b). Mortality is estimated as 0.23. Recruit deviations in the west are estimated from 1982.
The trawl selectivity is wider than that in the east (Figure 9.2).

The cpue fit is good. The increase in the last year is against a declining trend and is not predicted. The length and age data fit well.

Fishery: For the fishery, the RBC for 2008 is 688 tonnes under the 20:48:48 rule and 858 tonnes under the 20:40:48 rule (Tables 4a-4b).

Projections and depletion beyond 2008 for each of the above rules are listed in Tables 4a-4b. These suggest a long term sustainable yield of almost 1450 tonnes under the 20:48:48 rule and almost 1600 tonnes under the 20:40:48 rule (roughly 45:55 east and west). The east is currently more depleted than the west because it had higher catches in the past.

Both zones had relatively high recruitment during the 1990s, which has subsequently declined. The dome shaped selectivity for the east (both for trawl and Kapala) is very pronounced. While trawl catches predominated, this would have allowed a partial refuge in size for larger ling, but this refuge is increasingly removed as non-trawl catches increase.

9.3.2 Sensitivity tests

The model was run with variations from the reference case. These included

Estimating male mortality separately
Changing steepness to 0.65
Changing steepness to 0.85
Changing mortality to 0.18
Changing mortality to 0.25
Decreasing σ_R.
Increasing σ_R.
Doubling the weighting on the age at length data
Halving the weighting on the age at length data
Doubling the weighting on the CPUE
Halving the weighting on the CPUE
Doubling the weighting on the length data
Halving the weighting on the length data

In the east, the model was also run with estimating recruits from 1977 and from 1982 and omitting the 2005-6 length data.

These are summarised in Table 5. Generally, decreasing mortality, σ_R or the weighting on the cpue decreased the stock size and the long term catch. Estimating a separate male mortality made little difference.

The east was more stable to the sensitivity tests. The SSB and the long term catch did not change by much. In the west, the stock size and long term catch were sensitive to changes in mortality, σ_R and the weighting on the age at length data.

9.3.3 Alternative 2007 catch scenarios

Table 6 summarises the RBC for the reference case and for a range of alternative 2007 catch scenarios. Options B (900t) and C (800t) are possible outcomes following the buyout. Option A uses the proportions of option B with a 1200 tonne catch. These were requested by the August 21-22 SlopeRAG meeting.

9.4 Acknowledgements

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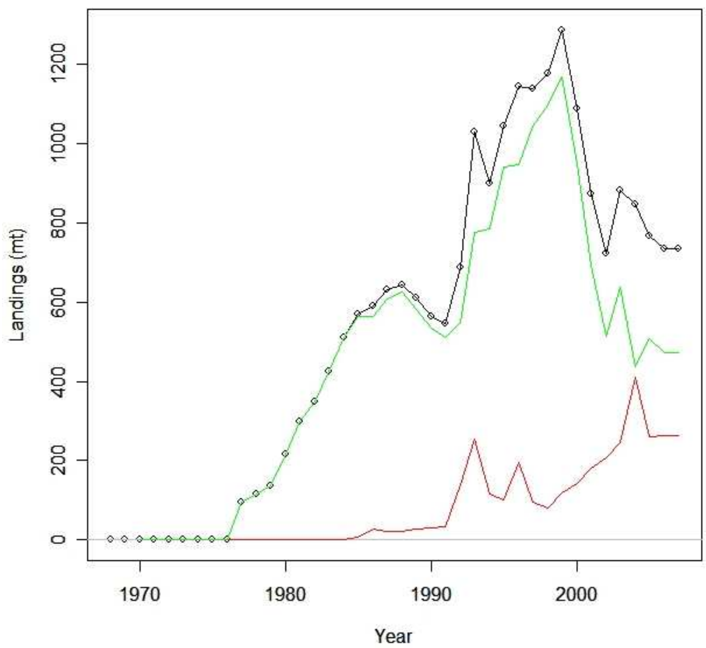


Figure 9.1a. Landed catch for the period 1977 – 2005 for the Eastern Zone. Black (upper) is total catch, blue (middle) is trawl catch and red (lower) is non trawl catch. Some discards are included for 1997 – 2001.

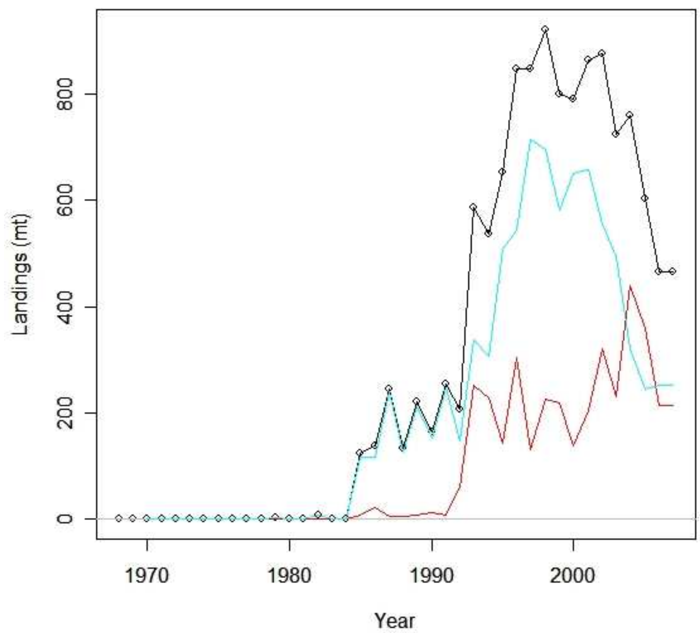


Figure 9.1b. Landed catch for the period 1979 – 2005 for the Western Zone. Black (upper) is total catch, blue (middle) is trawl catch and red (lower) is non trawl catch. Some discards are included for 1997 – 2001.

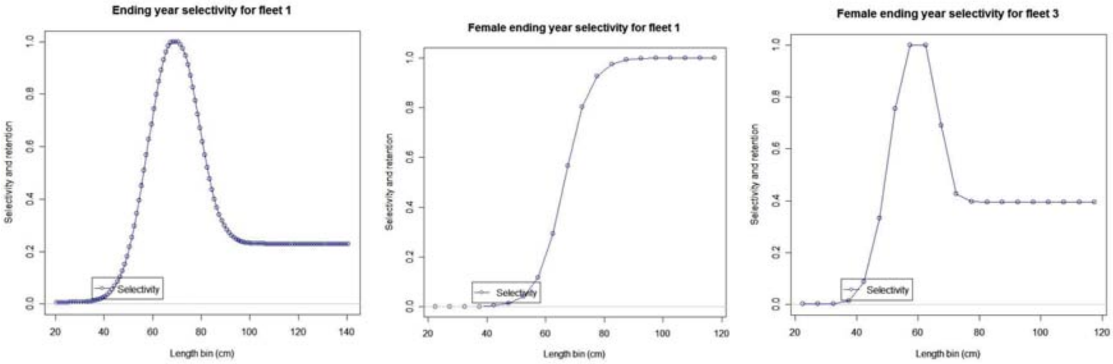


Figure 9.2a. Estimated selectivity at length for trawl (left), non trawl (centre) and Kapala (right) for the Eastern Zone.

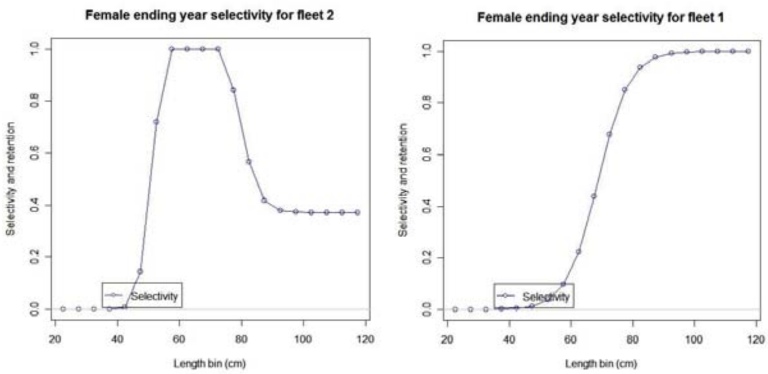


Figure 9.2b. Estimated selectivity at length for trawl (left) and non trawl (right) for the Western Zone.

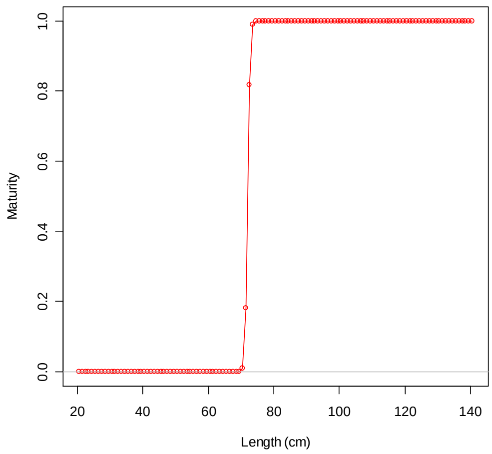


Figure 9.3. Maturity at length.

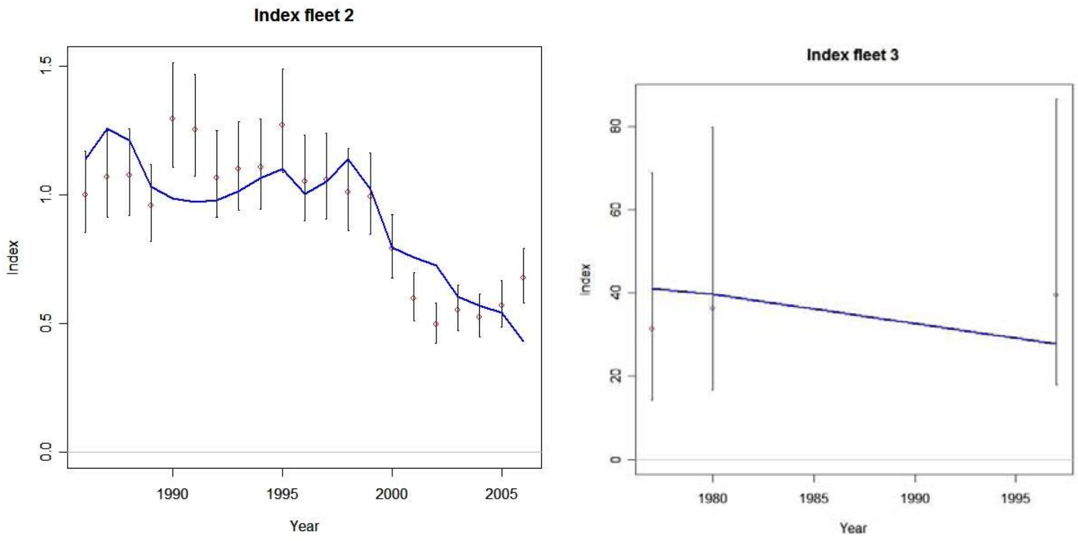


Figure 9.4a. Observed and estimated catch rates for trawl (left) and Kapala (right) for the Eastern Zone.

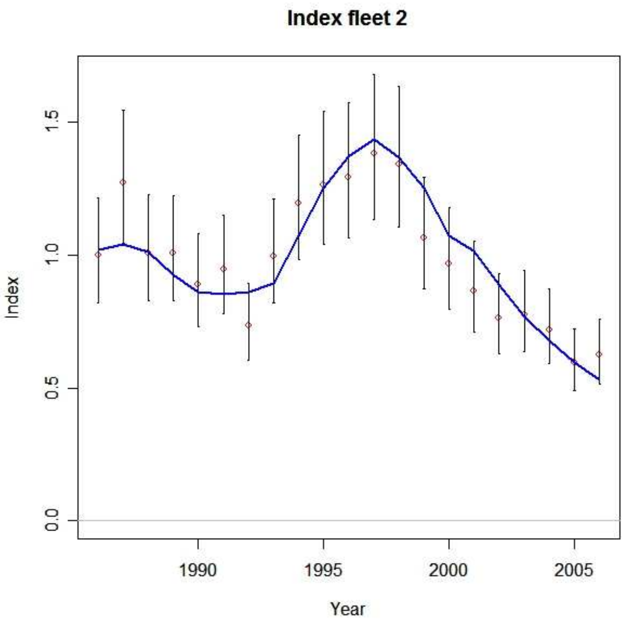


Figure 9.4b. Observed and estimated catch rates for trawl in the Western Zone.

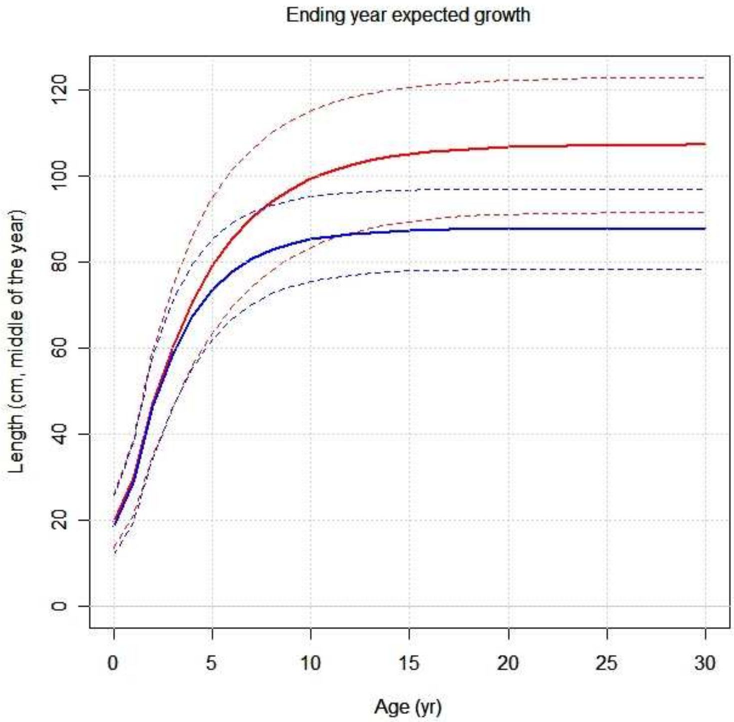


Figure 9.5a. Estimated growth curve for females (red, upper) and for males (blue, lower) in the Eastern Zone.

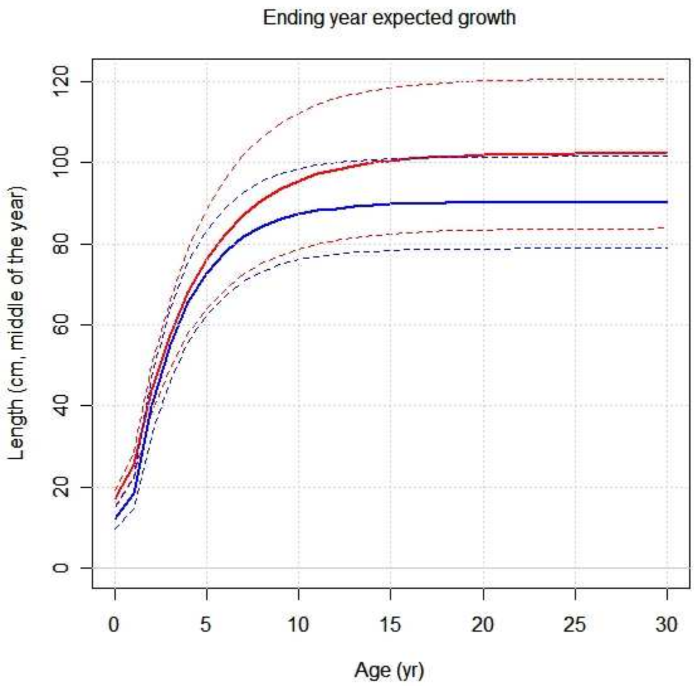


Figure 9.5b. Estimated growth curve for females (red, upper) and for males (blue, lower) in the Western Zone.

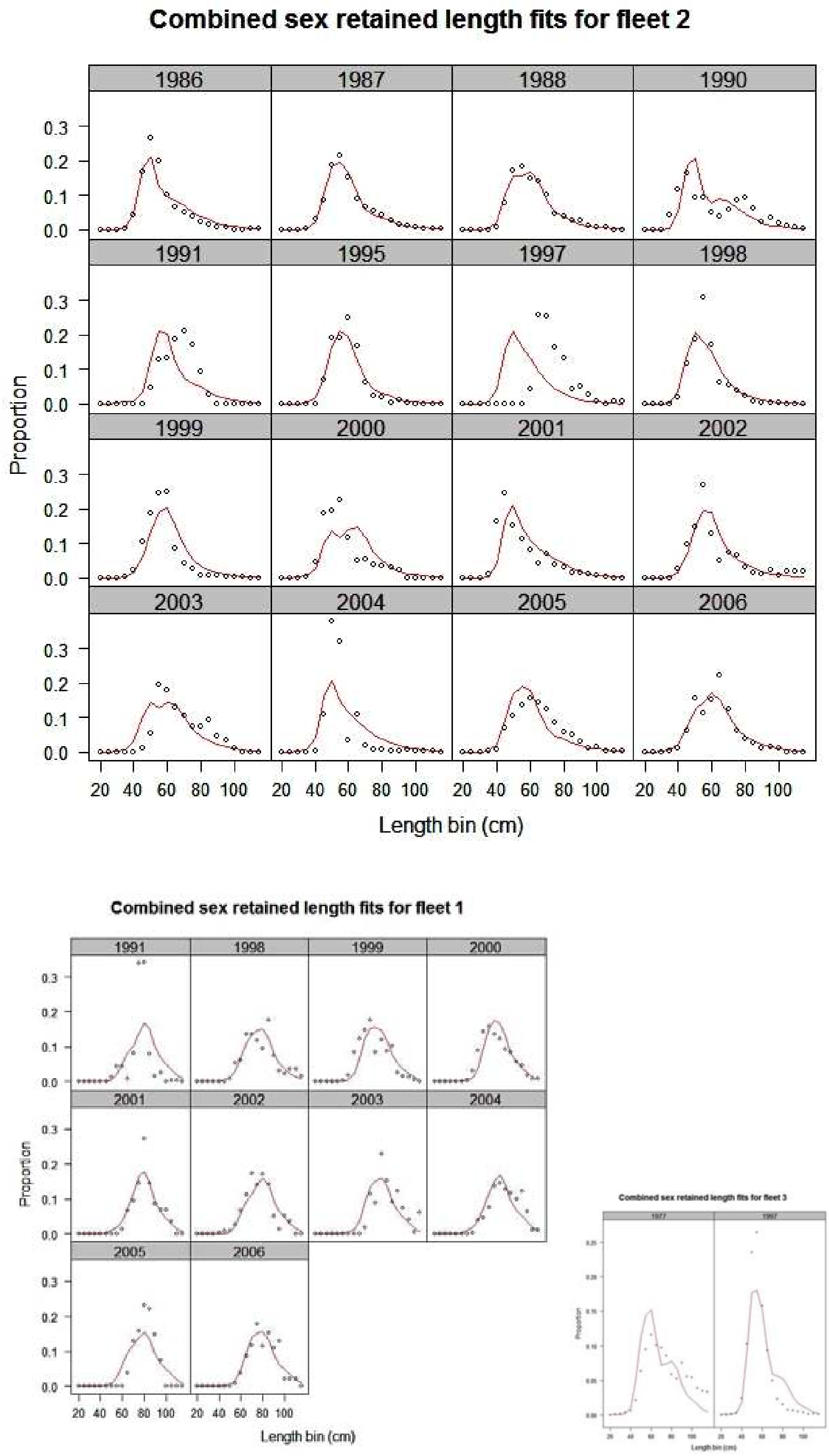


Figure 9.6a. Observed and estimated Sydney Fish Market length-frequency data during 1986 – 1990 and port-based data from 1991 for trawl (upper), port based length-frequency composition from 1991 for non-trawl (lower left) and Kapala length-frequency data (lower right) in the Eastern Zone.

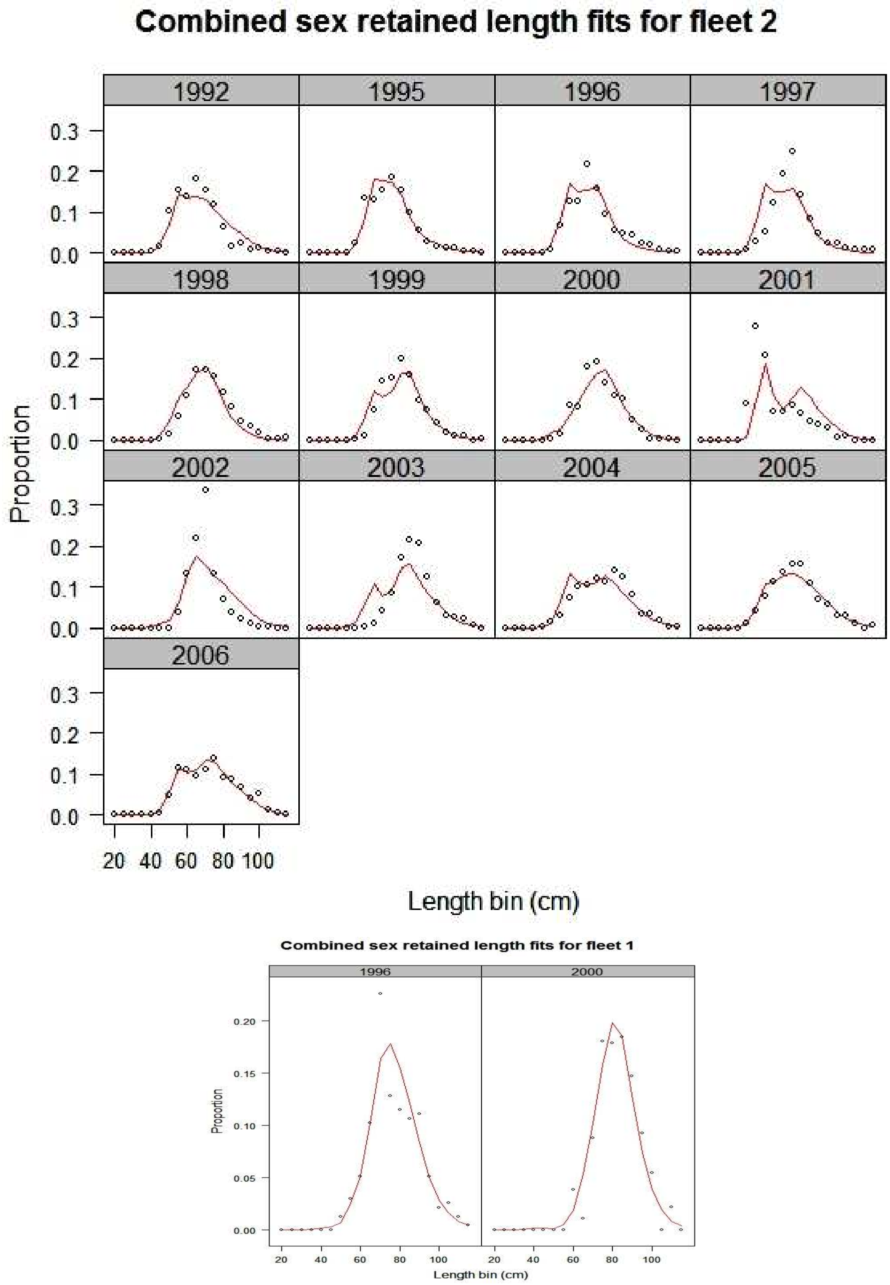


Figure 9.6b. Observed and estimated length-frequency data from 1992 for trawl (upper) and for non-trawl (lower) in the Western Zone.

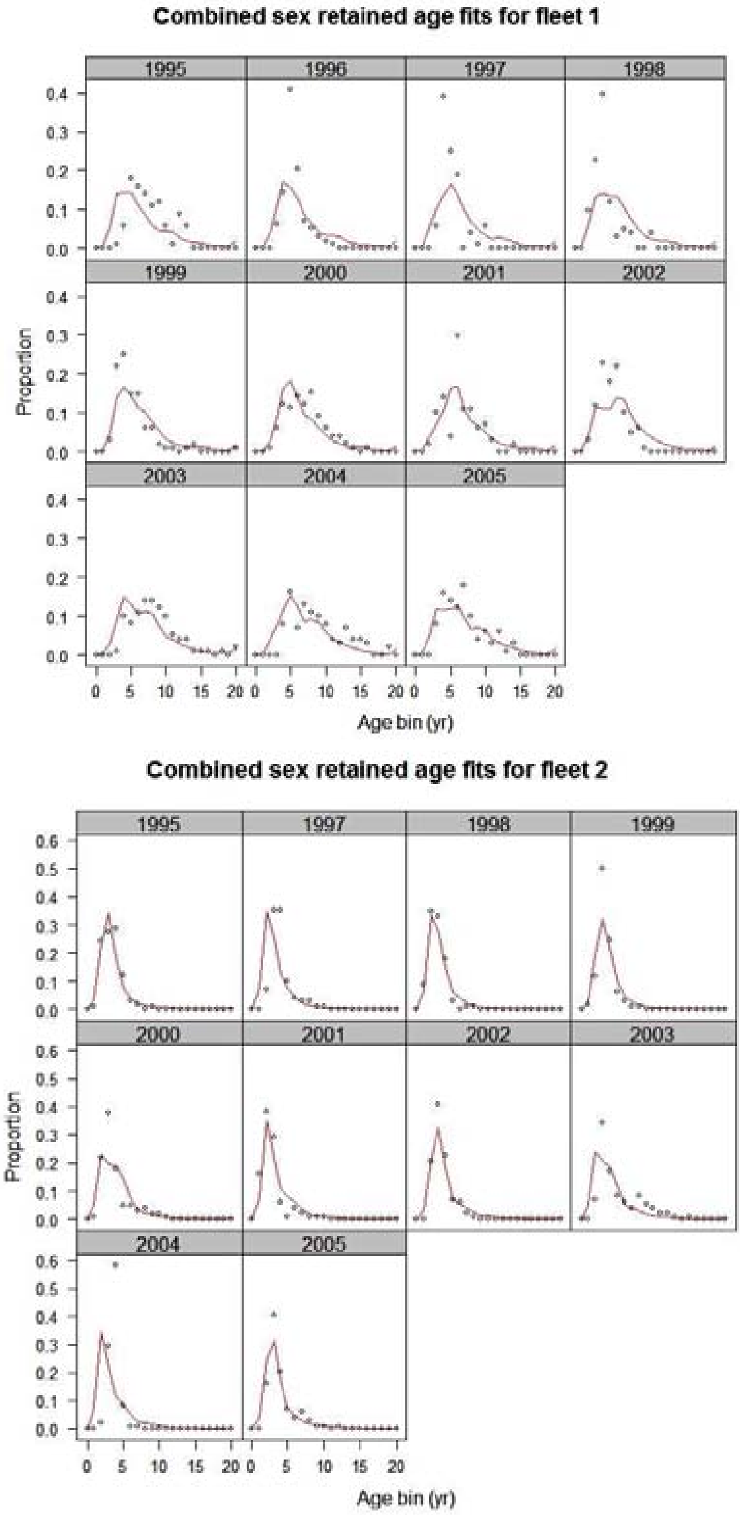


Figure 9.7a. Observed and estimated age data from 1995 for non-trawl (upper) and for trawl (lower) in the Eastern Zone.

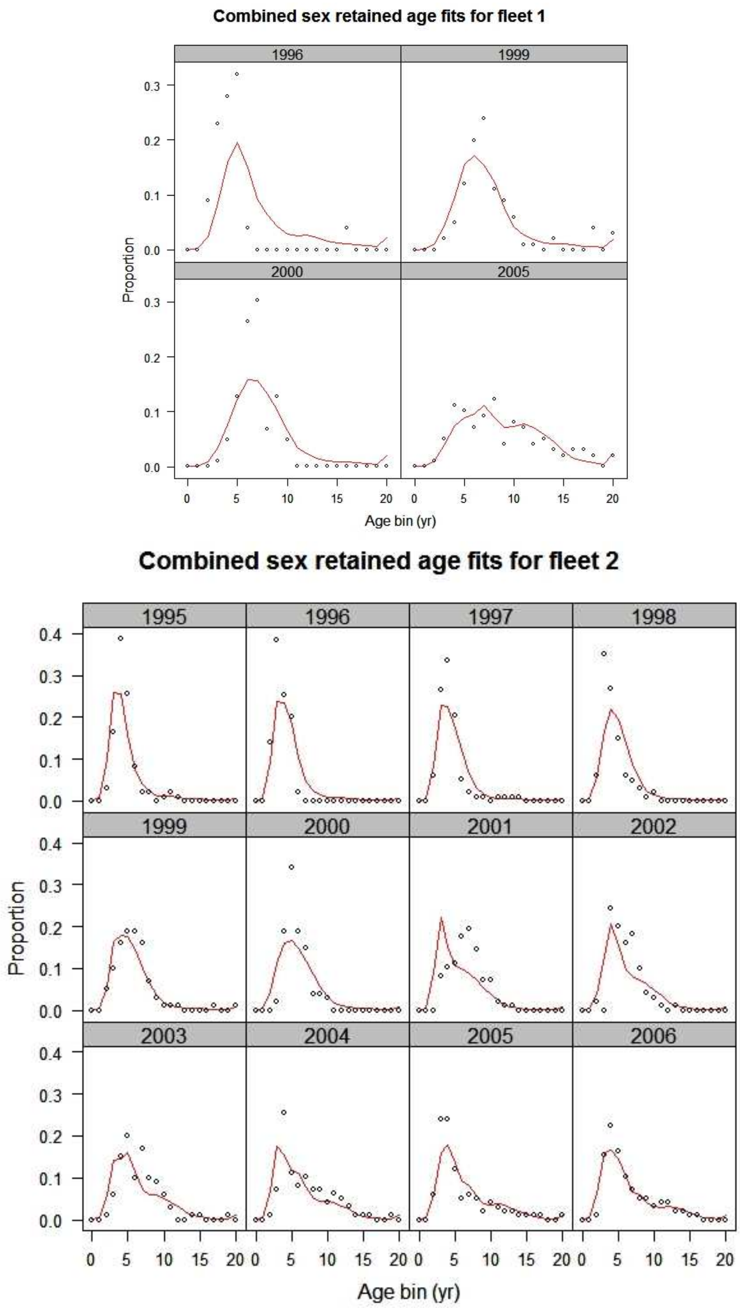


Figure 9.7b. Observed and estimated age data from 1995 for non-trawl (upper) and for trawl (lower) in the Western Zone.

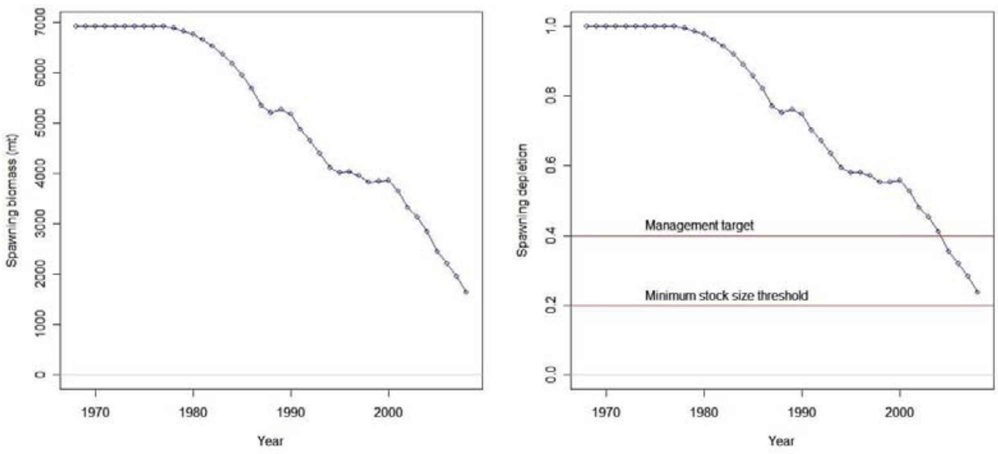


Figure 9.8a. Estimated female spawning biomass (left) and spawning biomass depletion (right) for the Eastern Zone.

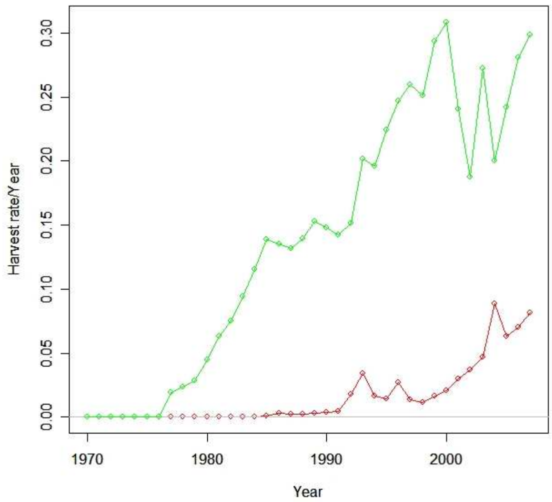


Figure 9.8b. Harvest rate by gear type for the Eastern Zone. The harvest rate for trawl is green/blue (upper) and for non-trawl is red (lower).

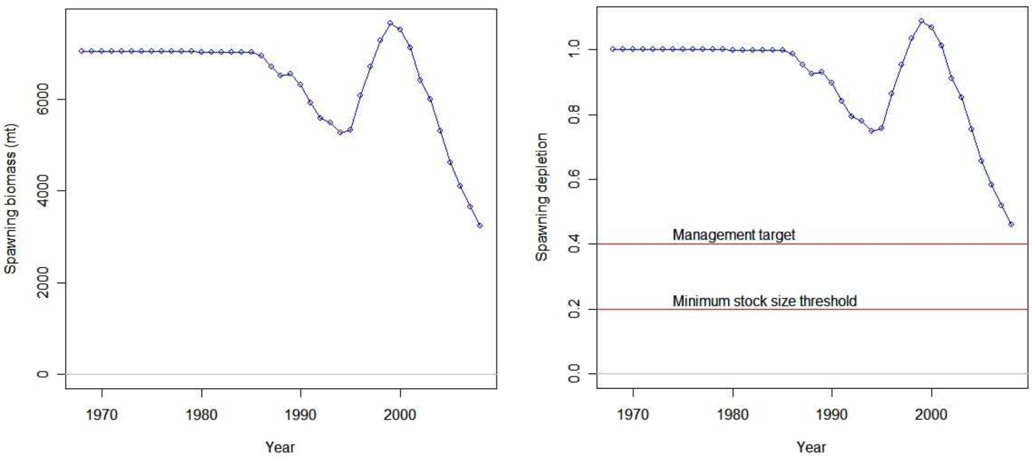


Figure 9.9a. Estimated female spawning biomass (left) and spawning biomass depletion (right) for the Western Zone.

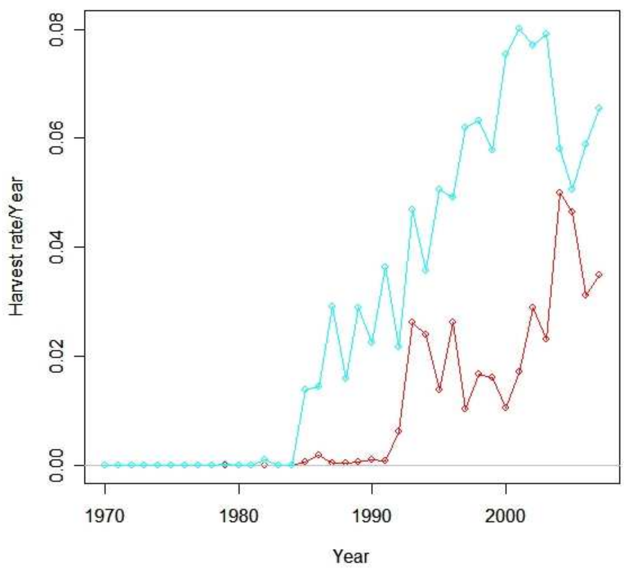


Figure 9.9b. Harvest rate by gear type for the Eastern Zone . The harvest rate for trawl is green/blue (upper) and for non-trawl is red (lower).

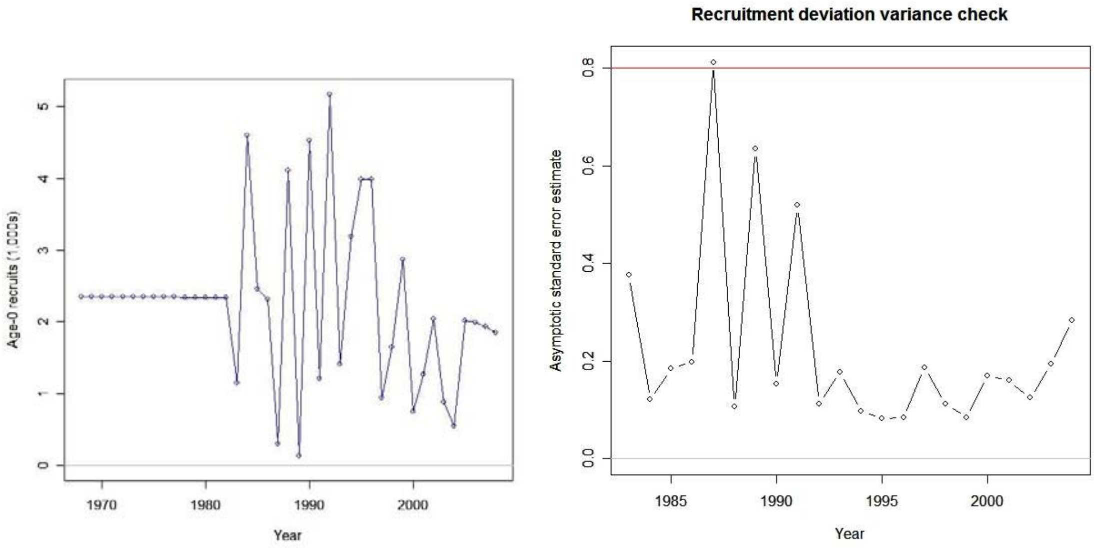


Figure 9.10a. Annual recruitment for the Eastern Zone (left) and recruitment deviation variance check (right)

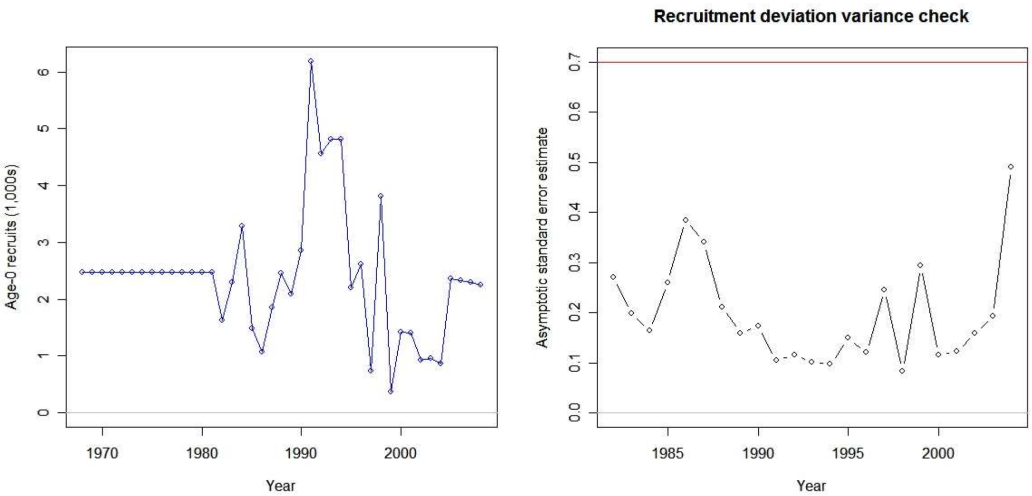


Figure 9.10b. Annual recruitment for the Western Zone (left) and recruitment deviation variance check (right)

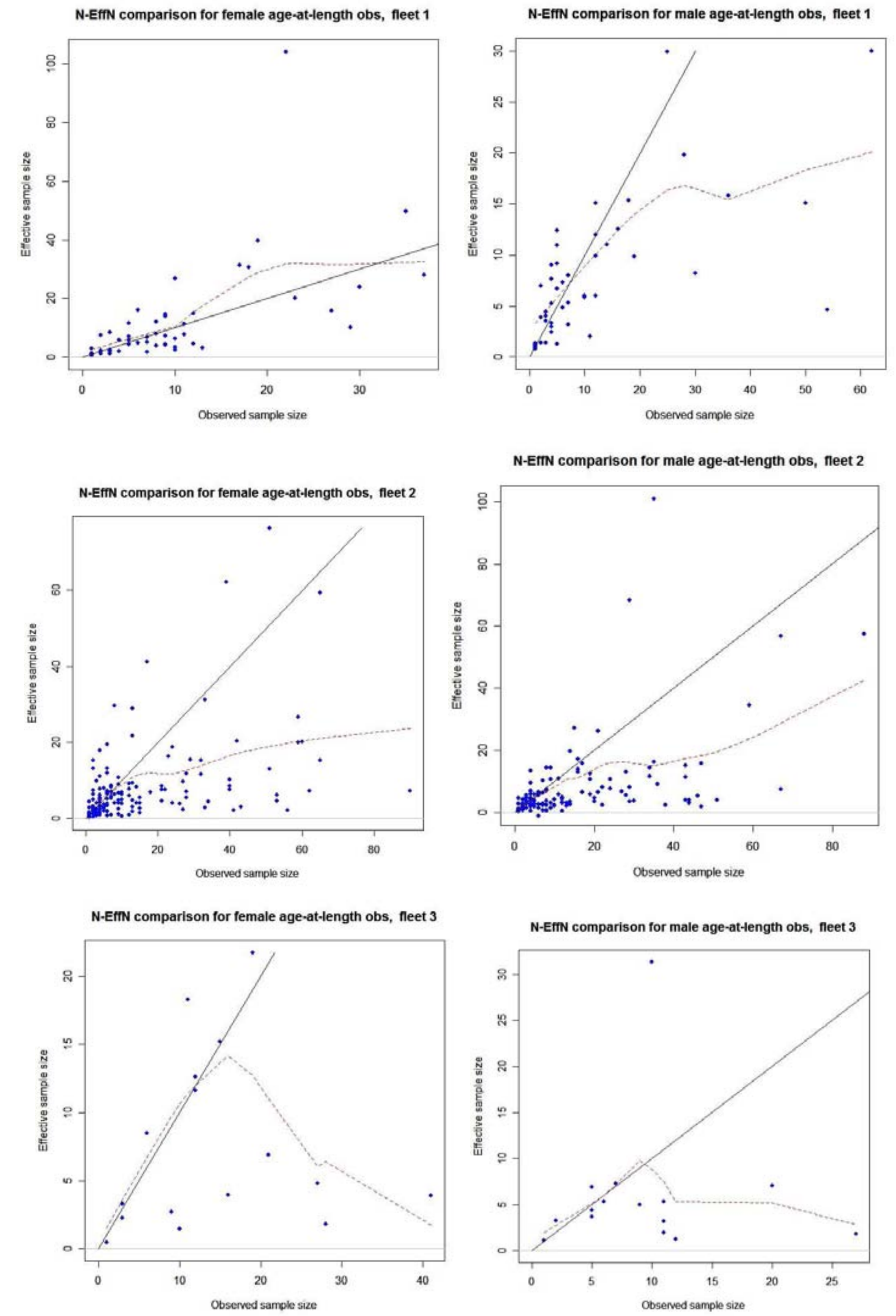


Figure 9.11a. Age at length diagnostics from the East (fleet 3 is the Kapala survey).

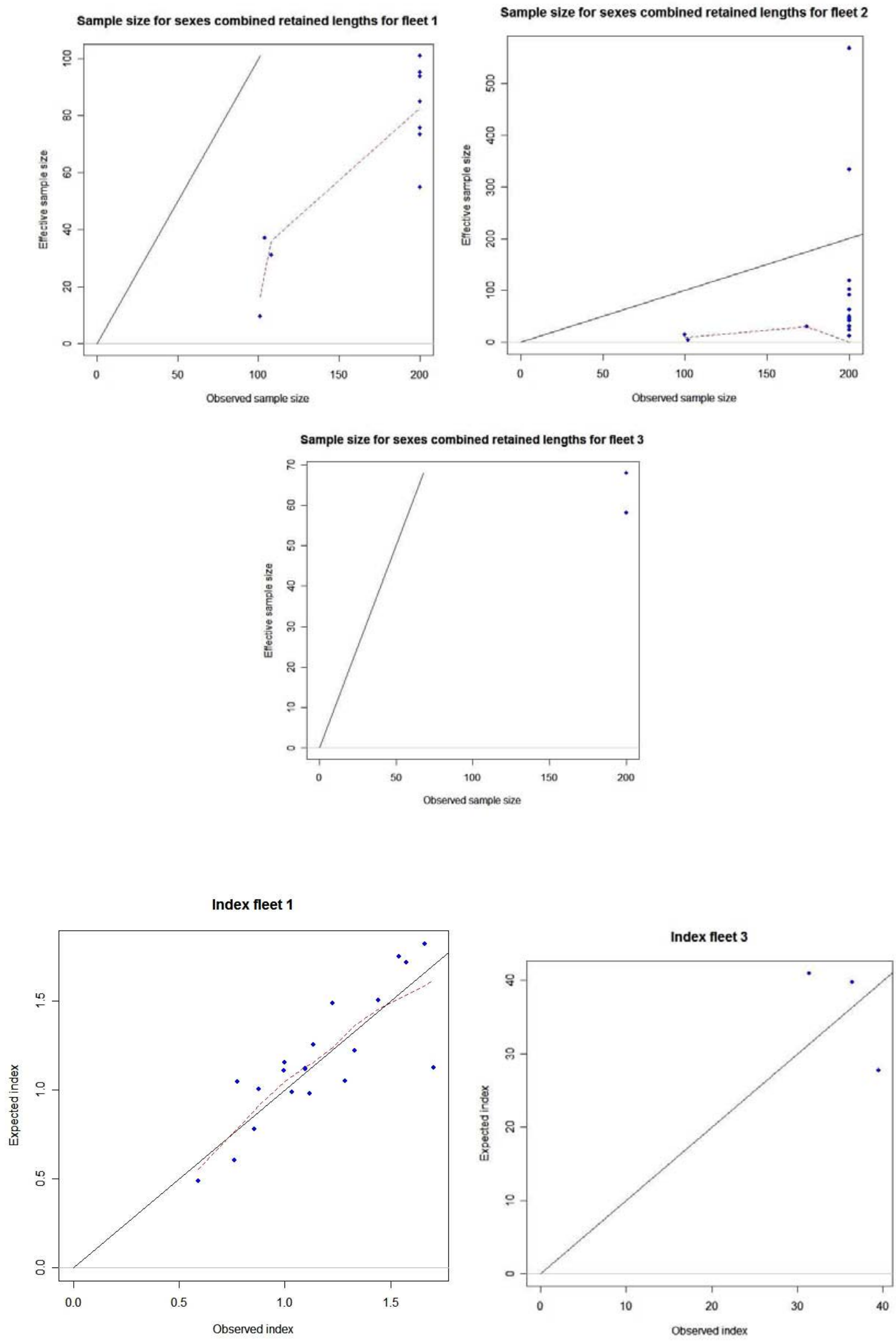


Figure 9.11b. Diagnostics for length and cpue fits in the East.

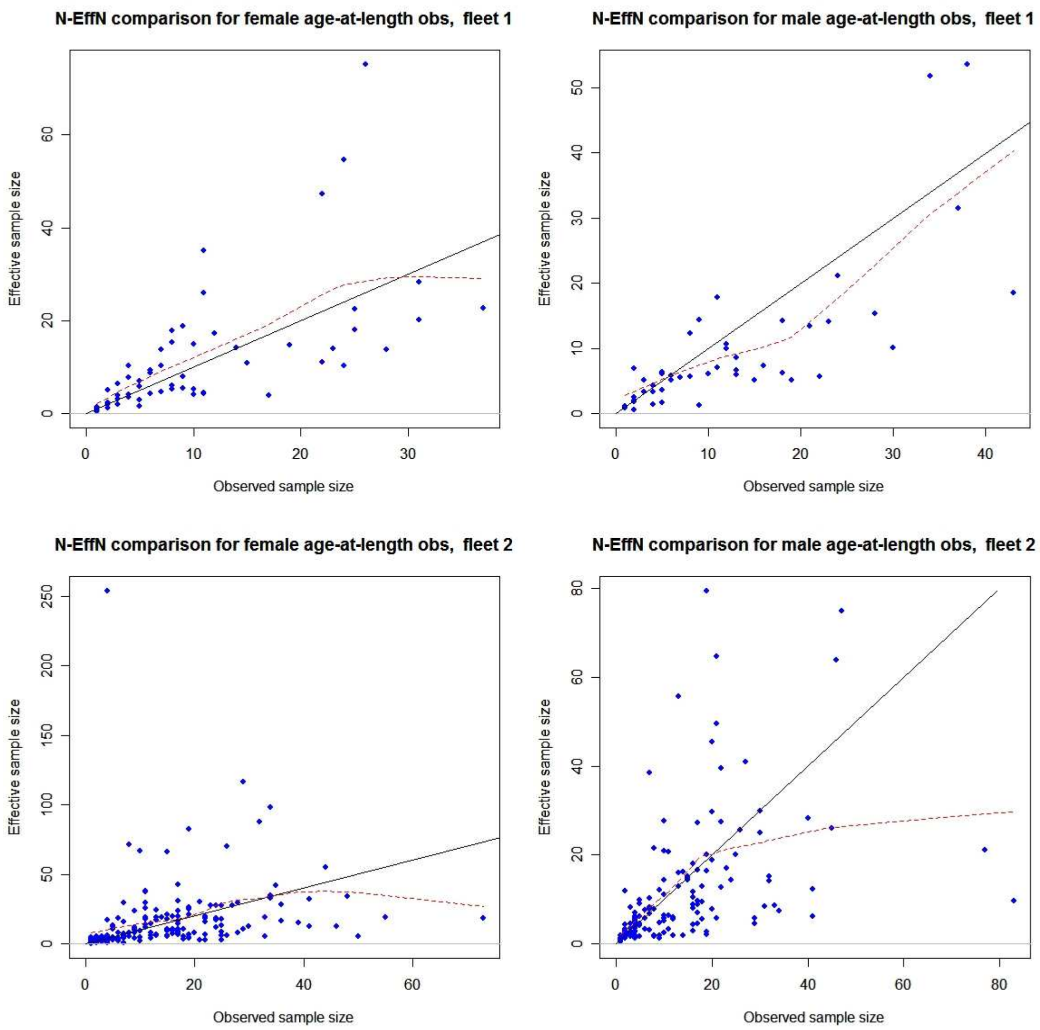


Figure 9.12a. Age at length diagnostics from the West.

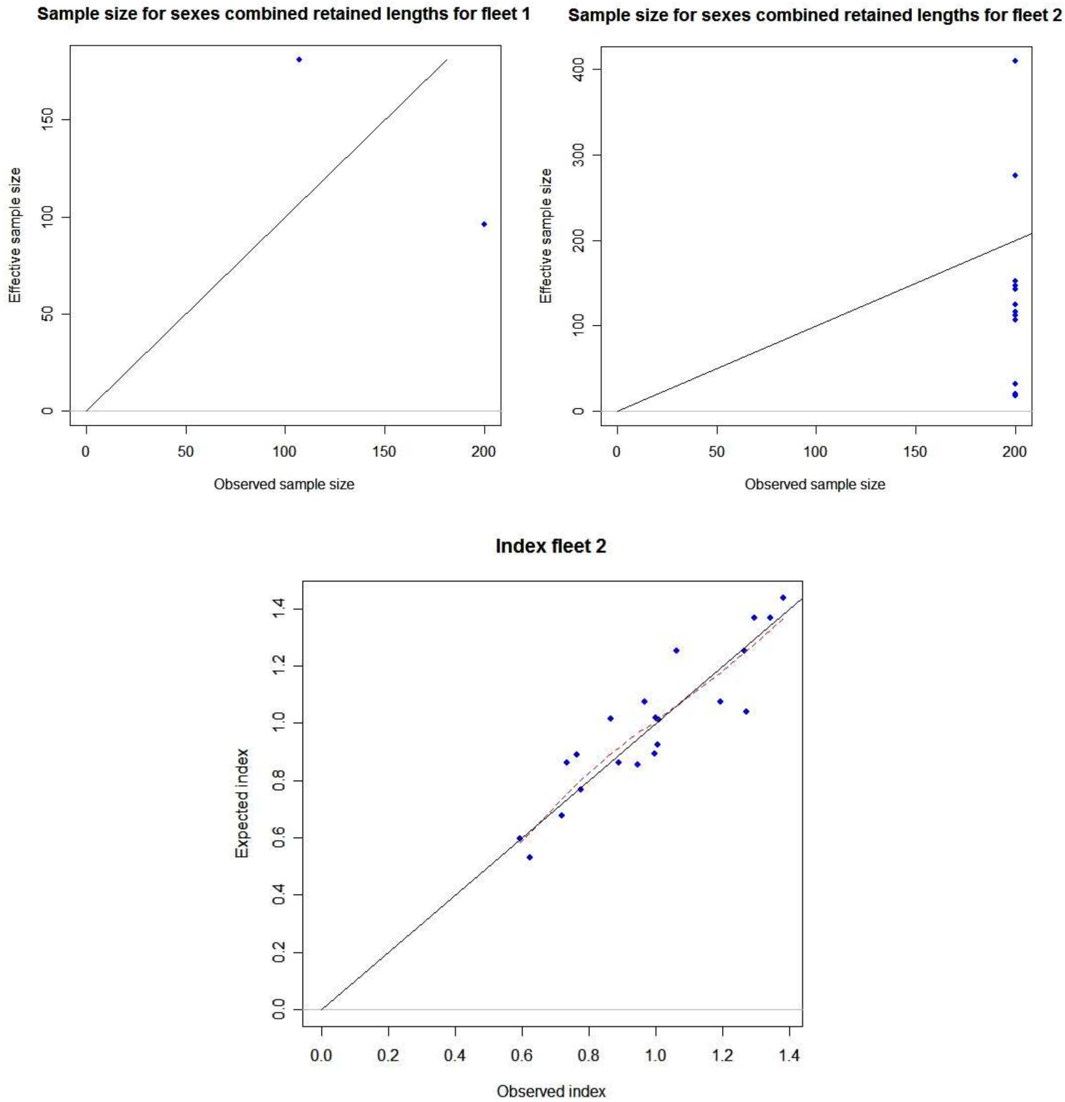


Figure 9.12b. Length and cpue diagnostics from the West.

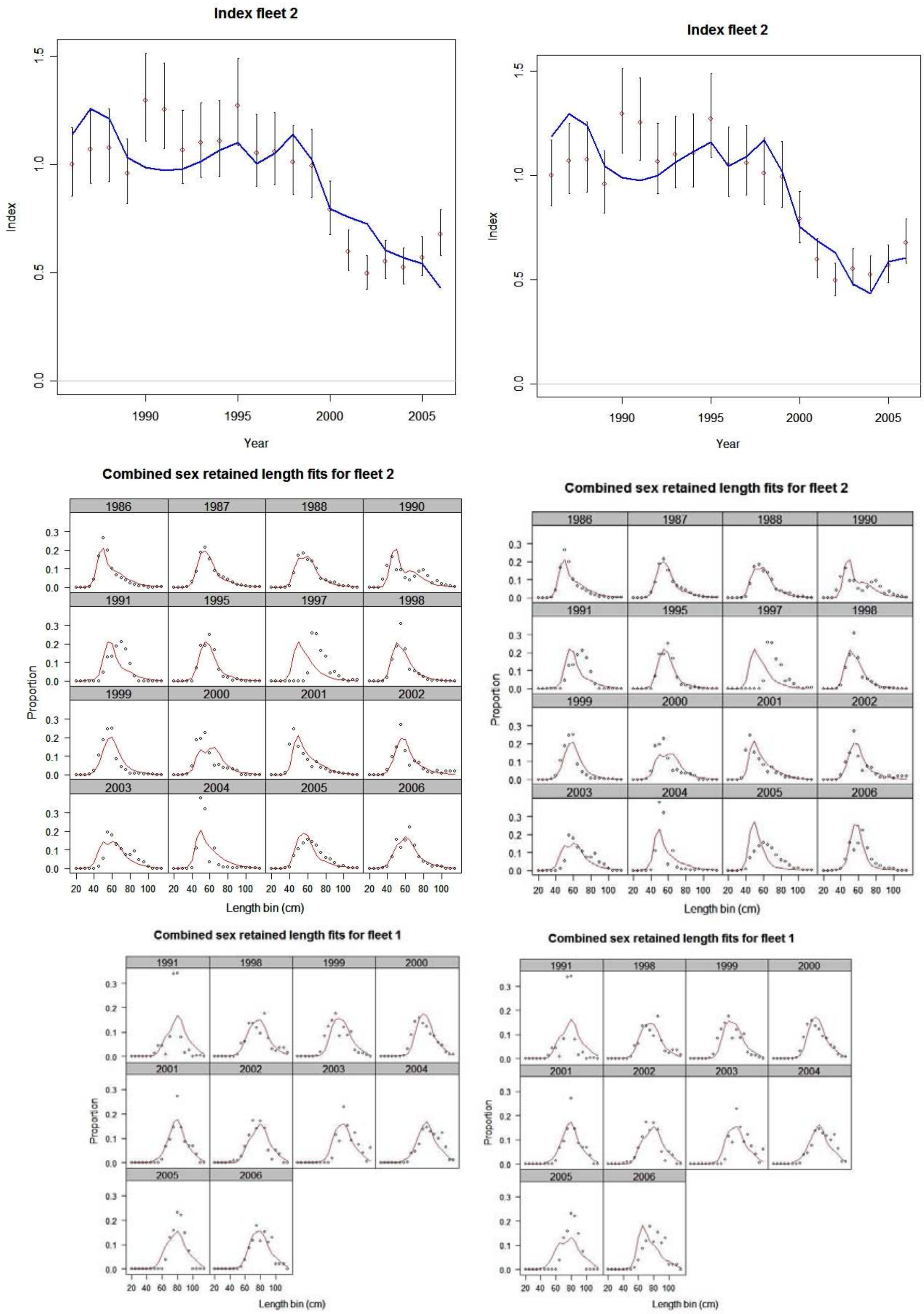


Figure 9.13a. Comparison of cpue and length fits (trawl, centre and non-trawl, lower) for the full length frequency data set (left) and for length data until 2004 only (right).

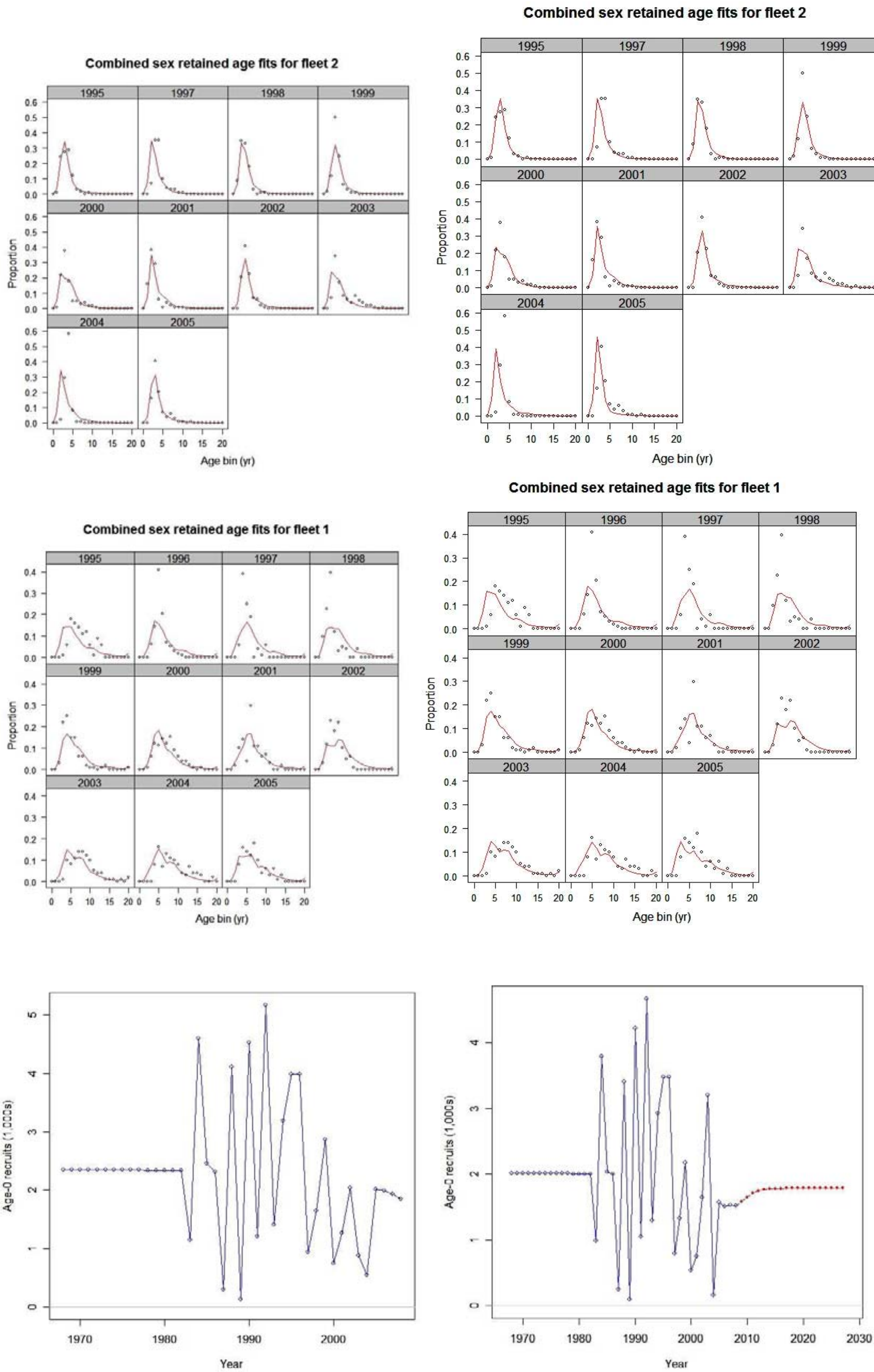
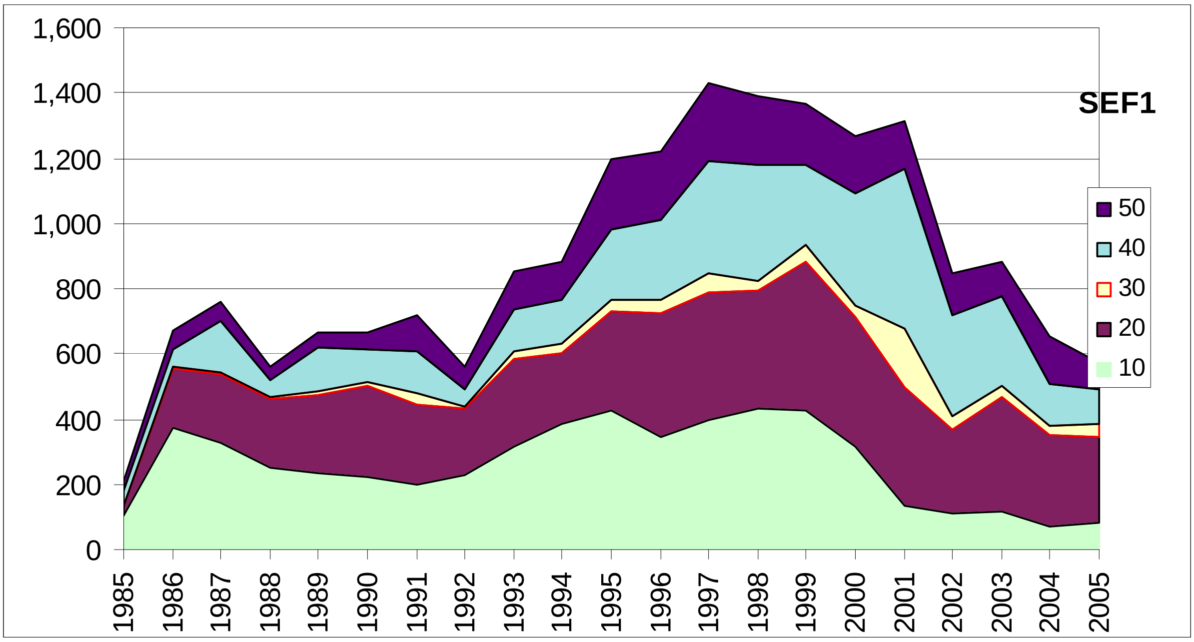


Figure 9.13b. Comparison of age data fits (trawl, above and non-trawl, centre) and recruitment (below) for the full length frequency data set (left) and for length data until 2004 only (right).



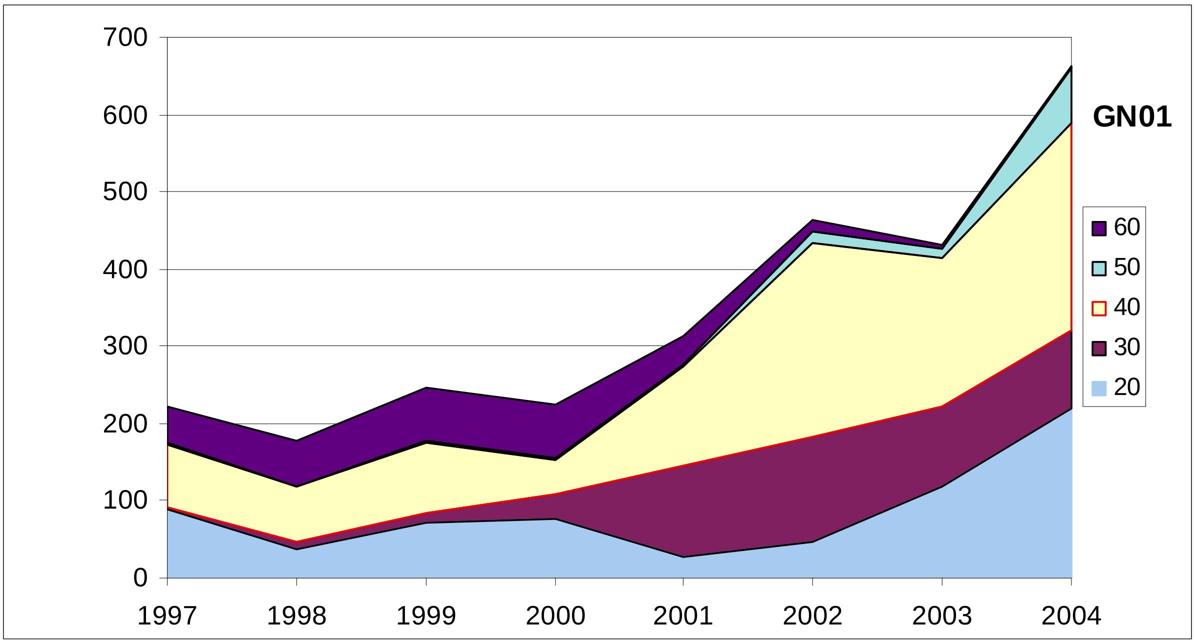


Figure 9.14. Catches (tonnes) from SEF1 (1985-2005, upper) and GN01 (1997-2005, lower) by calendar year, fishing method and zone for the 5 most fished zones (the full data set is in Table 2).

Table 1. Reported catches and estimated discards (1998-2002) for each zone and gear by origin (State or Commonwealth) .

Year	**Victoria**				**Tasmania**				**NSW**		**Commonwealth**				**Total catch (modelled)**					**Total catch**			
	East		West		East		West		East		East		West		East		West			Gear			
	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Trawl	NT	Total	Trawl	NT	East	West
1977									95						95	0			95	95	0	95	0
1978									114						114	0			114	114	0	114	0
1979	1	0	3	0					136						138	0	3	0	140	140	0	138	3
1980	0	0	0	0					215						215	0	0	0	215	215	0	215	0
1981	0	0	0	0					299						299	0	0	0	299	299	0	299	0
1982	8	0	9	0					340						348	0	9	0	357	356	0	348	9
1983	8	0	0	0					419						427	0	0	0	427	427	0	427	0
1984	4	1	0	0					507						511	1	0	0	513	512	1	512	1
1985															564	8	116	8	695	680	15	571	124
1986	1	9	0	4		18		18	3		561	0	116	0	565	27	116	23	730	681	50	592	139
1987	10	18	0	0		4		4	2		597	0	241	0	609	22	241	4	876	850	26	631	245
1988	28	15	0	0		5		5	7		590	0	127	0	625	20	127	5	777	752	25	645	132
1989	33	22	0	2		7		7	2		548	0	212	0	583	29	212	8	832	795	37	611	221
1990	17	20	0	2		10		10	3		515	0	153	0	535	30	153	12	729	688	42	565	164
1991	20	26	0	1		7		7	4		488	0	247	0	512	33	247	9	801	759	42	545	256
1992	36	114	3	0		27		58	2		510	0	145	1	548	141	148	59	896	696	200	689	208
1993	67	177	8	1		76		249	2		707	1	329	1	776	254	337	251	1618	1113	505	1030	588
1994	42	33	0	0		83		228	3		740	1	307	1	785	116	307	229	1437	1092	345	901	536
1995	39	81	0	0		20		143	2		901	0	509	0	942	101	509	144	1697	1452	245	1044	653
1996	36	102	0	2		94		300	6		906	1	543	2	948	197	543	304	1992	1491	501	1145	847
1997		**Discards**				119		107	5		1040	94	716	132	1045	94	716	132	1987	1761	226	1139	848
1998		25		73		3		3	4		1000	52	692	150	1098	80	696	226	2100	1794	306	1178	922
1999		16		30		11		11	3		1158	92	543	178	1169	118	581	219	2087	1750	337	1287	800
2000		7		8					10		938	121	651	130	949	141	652	138	1880	1601	279	1090	790
2001		2		3					6		688	174	657	202	695	180	659	205	1738	1353	385	874	864
2002		3		4							514	206	557	316	514	208	557	321	1600	1071	529	723	877
2003											636	246	493	231	636	246	493	231	1607	1130	477	883	725
2004											438	410	320	441	438	410	320	441	1608	758	851	848	760
2005											508	260	245	360	508	260	245	360	1372	753	619	768	604
2006											474	262	252	213	474	262	252	213	1201	726	475	736	465

Notes: Zero catches are those with less than 0.5 tonne, all catches are rounded to the nearest tonne.
Catches with unknown gear are reported as non-trawl (for NSW, it is included in trawl catches)
SEF1 was inroduced in 1985.
Estimated discards are only listed underneath Victoria for convenience.
The 2007 catch is assumed to total to the quota, and follow the 2006 catch for gear type and east/west split.

Sources Pease (1995), Wayte & Smith(2003), PIRVic data set (July 2006), Klaer (2003b) data

Table 2. Catch summary from SEF1 (1985-2005) and GN01 (1997-2004) by calendar year, fishing method and zone

Year	Records	Catch(t) Zone 10	20	30	40	50	60	80	East	West	Total
SEF1											
1985	1,992	105	30	1	47	29	0		135	76	213
1986	7,868	371	185	3	52	63	1		559	115	679
1987	7,041	325	214	3	160	56	3		542	219	765
1988	6,242	251	209	5	54	43	3		465	100	567
1989	6,943	236	237	9	139	46	2		482	187	672
1990	5,942	222	281	12	101	49	2		514	153	668
1991	7,157	201	242	33	133	107	1		477	242	735
1992	6,489	230	203	7	48	71	6		441	125	567
1993	8,455	314	272	21	130	118	35		607	283	892
1994	9,728	386	213	31	134	116	11		630	261	895
1995	11,722	427	303	37	215	216	2		767	433	1,209
1996	11,829	345	378	43	243	215	1		765	458	1,231
1997	13,420	398	392	60	343	240	1		850	584	1,444
1998	12,907	434	359	28	356	210	2		821	569	1,394
1999	14,087	428	456	50	248	188	2		933	438	1,372
2000	14,379	317	393	38	345	171	3		748	520	1,269
2001	14,877	133	367	179	492	143	36		678	671	1,389
2002	12,906	114	255	39	311	130	1		408	442	851
2003	12,863	118	350	34	275	107	3		502	385	887
2004	11,217	69	282	30	126	150	2		381	278	659
2005	10,443	83	260	44	104	83	1		387	188	575
GN01											
1997		1	90	1	83	2	45	0	92	130	223
1998		0	38	8	72	1	59	0	46	132	178
1999		0	72	12	91	3	68	0	84	162	246
2000		0	76	32	46	3	67	0	108	116	223
2001		1	27	117	130	1	39	0	145	169	315
2002		0	48	135	250	15	16	0	183	281	464
2003		0	119	104	193	12	4	0	222	208	431
2004		0	218	101	270	72	1	50	320	393	713

Note: These catches are from SEF1 and GN01, hence they differ from the catches in table 1 which are based on SEF2 and SAN2.

Table 3a. Set parameters and values used in the reference case

Parameter or value		East	West
Biological parameters			
Age classes		Ages 0-20+	
Length classes		Lengths 20-120+ cm	
Length weight coefficients		a=0.00293, b=3.1	
Maturity logistic curve		inflection=72 cm, slope=-3.0	
SR steepness		0.75	
σ_R		0.8	0.7
Data used			
Catch-rates (CV)	Trawl	0.08	0.10
	Nontrawl		
	Survey	0.40	
Length-frequency sample size		Nsamp (max 200)	
Age at Length sample size		Nsamp	
Ageing error		yes	yes
Catch		1977-2006	1979-2006
Catch-rates (CV)	Trawl	1986-2006	1986-2006
	Nontrawl		
	Survey	1977,1980,1997	
Number of records (years)			
Length-frequency	Trawl	16	12
	Nontrawl	10	2
	Survey	2	
Age at Length		16	14

Note: Max effective sample size set to 200

Table 3b. Estimated biological parameters for the reference case

Parameter or value		East	West
Biological parameters			
Natural mortality		0.238	0.230
Growth - female			
	Lmin	19.2	14.3
	Lmax	107.3	101.8
	k	0.250	0.271
Growth -male			
	Lmin	16.1	4.4
	Lmax	87.2	90.1
	VBk	0.368	0.356

Table 4a. Current and projected depletion and RBC under the 20:40:48 rule.

Year	East		West		Total
	B/B0	RBC (t)	B/B0	RBC (t)	RBC (t)
2004	0.41		0.76		
2005	0.35		0.66		
2006	0.32		0.58		
2007	0.28		0.52		
2008	0.24	68	0.46	620	688
2009	0.25	107	0.40	639	745
2010	0.29	232	0.39	645	877
2011	0.34	398	0.40	699	1097
2012	0.38	532	0.42	716	1248
2013	0.40	603	0.43	727	1330
2014	0.42	612	0.44	735	1347
2015	0.42	621	0.44	742	1363
2016	0.43	630	0.45	748	1378
2017	0.44	637	0.45	753	1391
2018	0.44	643	0.46	758	1401
2019	0.45	648	0.46	762	1410
2020	0.45	652	0.46	766	1418
2021	0.46	656	0.47	768	1424
2022	0.46	658	0.47	771	1429
2023	0.46	661	0.47	773	1434
2024	0.47	663	0.47	775	1438
2025	0.47	665	0.47	776	1441
2026	0.47	666	0.47	777	1444
2025	0.47	668	0.48	778	1446

Table 4b. Current and projected depletion and RBC under the 20:40:40 rule

Year	East		West		Total
	B/B0	RBC (t)	B/B0	RBC (t)	RBC (t)
2004	0.41		0.76		
2005	0.35		0.66		
2006	0.32		0.58		
2007	0.28		0.52		
2008	0.24	84	0.46	774	858
2009	0.25	129	0.39	755	884
2010	0.29	277	0.37	707	984
2011	0.33	465	0.38	762	1227
2012	0.37	605	0.39	820	1425
2013	0.39	677	0.40	853	1530
2014	0.39	705	0.40	859	1564
2015	0.40	717	0.40	857	1574
2016	0.40	723	0.40	857	1580
2017	0.40	728	0.40	856	1583
2018	0.40	731	0.40	856	1587
2019	0.40	734	0.40	857	1591
2020	0.40	735	0.40	858	1593
2021	0.40	736	0.40	858	1594
2022	0.40	736	0.40	858	1594
2023	0.40	736	0.40	858	1594
2024	0.40	736	0.40	858	1594
2025	0.40	736	0.40	858	1594
2026	0.40	736	0.40	858	1594
2027	0.40	736	0.40	858	1594

Table 5. Biomass estimates, depletion and RBC for the reference case and a range of sensitivity scenarios.

	-LN(L)	Female SpBio	SpBio 2008	B2008/B0	20:40:40 rule RBC2008	20:40:40 rule RBC2027	20:40:48 rule RBC2008	20:40:48 rule RBC2027	
East									
Reference case	3391.7	6926	1644	0.237	84	736	68	668	
Estimate recruits from 1977	3398.2	6987	1651	0.236	66	668	0	577	
Estimate recruits from 1982	3385.8	6945	1520	0.219	40	731	32	663	
Omit 2005-6 length data	3284.1	6269	1298	0.207	13	650	11	589	#
Estimate male M	3391.7	6991	1654	0.237	82	736	66	667	
h =0.65	3393.5	7154	1728	0.241	87	682	71	620	
h= 0.85	3390.3	6752	1583	0.234	82	780	66	703	
M =0.18	3426.4	6036	1189	0.197	0	463	0	417	
M =0.25	3392.2	6962	1686	0.242	101	769	82	698	
sigmaR=0.6	3390.5	6552	1563	0.239	82	691	66	627	#
sigmaR=1.0	3397.5	6691	1580	0.236	77	704	63	639	#
Double weighting on age data	5923.4	6336	1354	0.214	27	680	21	616	#
Halve weighting on age data	2112.8	7198	1820	0.253	126	744	102	675	#
Double weighting on CPUE	3433.4	7098	1862	0.262	162	774	131	703	#
Halve weighting on CPUE	3368.6	6341	1287	0.203	6	702	4	636	#
Double weighting on LF data	4143.4	5936	1328	0.224	39	577	32	522	#
Halve weighting on LF data	2993.9	7349	1791	0.244	117	830	94	754	#
West									
Reference case	2834.3	7037	3237	0.460	774	858	620	778	
Estimate male M	2833.9	6910	3239	0.469	820	890	657	809	
h =0.65	2835.8	6469	2817	0.435	620	710	500	648	
h= 0.85	2834.2	6955	3196	0.460	822	926	654	832	
M =0.18	2854.4	5147	1900	0.369	295	479	236	432	
M =0.25	2836.7	8623	4274	0.496	1122	1164	899	1056	
sigmaR=0.5	2843.1	5915	2814	0.476	694	712	555	647	
sigmaR=0.9	2833.4	8419	3560	0.423	845	1063	845	1063	
Double weighting on age data	5346.7	4944	1828	0.370	409	625	326	565	#
Halve weighting on age data	1552.6	13653	7909	0.579	1755	1635	1413	1488	#
Double weighting on CPUE	2844.5	7871	3782	0.480	916	974	734	884	#
Halve weighting on CPUE	2828.1	6613	2977	0.450	701	798	562	723	#
Double weighting on LF data	3068.3	6454	2932	0.454	645	756	518	685	#
Halve weighting on LF data	2688.0	5796	2349	0.405	640	752	510	681	#

\# The negative log likelihood is not comparable to that in the reference case.

Table 6. RBC for the reference case and a range of alternative 2007 catch scenarios for the 20:40:40 rule.

20:40:40 rule

year	**Reference case**					**900t - current proportions**					**1200t - "option A"**					**900t - "option B"**					**800t - "option C"**				
	East		West		RBC	East		West		RBC	East		West		RBC	East		West		RBC	East		West		RBC
	NT	tr	NT	tr		NT	tr	NT	tr		NT	tr	NT	tr		NT	tr	NT	tr		NT	tr	NT	tr	
2004	410	438	441	320	1609	410	438	441	320	1609	410	438	441	320	1609	410	438	441	320	1609	410	438	441	320	1609
2005	260	508	360	245	1372	260	508	360	245	1372	260	508	360	245	1372	260	508	360	245	1372	260	508	360	245	1372
2006	262	474	213	252	1201	262	474	213	252	1201	262	474	213	252	1201	262	474	213	252	1201	262	474	213	252	1201
2007	262	474	213	252	1201	197	355	160	189	901	300	267	300	333	1200	225	200	225	250	900	200	175	200	225	800
2008	25	59	326	448	858	35	81	332	454	901	50	59	331	429	869	63	73	339	438	913	68	78	339	442	928
2009	36	93	289	466	884	46	118	304	486	954	71	90	279	426	866	84	105	299	453	942	90	110	304	464	967
2010	80	197	258	449	984	91	221	266	460	1039	146	175	257	423	1001	159	188	268	438	1053	165	192	269	444	1070
2011	143	323	275	487	1227	151	339	279	491	1261	243	269	282	470	1264	252	278	286	476	1292	257	279	285	480	1301
2012	193	412	298	522	1425	198	421	299	523	1441	315	332	310	510	1467	320	336	311	512	1479	324	336	309	514	1483
2013	220	457	313	541	1530	222	461	314	541	1538	351	362	326	529	1568	353	365	327	530	1574	357	363	324	532	1576
2014	230	476	317	542	1564	231	478	317	542	1569	364	375	330	531	1600	366	377	330	531	1604	369	375	328	534	1606
2015	233	484	317	541	1574	234	485	317	541	1578	369	382	330	529	1610	371	383	330	530	1614	374	381	328	532	1615
2016	234	488	316	541	1580	235	489	317	541	1582	373	387	329	528	1617	374	388	330	530	1621	378	386	327	532	1623
2017	236	492	316	540	1583	237	492	317	540	1586	377	391	329	528	1624	377	391	329	529	1627	381	389	327	532	1628
2018	237	494	316	540	1587	238	495	317	541	1589	379	394	329	529	1631	380	394	329	529	1633	384	391	327	532	1633
2019	238	496	316	541	1591	238	496	317	541	1592	381	395	330	530	1636	382	395	330	530	1637	385	393	327	532	1637
2020	238	497	316	542	1593	239	497	317	541	1593	382	396	330	530	1639	382	396	330	531	1639	386	393	327	533	1640
2021	238	497	317	542	1594	239	497	317	541	1594	383	396	330	531	1640	383	396	330	531	1640	386	394	328	533	1641
2022	239	497	317	542	1594	239	497	317	541	1595	383	397	331	531	1641	383	397	330	531	1641	387	394	328	533	1641
2023	239	498	317	542	1594	239	497	317	541	1595	383	397	331	531	1641	383	397	330	531	1641	387	394	328	533	1641
2024	239	498	317	542	1594	239	497	317	541	1595	383	397	331	531	1641	383	397	330	531	1641	387	394	328	533	1642
2025	239	498	317	542	1594	239	497	317	541	1595	383	397	331	531	1641	383	397	330	531	1641	387	394	328	533	1642
2007	22%	39%	18%	21%		22%	39%	18%	21%		25%	22%	25%	28%		25%	22%	25%	28%		25%	22%	25%	28%	

Options B and C are possible outcomes following the buyout. Option A uses the proportions of option B with a 1200 tonne catch.

10. Silver Warehou (*Seriolella punctata*) Stock Assessment Based on Data up to 2006[6]

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10.1 Summary

This document presents an assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 1 May 2006. A full stock assessment for silver warehou was last performed in 2004 by Taylor and Smith (2004). This assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to be made. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, and (b) the addition of updated length frequencies, catches and catch-rates.

The base-case assessment estimates that current (2006/07) spawning stock biomass is 49% of virgin stock biomass. Fits to the length, age, and catch-rate data are reasonable. The fit to the catch rate index is substantially improved compared to previous assessments. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*. Likelihood profiles show that values for *M* larger than the base-case value of 0.25yr^{-1} are preferred.

The projected depletion in 2007/08 from the base-case model is 45%. The RBCs for the base-case model for 2007/08 are 2,244 t and 1,709 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,987 t and 1,814 t respectively.

10.2 Introduction

10.2.1 The Fishery

Silver warehou occur throughout the SESSF in depths to 500m. They are predominantly caught by trawl, although some non-trawl (gillnet) catches occur (Morison *et al*., 2007). Annual catches (landings and discards) of silver warehou are shown in Table 10.1. Large catches of silver warehou were first taken in the 1970's (Smith, 1994) and catches increased to over 4,400 t in 2002/03. Catches have since declined, with 2,700 t caught in 2005/06. Discard tonnage and length frequency are very variable and appear market driven. Silver warehou have also been captured off western Tasmania as bycatch of the winter spawning blue grenadier fishery in recent years.

The TAC for calendar years 2005 and 2006 was 4,400 t and for 2007 the TAC is 3,227 t. The actual catch in these years was 2,908 (435 t discards) in 2005 and 2374 t in 2006.

[6] Paper presented to the Slope Resource Assessment Group on 21 and 22 August, 2007

The percentage of the TAC caught has ranged between 61% and 77% between 2002 and 2005 (SESSF, 2006).

10.2.2 Stock structure

A recent stock-structure study indicated that a single stock exists east and west of Bass Strait (Morison *et al*., 2007). A common stock had previously been assumed for management purposes and is assumed for the assessment presented here.

10.2.3 Previous Assessments

A full quantitative assessment for silver warehou was last performed in 2004 (Taylor and Smith, 2004). The model applied was an age-structured integrated assessment coded in ADMB. It indicated that biomass levels were around 60% of virgin biomass. The population biomass trajectories were declining following lower than average recruitment and higher catches subsequent to the large recruitments in 1993 and 1994. Projections conducted in 2006 (Taylor, 2006) indicated that the spawning biomass would be around 48% of initial levels in 2007.

10.2.4 Modifications to the previous assessments

A substantial number of modifications have been made to the previous assessment, including updating data to 2005/06. The previous assessment (Taylor and Smith, 2004) was individually written using the software package ADMB (Thomson, 2001; 2002a). The current assessment uses the package SS2 which overcomes some of the technical shortcomings previously identified.

10.2.4.1 Data-related issues

(a) The discard mass has been added into the landings.
(b) Port-based length-frequency data up to 2005/06 have been included in the assessment.
(c) The catch-rate time series has been updated (Haddon, 2007).
(d) Conditional age-at-length information has been included in the assessment instead of age compositions constructed from age-length keys and length-frequency distributions. This better mimics the structure of the data and also enables estimation of the parameters of the growth curve within the assessment.
(e) Age-reading error (Table 10.2) has been accounted for when fitting to the conditional age-at-length data.
(f) The weighting on the length frequency and the conditional age-at-length data has been altered in line with current agreed practice.

10.2.4.2 Model-related issues

(a) The parameters of the growth curve are estimated within the assessment.
(b) Previous assessments ignored the age-composition data for animals 2 and younger. All ages are included in the likelihood function because Stock Synthesis 2 is better able to account for age-composition information for the younger animals.

10.3 Methods

10.3.1 The data and model inputs

10.3.1.1 Biological parameters

Previous assessments have pre-specified the values of the von Bertalanffy growth parameters, but it has been possible in this assessment to estimate these parameters within the model-fitting procedure because SS2 can accept age-at-length data as an input. Estimating the parameters of the von Bertlanffy growth curve within the assessment is more appropriate because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

This assessment follows that of Taylor and Smith (2004) and other previous assessments in setting the base-case value for natural mortality, M, to 0.25yr^{-1} and examining the sensitivity of the results to M=0.2yr^{-1} and M=0.3yr^{-1}. Thomson (2002a) attempted to estimate M within the assessment but found that the results of the assessment were very sensitive to the (assumed) value for this parameter. The value of M for the base-case model is the same as that used in New Zealand (Annala *et al.*, 2000). A sensitivity analysis across a range of values of M is conducted in this assessment and used to construct a likelihood profile for M. The base-case value for the steepness of the stock-recruitment relationship, h, is 0.75. A sensitivity test involves treating this parameter as estimable.

Silver warehou become sexually mature at a length of about 37 cm. Fecundity is assumed to be proportional to spawning biomass. The parameters of the length-weight relationship are the same as those used in previous assessments (a=0.65 x 10^{-5}, b=3.27). These values are taken from Taylor and Smith (2004) and were provided by David Smith (*unpublished data).*

10.3.1.2 Fleets

The assessment for silver warehou is based on a single trawl fleet, with time-invariant logistic selectivity. While there is some non-trawl catch, it is small and the results of previous assessments (e.g. Thomson, 2001) were insensitive to the inclusion of the non-trawl catches.

10.3.1.3 Landed catches

The model uses a ‘biological year’ (1 May to 30 April) in preference to a calendar year. Historically, this was done to better reflect the biology of the stock (Thomson, 2002a). However, future assessments should consider the value (and model sensitivity) of moving to calendar year. In the text and figures of this document, the biological year 1985/86 is referred to as “1985”. Landings of silver warehou prior to the start of SEF1 record-keeping in 1986 are not considered to have been large. However, a linear increase in catch from 1979 to the first year of SEF1 catches was used as an estimate of pre-SEF1 catch, following Punt *et al*. (2005).

The landings for the more recent years (1986 – 2006) were extracted from the South East Fishery (SEF) logbook database. From 1992 onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. The annual logbook catches from 1992 onwards have been scaled up by the ratio of the landed catches to the logbook catches (Thomson, 2002b). Annual catches (landings and discards) are shown in Figure 10.1.

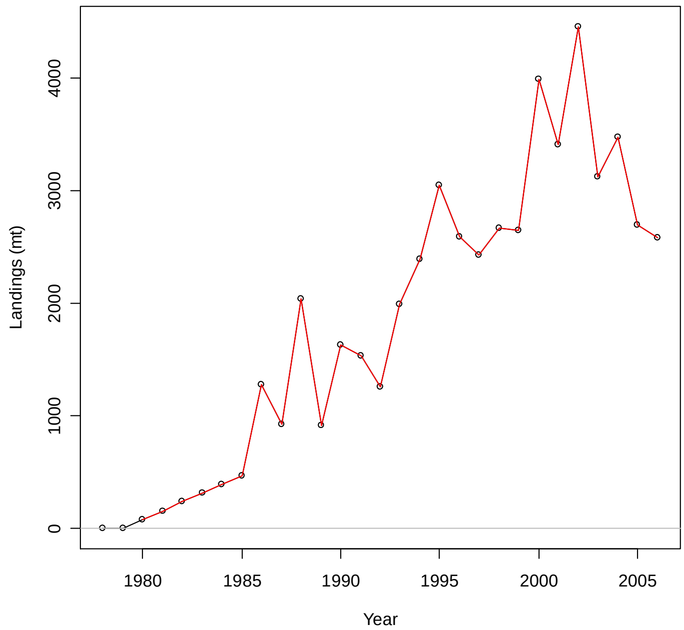

Figure 10.1.The catch of silver warehou (the sum of landed and discard catches) in the SESSF.

10.3.1.4 Discarded catches

Information on the discard rate of silver warehou is available from the ISMP for 1993-2006. These data are summarised in Table 10.1 and Figure 10.2. Discard rates vary amongst years, and have been up to 18% (in 1995). Thomson (2002a) states that members of the fishing industry had indicated that discarding of silver warehou occurs when market prices are low and is therefore not related to the size of the fish caught. However, close examination of the ISMP data on the length frequency of catches and discards shows that there are times when discarding of silver warehou is size-related. There is no clear pattern indicating when discarding will be market-related and when it will be size-related. Consequently, the mass of fish that were estimated to have been discarded by the trawl fleet was added to the landed catch and not treated as a separate data source for the base case analysis. The average discard rate for 1993 to 2006 (0.08) was assumed for the years prior to 1993 to calculate the discard mass to add to the landings data.

In addition, a number of factory trawlers have operated since 1997 in the spawning fishery for blue grenadier. These trawlers have fishmeal plants which absorb all fish that might otherwise have been discarded. Thus, the factory vessels effectively have zero discard rates (Thomson, 2002b). ISMP sampling occurs aboard ‘wet boats’ only and not aboard factory trawlers. The discard rates therefore apply to the ‘wet boats’ only. The overall discard rate for the year is therefore computed by adjusting the 'wet boat' discard rates by the proportion of the catch not taken by factory vessels.

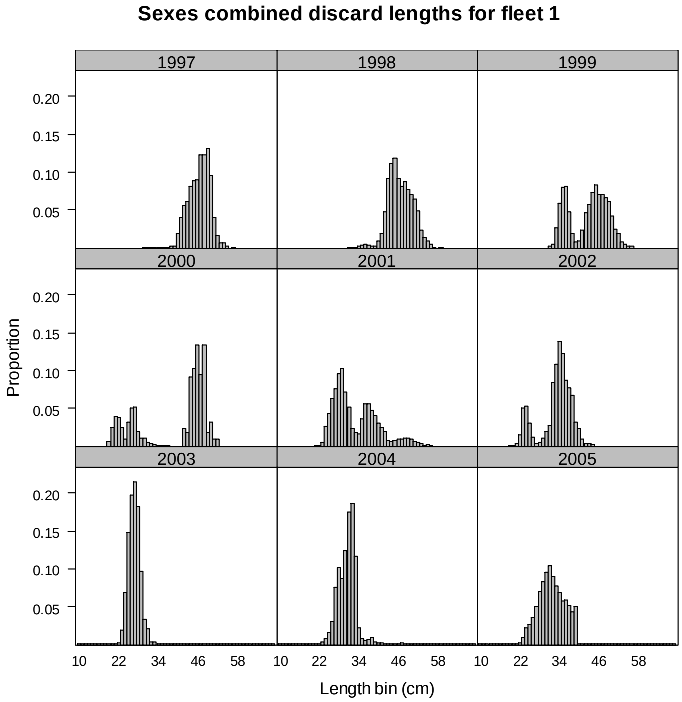

Figure 10.2. The discard length frequencies for silver warehou.

10.3.1.5 Catch rate indices

Catch and effort data from the SEF1 logbook database from the period 1986/87 -2005/6 were standardised using GLMs to obtain indices of relative abundance (Haddon, 2007; Table 10.1). The restrictions used in selecting data for analysis were: (a) vessels had to have been in the trawl fishery for three or more years, and (b) the catch rate had to be larger than zero. No restrictions were placed on the depth of shot.

10.3.1.6 Length composition data

Length composition information for the retained component of the catch by the trawl fleet is available from port sampling for 1992-2005. Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch. However, as discussed above, these data are not used in the assessment.

10.3.1.7 Age composition data

Age-at-length measurements, based on sectioned otoliths provided by the CAF, were available for the years 1988/89 and 1992/93-2005/06. An estimate of the standard deviation of age-reading error was calculated using data supplied by Kyne Krusic Golub of PIRVic and a variant of the method of Richards *et al.* (1992).

10.3.2 Stock Assessment method

10.3.2.1 Population dynamics model and parameter estimation

A single-sex stock assessment for silver warehou was conducted using the software package SS2 (version 2; Methot, 2007). SS2 is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for silver warehou. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS2 user manual (Methot, 2005) and is not reproduced here. Some key features of the base-case model are:

(a) Silver warehou constitute a single stock with in the area of the fishery.
(b) The population was at its unfished (virgin) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1979.
(c) The CVs of the CPUE indices for the trawl fleet were set equal to the model-estimated standard errors (0.18).
(d) Selectivity for the trawl fleet is length-specific, logistic and time-invariant. The two parameters of the selectivity function were estimated within the assessment.
(e) The rate of natural mortality, *M*, is assumed to be constant with age, and also time-invariant. The base-case value for *M* is 0.25 yr^{-1}.
(f) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at virgin spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1980 to 2006. Deviations are not estimated prior to 1980 because there are insufficient data prior to 1980 to permit reliable estimation of recruitment residuals. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 0.6, based on previous assessment parameterisations.
(g) A plus-group is modelled at age 23 yr.
(h) Growth of silver warehou is assumed to be time-invariant, in that there is no change over time in mean size-at-age, with the distribution of size-at-age being estimated along with the remaining growth parameters within the assessment. No differences in growth related to gender are modelled, because the stock is modelled as a single-sex.

10.3.2.2 Sensitivity tests

A number of sensitivity tests are used to examine the sensitivity of the results of the model to some of the assumptions and data inputs:

a) Values for *M* between 0.2 yr^{-1} and 0.5 yr^{-1}.
b) *M* estimated rather than pre-specified.
c) *h* estimated rather than pre-specified.
d) $\sigma_r = 0.7$

The results of the base-case analysis and the sensitivity tests are summarized using the following quantities:

(a) SB_0	the average unexploited spawning biomass,
(b) SB_{2007}	the spawning biomass at the start of 2007/08,
(c) SB_{2007}/SB_0	the depletion level at the start of 2007/08, i.e. the 2007/08 spawning biomass expressed as a percentage of the virgin spawning biomass
(d) –lnL	the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data),
(e) 2007/08 RBC 20:40:40	the 2007/08 RBC calculated using the 20:40:40 harvest rule,
(f) 2007/08 RBC 20:40:48	the 2007/08 RBC calculated using the 20:40:48 harvest rule.
(g) Long term RBC 20:40:40	the long term RBC calculated using the 20:40:40 harvest rule,
(h) Long term RBC 20:40:48	the long term RBC calculated using the 20:40:48 harvest rule.

10.4 Results and discussion

10.4.1 The base-case analysis

10.4.1.1 Parameter estimates

Figure 10.3 (left) shows the estimated growth curve for silver warehou. All growth parameters are estimated. The estimates of the growth parameters are: (a) *Lmin*=13.4cm, (b) *Lmax*=50cm, (c) k=0.353yr^{-1}, and (d) cv of growth = 0.071. The parameters that define the selectivity function are the length at 50% selection and the spread. The estimates of these parameters for the base-case analysis are 41.8cm and 11.6cm respectively. Figure 10.3 (right) shows the estimated selectivity function. The estimate of the parameter that defines the initial numbers (and biomass), ln(R_0) is 9.01.

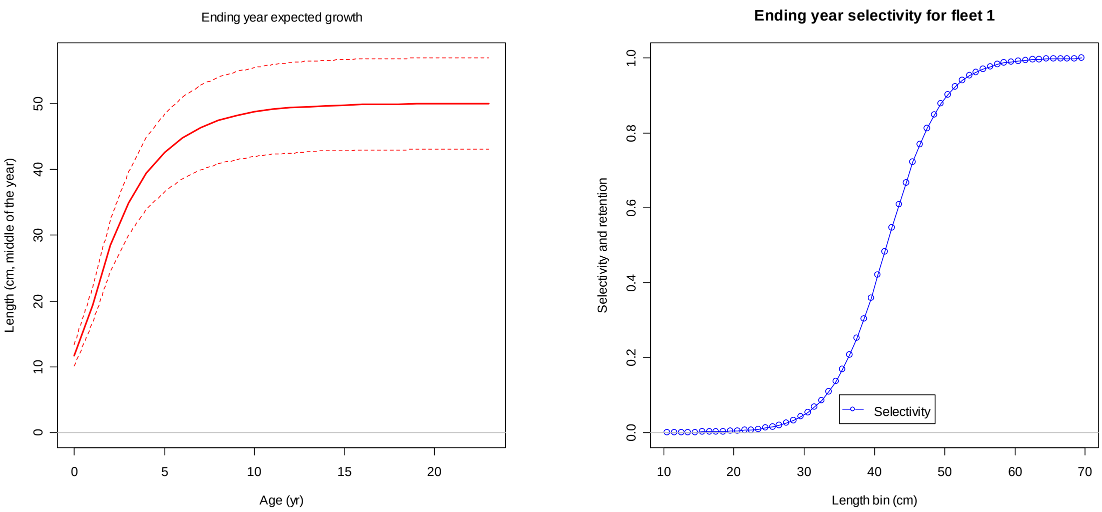

Figure 10.3.The model estimated growth function (left) and selectivity pattern (right) for silver warehou.

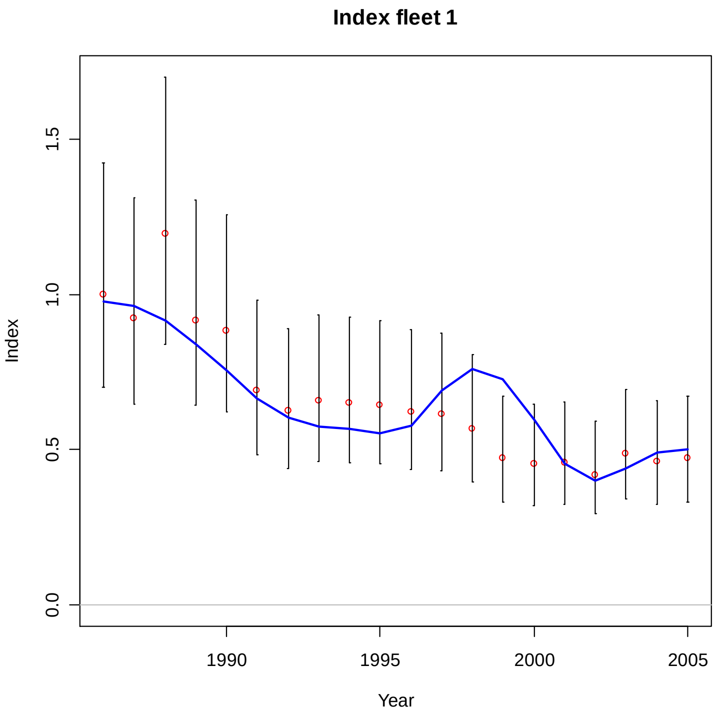

Figure 10.4 Observed (solid dots) and model-predicted (lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

10.4.1.2 Fits to the data

The fits to the catch rate indices (Figure 10.4) are reasonably good and substantially better than those of previous assessments (Thomson, 2002a; Taylor and Smith, 2004). The increase in predicted cpue in the late 1990s, driven by the large recruitment during 1993, is not seen in the observed catch-rates. This was an issue for previous assessments, which were also not able to fit the early catch rates, unlike the model presented here.

The base-case analysis is able to mimic the retained length-frequency distributions adequately (Figure 10.5 top). The fits to the age-composition data are shown in Figure 10.5 (bottom). It should be noted that these age-compositions were not fitted to directly, as conditional age-at-length data were used instead. However, the fits to the age-compositions provide a means of checking the adequacy of the model; the model mimics the observed age data very well.

10.4.1.3 Assessment outcomes

The current spawning stock biomass is estimated by the base-case analysis to be 49% of virgin stock biomass (i.e. 2006/07 spawning biomass relative to virgin spawning biomass). The left panel of Figure 10.6 shows the time trajectory of female spawning stock biomass corresponding to the base-case analysis, and the right hand panel shows the spawning stock depletion. The stock declines slowly from the beginning of the fishery in 1980, before a sharp decline in the late-1980s corresponding to an increase in catch. The recovery in the late-1990s is driven by the high 1993 recruitment (Figure 10.7 , left panel). After this, the stock declined following poor recruitments until 2003 when it increased somewhat following better recruitments after 1999.

10.4.1.4 Application of the harvest control rule

An estimate of the catch for biological year 2006/07 is needed to run the model forward to calculate the 2007/08 spawning biomass and depletion. The landed catch for 2006/07 was 2,387 t (John Garvey, pers. comm.). The discard rate for 2006/07 is not yet available and had consequently to be estimated. The estimate of 2006/07 discard rate is obtained by applying the weighting scheme of 8:4:2:1 to the previous 4 years' discard rates. This gives a discard rate for 2006/07 of 0.077 and a discard mass of 198 t. The total catch is then 2,585 t. The depletion in 2007/08 under the base-case parameterisation is estimated to be 45%. An application of the Tier 1 harvest control rules under each of the two target level scenarios (40% and 48%) leads to the following 2007/08 and long-term RBCs:

Control Rule	2007/08 RBC	Long-term RBC
20:40:48	1,709 t	1,814 t
20:40:40	2,244 t	1,987 t

An example of the time-series of RBCs and corresponding spawning biomass for the 20:40:40 harvest control rule is shown in Figure 10.8 and a table of the time series of projected RBCs and depletions is in Table 10.4.

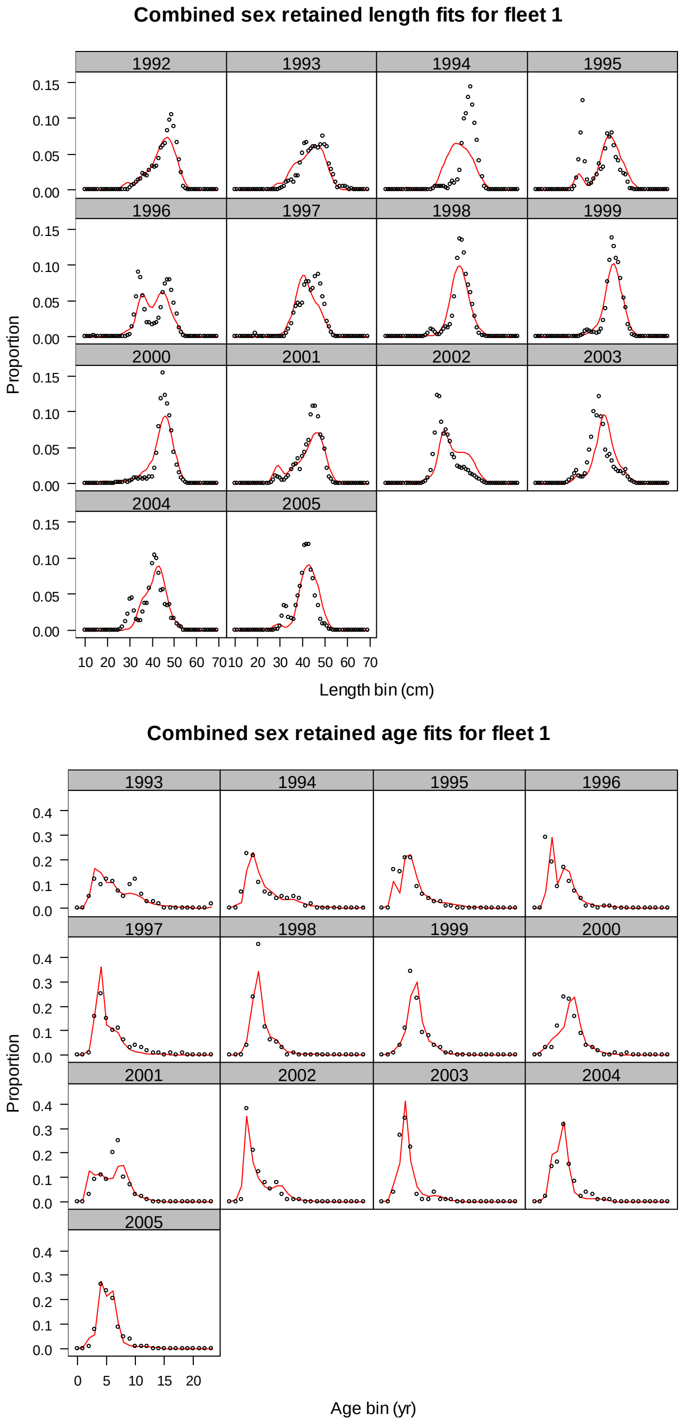

Figure 10.5. The observed and model-predicted fits to the length (top) and age (bottom) data for silver warehou.

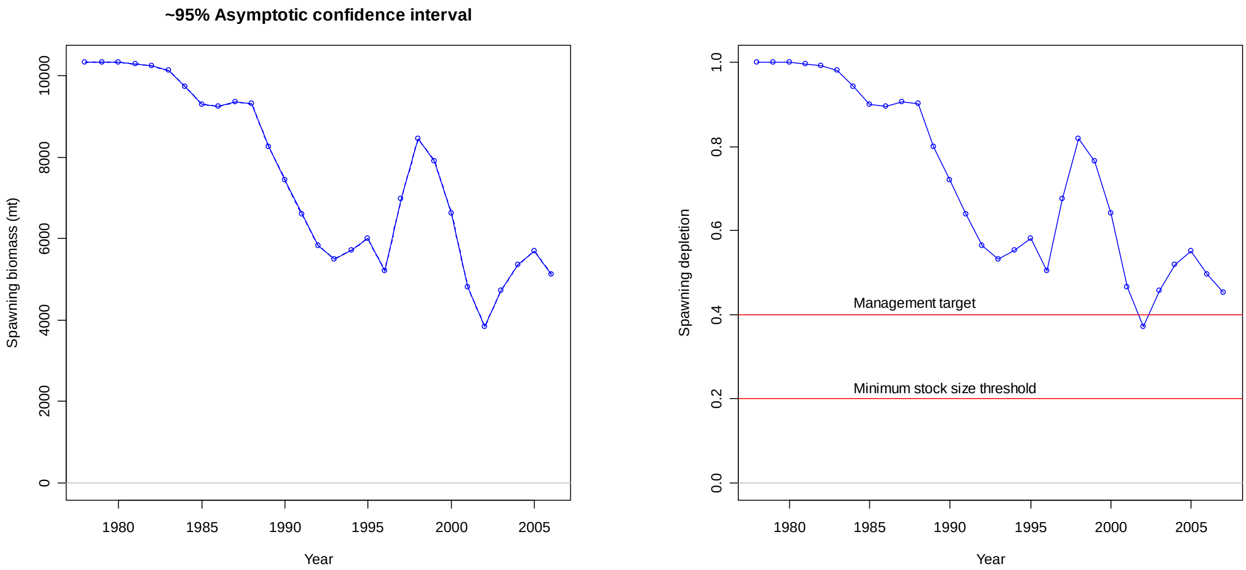

Figure 10.6 Time-trajectories of female spawning biomass, and spawning biomass depletion corresponding to the MPD estimates for the base-case analysis.

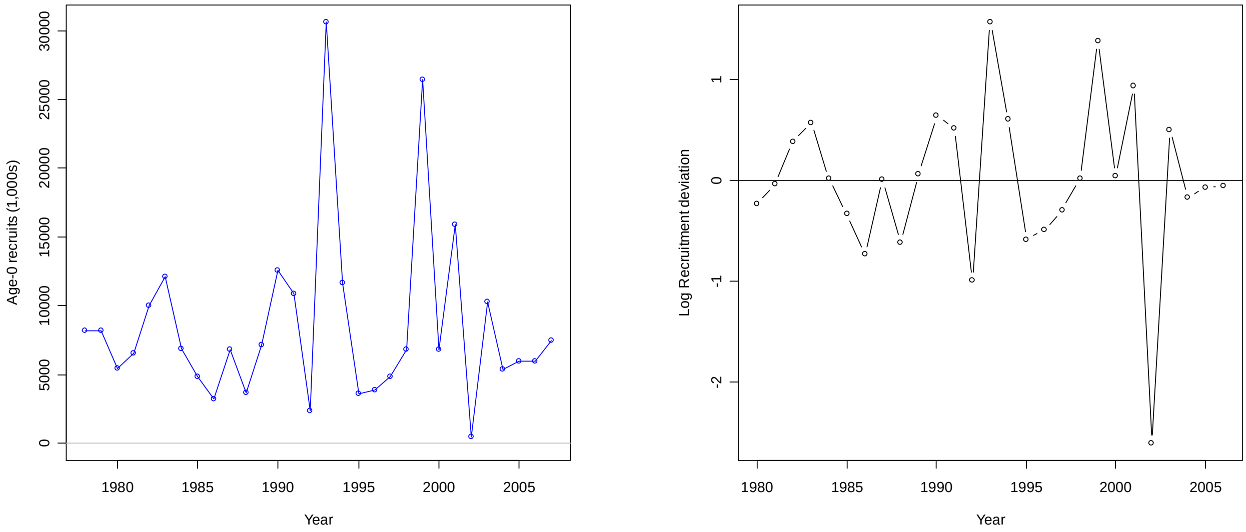

Figure 10.7 Time-trajectories of recruitment (left) and recruitment deviations (right) for the base-case analysis.

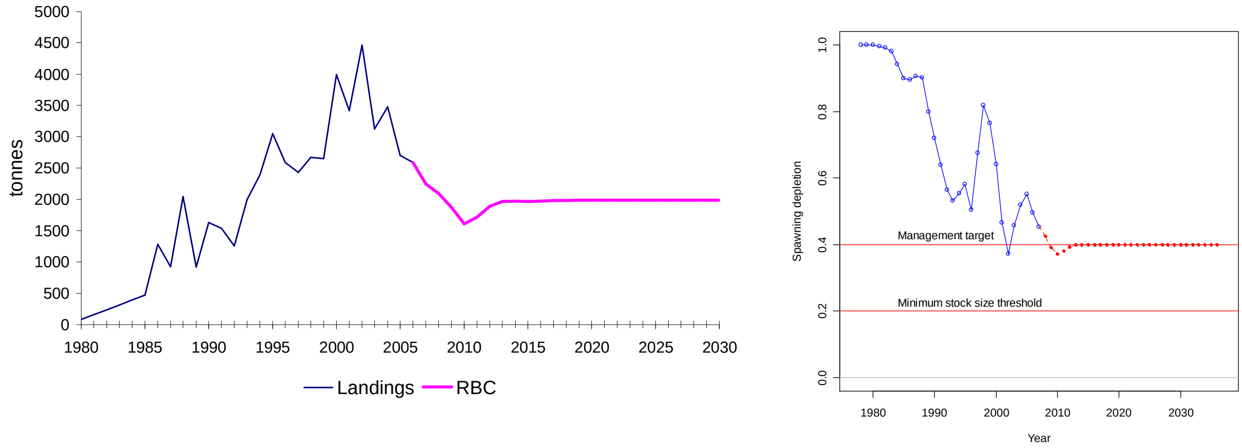

Figure 10.8. The projection of RBCs (left) and its corresponding relative spawning biomass (right) under the 20:40:40 rule for silver warehou.

10.4.2 Sensitivity tests

Results of the sensitivity tests are shown in Table 10.3. The results are sensitive to the assumed value for natural mortality, but less so to steepness and σ_R (relative to the base-case). Various components of the likelihood function are plotted as a function of *M* in Figure 10.9 to explore the sensitivity of the model outcomes to the assumed value for natural mortality. Figure 10.9 clearly shows that higher values of natural mortality than the base-case value of 0.25yr^{-1} are supported by the data. Likelihood components relating to recruitment and the length data show minimums around M = 0.3yr^{-1}, whereas the best fits to the age and cpue data occur for larger values of *M*. The model estimated value for *M* is 0.38 yr^{-1}.

10.4.3 Discussion

This document presents an assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 1 May 2006. A full stock assessment for silver warehou was last performed in 2004 by Taylor and Smith (2004). This assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to be made. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, and (b) the addition of updated length frequencies, catches and catch-rates.

The base-case analysis estimates that 2007/08 spawning stock biomass will be 45% of virgin stock biomass. Depletion across all sensitivities varied between 37% (M=0.2yr^{-1}) and 66% (M=0.38 yr^{-1}). Fits to the length, age, and catch rate data are all reasonable. The fit to the catch rate data is substantially better than the previous assessments. The RBCs for the base-case model for 2007/08 are 2,244 t and 1,709 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,987 t and 1,814 t respectively.

Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*. Likelihood profiles show that values for *M* larger than the base-case value of 0.25yr^{-1} are preferred.

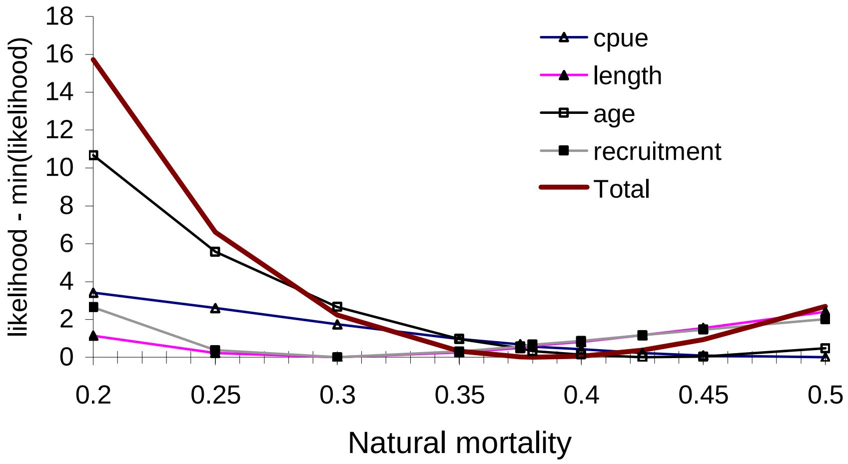

Figure 10.9. A plot of the various likelihood components as a function of natural mortality. The plotted value is the contribution to the likelihood function at each value of *M* less the minimum likelihood (across all values of *M*).

10.5 Acknowledgements

The members of the SESSF stock assessment group – Neil Klaer, Jemery Day, Rich Little, Sally Wayte, Fred Pribac, Bruce Taylor and Tony Smith – are thanked for their generous advice and comments during the development of this assessment. Thanks also to the providers of data for this assessment – Matt Koopman and Neil Klaer for the provision of stock assessment data (in a very useful format), Malcolm Haddon (TAFI) for the calculation of the recent catch-rate indices and Kyne Krusic-Golub (PIRVic) for the provision of ageing data.

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Table 10.1.The annual discard rate, the proportion of factory vessels, the adjusted discard rate, the landed catch, the discard mass, the total catch (tonnes) and the standardised catch rate (Haddon, 2007) for silver warehou.

	Discard rate (%)	Proportion factory vessels	Adjusted discard rate (%)	Landed (t)	Discard (t)	Total (t)	Catch rate
1979						0	
1980						78	
1981						156	
1982						234	
1983						312	
1984						390	
1985		0	7.93	431	37	468	
1986		0	7.93	1178	102	1280	1
1987		0	7.93	851	73	924	0.9217
1988		0	7.93	1879	162	2040	1.1951
1989		0	7.93	844	73	917	0.9172
1990		0	7.93	1500	129	1629	0.8831
1991		0	7.93	1414	122	1536	0.6899
1992		0	7.93	1156	100	1255	0.6265
1993	2.78	0	2.78	1937	55	1993	0.6564
1994	3.57	0	3.57	2304	85	2389	0.6516
1995	18.49	0	18.49	2484	564	3048	0.6441
1996	0.79	0	0.79	2568	20	2588	0.6221
1997	8.10	0.01	8.02	2236	195	2431	0.6153
1998	16.50	0.02	16.17	2239	432	2671	0.5659
1999	3.89	0.13	3.38	2559	90	2649	0.4731
2000	10.19	0.22	7.95	3675	317	3992	0.4554
2001	5.56	0.17	4.62	3256	158	3414	0.4596
2002	14.92	0.34	9.84	4021	439	4460	0.4175
2003	7.97	0.18	6.53	2920	204	3124	0.4873
2004	12.25	0.04	11.76	3069	409	3478	0.4618
2005	5.65	0	5.65	2547	153	2699	0.4713
2006			7.68	2387	198	2585	

Table 10.2. The standard deviation of age reading error.

age	std dev
0	0.152
1	0.152
2	0.265
3	0.373
4	0.475
5	0.572
6	0.665
7	0.753
8	0.836
9	0.915
10	0.99
11	1.062
12	1.129
13	1.194
14	1.255
15	1.313
16	1.369
17	1.421
18	1.441
19	1.474
20	1.502
21	1.524
22	1.542
23	1.555

Table 10.3. Summary of results for the base-case analysis and the sensitivity tests.

Model	-ln L	SB_0	SB_{2007}	SB_{2007}/SB_0	20:40:40 harvest strategy 2007/08 RBC (t)	20:40:40 harvest strategy Long term RBC (t)	20:40:48 harvest strategy 2007/08 RBC (t)	20:40:48 harvest strategy Long term RBC (t)
base case (M=0.25, h=0.75, σ_R=0.6)	1,078.5	20,682	9,382	0.45	2,244	1,987	1,709	1,814
M=0.2	1,087.6	20,332	7,471	0.37	1,194	1,571	910	1,434
M=0.3	1,074.1	21,625	11,583	0.54	3,357	2,501	2,555	2,282
M=0.38 (est)	1,071.9	25,583	16,940	0.66	6,509	3,871	4,943	3,523
σ_R=0.7	1,072.0	21,267	9,457	0.44	2,250	2,042	1,714	1,865
h=0.70 (est)	1,078.5	20,844	9,329	0.45	2,126	1,908	1,629	1,752

Table 10.4. The time series of RBCs and corresponding depletions relative to initial levels as a function of natural mortality and the harvest control rule.

	M=0.25				*M*=0.30				*M*=0.38 (est)			
	20:40:40		20:40:48		20:40:40		20:40:48		20:40:40		20:40:48	
	RBC	Depletion	RBC	Depletion	RBC	Depletion	RBC	Depletion	RBC	Depletion	RBC	Depletion
2007	2244	0.45	1709	0.45	3357	0.54	2555	0.54	6509	0.66	4943	0.66
2008	2092	0.43	1675	0.45	2946	0.47	2386	0.50	5045	0.52	4188	0.57
2009	1872	0.39	1624	0.43	2659	0.42	2249	0.47	4308	0.44	3747	0.50
2010	1607	0.37	1591	0.41	2424	0.39	2171	0.45	4015	0.41	3547	0.48
2011	1716	0.38	1599	0.42	2403	0.39	2160	0.45	3967	0.41	3508	0.47
2012	1887	0.39	1633	0.43	2513	0.40	2186	0.46	3986	0.41	3530	0.48
2013	1962	0.40	1673	0.44	2522	0.40	2215	0.47	3982	0.41	3547	0.48
2014	1971	0.40	1706	0.45	2521	0.40	2236	0.47	3953	0.41	3546	0.48
2015	1966	0.40	1730	0.46	2514	0.40	2248	0.47	3924	0.41	3538	0.48
2016	1970	0.40	1747	0.46	2509	0.40	2255	0.47	3906	0.40	3531	0.48
2017	1977	0.40	1761	0.47	2506	0.40	2261	0.48	3897	0.40	3528	0.48
2018	1982	0.40	1772	0.47	2505	0.40	2265	0.48	3892	0.40	3527	0.48
2019	1985	0.40	1781	0.47	2505	0.40	2269	0.48	3887	0.40	3527	0.48
2020	1985	0.40	1788	0.47	2504	0.40	2272	0.48	3883	0.40	3526	0.48
2021	1985	0.40	1794	0.47	2503	0.40	2275	0.48	3880	0.40	3525	0.48
2022	1986	0.40	1798	0.48	2503	0.40	2276	0.48	3877	0.40	3525	0.48
2023	1986	0.40	1802	0.48	2502	0.40	2278	0.48	3876	0.40	3524	0.48
2024	1986	0.40	1804	0.48	2502	0.40	2279	0.48	3875	0.40	3524	0.48
2025	1986	0.40	1807	0.48	2502	0.40	2280	0.48	3874	0.40	3524	0.48
2026	1987	0.40	1808	0.48	2502	0.40	2280	0.48	3873	0.40	3524	0.48
2027	1987	0.40	1810	0.48	2502	0.40	2281	0.48	3872	0.40	3524	0.48
2028	1987	0.40	1811	0.48	2502	0.40	2281	0.48	3872	0.40	3523	0.48
2029	1987	0.40	1812	0.48	2502	0.40	2281	0.48	3872	0.40	3523	0.48
2030	1987	0.40	1812	0.48	2501	0.40	2281	0.48	3872	0.40	3523	0.48
2031	1987	0.40	1813	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48
2032	1987	0.40	1813	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48
2033	1987	0.40	1813	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48
2034	1987	0.40	1814	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48
2035	1987	0.40	1814	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48
2036	1987	0.40	1814	0.48	2501	0.40	2282	0.48	3871	0.40	3523	0.48

11. Preliminary Eastern Gemfish (*Rexea solandri*) Stock Assessment Based on Data to 2006[7]

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11.1 Summary

This document presents an assessment of eastern gemfish (*Rexea solandri*) in the SESSF using data up to 31 December 2006. A partial stock assessment for eastern gemfish was last performed in 2000 by Punt (2000). The 2007 assessment is performed using the stock assessment package SS2, which provides a standardised platform for doing stock assessment. Catch data were incorporated from 1968, state catches were included and additional length composition data was used dating back to 1975. Changes from the 2000 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data (c) the addition of updated length frequencies, catches and catch-rates, (d) the inclusion of discards and (e) including ageing error was in the model.

The base-case assessment estimates that current (2007) spawning stock biomass is 10% of unexploited stock biomass. Fits to the length, age, and catch-rate data are reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements and the history of the fishery. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*.

11.2 Introduction

11.2.1 The Fishery

Eastern gemfish have been mainly caught by demersal board trawlers targeting the winter spawning migration in depths of about 400m. The trawl fishery developed in the late 1960's and early 1970's, with a recorded peak catches of around 5 000 tonnes in 1980, which then declined to less than 300 tonnes in recent years under much reduced TACs. Gemfish are also caught by droplining, auto-longline and gillnet methods. The catch by NSW dropliners has increased since the 1980's.

11.2.2 Stock structure

Gemfish are caught along the edge of the continental shelf of southern Australia and New Zealand. The eastern gemfish is caught from eastern Tasmania to northern NSW.

[7] Paper presented to the Shelf Resource Assessment Group on September 4 and 5, 2007

A genetically distinct stock, western gemfish, occurs to the west of Tasmania. Eastern gemfish mature at about 3-6 years of age and have been aged to 17 years. Mature fish migrate north along the NSW shelf break during winter and aggregate prior to spawning.

11.2.3 Previous Assessments

Beginning in 1988, a series of cohort analyses were initiated (Allen 1989, 1992). In 1994, several other catch-at-age methods were applied by various researchers. These are described in the annual Stock Assessment Reports prepared by SEFAG (e.g. Chesson 1995). Although the results of these analyses differ in their details, they show a similar overall pattern, namely a decline in adult biomass in the early 1980's and weak cohorts spawned in the late 1980's.

A 3,000t TAC was introduced for eastern gemfish in 1988 in response to the decline in catch rates and mean fish size in the early 1980's. The TAC was progressively reduced to zero in 1993 based on the results of subsequent cohort analyses and apparent declines in recruitment. The TAC remained at zero for 1994, 1995 and 1996, with trip limits to allow for unavoidable bycatch.

A consensus emerged in 1996 among the modellers of eastern gemfish that the model desribed by Punt (1996) was the most appropriate and flexible approach for future analysis (Chesson 1996). There was also strong support for the need to gain new catch rate information from an experimental fishing survey, since the imposition of the zero TAC in 1993 had effectively ended the existing catch rate series.

An eastern gemfish workshop in April 1996 confirmed the desirability of a survey and proposed the formation of the Eastern Gemfish Assessment Group (EGAG). EGAG developed both the trawl survey and a new and more comprehensive assessment of the status of the resource, together with a preliminary evaluation of possible future harvest options. The EGAG assessment, summarised in its March 1997 report, indicated a high probability that the stock had recovered above the reference point of 40% of the 1979 biomass[8]. The report also emphasised the variability in recruitment to the stock, and the possible benefits of a flexible approach to the setting of future TACs.

In 1997, based on the 1996 assessment report, a recommendation of a TAC of 1,200t was made for 1997, with 1,000t allocated to the SEF trawl sector. However, trawl catches for the winter fishery amounted to only 358t. Analysis of standardised catch rates showed a substantial reduction in CPUE from 1996 to 1997. The subsequent 1997 assessment showed the stock to be below the 40% reference point, and EGAG recommended a zero targeted TAC for 1998, but with an allocated bycatch quota of 300t.

Standardised CPUE from surveys in 1998 were below the peak in 1996, and subsequent re-analysis of CPUE in the 1999 assessment, using GLMs (Larcombe 1999), suggested a more pessimistic situation regarding gemfish abundance. The most recent assessment was performed in 2000, which again estimated the biomass to be below the 40% reference point.

[8] Reference here to 40% should not be confused with the recent use of $0.4B_0$ as a proxy for B_{MSY}.

11.2.4 Modifications to the previous assessments

The current assessment differs in several ways from the 2000 assessment. In particular, it uses the package Stock Synthesis 2 (SS2) (Methot, 2005). Other data modifications have also occurred.

11.2.4.1 Data-related modifications

a) Two further CPUE series based on analyses of SEF logbook data have been included in the assessment. One CPUE series corresponds to the spawning season (June to September), while the other corresponds to the non-spawning season (September to May) (Haddon 2007).
b) Recent length frequencies from the Sydney Fish Market have been included in the assessment
c) The age-composition data are now included in the assessment as conditional age-at-length information, instead of a age-compositions constructed from age-length keys and length-frequencies. This enables estimation of the parameters of the growth curve within the assessment (rather than these parameters being set based on auxiliary information).
d) ShelfRAG agreed (April 2007) to use the Punt *et al*. (2001) catch series B as the most appropriate.
e) The age-reading error matrix has been updated.
f) The weighting on the length frequency data (sample sizes) has been altered (in line with current agreed practice).
g) Catch, discard, length-composition, age-at-length, and catch rate data from 2006 have been added.

11.2.4.2 Model-related modifications

1. Four fleets (a non-trawl fleet, a fleet targeting the winter spawning run, a non-spawning season fishery fleet, and a recent spawning season bycatch fishery fleet) are included in the model.

2. Discard data were available for the winter targeted fleet, the summer fleet and the recent spawning season bycatch fleet, and retention was assumed to be asymptotic and different for each fleet.

3. The growth curve parameters ($L_{min,}$ and k) are estimated within the assessment, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths. The parameter L_{max} was not estimated, but set to the 107 cm for females and 97 cm for males based on Rowlings (1999).

11.3 Methods

11.3.1 The data and model inputs

11.3.1.1 Biological parameters

In common with previous assessments, the current assessment is based on a two-sex model. The previous assessments, however, also used pre-specified values for the parameters of the Von Bertalanffy growth equation for each sex. SS2, however, can accept conditional age-at-length data as an input so it was possible to estimate these parameters within the model-fitting process in this assessment. This is a more appropriate approach because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

Natural mortality, *M*, used in the previous assessment was 0.38 yr^{-1} for females and 0.57 yr^{-1} for males. Sensitivity to these values is examined by estimating these parameters. In the base-case, steepness, *h*, was estimated.

Eastern gemfish become sexually mature at about three to five years of age, and females grow to a maximum length of about 107 cm and males 97 cm (Rowling 1999). Based on this information we modelled maturity as a logistic function of length, with 50% maturity at 70 cm and 95% maturity at 80 cm. Sensitivity to these values is examined. Fecundity-at-length is assumed to be proportional to weight-at-length. The parameters of the length-weight relationship are the same as those used in previous assessments (a=1.43 x 10^{-6}, b=3.39). These values are taken from Rowling (1999).

11.3.1.2 Fleets

The assessment data for eastern gemfish were separated into four fleets, which represent one or more gear or temporal differences in the fishery.

1. non-trawl fleet that has operated since 1984;

2. a fleet targeting the winter spawning run, that has operated 1968 -2000 (Punt *et al*., 2001);

3. a non-spawning season (summer) fleet that has operated 1968- present; and

4. a recent winter spawning season bycatch fleet that has operated since 2000.

Selectivities for the non-trawl, and winter targeted were assumed to be asymptotic, while the recent winter spawning season bycatch fleet, and summer fleet, were assumed to have a double normal form, to allow the possibility that selectivity was dome-shaped.

11.3.1.3 Landed catches

A landed catch history for eastern gemfish, separated into the four fleets, is shown in Figure 11.1 and Table 11.1. The time series for the winter targeted and summer fleets for 1968 to 2000 were taken from Punt *et al*. (2001) Series B as requested by ShelfRAG. The catches for the winter targeted fleet from Series B, were reduced by the NSW dropline catches for this period, as these catches were included in the non-trawl fleet. The summer catches since 2000 were obtained from the SEF logbook database. The catches by the non-trawl fleet were set to the non-trawl NSW state catches in Punt *et al*. (2000), which agreed closely with the Fishery Assessment Report (Smith and Wayte 2003). The non-trawl catches for more recent years were obtained from SAN and added to the NSW catches from Koopman (2006). The catches from the winter bycatch fleet, were obtained from the logbook databases.

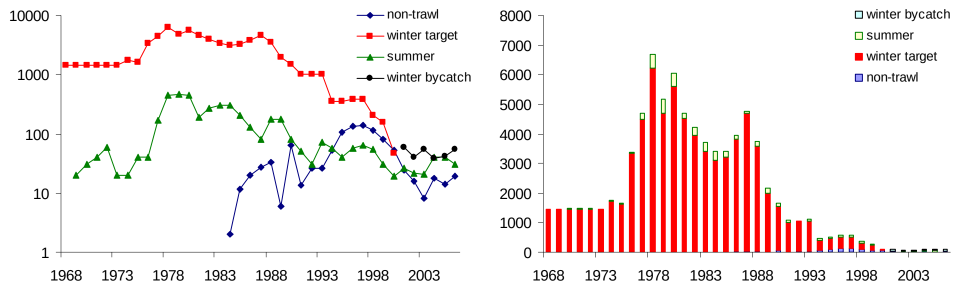


Figure 11.1. Catches of eastern gemfish by fleet (1968 – 2006) on a) log-scale and b) linear scale.

11.3.1.4 Discard rates

Information on the discard rate for eastern gemfish is available from the ISMP for 1993-2006. These data are summarised in Table 11.2. Discards prior to 2000 were assumed to be in the winter target fishery. These data agree with discard rates for the fishery used by Punt *et al*. (2001) for 1998, and 1999 of 0.065 and 0.214 respectively. Punt *et al*. (2001) did not have discard rates for the years prior to 1998, and assumed zero discard for 2000. There is less agreement between the recent estimates of discard rate for the summer fleet and those used by Punt *et al*. (2001). Compared to Table 11.2, the discard rates used by Punt *et al*. (2001) for 1998, 1999 and 2000 were 0.352, 0.342 and 0.057.

11.3.1.5 Catch rate indices

A standardised catch rate (CPUE) index is available for three fleets: (1) the winter targeted fleet, (2) the summer fleet, and (3) the winter spawning season bycatch fleet (Table 11.3, Table 11.4, and Table 11.5). Punt *et al*. (2000) developed the standardised catch rate index for 1973-1998 (Table 11.3). Catch and effort information from the SEF1 logbook database for the period 1986-2006 were standardised using GLM analysis to obtain indices of relative abundance for the summer (Table 11.4) and winter spawning season bycatch (Table 11.5) trawl fleets (Haddon, 2007). The restrictions used in selecting the data for the analyses of the catch and effort data on which Table 11.4 and Table 11.5 are based were: (a) vessels had to have been in the fishery for three or more years, and (b) the catch had to be non-zero. In addition, only data from June to September 1993-2006 in the depth range 300m – 500m were used to calculate the index for the winter spawning season bycatch trawl fleet, while only data from October – May, 1986-2006 and shallower than 300m were used to calculate the index for the non-spawning season (summer) trawl fleet.

11.3.1.6 Length composition data

Sex-disaggregated and sex-aggregated length-frequency data are available for eastern gemfish. The data and its level of disaggregation differ among fleets. Namely,

a) Non-trawl fleet: sex-aggregated length-frequencies for 1993-2005 (Table 11.6, Kevin Rowling, pers. comm.)

b) Winter targeted trawl fleet: sex-disaggregated length-frequencies for 1980-1999 (Punt 2000, Table 11.7) and sex-aggregated length-freqencies for 1975-2006 (Table 11.8 and Table 11.9, Kevin Rowling, pers. comm.).

c) Summer fleet: sex-aggregated length-frequencies for 1975-2000 from Punt (2000) and for 2000-2006 from the ISMP database (Table 11.10).

d) Winter bycatch fleet: sex-aggregated length-frequencies for 2000-2006 from the ISMP database.

Onboard data collected by the ISMP were used to calculate the length-frequency of the discarded component of the catch by the summer, winter targeted and winter bycatch fleets (Table 11.11, Table 11.12 and Table 11.13).

11.3.1.7 Age composition data

Age-at-length measurements, based on otolith measurements, provided by the Central Ageing Facility (CAF), were available for 1993-2006 for the winter targeted fleet (data prior to 2000) and the winter bycatch fleet (data after 2000) (Table 11.14 and Table 11.15). An estimate of the standard deviation of age reading error was calculated by André Punt (pers. comm, 2007) using data supplied by Kyne Krusic-Golub of PIRVic (Table 11.16).

11.3.2 Stock Assessment method

11.3.2.1 Population dynamics model and parameter estimation

A two-sex stock assessment for eastern gemfish was conducted using the software package SS2 (version 2; Methot 2007). SS2 is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for eastern gemfish. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS2 technical description (Methot, 2005) and is not reproduced here. Some key features of the base-case analysis are:

a) Eastern gemfish constitute a single stock with the area of the fishery

b) As in the last assessment (Punt, 2000), the population is assumed to have been at its unfished (unexploited) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1968.

c) The CVs assumed for the catch rate indices for winter bycatch and summer fleets were set equal to the model-estimated standard errors of these indices (Table 11.3 and Table 11.4).

d) Four fishing fleets are modelled.

e) Selectivity varies among fleets, but the selectivity pattern for each fleet except, that for the winter targeted fleet is being time-invariant. The selectivity for the winter targeted fleet is assumed to have changed in 1993 when the TAC was set to zero. SS2 models fleet specific selectivity as a function of length. Each fleet is assumed to have logistic selectivity, except for the winter bycatch fleet, which is assumed to have dome-shaped selectivity. The two parameters of the logistic function and the six parameters of the double normal (dome-shaped) selectivity functions are estimated within the assessment.

f) Retention is a logistic function of length, and the inflection and slope of this function are estimated for those fleets where discard information was available (the winter targeted trawl, the summer trawl and the winter bycatch fleets). A large discontinuity in the summer fleetdiscard rates in 2003 (Table 11.2) prompted the use of different retention curves for this fleet. The sensitivity of the results to this assumption is examined.

g) The rate of natural mortality, *M*, is assumed to be independent of age and time, and to differ between the sexes. The rate of natural mortality for the base-case analysis is 0.38 yr^{-1} and 0.56 yr^{-1} for females and males respectively, based on the results of the last assessment. Estimating rather than fixing *M* is considered in the tests of sensitivity.

h) Recruitment is assumed to follow a Beverton-Holt stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, *h*. Steepness is estimated for the base-case analysis. The value of the parameter that determines the magnitude of the process error in annual recruitment, σ_r, was set equal to 0.6, so that the standard deviation of the estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_r.

i) The plus-group age is set to 25 yr. Growth of eastern gemfish is assumed to be sex-dependent and time-invariant, in that there has been no change over time in mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve along within the assessment.

j) All sample sizes for length frequency data greater than 200 were set to 200. This is because the appropriate sample sizes for the length frequency data relate more to the number of shots sampled, than the number of fish measured. The length frequency data would be given too much weight relative to other data sources had the number of fish measured been used as the effective sample sizes when fitting the model. The length-frequency and age-composition sample sizes for the fleets were also tuned so that the input sample sizes equalled the effective sample size calculated by the model.

k) The estimated and pre-specified parameters of the model are shown in Table 11.17.

11.3.2.2 Sensitivity tests

A number of sensitivity tests were used to examine the sensitivity of the results of the model to some of the assumptions and data inputs:

1. using the ISMP CPUE data for the winter bycatch fleet, instead of the data in Table 11.5;

2. not allowing for time varying retention for summer fleet;

3. estimating rather than pre-specifying *M*. (while simultaneously pre-specifying steepness at 0.4 rather that treating it as an estimable parameter.)

4. assuming that 50% maturity occurs at 60 cm, and 95% at 73 cm.

5. ignoring the low discard rates for the summer fleet for 1993 and 1996.

6. doubling the emphasis placed on each of the data sources (catch-rates, length-frequency and age-composition)

7. in lieu of 2007 survey results, assuming a 2006 CPUE for targeted winter bycatch fleet from recent survey of 80%, 100%, and 120% of 1998 level

The results of the sensitivity tests are summarized by the following quantities:

a) SB_0 the average unexploited female spawning biomass.

b) SB_{2007} the female spawning biomass at the start of 2007.

c) SB_{2007}/SB_0 the depletion level at the start of 2007, i.e. the 2007 spawning biomass expressed as a fraction of the unexploited spawning biomass.

d) $-lnL$ the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data).

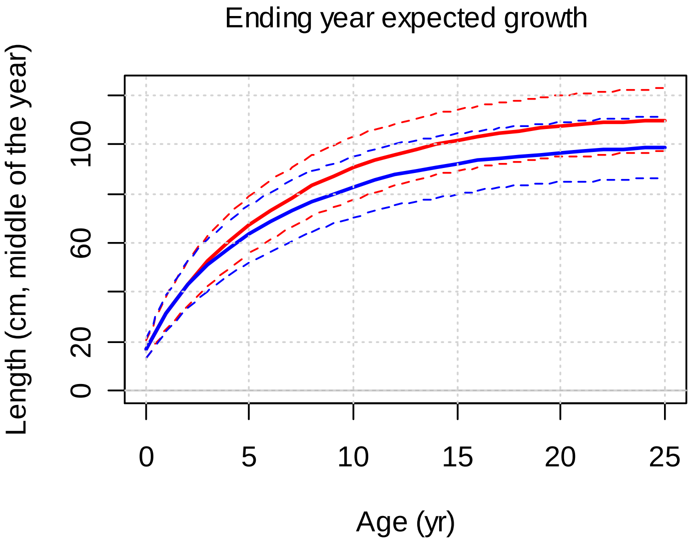
e) the likelihood component of the crash penalty, since the both this model and the previous model Punt (2000) found it difficult to maintain the full age class distribution of the population through time, without an age-class appearing to go extinct.

11.4 Results and discussion

11.4.1 The base-case analysis

11.4.1.1 Fits to the data

The estimated growth curve is shown in Figure 11.2. The growth parameters estimated were the von Bertalanffy growth rate, and the length of the lower age bound, as well as the coefficient of variation. The estimated parameter values are 38.44 cm at age 2 and rate vonBertanffy



Sex	Parameter	Estimated Value
Female	length at 2 years	38.44 cm
	k	0.141
Male	length at 2 years	38.71
	k	0.146

Figure 11.2. Estimated growth curve for male (blue) and female (red) eastern gemfish, and growth parameters. The dotted lines indicate approximate 95% confidence intervals for size of an individual of the age concerned.

The fits to the catch-rate indices (Figure 11.3) are reasonable, although there is some evidence for mis-specification in the fit to the catch-rate index for the winter bycatch fleet. The fits to the discard rate data for the targeted winter trawl and summer trawl fleets are also reasonable (Figure 11.4), although the latter is due in no small part because allowance is made for a change in retention in 2003 The fit of the model to the discarded length-frequency data are shown in Appendix B (Section 11.8). The fits to these data are variable, although this is not surprising, because the observed discard length frequencies are quite variable from year to year, and sample sizes are small.

The base-case model is able to mimic the retained length-frequency data adequately (Appendix B, Section 11.8). The fits to the data for the non-trawl and winter targeted fleets are better than those to the more recent winter bycatch fleets. This is particularly the case for the winter targeted fleet, perhaps because the number of fish measured was generally very high for this fleet, which tends to lead to smoother observed distributions.

The fits to the age composition data are shown in Appendix C (Section 11.9). These particular age frequencies did not have length data associated with them (i.e. conditional age-at-length data) and so they were fitted to directly, without being used to estimate growth. The model mimics the observed age data well.

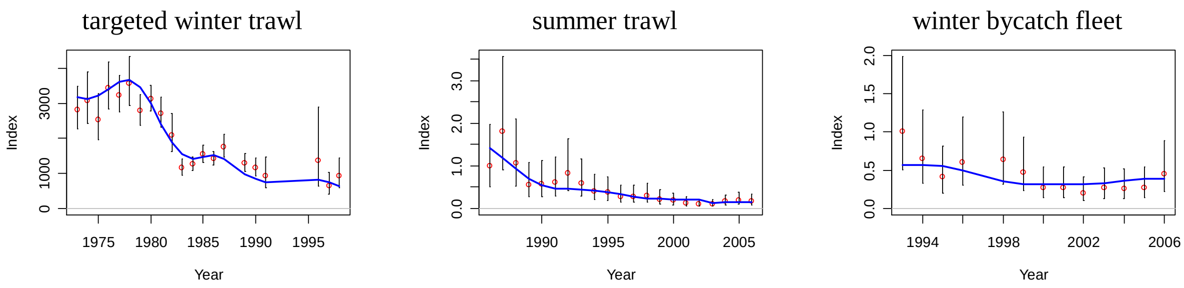


Figure 11.3. Observed (solid dots) and model-predicted (lines) catch rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

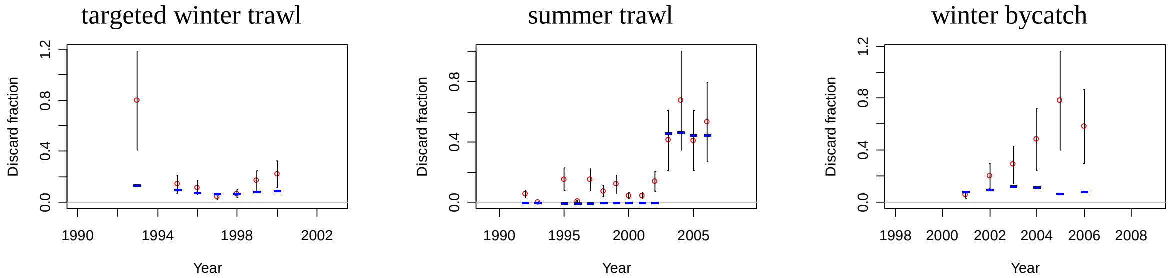
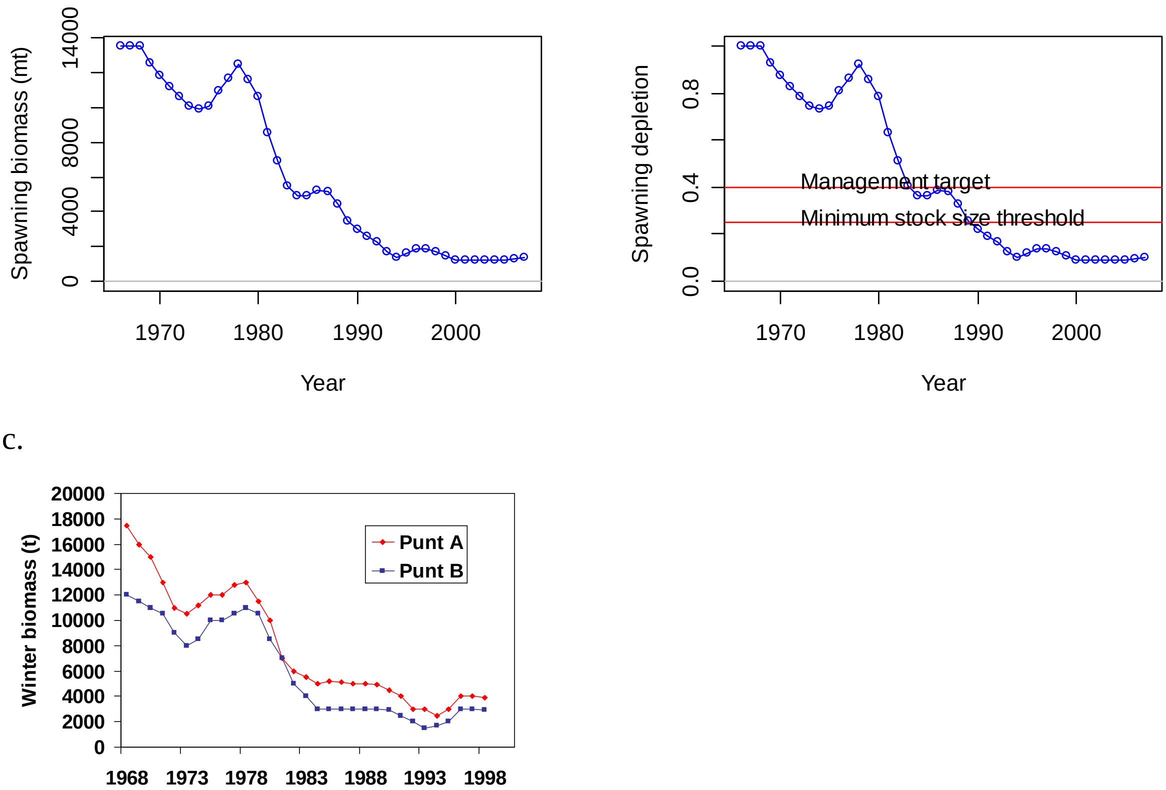


Figure 11.4. Observed (solid dots) and model-predicted (lines) discard rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

11.4.1.2 Assessment outcomes

The left panel of Figure 11.5 shows the time trajectory of female spawning stock biomass from the base-case model, and the right panel shows the spawning stock depletion. The stock declines from the beginning of the fishery in 1968, fluctuates during the 1970's, before declining in the 1980's and 1990's, due to a period of low recruitments and high catches.

a. b.



c.

Figure 11.5. Time-trajectories of a. female spawning biomass, and b. spawning biomass depletion for the base-case analysis, and c. results from Punt 2000.

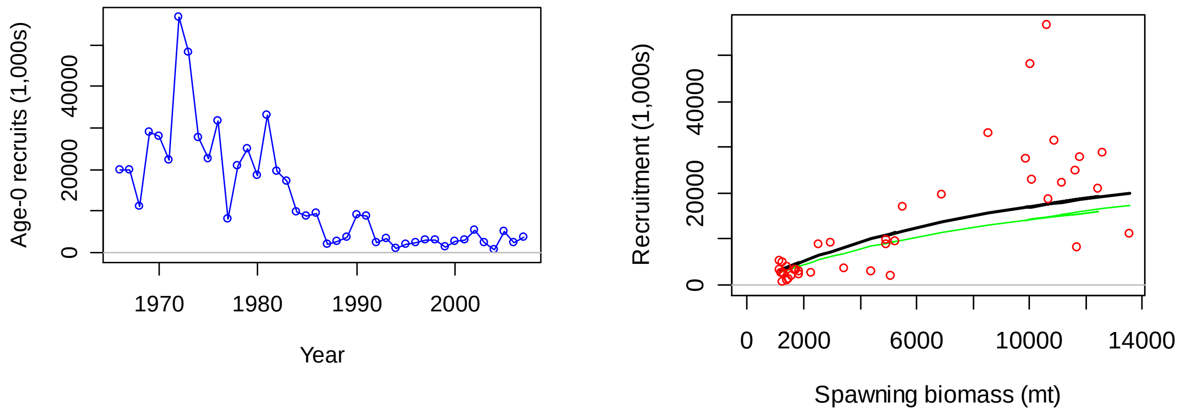


Figure 11.6. Time-trajectories of recruitment from the base-case analysis, and stock recruitment relationship.

The time-trajectories of recruitment is shown in Figure 11.6. The model estimates that most of the recruitments during the last 25 years have been relatively low. This contrasts with the earlier period in the 1970's when recruitment is highly variable. The steepness from the stock recruitment relationship was estimated to be 0.34. The current 2007 spawning stock biomass is estimated by the base-case model to be 10 % of unexploited stock biomass.

11.4.2 Sensitivity tests

The results of the sensitivity tests are shown in Table 11.18. The effect of using the ISMP CPUE data for the winter bycatch fleet, rather than the data in Table 11.5, is to increase the relative biomass level in 2007 from 10% to 17% of SB_0. This is because the most recent (2003-2006) ISMP CPUE indices are relatively high (Figure 11.7) compared to the indices for the earlier years (Figure 11.7), a trend not evident from the CPUE indices based on analysing the logbook data (Figure 11.3).

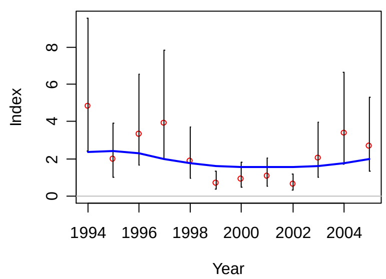


Figure 11.7. Time series of observed (solid dots) from the ISMP CPUE indices for eastern gemfish, and the corresponding model-predictions. The vertical lines indicate approximate 95% confidence intervals for the data.

The effect of using a single retention curve through time for the summer fleet, does not greatly affect the 2007 relative biomass level, but as expected, leads to a markedly poorer fit to the data (higher negative log-likelihood). The effect of estimating, rather than pre-specifying, natural mortality *M* is to increase the 2007 relative biomass level substantially to 29% SB_0. However, the estimated values for female and male *M* however are relatively high (0.49 yr^{-1} and 0.8 yr^{-1}, respectively) and do not appear to be biologically realistic, because *inter alia* an *M* of 0.8 yr^{-1} implies that less then 1% of males survive to age 6. The effect of reducing the length at maturity from 70 cm to 60 cm had a little effect on the 2007 relative biomass, but did lead to improved fits to the data. A length-at 50%-maturity of 60 cm is inconsistent with the results of previous research (Rowling 1999). Changing the weights assigned to the CPUE, age and length data has little effect on the 2007 relative biomass. The results for different 2006 survey CPUEs, show that the assessment will be more optimistic even if this CPUE is only 120% of that in 1998. It should be noted that the results for the sensitivity tests that examine different survey outcomes do not include any survey length or age data.

11.4.3 Discussion

This document presents an assessment of eastern gemfish (*Rexea solandri*) in the SESSF using data up to 1 May 2006. A full stock assessment was last performed by Punt (2000). This assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to be made. Changes from the 2000 assessment include: (a) the estimation of the growth parameters within the assessment, and (b) the addition of updated length frequencies, catches and catch-rates.

The base-case analysis estimates that female spawning stock biomass in 2007 will be 10% of unexploited female spawning stock biomass. Depletion across all sensitivities varied between 10% (female *M*=0.38yr^{-1}, male *M*=0.56 yr^{-1}) and 29% (female *M*=0.49 yr^{-1}, male *M*=0.80 yr^{-1}) for the cases that fit the data adequately. The fits to the length, age, and catch rate data are all reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements and the history of the fishery. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*.

11.5 Acknowledgements

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Table 11.1. Catches (tonnes) by fleet.

Year	Non trawl	Targeted winter	Summer	Winter bycatch
1968	0	1440	0	0
1969	0	1440	20	0
1970	0	1440	30	0
1971	0	1440	40	0
1972	0	1440	60	0
1973	0	1440	20	0
1974	0	1732	20	0
1975	0	1612	40	0
1976	0	3352	40	0
1977	0	4506	170	0
1978	0	6222	450	0
1979	0	4702	460	0
1980	0	5600	440	0
1981	0	4510	190	0
1982	0	3960	270	0
1983	0	3410	305	0
1984	2.00	3096	300	0
1985	11.43	3191	205	0
1986	19.58	3802	130	0
1987	26.81	4656	80	0
1988	33.04	3537	175	0
1989	6.02	1986	175	0
1990	64.08	1501	80	0
1991	13.52	1004	50	0
1992	26.02	1004	30	0
1993	26.33	1010	72	0
1994	53.00	355.5	56	0
1995	108.01	354.5	40	0
1996	134.16	384	56	0
1997	137.16	380	63	0
1998	114.1	203	55	0
1999	79.64	158	30	0
2000	52.18	46	19	0
2001	24.00	0	25.88	60.20
2002	16.00	0	21.46	39.49
2003	8.00	0	20.59	55.00
2004	18.00	0	40.60	39.10
2005	14.00	0	40.41	40.99
2006	18.98	0	30.79	54.25

Table 11.2. Discard rates

Fleet	Year	Discard Rate	CV
Summer Trawl	1992	0.05	0.25
	1993	0.002	0.25
	1995	0.15	0.25
	1996	0.01	0.25
	1997	0.15	0.25
	1998	0.07	0.25
	1999	0.12	0.25
	2000	0.04	0.25
	2001	0.04	0.25
	2002	0.13	0.25
	2003	0.41	0.25
	2004	0.67	0.25
	2005	0.41	0.25
	2006	0.53	0.25
Winter Targeted Trawl	1993	0.79	0.25
	1995	0.14	0.25
	1996	0.12	0.25
	1997	0.05	0.25
	1998	0.06	0.25
	1999	0.17	0.25
	2000	0.22	0.25
Winter bycatch	2001	0.05	0.25
	2002	0.20	0.25
	2003	0.29	0.25
	2004	0.48	0.25
	2005	0.78	0.25

Table 11.3. Standardised catch rates for the winter targeted trawl fleet.

Year	Catch Rate	CV
1973	2811	0.11
1974	3082	0.12
1975	2533	0.13
1976	3440	0.1
1977	3237	0.08
1978	3562	0.1
1979	2780	0.08
1980	3127	0.06
1981	2717	0.08
1982	2100	0.13
1983	1163	0.1
1984	1259	0.08
1985	1537	0.08
1986	1414	0.07
1987	1766	0.09
1989	1294	0.1
1990	1165	0.11
1991	930	0.23
1996	1371	0.38
1997	643	0.24
1998	926	0.23

Table 11.4. Standardised catch rates for the summer trawl fleet.

Year	Catch rate	CV
1986	1	0.35
1987	1.8	0.35
1988	1.06	0.35
1989	0.55	0.35
1990	0.57	0.35
1991	0.61	0.35
1992	0.82	0.35
1993	0.59	0.35
1994	0.41	0.35
1995	0.37	0.35
1996	0.28	0.35
1997	0.28	0.35
1998	0.3	0.35
1999	0.22	0.35
2000	0.18	0.35
2001	0.14	0.35
2002	0.11	0.35
2003	0.11	0.35
2004	0.16	0.35
2005	0.19	0.35
2006	0.17	0.35

Table 11.5. Standardised catch rates for the winter bycatch trawl fleet.

Year	Catch rate	CV
1993	1	0.35
1994	0.65	0.35
1995	0.41	0.35
1996	0.6	0.35
1998	0.64	0.35
1999	0.47	0.35
2000	0.27	0.35
2001	0.27	0.35
2002	0.21	0.35
2003	0.27	0.35
2004	0.26	0.35
2005	0.27	0.35
2006	0.45	0.35

Table 11.6. Length composition data for the non-trawl fleet

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
30	0.01	0	0	0	0	0	0	0	0	0.01	0	0
35	0.02	0.01	0	0.01	0.01	0	0.04	0.02	0.02	0.03	0.04	0
40	0.14	0.05	0.03	0.01	0.02	0.02	0.09	0.08	0.04	0.05	0.1	0.08
45	0.15	0.11	0.1	0.03	0.05	0.03	0.14	0.15	0.08	0.11	0.15	0.08
50	0.21	0.17	0.15	0.06	0.08	0.07	0.16	0.18	0.13	0.12	0.16	0.58
55	0.24	0.18	0.19	0.06	0.09	0.08	0.15	0.19	0.19	0.14	0.18	0.21
60	0.14	0.17	0.21	0.12	0.13	0.12	0.11	0.14	0.19	0.16	0.14	0.04
65	0.05	0.11	0.16	0.15	0.15	0.15	0.11	0.09	0.15	0.14	0.11	0
70	0.03	0.07	0.08	0.15	0.14	0.16	0.08	0.06	0.1	0.09	0.04	0
75	0.01	0.04	0.04	0.14	0.14	0.15	0.06	0.04	0.05	0.08	0.04	0
80	0.01	0.03	0.01	0.09	0.1	0.1	0.04	0.02	0.02	0.05	0.02	0
85	0	0.03	0.01	0.08	0.04	0.07	0.01	0.01	0.01	0.02	0.01	0
90	0	0.02	0	0.04	0.02	0.03	0.01	0	0	0.01	0	0
95	0	0.01	0	0.02	0.01	0.01	0	0	0	0	0	0
100	0	0	0	0.02	0.01	0	0	0	0	0	0	0
105	0	0	0	0.01	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0

Table 11.7. Combined sex, retained, length composition data for the targeted winter bycatch fleet

length	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0.01	0	0.01	0
40	0	0	0	0	0	0	0	0.01	0.01	0.01	0
45	0	0	0	0	0	0	0.03	0.01	0.01	0.02	0.02
50	0.02	0.01	0.01	0	0	0.01	0.03	0.02	0.02	0.04	0.04
55	0.06	0.01	0.01	0	0.01	0.01	0.01	0.03	0.01	0.06	0.05
60	0.14	0.02	0.03	0.01	0.02	0.03	0.04	0.04	0.08	0.09	0.12
65	0.05	0.09	0.12	0.08	0.07	0.11	0.12	0.11	0.19	0.18	0.21
70	0.17	0.14	0.23	0.27	0.26	0.22	0.24	0.22	0.24	0.21	0.22
75	0.27	0.27	0.24	0.27	0.32	0.26	0.23	0.24	0.2	0.18	0.16
80	0.13	0.25	0.18	0.17	0.19	0.2	0.16	0.15	0.14	0.11	0.09
85	0.07	0.11	0.1	0.1	0.08	0.1	0.08	0.09	0.06	0.06	0.05
90	0.04	0.06	0.04	0.05	0.03	0.04	0.04	0.04	0.03	0.03	0.02
95	0.03	0.03	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01
100	0.01	0.02	0.01	0.01	0	0.01	0.01	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

length	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0.01	0	0	0.02	0.02
40	0	0	0.01	0	0	0	0.09	0.11	0.04	0.25	0.14
45	0.02	0	0.01	0.01	0	0	0.02	0.12	0.09	0.12	0.05
50	0.04	0.02	0.04	0.02	0.01	0.01	0.01	0.15	0.23	0.04	0.07
55	0.06	0.06	0.05	0.02	0.04	0.02	0.01	0.03	0.18	0.1	0.05
60	0.11	0.15	0.15	0.06	0.06	0.04	0.02	0.02	0.09	0.12	0.04
65	0.19	0.23	0.26	0.19	0.12	0.1	0.03	0.03	0.04	0.12	0.09
70	0.24	0.23	0.24	0.3	0.21	0.19	0.09	0.05	0.02	0.1	0.18
75	0.17	0.16	0.14	0.21	0.24	0.22	0.2	0.09	0.03	0.05	0.19
80	0.09	0.08	0.06	0.1	0.18	0.22	0.23	0.14	0.07	0.03	0.11
85	0.04	0.04	0.02	0.05	0.08	0.11	0.16	0.13	0.08	0.02	0.04
90	0.02	0.01	0.01	0.02	0.04	0.06	0.08	0.08	0.07	0.02	0.01
95	0.01	0.01	0	0.01	0.01	0.02	0.03	0.03	0.04	0.02	0.01
100	0	0	0	0	0.01	0	0.01	0.01	0.01	0.01	0.01
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

(Table 11.7 Continued)

length	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0
35	0	0.04	0.02	0.16	0.04	0.03	0.05	0.17	0	0
40	0.01	0.09	0.11	0.36	0.02	0.3	0.12	0.39	0.01	0.01
45	0.01	0.03	0.15	0.06	0.03	0.16	0.09	0.13	0.24	0.03
50	0.04	0.04	0.12	0.11	0.05	0.05	0.13	0.1	0.25	0.09
55	0.03	0.02	0.04	0.09	0.04	0.07	0.08	0.07	0.11	0.18
60	0.05	0.03	0.04	0.06	0.07	0.07	0.1	0.03	0.06	0.24
65	0.08	0.04	0.06	0.03	0.26	0.04	0.14	0.03	0.07	0.19
70	0.19	0.1	0.09	0.04	0.25	0.08	0.15	0.03	0.08	0.12
75	0.27	0.18	0.13	0.04	0.13	0.1	0.07	0.02	0.07	0.07
80	0.21	0.21	0.12	0.03	0.06	0.06	0.04	0.01	0.05	0.03
85	0.08	0.14	0.07	0.02	0.03	0.03	0.01	0.01	0.02	0.02
90	0.02	0.05	0.03	0.01	0.04	0	0	0	0.02	0.01
95	0.01	0.01	0.01	0	0	0.01	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0

Table 11.8. Female, retained, length composition data for the targeted winter bycatch fleet

length	1980	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
10	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0.03	0.02
45	0	0	0	0	0	0	0	0	0	0	0	0.02	0.01
50	0	0.01	0	0	0.01	0.02	0.01	0.01	0	0	0.01	0	0.01
55	0	0.01	0	0	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
60	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.03	0.01	0.02	0.01	0	0
65	0.04	0.03	0.08	0.07	0.12	0.08	0.12	0.17	0.07	0.04	0.02	0.01	0.01
70	0.14	0.14	0.22	0.23	0.24	0.29	0.28	0.32	0.32	0.13	0.11	0.04	0.02
75	0.28	0.32	0.27	0.28	0.25	0.27	0.26	0.26	0.29	0.3	0.24	0.2	0.05
80	0.26	0.23	0.22	0.19	0.17	0.16	0.14	0.11	0.16	0.27	0.3	0.3	0.17
85	0.15	0.14	0.11	0.11	0.1	0.07	0.07	0.05	0.09	0.13	0.17	0.22	0.31
90	0.07	0.07	0.05	0.05	0.04	0.04	0.03	0.02	0.04	0.06	0.09	0.12	0.23
95	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.04	0.05	0.11
100	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01	0.04
105	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0

(Table 11.8 Continued)

length	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0.01	0	0	0	0	0.01	0	0	0	0.03	0.01	0
40	0.07	0.2	0	0.01	0	0.03	0.16	0	0.12	0.07	0.38	0.03	0
45	0.02	0.14	0	0	0	0.01	0.04	0	0.08	0.02	0.17	0.06	0
50	0.16	0.02	0.03	0.01	0.01	0.05	0.04	0	0.01	0.08	0.06	0.27	0.02
55	0.03	0.05	0.02	0.01	0.02	0.04	0.06	0.02	0.04	0.08	0.11	0.14	0.04
60	0.06	0.08	0.01	0	0.01	0.02	0.11	0.04	0.1	0.06	0.05	0.04	0.14
65	0.05	0.11	0.03	0.01	0.01	0.02	0.07	0.28	0.08	0.16	0.04	0.1	0.27
70	0.02	0.12	0.14	0.05	0.03	0.12	0.1	0.34	0.15	0.27	0.06	0.11	0.21
75	0.03	0.09	0.32	0.23	0.1	0.23	0.17	0.17	0.2	0.14	0.04	0.1	0.16
80	0.09	0.04	0.28	0.33	0.29	0.26	0.12	0.06	0.13	0.08	0.03	0.08	0.08
85	0.16	0.02	0.09	0.24	0.31	0.13	0.05	0.04	0.06	0.02	0.02	0.03	0.05
90	0.18	0.04	0.02	0.07	0.17	0.06	0.04	0.04	0.01	0	0.01	0.03	0.02
95	0.11	0.04	0.02	0.02	0.04	0.02	0.02	0	0.01	0	0	0	0.01
100	0.02	0.01	0.01	0.02	0.01	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11.9. Male, retained, length composition data for the targeted winter bycatch fleet

length	1980	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
10	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0.03	0.01	0.02	0	0	0	0	0	0	0	0.02
40	0	0.01	0.01	0.01	0	0	0.01	0.02	0	0	0.01	0.21
45	0	0.02	0.03	0.03	0.04	0.03	0.01	0.01	0.02	0	0	0.03
50	0.02	0.04	0.04	0.09	0.08	0.06	0.03	0.07	0.05	0.02	0.02	0.02
55	0.01	0.05	0.02	0.12	0.09	0.12	0.1	0.07	0.03	0.08	0.04	0.02
60	0.06	0.08	0.17	0.16	0.21	0.21	0.26	0.26	0.13	0.12	0.09	0.06
65	0.18	0.2	0.32	0.29	0.3	0.32	0.34	0.34	0.36	0.22	0.24	0.1
70	0.32	0.32	0.25	0.19	0.19	0.19	0.19	0.18	0.28	0.31	0.31	0.21
75	0.25	0.16	0.11	0.07	0.07	0.05	0.06	0.04	0.1	0.16	0.18	0.22
80	0.12	0.07	0.04	0.02	0.02	0.02	0.01	0.01	0.02	0.06	0.09	0.08
85	0.03	0.02	0.01	0	0	0	0	0	0.01	0.01	0.02	0.03
90	0	0	0	0	0	0	0	0	0	0	0.01	0
95	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0

(Table 11.9 Continued)

length	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0
35	0	0	0.03	0.01	0.01	0.04	0.01	0.05	0	0.03	0.07	0.2	0.02	0
40	0.07	0.02	0.29	0.03	0.04	0.22	0.05	0.19	0	0.21	0.09	0.43	0.05	0.02
45	0.09	0.13	0.09	0.02	0.01	0.1	0.07	0.06	0.07	0.07	0.2	0.14	0.47	0.06
50	0.18	0.27	0.06	0.05	0.04	0.02	0.07	0.14	0.07	0.21	0.2	0.14	0.26	0.13
55	0.05	0.26	0.13	0.05	0.02	0.02	0.05	0.18	0.14	0.28	0.1	0.04	0.08	0.28
60	0.05	0.11	0.15	0.08	0.03	0.02	0.07	0.09	0.24	0.08	0.14	0.02	0.06	0.3
65	0.07	0.04	0.13	0.19	0.06	0.03	0.12	0.1	0.38	0.04	0.12	0.01	0.02	0.14
70	0.11	0.03	0.07	0.31	0.25	0.09	0.16	0.08	0.03	0.04	0.06	0.01	0.02	0.05
75	0.18	0.04	0.02	0.18	0.32	0.16	0.22	0.06	0	0.04	0.01	0.01	0.01	0.01
80	0.15	0.06	0.01	0.05	0.16	0.2	0.13	0.02	0.07	0	0	0.01	0.01	0
85	0.05	0.04	0.01	0.02	0.03	0.07	0.04	0.02	0	0.01	0	0	0	0
90	0.01	0.01	0	0.01	0.03	0.01	0.01	0	0	0	0	0	0	0
95	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11.10. Combined sex, retained, length composition data for the summer fleet

length	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0.11	0.11	0	0	0.01	0.01	0.13	0.2	0.06	0.17
35	0.04	0	0.1	0.02	0.03	0.05	0.06	0.12	0.1	0.15	0.01
40	0.09	0.08	0.11	0.14	0.03	0.14	0.23	0.02	0.29	0.16	0.24
45	0.32	0.33	0.13	0.21	0.1	0.22	0.24	0.11	0.16	0.28	0.23
50	0.34	0.09	0.06	0.06	0.27	0.12	0.11	0.33	0.06	0.21	0.2
55	0.16	0.17	0.05	0.1	0.26	0.11	0.1	0.17	0.07	0.09	0.09
60	0.03	0.14	0.06	0.1	0.06	0.15	0.06	0.03	0.07	0.02	0.04
65	0.01	0.05	0.15	0.08	0.04	0.08	0.06	0.03	0.03	0.01	0.01
70	0.01	0	0.13	0.12	0.05	0.04	0.05	0.02	0.01	0	0
75	0.01	0.01	0.05	0.1	0.07	0.03	0.04	0.02	0.01	0	0.01
80	0	0.01	0.03	0.05	0.05	0.03	0.02	0.01	0	0	0
85	0	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0	0	0
90	0	0	0.01	0.01	0.01	0.01	0	0	0	0	0
95	0	0	0.01	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

(Table 11.10 Continued)

length	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
30	0	0.29	0	0	0	0	0.47	0.11	0.03	0.07
35	0.03	0	0.19	0.01	0	0	0.24	0.23	0.12	0.13
40	0.24	0.02	0.31	0.16	0.13	0	0.06	0.28	0.2	0.16
45	0.48	0.04	0.26	0.45	0.47	0.33	0.14	0.3	0.26	0.17
50	0.11	0.04	0.12	0.13	0.22	0.07	0.01	0.06	0.17	0.18
55	0.04	0.1	0.05	0.08	0.17	0.3	0.07	0	0.11	0.15
60	0.03	0.16	0.03	0.05	0.02	0.3	0.01	0	0.03	0.08
65	0.02	0.14	0.01	0.05	0	0	0	0	0.01	0.04
70	0.02	0.11	0.01	0.04	0	0	0	0	0.01	0.01
75	0.02	0.06	0	0.02	0	0	0	0	0.01	0.01
80	0.01	0.02	0.01	0.01	0	0	0	0.01	0.02	0
85	0	0.01	0.01	0	0	0	0	0	0.02	0
90	0	0	0	0	0	0	0	0	0.01	0
95	0	0	0	0	0	0	0	0	0.01	0
100	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0

length	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0.01	0.01	0.03	0	0	0
30	0.03	0.02	0.18	0	0.09	0.08	0.06	0.31	0	0.01	0
35	0.28	0.28	0.41	0.04	0.14	0.11	0.32	0.22	0.13	0.4	0
40	0.07	0.18	0.13	0.32	0.38	0.12	0.28	0.13	0.47	0.12	0.08
45	0.05	0.15	0.15	0.54	0.31	0.35	0.22	0.25	0.35	0.2	0.24
50	0.07	0.14	0.06	0.09	0.03	0.2	0.07	0.06	0.04	0.21	0.3
55	0.04	0.04	0.03	0.01	0.02	0.03	0.03	0	0.01	0.04	0.17
60	0.04	0.01	0.01	0	0	0.04	0.01	0	0	0.01	0.13
65	0.1	0.02	0.01	0	0	0.03	0	0	0	0	0.07
70	0.11	0.04	0.01	0	0	0.01	0	0	0.01	0	0
75	0.09	0.05	0	0	0	0.01	0	0	0	0	0
80	0.05	0.04	0.01	0	0	0	0	0	0	0	0
85	0.01	0.01	0	0	0	0	0	0	0	0	0
90	0.02	0	0	0	0	0	0	0	0	0	0
95	0.02	0	0	0	0	0	0	0	0	0	0
100	0.01	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

Table 11.11. Discarded length composition data (combined sex) for the summer fleet

length	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0
15	0.09	0	0	0	0.01	0	0
20	0.9	0.04	0.03	0.32	0.04	0.59	0.26
25	0	0.26	0.04	0.32	0.06	0.04	0.1
30	0	0.63	0.78	0.3	0.22	0.16	0.32
35	0.01	0.07	0.15	0.06	0.5	0.14	0.21
40	0	0	0	0	0.16	0.04	0.08
45	0	0	0	0	0.01	0.02	0.02
50	0	0	0	0	0	0	0.01
55	0	0	0	0	0	0.01	0
60	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0

Table 11.12. Discarded length composition data (combined sex) for the targeted winter trawl fleet

length	1998	1999	2000
10	0	0	0
15	0	0	0
20	0.01	0.16	0
25	0.75	0.51	0.09
30	0.07	0.32	0.03
35	0.01	0	0.19
40	0.12	0	0.64
45	0.02	0	0.04
50	0.01	0	0.01
55	0.01	0	0
60	0	0	0
65	0	0	0
70	0	0	0
75	0	0	0
80	0	0	0
85	0	0	0
90	0	0	0
95	0	0	0
100	0	0	0
105	0	0	0
110	0	0	0
115	0	0	0
120	0	0	0

Table 11.13. Discarded length composition data (combined sex) for the targeted winter bycatch fleet

length	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0
15	0	0	0	0	0	0
20	0.09	0.01	0.08	0.02	0.03	0.44
25	0.6	0.58	0.64	0.01	0.04	0.52
30	0.16	0.4	0.21	0	0	0
35	0.01	0	0	0.17	0.07	0.01
40	0.1	0.01	0.01	0.67	0.63	0.02
45	0.03	0.01	0.01	0.1	0.19	0
50	0.01	0	0.02	0.01	0.03	0
55	0	0	0.01	0	0.01	0
60	0	0	0.01	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0
75	0	0	0	0	0	0
80	0	0	0	0	0	0
85	0	0	0	0	0	0
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0
105	0	0	0	0	0	0
110	0	0	0	0	0	0
115	0	0	0	0	0	0
120	0	0	0	0	0	0

Table 11.14. Male age composition data of targeted winter fleet

age	1980	1982	1984	1986	1988	1990	1991	1992
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0.02	0.02	0	0.02	0.01	0.01	0.22
3	0.02	0.04	0.07	0.06	0.07	0.02	0.04	0.04
4	0.07	0.13	0.26	0.22	0.16	0.16	0.28	0.04
5	0.28	0.24	0.34	0.39	0.47	0.17	0.31	0.11
6	0.33	0.36	0.22	0.23	0.22	0.36	0.15	0.22
7	0.19	0.13	0.06	0.08	0.05	0.21	0.07	0.21
8	0.08	0.06	0.02	0.01	0	0.05	0.09	0.08
9	0.02	0.02	0	0.01	0	0.02	0.03	0.05
10	0	0.01	0	0	0	0	0.01	0.02
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0

Table 11.15. Female age composition data of targeted winter bycatch fleet

age	1980	1982	1984	1986	1988	1990	1991	1992
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0.01
3	0	0.01	0	0.01	0.02	0	0.01	0.01
4	0.01	0.02	0.03	0.04	0.02	0.02	0.07	0.01
5	0.1	0.09	0.19	0.21	0.26	0.07	0.21	0.1
6	0.27	0.35	0.35	0.38	0.41	0.28	0.28	0.3
7	0.3	0.25	0.22	0.2	0.19	0.33	0.25	0.28
8	0.15	0.12	0.11	0.09	0.06	0.17	0.13	0.15
9	0.08	0.07	0.06	0.04	0.02	0.08	0.04	0.09
10	0.09	0.08	0.05	0.03	0.02	0.05	0.03	0.04
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0

Table 11.16. Aging error CVs.

age	st. dev.
0	0.046248
1	0.046248
2	0.393378
3	0.521081
4	0.568061
5	0.585344
6	0.591702
7	0.594041
8	0.594902
9	0.595218
10	0.595335
11	0.595335
12	0.595335
13	0.595335
14	0.595335
15	0.595335
16	0.595335
17	0.595335
18	0.595335
19	0.595335
20	0.595335
21	0.595335
22	0.595335
23	0.595335
24	0.595335
25	0.595335

Table 11.17. Estimated and pre-specified parameters of the model.

Estimated parameters	Number of parameters
Unexploited recruitment	1
Steepness, *h*	1
Recruitment deviations 1968 – 2006	38
Growth	8
Selectivity	22
Retention	9
Pre-specified parameters	**Values**
Rate of natural mortality, *M*	0.38, 0.56
Recruitment variability , σ_r	0.6
Maturity inflection	70
Maturity slope	-0.25
Length-weight scale, *a*	1.43×10^{-6}
Length-weight power, *b*	3.39

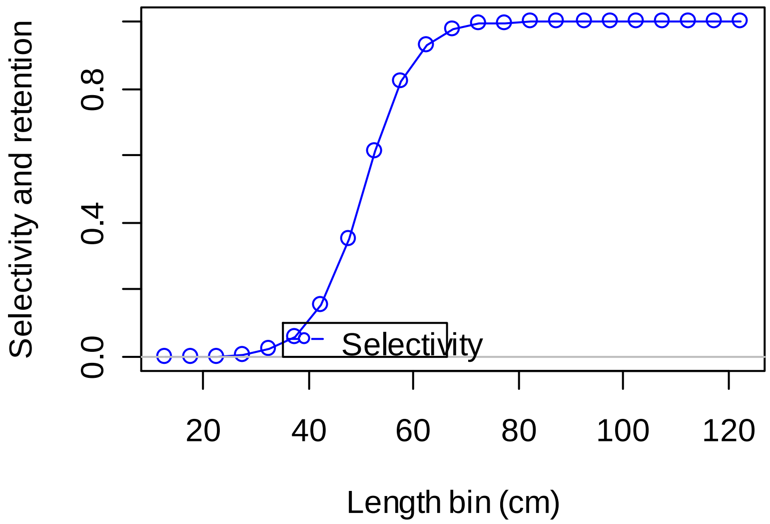
Table 11.18. Summary of results for the base-case and sensitivity tests.

Model	-ln L	Crash penalty	Female SB_0	Female SB_{2007}	SB_{2007}/SB_0
0. base-case	1,464.73	2.9	13,534	1,2937	0.10
1. substitute ISMP for winter bycatch fleet	1,465.53*	1.2	14,328	2,142	0.17
2. single retention block for summer fleet retention	1,858.69	2.1	14,160	1,057	0.08
3. estimate M, fix h (0.4)	1,447.44	0.39	13,359	3,623	0.29
4. Alternative maturity parameters	1,395.02	2.3	16,920	1,921	0.12
5. remove fleet 3 low discards	1,354.71*	2.4	13,411	1,288	0.11
6. fix growth parameters	1,911.77	0	18,019	2,095	0.13
7. double emphasis on CPUE	1,428.21*	4.0	12,818	1,202	0.10
8. double emphasis on length comps.	1,749.11*	3.0	12,715	1,251	0.11
9. double emphasis on age comps	2,285.44*	3.6	12,609	2,296	0.18
10. fleet 2 2006 CPUE – 80% 1998 level	1,394.05*	2.2	13,374	1,384	0.11
11. fleet 2 2006 CPUE – 1998 level	1,395.07*	2.3	13,413	1,493	0.12
12. fleet 2 2006 CPUE – 120% 1998 level	1,431.37*	2.0	13,627	2,812	0.22

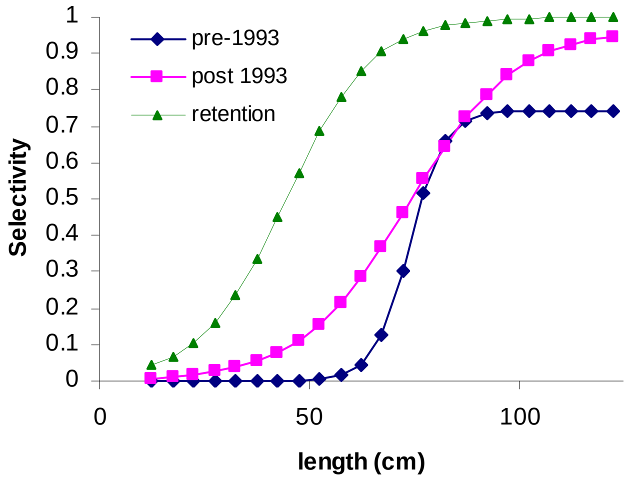
* not comparable with the negative log-likelihood of the base case analysis

11.7 Appendix A: Fleet selectivities

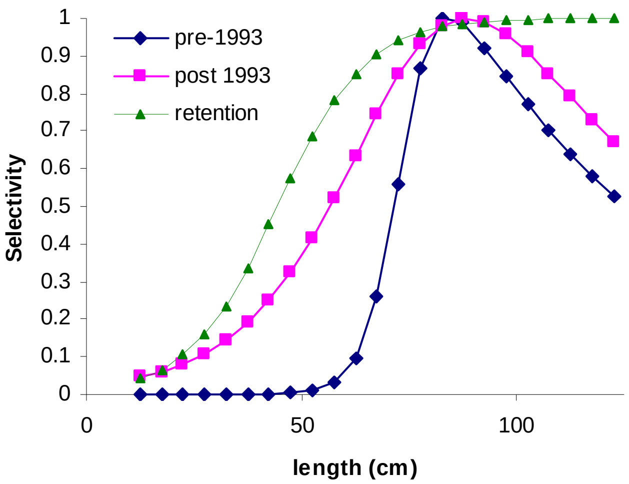
Non-trawl selectivity



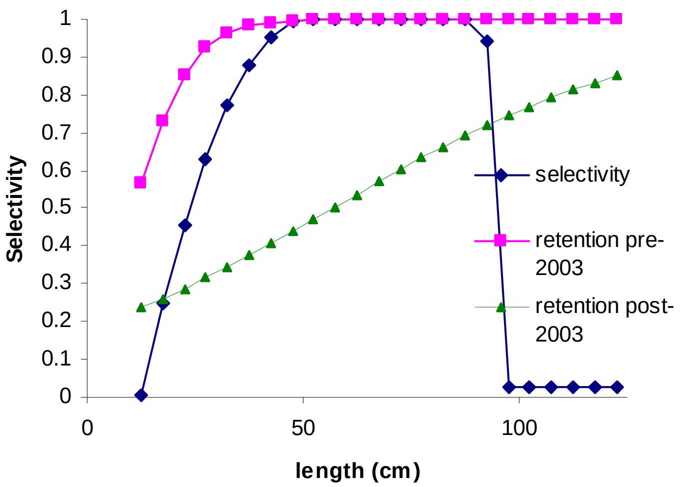
Female, targeted winter fleet



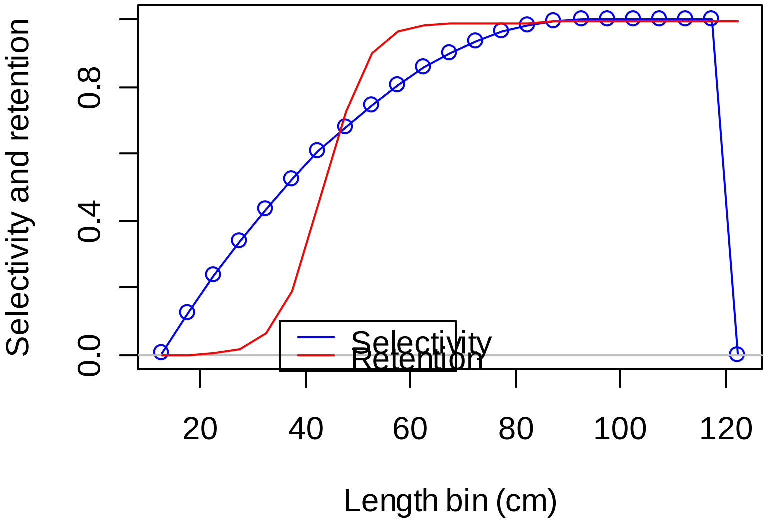
Male, targeted winter fleet



Summer fleet

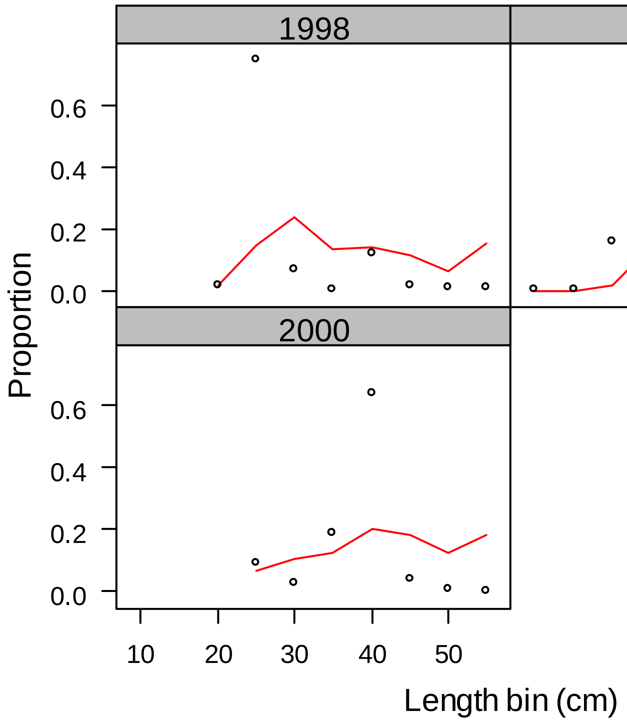


winter bycatch fleet

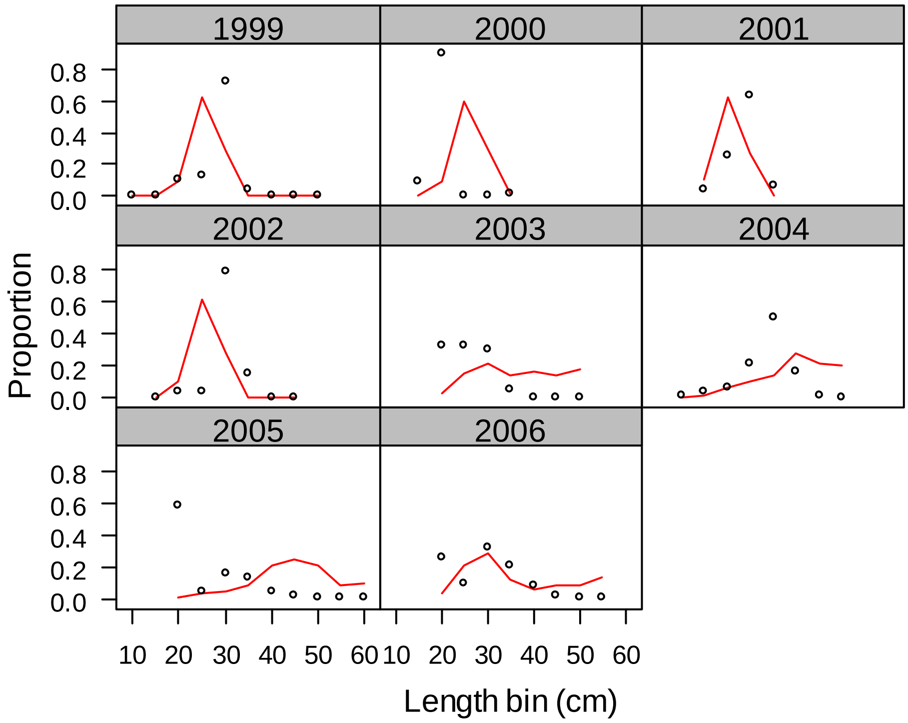


11.8 Appendix B: Fits to the length composition data

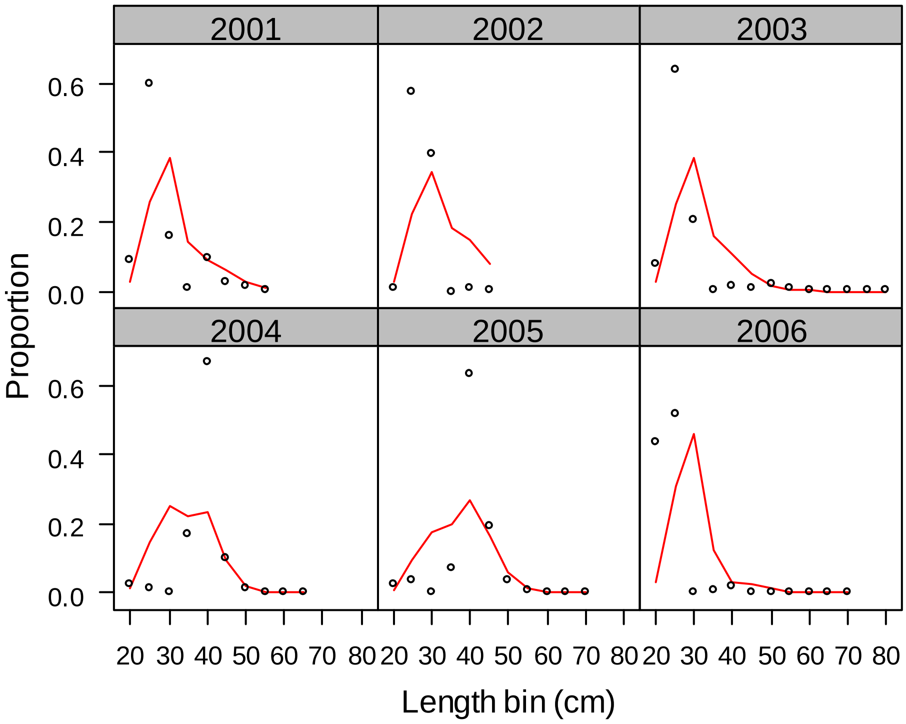
Discarded – combined sex, targeted winter trawl fleet



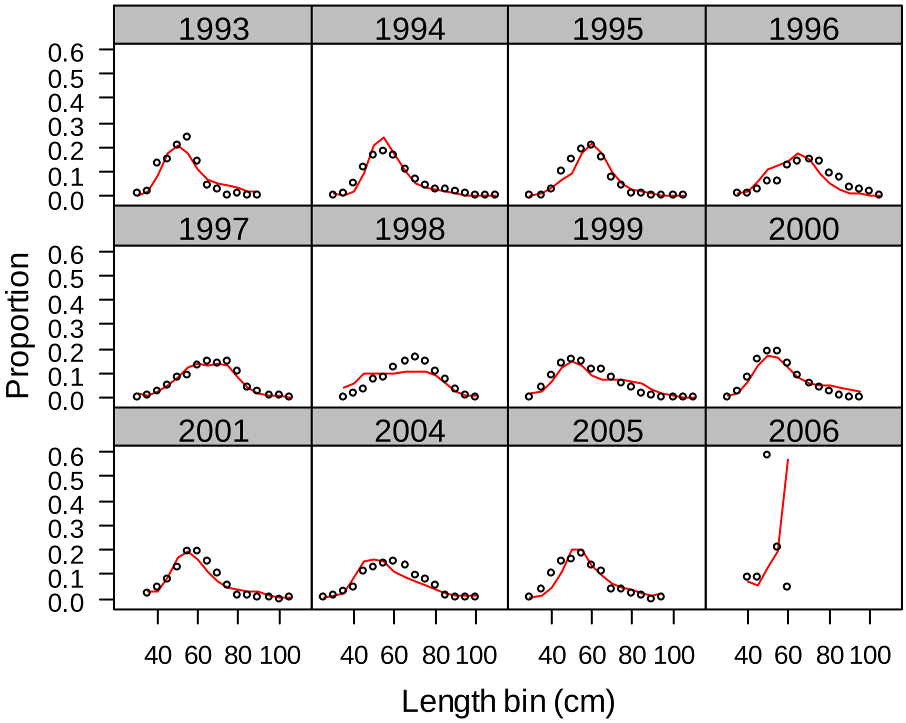
Discarded – combined sex, summer trawl fleet



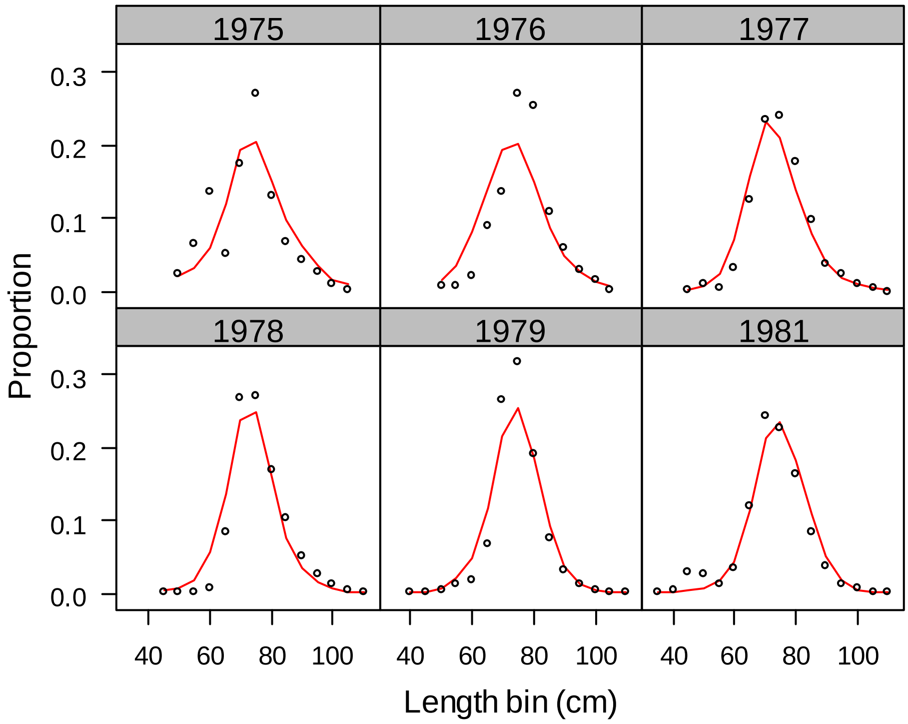
Discarded – combined sex, winter bycatch fleet



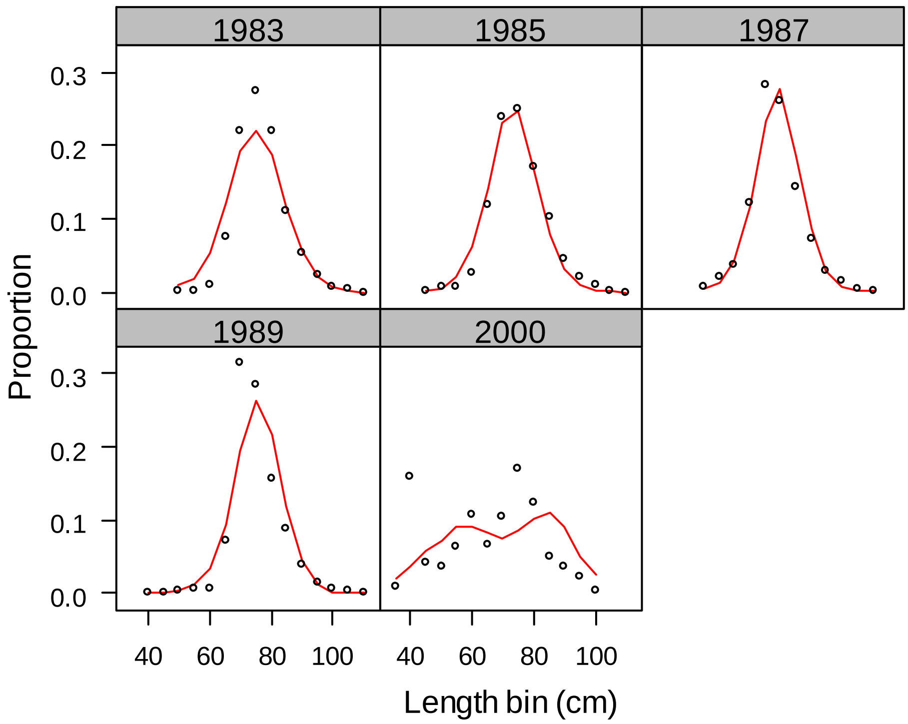
Retained – combined sex, non-trawl fleet



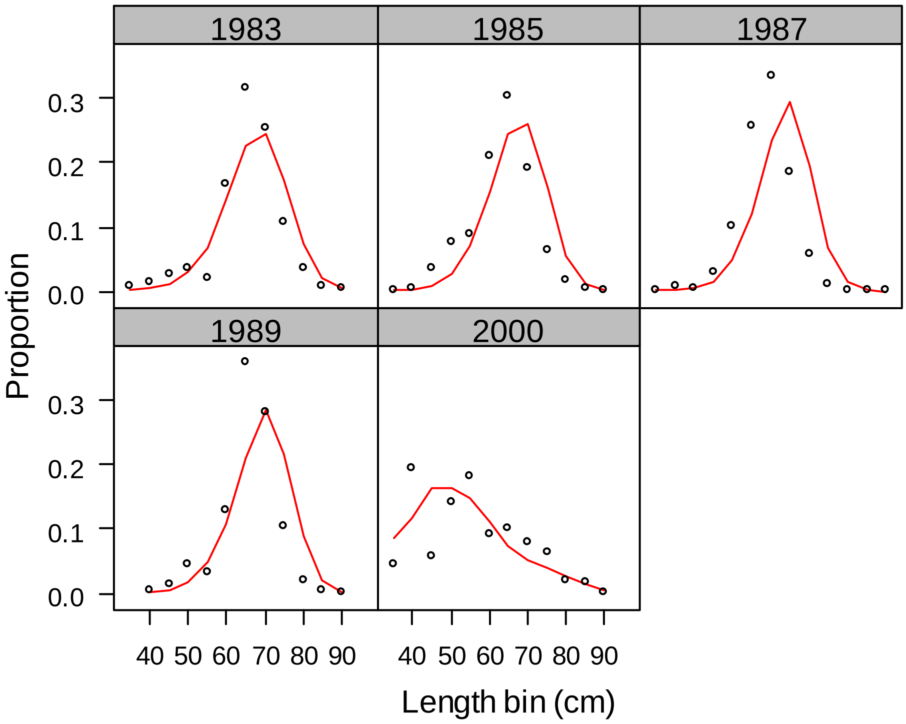
Retained – combined sex, targeted winter trawl fleet



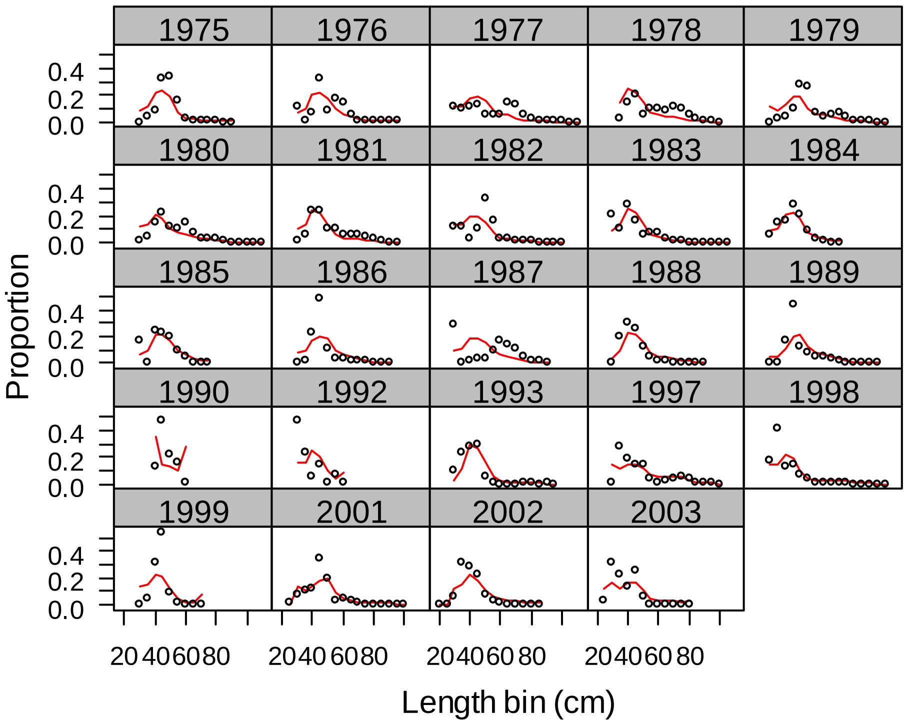
Retained – female, targeted winter trawl fleet



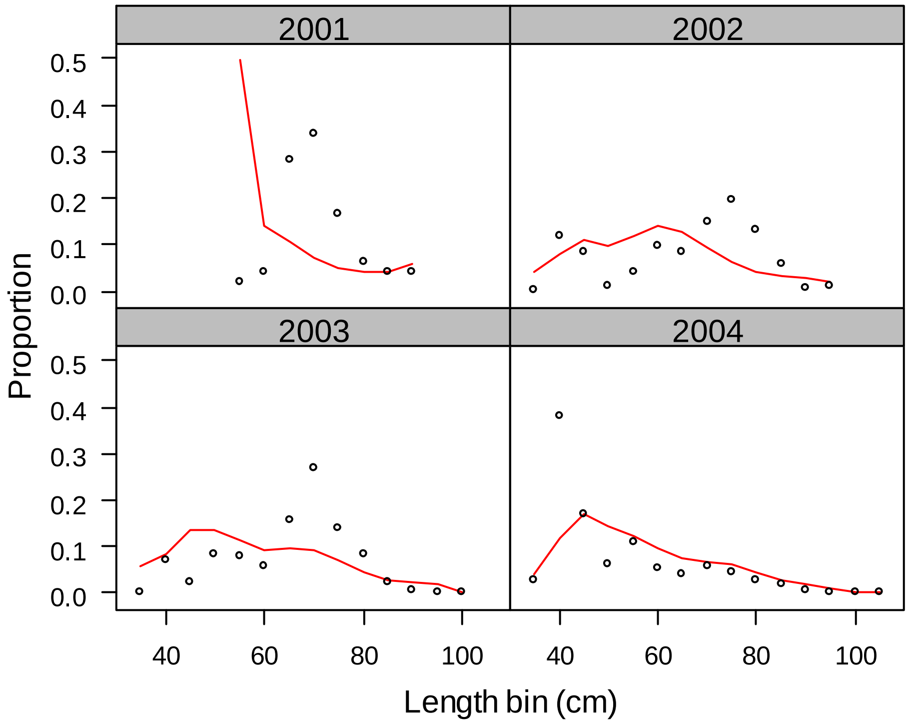
Retained – male, targeted winter trawl fleet



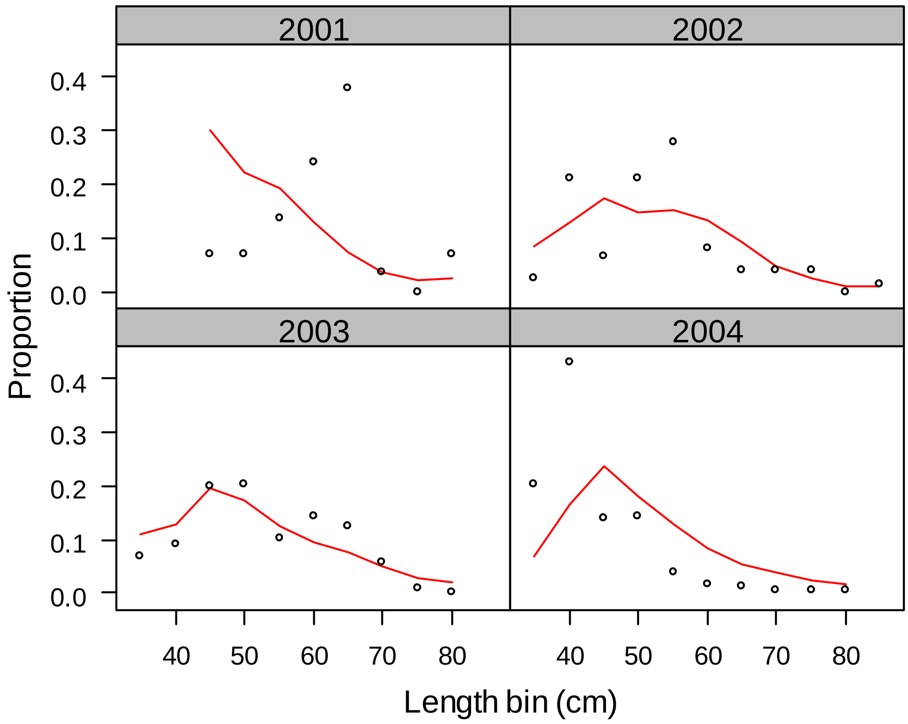
Retained – combined sex, summer trawl fleet



Retained –female, winter bycatch fleet

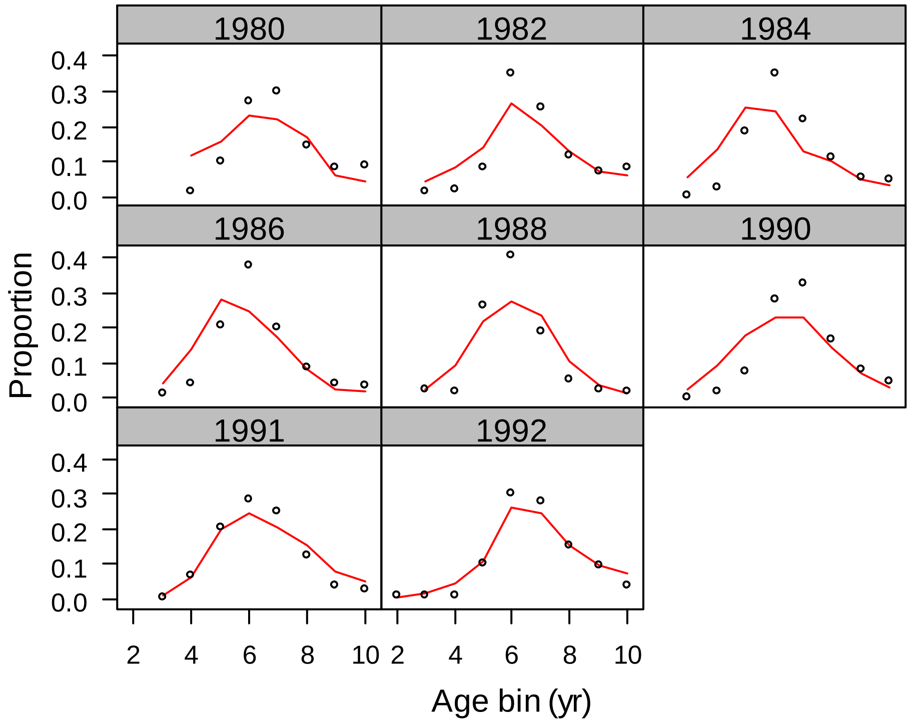


Retained –male, winter bycatch fleet

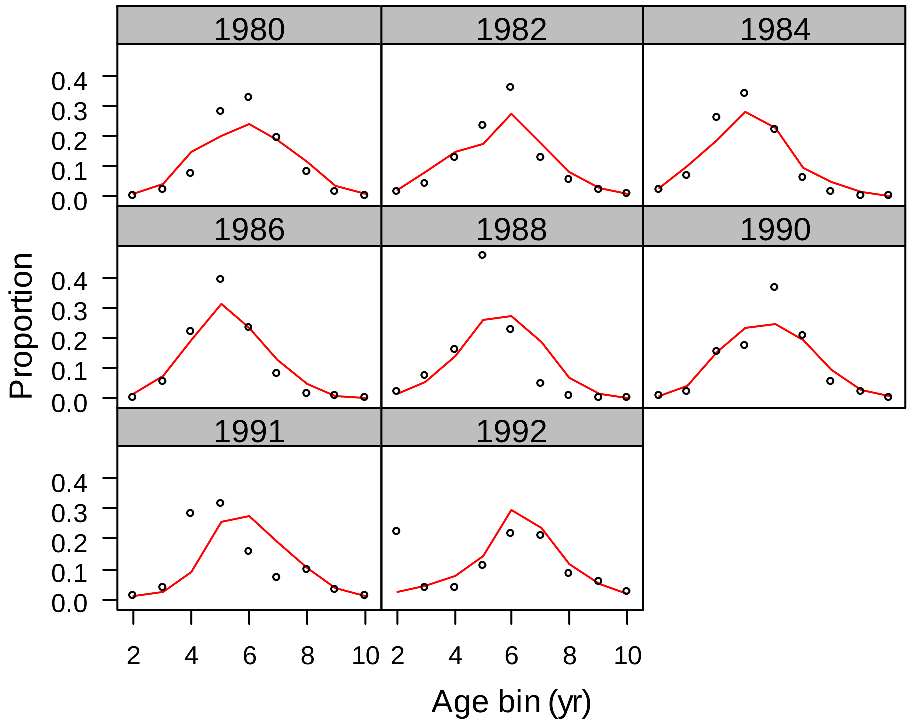


11.9 Appendix C: Fits to the age composition data

Female, winter targeted trawl



Male, winter targeted trawl



12. Eastern Gemfish (*Rexea solandri*) stock assessment based on 2007 survey data

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12.1 Summary

This document presents an assessment of eastern gemfish (*Rexea solandri*) in the SESSF including 2007, predominantly survey, data. A preliminary stock assessment for eastern gemfish was last performed using data up to December 2006 (Little *et al.*, Chpt 11). Prior to that stock assessment, the last stock assessment was performed in 2000 by Punt (2000). As in Little *et al.* (Chpt 11), the current assessment is performed using the stock assessment package SS2, which provides a standardised platform for conducting stock assessments. Catch data were incorporated from 1968, state catches were included, and length-frequency data dating back to 1975 were used. Changes from Little *et al*. (Chpt 11) include updated and, sometimes assumed, 2007 catches for the non-trawl (mainly dropline), winter targeted trawl (survey), summer trawl and winter bycatch trawl fleets. Also included were 2007 length-frequencies for the non-trawl, winter targeted and winter bycatch trawl fleets, as well as age-compositions from the winter targeted trawl fleet (the 2007 survey). A 2007 CPUE value for the winter targeted fleet was calculated and used in the assessment, and the 2006 ISMP CPUE series was used as an index for the winter bycatch trawl fleet. As in Little *et al.* (Chpt 11), changes from the 2000 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data, (c) the addition of updated length-frequencies, catches and catch-rates, (d) the inclusion of discards and (e) allowance for ageing error.

The base-case assessment estimates that current (2007/08) spawning stock biomass is 14% of the unexploited spawning stock biomass. Fits to the length, age, and catch-rate data are reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements, and the history of the fishery. Exploration of model sensitivity shows that the model outputs are sensitive to the recent (2007) CPUE trawl survey index.

12.2 Introduction

12.2.1 2.1 The Fishery

Eastern gemfish have been mainly caught by demersal board trawlers targeting the winter spawning migration in depths of about 400 m. The trawl fishery developed in the late 1960's and early 1970's, with a recorded peak catch of around 5 000 t in 1980, which has declined to less than 300 t in recent years under much reduced TACs. The target TAC for eastern gemfish has been zero for most of the past decade, and a "bycatch" fishery has operated under this reduced level of TAC. Gemfish are also caught by droplining, auto-longline and gillnet methods. The catch by NSW dropliners increased to around 100 t in the 1990s, but has been reduced under a 50 kg trip limit since 2000.

12.2.2 Stock structure

Gemfish are caught along the edge of the continental shelf of southern Australia and New Zealand. The eastern gemfish is caught from eastern Tasmania to northern NSW. Genetically distinct stocks occur to the west of Tasmania and probably also in New Zealand (Colgan and Paxton, 1997). Eastern gemfish mature at about 3-6 years of age and have been aged to 17 years. Mature fish migrate north along the NSW shelf break during winter and aggregate prior to spawning.

12.2.3 Previous Assessments

Beginning in 1988, a series of cohort analyses were initiated (Allen 1989, 1992). In 1994, several other catch-at-age methods were applied by various researchers. These are described in the annual Stock Assessment Reports prepared by SEFAG (e.g. Chesson 1995). Although the results of these analyses differ in their details, they show a similar overall pattern, namely a decline in adult biomass in the early 1980's and weak cohorts spawned in the late 1980's.

A 3,000 t TAC was introduced for eastern gemfish in 1988 in response to the decline in catch rates and mean fish size in the early 1980's. The TAC was progressively reduced to zero in 1993 based on the results of subsequent cohort analyses and apparent declines in recruitment. The TAC remained at zero for 1994, 1995 and 1996, with trip limits to allow for unavoidable bycatch.

A consensus emerged in 1996 among the modellers of eastern gemfish that the model described by Punt (1996) was the most appropriate and flexible approach for future analysis (Chesson 1996). There was also strong support for the need to gain new catch rate information from an experimental fishing survey, since the imposition of the zero TAC in 1993 had effectively ended the existing catch rate series.

An eastern gemfish workshop in April 1996 confirmed the desirability of a survey and proposed the formation of the Eastern Gemfish Assessment Group (EGAG). EGAG developed both the trawl survey and a new and more comprehensive assessment of the status of the resource, together with a preliminary evaluation of possible future harvest options. The EGAG assessment, summarised in its March 1997 report, indicated a high probability that the stock had recovered to above the reference point of 40% of the 1979 biomass[9]. The report also emphasised the variability in recruitment to the stock, and the possible benefits of a flexible approach to the setting of future TACs.

In 1997, based on the 1996 assessment report, a recommendation of a TAC of 1 200 t was made for 1997, with 1 000t allocated to the SEF trawl sector. However, trawl catches by the winter fishery during 1997 amounted to only 358 t. Analysis of

[9] Reference here to 40% should not be confused with the recent use of $0.4B_0$ as a proxy for B_{MSY}.

standardised catch rates showed a substantial reduction in CPUE from 1996 to 1997. The subsequent 1997 assessment showed the stock to be below the 40% reference point. A zero targeted TAC for 1998 was recommended, but with an allocated bycatch quota of 300 t.

Standardised CPUE from surveys in 1998 were below the peak in 1996, and subsequent re-analysis of CPUE in the 1999 assessment using GLMs (Larcombe, 1999), suggested a more pessimistic assessment of gemfish abundance. The most recent assessment was performed in 2000, which again estimated the biomass to be well below the 40% reference point.

Recently, in an effort to aid in assessing the status of the stock, a trawl survey was conducted in winter 2007 in which two vessels were awarded a tender to survey the spawning stock during the winter spawning run. The goal was to mimic the fishing practices of the winter targeted fleet, and hence extend the abundance index and associated data to 2007, for the fleet targeting the winter spawning run.

12.2.4 Modifications to the previous assessments

The current assessment differs in several ways from the 2000 assessment. In particular, it uses the package Stock Synthesis 2 (SS2) (Methot, 2005). Changes to the data on which the assessment is based have also occurred.

12.2.4.1 Data-related changes

In addition to the data included in the preliminary stock assessment (Little *et al.*, Chpt 11), this assessment also uses the data from the 2007 survey (catches, catch-rates, length-frequencies and age-compositions) and as much of the fisheries data for 2007 as possible:

a) 2007 length-frequencies from the Sydney Fish Market for the non-trawl and the winter bycatch trawl fleets, and
b) 2007 catches for the non-trawl, winter bycatch, and summer trawl fleets.

The other data sources included the assessment are:

a) two CPUE series, one derived from ISMP data, corresponding to the spawning season (June to September), and another derived from logbook data, corresponding to the non-spawning season (September to May) (Haddon, 2007),
b) CAF (Central Ageing Facility) age-composition data used to construct conditional age-at-length information (the previous 2000 assessment included age-compositions constructed from age-length keys and length-frequencies, which precluded estimating the parameters of the growth curve within the assessment),
c) the Punt *et al*. (2001) catch series B – selected by ShelfRAG as the most appropriate catch series for the winter targeted fleet,
d) an age-reading error matrix, and
e) catch, discard, length-frequency, age-at-length for each fleet.

12.2.4.2 Model-related modifications

As in Little *et al.* (Chpt 11), model specifications include:

a) four fleets (a non-trawl fleet, a fleet targeting the winter spawning run, a non-spawning (summer) season fleet, and a recent (spawning season) winter bycatch fleet); it was assumed the 2007 survey was part of the winter targeted spawning run fleet;

b) the assumption that the retention curves for the winter targeted spawning run fleet, the summer (non-spawning season) fleet and the recent spawning season bycatch trawl fleet are asymptotic, time-invariant and different among fleets;

c) estimation of the parameters of the growth curve ($L_{min,}$ and k) in the assessment, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths;. the parameter L_{max} was not estimated, but set to the 107 cm for females and 97 cm for males based on Rowling (1999); and

d) selection of input sample sizes for the length frequency data so that the effective sample sizes calculated by SS2 are equivalent to the input sample sizes.

12.3 Methods

12.3.1 The data and model inputs

The parameters estimated by the model are shown in Table 12.1, and sensitivity to a range of inputs is outlined in Table 12.2.

12.3.1.1 Biological parameters

In common with previous assessments, the current assessment is based on a two-sex model. The previous assessment of Punt (2000), however, used pre-specified values for the parameters of the von Bertalanffy growth equation for each sex. The stock assessment modelling package SS2 can, however, accept conditional age-at-length data as an input so it was possible to estimate these parameters within the model-fitting process in this assessment. This is a more appropriate approach because it better accounts for the effect of gear selectivity on the age-at-length data collected from the fishery and the effect of ageing error.

The values for natural mortality, *M*, estimated in the previous assessment, were used in the current assessment as pre-specified inputs (0.38 yr^{-1} for females and 0.57 yr^{-1} for males). Sensitivity to these values is examined by estimating them. Steepness, *h*, was estimated in the base-case model (Table 12.1).

Eastern gemfish become sexually mature at about three to five years of age, and females have an l_{inf} of about 107 cm and males 97 cm (Rowling 1999). Based on this information we modelled maturity as a logistic function of length, with 50% maturity at 70 cm and 95% maturity at 80 cm. Fecundity-at-length is assumed to be proportional to weight-at-length. The parameters of the length-weight relationship are the same as those used in previous assessments (a=1.43 x 10^{-6}, b=3.39; Rowling 1999).

12.3.1.2 Fleets

The assessment data for eastern gemfish were separated into four fleets, which represent one or more gear or temporal differences in the fishery:

a) a non-trawl fleet for which data are available since 1984;

b) a fleet targeting the winter spawning run, that operated during 1968 - 2000 (Punt *et al.*, 2001), and operated during winter 2007 in the form of a trawl survey;

c) a non-spawning season (summer) trawl fleet that has operated since 1968; and

d) a recent winter spawning season bycatch trawl fleet that has operated since 2000.

Selectivity for the non-trawl, winter targeted spawning run and recent winter spawning season bycatch trawl fleets were assumed to be asymptotic, while that for the summer trawl fleet was assumed to have a double normal form, to allow the possibility that selectivity was dome-shaped.

12.3.1.3 Landed catches

A landed catch history for eastern gemfish, separated into the four fleets, is shown in Figure 12.1 and Table 12.3. The time series for the winter targeted and summer trawl fleets for 1968 to 2000 were taken from Punt *et al.* (2001) Series B, as requested by ShelfRAG, except that these catches were reduced by the catches by the NSW dropline fleet over this period, as these catches were included in the catch time-series for the non-trawl fleet. The catches by the summer trawl fleet since 2000 were obtained from the SEF logbook database. The catches by the non-trawl fleet were set to the non-trawl NSW state catches in Punt *et al.* (2000), which agreed closely with the Fishery Assessment Report (Smith and Wayte 2003). The non-trawl catches for more recent years were obtained from the SAN database and added to the NSW catches from Koopman (2006). The catches by the winter bycatch trawl fleet were obtained from the logbook database. For the most recent year (2007), 17 t were taken by the trawl survey and assigned to the winter targeted spawning run fleet while 40 t was judged to have been taken by the winter bycatch trawl fleet in 2007. It was assumed that 15 t will be taken by the non-trawl fleet and 30 t by the summer trawl fleet in 2007.

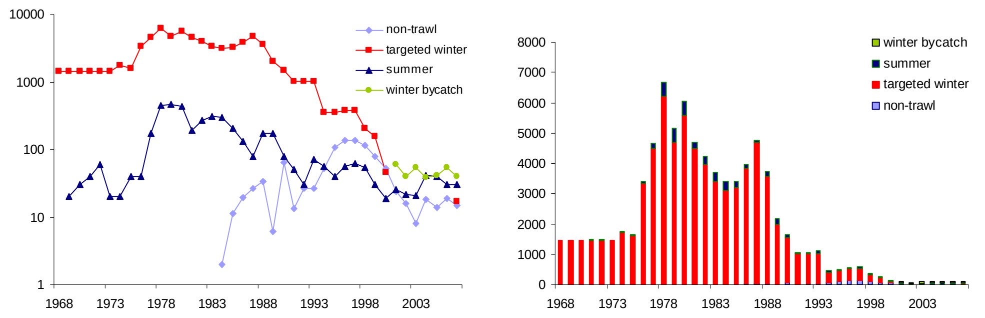


Figure 12.1. Catches of eastern gemfish by fleet (1968 – 2007) on a) log-scale and b) linear scale.

12.3.1.4 Discard rates

Information on the discard rate for eastern gemfish is available from the ISMP for 1993-2006 (it was not possible to estimate discard rates for 2007). These data are summarised in Table 12.4. Discard rates for the winter seasons prior to 2000 were assumed to have come from the winter targeted spawning run fleet. These data agree with discard rates for the winter targeted spawning run fleet used by Punt *et al.* (2001) for 1998, and 1999 of 0.065 and 0.214 respectively. Punt *et al*. (2001) incorporated discards into the catch series for the years prior to 1998, and assumed zero discard for 2000. There is less agreement between the recent estimates of discard rate for the summer trawl fleet and those used by Punt *et al.* (2001). Compared to Table 12.4, the discard rates used by Punt *et al*. (2001) for 1998, 1999 and 2000 were 0.352, 0.342 and 0.057. The summer trawl fleet discard rates were also highly inconsistent from 1992 to 1997, with two years, namely 1993 and 1996, having rates below 1%. These values were disregarded when applying the model because of the difficultly the model would have in trying to fit such low numbers.

12.3.1.5 Catch rate indices

A standardised catch rate (CPUE) index was available for three fleets: (1) the winter targeted spawning run fleet, (2) the summer trawl fleet, and (3) the winter spawning season bycatch trawl fleet (Table 12.5, Table 12.6, and Table 12.7). Punt *et al.* (2000) developed the standardised catch rate index for 1973-1998 for the targeted spawning run fleet (Table 12.5). A standardised value of 1,063 kg/day was calculated for the recent trawl survey (Appendix A, Section 12.8). Sensitivity of the model to this value is examined.

Catch and effort information from the SEF1 logbook database for the period 1986-2006 were standardised using a GLM analysis to obtain indices of relative abundance for the summer trawl fleet (Table 12.6, Haddon, 2007). The restrictions used when selecting the data for the analyses of the catch and effort data on which Table 12.6 were based were: (a) vessels had to have been in the fishery for three or more years, and (b) the catch had to be non-zero. Only data from October – May, 1986-2006 and shallower than 300 m were used to calculate the index for the summer trawl fleet. The index used for the winter bycatch trawl fleet was obtained from the ISMP data (Walker *et al.*, 2007).

12.3.1.6 Length-frequency data

Sex-disaggregated and sex-aggregated length-frequency data are available for eastern gemfish. The data, and its level of disaggregation, differ among fleets. Namely:

a) Non-trawl fleet: combined sex length-frequencies for 1993-2007 (Table 12.8)

b) Winter targeted spawning run fleet: combined sex length-frequencies for 1975-2000 (Table 12.8) and sex-specific length-frequencies for 1980-2000, (Punt 2000, Table 12.10 and Table 12.11) plus the 2007 survey data.

c) Summer trawl fleet: combined sex length-frequencies for 1975-1999 from Punt (2000) and for 2000-2006 from the ISMP database (Table 12.12).

d) Winter bycatch trawl fleet: combined sex length-frequencies for 2000-2007 from the ISMP database and NSW DPI (Table 12.13 and Table 12.14).

Onboard data collected by the ISMP were used to calculate the length-frequency of the discarded component of the catch by the summer, winter targeted and winter bycatch trawl fleets (Table 12.15, Table 12.16 and Table 12.17).

12.3.1.7 Age-composition data

Age-at-length measurements, based on otolith ageing measurements, were provided by the Central Ageing Facility (CAF). The age data for 1980-1992 were supplied to the model as proportional age-composition data (Table 12.18 and Table 12.19) while the data for the more recent years (1993-2000 and 2007) were supplied to the model in the form of conditional age-at-length data by fleet. Estimates of the age-specific standard deviation of age-reading error were calculated by André Punt using data supplied by Kyne Krusic-Golub of PIRVic (Table 12.20).

12.3.2 Stock Assessment method

12.3.2.1 Population dynamics model and parameter estimation

A two-sex stock assessment for eastern gemfish was conducted using the software package SS2 (version 2; Methot 2007). SS2 is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for eastern gemfish. The population dynamics model, and the statistical approach used in fitting the model to the various types of data, is outlined fully in the SS2 technical description (Methot, 2005) and is not reproduced here. Some key features of the base-case analysis for eastern gemfish are:

1. Eastern gemfish constitute a single stock within the area of the fishery.

2. As in the last assessment (Punt, 2000), the population is assumed to have been at its unfished (unexploited) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1968.

3. The CVs assumed for the catch rate indices for winter bycatch and summer trawl fleets were set equal to the model-estimated standard errors of these indices (Table 12.5 and Table 12.6).

4. Four fishing fleets are modelled.

5. Selectivity varies among fleets, but the selectivity pattern for each fleet, except that for the winter targeted spawning run fleet, is assumed to be time-invariant. The selectivity for this fleet is assumed to have changed in 1993 when the TAC was set to zero. SS2 models fleet- specific selectivity as a function of length. The non-trawl, the winter targeted and winter bycatch trawl fleets are assumed to have logistic selectivity, while the summer trawl fleet is assumed to have dome-shaped selectivity. The two parameters of the logistic function and the six parameters of the double normal (dome-shaped) selectivity functions are estimated within the assessment.

6. Retention is assumed to be a logistic function of length, and the inflection and slope of this function are estimated for those fleets for which discard information was available (the winter targeted spawning run, the summer trawl and the winter bycatch trawl fleets).

7. The rate of natural mortality, *M*, is assumed to be independent of age and time, and to differ between the sexes. The rate of natural mortality for the base-case analysis is 0.38 yr^{-1} and 0.56 yr^{-1} for females and males respectively (Punt 2000).

8. Recruitment is assumed to follow a Beverton-Holt stock-recruitment relationship, parameterised in terms of the average recruitment at at unfished equilibrium, R_0, and the steepness parameter, *h*. Steepness is estimated for the base-case analysis. The value of the parameter that determines the magnitude of the process error in annual recruitment, σ_r, was set equal to 0.6, so that the standard deviation of the estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_r.

9. The plus-group age was set to 20 yr. Growth of eastern gemfish is assumed to be sex-dependent and time-invariant, in that there has been no change over time in mean size-at-age, with the distribution of size-at-age being determined by the fitting of the growth curve within the assessment.

10. All sample sizes for length-frequency data greater than 200 were set to 200. This is because the appropriate sample sizes for the length-frequency data are likely to relate more to the number of shots sampled, than the number of fish measured. The length frequency data would be given too much weight relative to the other data sources had the number of fish measured been used as the effective sample sizes when fitting the model. The length-frequency and age-composition sample sizes for the fleets were also tuned so that the input sample sizes equalled the effective sample size calculated by the model.

The estimated and pre-specified parameters of the model are shown in Table 12.1.

12.3.2.2 Sensitivity tests

A number of sensitivity tests were used to explore the sensitivity of the results of the model to some of its assumptions and data inputs (Table 12.2):

1. omit, in turn, the 2007 CPUE index, the 2007 length frequency data, and the 2007 age-composition data from the model;

2. replace the 2007 survey age-composition with an age-composition derived by multiplying the 2007 length frequency data from the winter bycatch trawl by the age-length key data from the survey, and summing across length bins;

3. because the data for the latter part of the season was inconsistent with the rest, and possibly not representative of the spawning season run, we replaced the 2007 survey length frequency with a survey length frequency based only on shots from 2 - 16 July 2007

4. use 1,392 kg/day as the CPUE value for the 2007 survey (Appendix A, Section 12.8);

5. use 750 kg/day as the CPUE value for the 2007 survey (Appendix A, Section 12.8);

6. fix the parameters of the growth curve to those determined by Rowling (1999) instead of estimating them

7. estimate rather than pre-specify natural mortality, *M*

8. use an alternative catch series (catch series A of Punt *et al*. (2001))

9. double the emphasis placed on each of the data sources (catch-rates, length-frequency and age-composition)

10. halve the emphasis placed on each of the data sources (catch-rates, length-frequency and age-composition)

The results of the sensitivity tests are summarized by the following quantities:

1. SB_0 the average unexploited female spawning biomass.

2. SB_{2008} the female spawning biomass at the start of 2008

3. SB_{2008}/SB_0 the depletion level at the start of 2008, i.e. the 2008 spawning biomass expressed as a fraction of the unexploited spawning biomass.

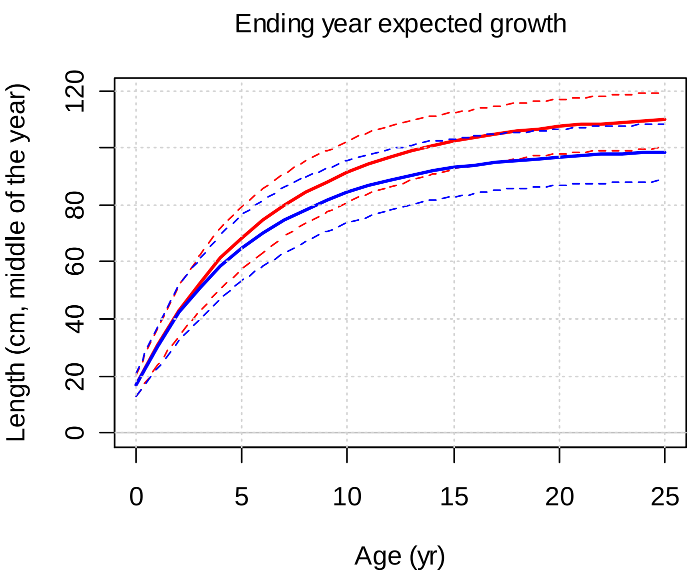
4. $-lnL$ the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data).

12.4 Results

12.4.1 The base-case analysis

12.4.1.1 Fits to the data

The estimated growth curve is shown in Figure 12.2.



Sex	Parameter	Estimated Value
Female	length at 2 years	37.51 cm
	k	0.154
Male	length at 2 years	37.21 cm
	k	0.165

Figure 12.2. Estimated growth curve for male (blue) and female (red) eastern gemfish, and the parameters of the growth curve. The dotted lines indicate approximate 95% confidence intervals for size of an individual of the age concerned.

The fits to the catch-rate indices (Figure 12.3) are reasonable, but the model is unable to fit well the CPUE indices prior to 1998 for the summer trawl fleet. The estimated selectivity and retention curves are shown in Appendix B (Section 12.9). The selectivity pattern for the winter targeted spawning run fleet after 1993 is qualitatively similar to the selectivity pattern for the winter bycatch trawl fleet. The model is unable to mimic the high discard rates, especially when the data are highly discontinuous (Figure 12.4). The fits to the discarded length-frequency data are variable (Appendix C, Section 12.10), although this is not surprising, because the observed discard length frequencies are quite variable from year to year, and sample sizes are small.

The base-case model is able to mimic the retained length-frequency data adequately (Appendix C, Section 12.10). The fits to the data for the non-trawl and winter targeted spawning run fleets are better than those to the more recent winter bycatch trawl fleet. The fits are particularly good for the winter targeted spawning run fleet, probably because the number of fish measured was generally very high for this fleet, which tends to lead to smoother observed distributions.

The fits to the age-composition data are shown in Appendix D (Section 12.11) and to the age data implied from the conditional age at length are shown in Appendix E (Section 12.12). Many of the fits are adequate. The exception to this is in the fit to the implied age distributions of female fish from the winter targeted trawl for the years 1993 and 1994, and to the implied age distributions for male fish from 1993 to 1999 (Appendix E, 12.12). The relatively fewer age data for the years after 1992 mean that poor fits are not totally unexpected. The fits to the age-composition data for the summer and winter bycatch trawl fleets are poor, but these are again cases in which sample sizes are low (Appendix E, Section 12.12).

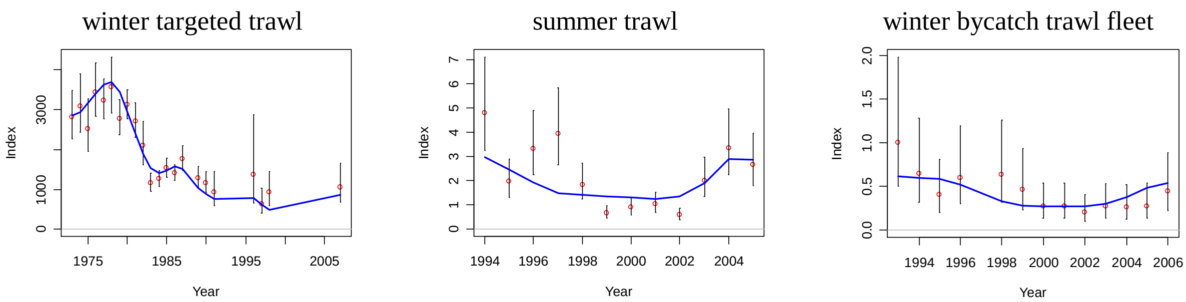


Figure 12.3. Observed (solid dots) and model-predicted (lines) catch rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

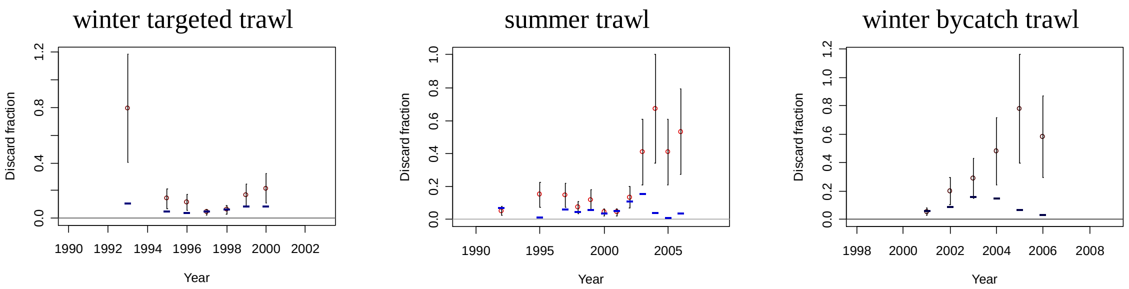


Figure 12.4. Observed (solid dots) and model-predicted (lines) discard rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

12.4.1.2 Assessment outcomes

Figure 12.5a shows the time trajectory of female spawning stock biomass from the base-case model, and Figure 12.5b shows the spawning stock depletion. The stock is estimated to have declined from the beginning of the fishery in 1968, fluctuated in abundance during the 1970's, before declining in the 1980's and 1990's, due to a period of low recruitments and high catches.

The model estimates that most of the recruitments during the last 25 years have been relatively weak. This contrasts with the 1970's when recruitment was highly variable, but higher on average (Figure 12.5c, d and e). The steepness from the stock recruitment relationship was estimated to be 0.4. The current 2007 spawning stock biomass is estimated by the base-case model to be 14 % of unexploited stock biomass.

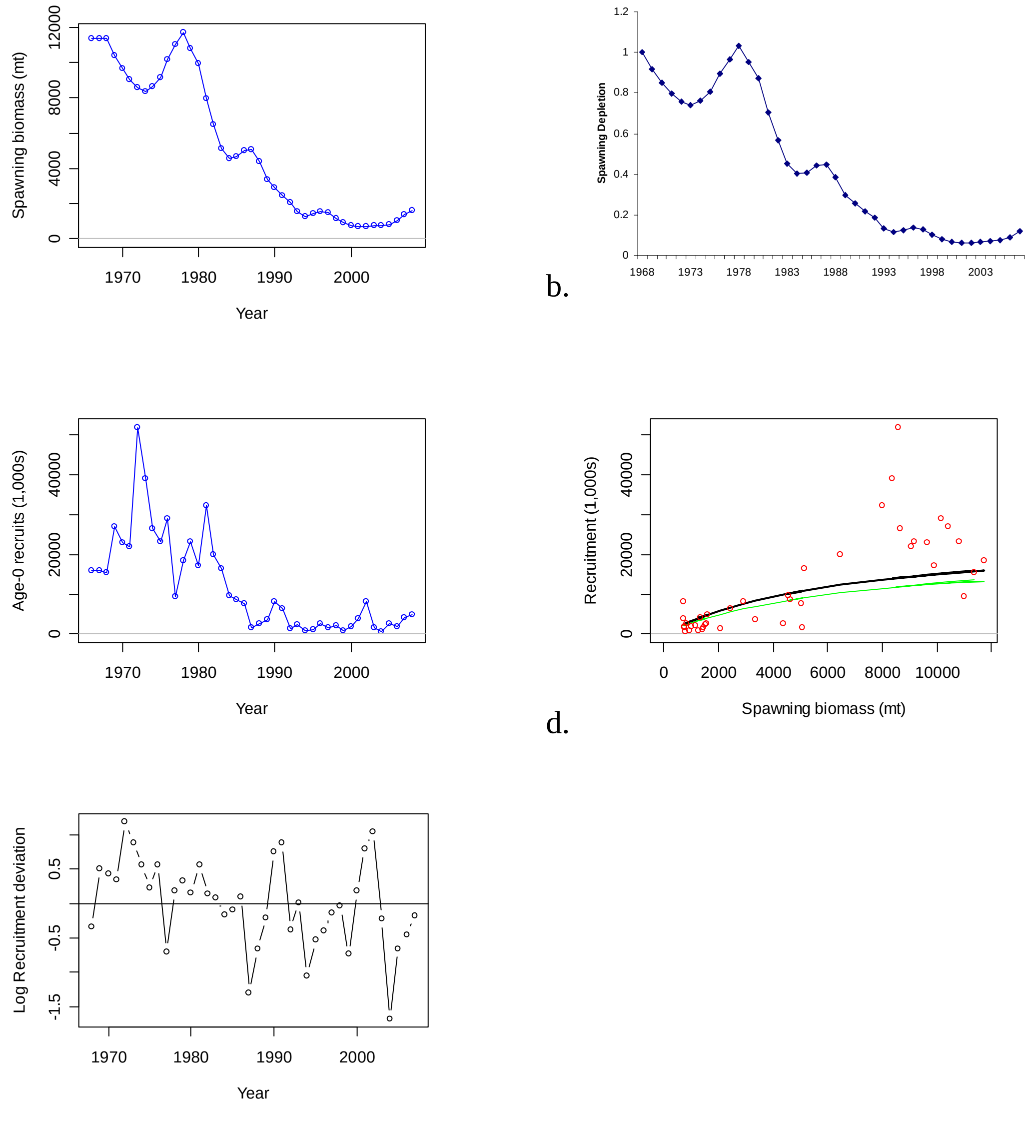


Figure 12.5. Base-case time-trajectories of (a) female spawning biomass, (b) spawning biomass depletion, (c) recruitment, (d) the stock recruitment relationship, and (e) the recruitment residuals.

12.4.2 Sensitivity tests

The results from the sensitivity analyses are shown in Table 12.2. The effect of changing the survey CPUE from 1,063 to 1,392 kg/day increased the relative spawning biomass at the start of 2008 from 14% to 23%, while decreasing it to 750 kg/day resulted in a reduction in this relative spawning biomass to 11%. Similarly, omitting the survey CPUE index gave a depletion level of about 11%, which is close to the 10% depletion level found in the base case of the preliminary assessment without the 2007 data (Little *et al*. 2007). The effect of estimating rather than pre-specifying natural mortality *M*, is to increase the relative biomass level in 2008 to 0.24 SB_0. The estimated values for *M* were, however, at the maxima specified (0.57 yr^{-1} for females and 0.93 yr^{-1} for males), and do not appear to be biologically realistic. Changing the weights assigned to the CPUE, the length and the age frequency data led to 2008 depletion levels between 11% and 22%.

12.4.3 Discussion

This document presents an assessment of eastern gemfish (*Rexea solandri*) in the SESSF using 2007 trawl survey data, and as much 2007 data as could be obtained. Some of the fleet catches had to be assumed based on recent levels and trends, as 2007 is not finished yet. This stock assessment is again based on SS2. The last full stock assessment was performed by Punt (2000). The use of SS2, has enabled some changes and technical improvements to be made, including: (a) estimation of the growth parameters within the assessment, and (b) addition of updated length frequencies, catches and catch-rates.

The base-case analysis estimated that female spawning stock biomass at the start of 2008 will be 14% of unexploited female spawning stock biomass. Depletion across all sensitivities ranged between 11% and 24%. The fits to the length, age, and catch rate data are all reasonable. RBCs (recommended biological catches) were not calculated for eastern gemfish because the stock is assessed to be below $0.2B_{0,}$ the current management arrangements, and the history of the fishery. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*, as well as the CPUE from the 2007 survey.

The estimates of initial biomass from the current and 2000 stock assessments are similar (about 12,000 t). However, the two assessments diverge in terms of current biomass. For example, the current assessment estimates the 1998 spawning biomass at under 2 000 t (Figure 12.5), while the 2000 assessment estimated this biomass to be between 2 000 and 4 000 t (Figure 12.6). The 2000 assessment also estimated a much stronger 1996 cohort (Figure 12.6) than the current assessment (Figure 12.5c).

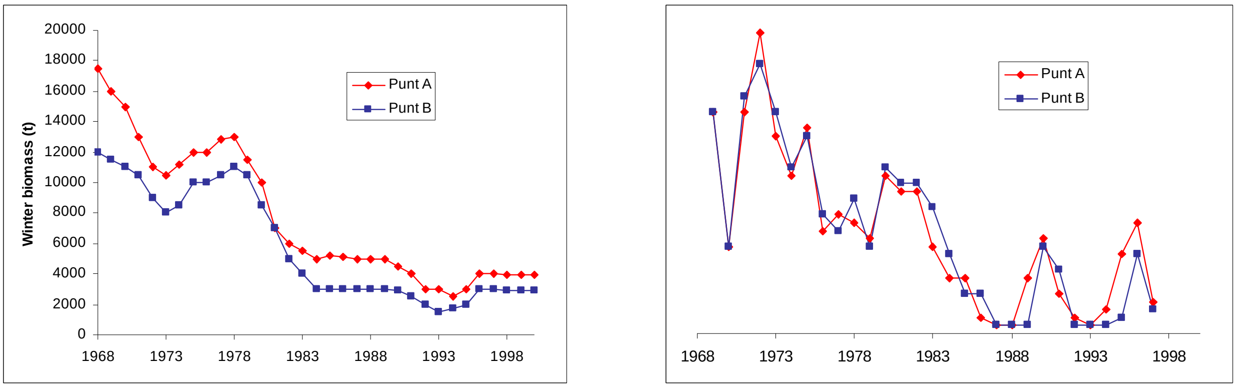


Figure 12.6. Time-trajectories of biomass (left panel) and recruitment (right panel) from Punt (2000).

One important difference in the assessment from the previous assessment in 2000 is the estimation of growth within the model. The estimated growth curve in the SS2 stock assessment framework was slightly different from that used in the 2000 stock assessment. In the current assessment however, fixing the growth parameter to those used in the 2000 assessment led to slightly lower estimates of biomass than when the growth parameters were estimated (Table 12.2).

In general, the model fit to the discard rates are rather poor. Specifically, the model had difficulty fitting to the large change in discarding experienced by the summer trawl fleet in 2003, and the steady increase in discard rate by the winter bycatch trawl fleet to levels above 50%. This poor fit is possibly due to the discard data being driven by TAC cuts or trip limits. The fit of discard rates for the summer trawl fleet for 2003 to 2005 is particularly poor given that this is when the 'strong' 2002 cohort entered the fishery and was discarded en masse.

12.4.4 Further Work

Ways that might improve future assessments of eastern gemfish include:

1. Adding the 2007 data to the assessment in its entirety.
2. Conduct retrospective analyses.
3. Resolving the poor fits to the discard rate data.
4. A 2008 spawning run survey to resolve uncertainty in the recent 2007 survey catch rates.

12.5 Acknowledgements

The other members of the SESSF stock assessment group at CMAR –Neil Klaer, Jemery Day, Sally Wayte, Geoff Tuck, Fred Pribac and Tony Smith – are thanked for their generous advice and comments during the development of this assessment. Thanks also to the providers of data for this assessment – Neil Klaer for the provision of stock assessment data in a very useful format, Malcolm Haddon (TAFI) for the calculation of the recent catch rate indices, and Kyne Krusic-Golub and Simon Robertson (PIRVic) for the provision of ageing data. Thanks to the members of Shelf Resource Assessment Group for their helpful discussions and advice during the development of this assessment.

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12.7 Tables

Table 12.1. Estimated and pre-specified parameters of the model.

Estimated parameters	Number of parameters
Unexploited recruitment	1
Steepness, *h*	1
Recruitment deviations 1968 – 2007	38
Growth	8
Selectivity	23
Retention	6
Pre-specified parameters	**Values**
Rate of natural mortality, *M* (yr^{-1})	0.38, 0.56 (F/M)
Recruitment variability , σ_r	0.6
Maturity inflection	70
Maturity slope	-0.25
Length-weight scale, *a*	1.43×10^{-6}
Length-weight power, *b*	3.39

Table 12.2. Summary of results for the base-case model and the sensitivity tests.

Model	-ln L	Female SB_0	Female SB_{2008}	SB_{2008}/SB_0
0. base-case	1 535	11 371	1 591	0.14
1. use alternative survey age composition	1 518	12 964	1 555	0.12
2. use alternative survey length frequencies	1 547	11 225	2 469	0.22
3. use 1392 kg/day as 2007 survey CPUE	1 589	11 233	2 583	0.23
4. use 750 kg/day as 2007 survey CPUE	1 541	13 523	1 487	0.11
5. omit 2007 survey CPUE index	1 546*	13 662	1 502	0.11
6. omit 2007 survey length frequencies	1 513*	13 128	1 575	0.12
7. omit 2007 survey age composition	1 521*	12 210	1 465	0.12
8. fix growth parameters	1 965*	18 622	2 420	0.13
9. estimate M	1 493*	19 435	4 664	0.24
10. use catch series A from Punt *et al*. (2001)	1 556*	10 139	1 520	0.15
11. double emphasis on CPUE	1 603*	12 768	1 532	0.12
12. double emphasis on length comps.	2 054*	11 100	2 109	0.19
13. double emphasis on age comps	2 388*	11 587	2 549	0.22
14. double emphasis on length at age comps	1 535*	11 371	1 591	0.14
15. halve emphasis on CPUE	1 493*	13 731	1 510	0.11
16. halve emphasis on length comps.	1 302*	10 880	2 176	0.20
17. halve emphasis on age comps	1 107*	13 225	1 587	0.12
18. halve emphasis on length at age comps	1 535*	11 371	1 591	0.14
* not comparable to the base case				

Table 12.3. Catches (tonnes) by fleet.

Year	Non trawl	Winter targeted	Summer trawl	Winter bycatch trawl
1968	0	1440	0	0
1969	0	1440	20	0
1970	0	1440	30	0
1971	0	1440	40	0
1972	0	1440	60	0
1973	0	1440	20	0
1974	0	1732	20	0
1975	0	1612	40	0
1976	0	3352	40	0
1977	0	4506	170	0
1978	0	6222	450	0
1979	0	4702	460	0
1980	0	5600	440	0
1981	0	4510	190	0
1982	0	3960	270	0
1983	0	3410	305	0
1984	2.00	3096	300	0
1985	11.43	3191	205	0
1986	19.58	3802	130	0
1987	26.81	4656	80	0
1988	33.04	3537	175	0
1989	6.02	1986	175	0
1990	64.08	1501	80	0
1991	13.52	1004	50	0
1992	26.02	1004	30	0
1993	26.33	1010	72	0
1994	53.00	355.5	56	0
1995	108.01	354.5	40	0
1996	134.16	384	56	0
1997	137.16	380	63	0
1998	114.1	203	55	0
1999	79.64	158	30	0
2000	52.18	46	19	0
2001	24.00	0	25.88	60.20
2002	16.00	0	21.46	39.49
2003	8.00	0	20.59	55.00
2004	18.00	0	40.60	39.10
2005	14.00	0	40.41	40.99
2006	18.98	0	30.79	54.25
2007	15	17	30	40

Table 12.4. Discard rates

Fleet	Year	Discard Rate	CV
Summer Trawl	1992	0.05	0.25
	1993	0.002*	0.25
	1995	0.15	0.25
	1996	0.007*	0.25
	1997	0.15	0.25
	1998	0.07	0.25
	1999	0.12	0.25
	2000	0.04	0.25
	2001	0.04	0.25
	2002	0.13	0.25
	2003	0.41	0.25
	2004	0.67	0.25
	2005	0.41	0.25
	2006	0.53	0.25
Winter Targeted Trawl	1993	0.79	0.25
	1995	0.14	0.25
	1996	0.12	0.25
	1997	0.05	0.25
	1998	0.06	0.25
	1999	0.17	0.25
	2000	0.22	0.25
Winter bycatch trawl	2001	0.05	0.25
	2002	0.20	0.25
	2003	0.29	0.25
	2004	0.48	0.25
	2005	0.78	0.25

* omitted from analysis

Table 12.5. Standardised landed catch rates for the winter targeted trawl fleet.

Year	Catch Rate	CV
1973	2811	0.11
1974	3082	0.12
1975	2533	0.13
1976	3440	0.1
1977	3237	0.08
1978	3562	0.1
1979	2780	0.08
1980	3127	0.06
1981	2717	0.08
1982	2100	0.13
1983	1163	0.1
1984	1259	0.08
1985	1537	0.08
1986	1414	0.07
1987	1766	0.09
1989	1294	0.1
1990	1165	0.11
1991	930	0.23
1996	1371	0.38
1997	643	0.24
1998	926	0.23
2007	1063	0.23

Table 12.6. Standardised landed catch rates for the summer trawl fleet.

Year	Catch rate	CV
1986	1	0.35
1987	1.8	0.35
1988	1.06	0.35
1989	0.55	0.35
1990	0.57	0.35
1991	0.61	0.35
1992	0.82	0.35
1993	0.59	0.35
1994	0.41	0.35
1995	0.37	0.35
1996	0.28	0.35
1997	0.28	0.35
1998	0.3	0.35
1999	0.22	0.35
2000	0.18	0.35
2001	0.14	0.35
2002	0.11	0.35
2003	0.11	0.35
2004	0.16	0.35
2005	0.19	0.35
2006	0.17	0.35

Table 12.7. ISMP catch rates for the winter bycatch trawl fleet.

Year	Catch rate	CV
1994	4.81	0.20
1995	1.96	0.20
1996	3.31	0.20
1998	3.94	0.20
1999	1.85	0.20
2000	0.66	0.20
2001	0.90	0.20
2002	1.03	0.20
2003	0.60	0.20
2004	2.01	0.20
2005	3.35	0.20
2006	2.68	0.20

Table 12.8. Length-frequency data for the non-trawl fleet

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2004	2005	2006	2007
10	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0.01	0	0	0
45	0.02	0.01	0	0	0.01	0	0.03	0.02	0.01	0.05	0.04	0.02	0.01
50	0.16	0.06	0.02	0.04	0.04	0.01	0.2	0.14	0.08	0.06	0.2	0.16	0.06
55	0.39	0.19	0.13	0.04	0.07	0.05	0.16	0.22	0.11	0.12	0.22	0.39	0.19
60	0.21	0.26	0.27	0.08	0.13	0.11	0.17	0.24	0.23	0.19	0.16	0.21	0.26
65	0.09	0.18	0.27	0.1	0.1	0.11	0.12	0.16	0.22	0.18	0.16	0.09	0.18
70	0.08	0.11	0.16	0.13	0.12	0.11	0.1	0.08	0.18	0.14	0.11	0.08	0.11
75	0.02	0.05	0.09	0.18	0.18	0.19	0.08	0.06	0.09	0.11	0.05	0.02	0.05
80	0.01	0.03	0.02	0.17	0.18	0.18	0.07	0.05	0.04	0.08	0.04	0.01	0.03
85	0	0.04	0.01	0.1	0.09	0.14	0.03	0.02	0.02	0.03	0.02	0	0.04
90	0	0.03	0.01	0.05	0.04	0.07	0.01	0.01	0	0.02	0	0	0.03
95	0	0.02	0	0.06	0.01	0.01	0	0	0	0.01	0	0	0.02
100	0	0	0	0.04	0.01	0.01	0	0	0	0.01	0	0	0
105	0	0	0	0.01	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 12.9. Combined sex, retained, length-frequency data for the winter targeted spawning run fleet

length	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0.01	0	0.01	0
40	0	0	0	0	0	0	0	0.01	0.01	0.01	0
45	0	0	0	0	0	0	0.03	0.01	0.01	0.02	0.02
50	0.02	0.01	0.01	0	0	0.01	0.03	0.02	0.02	0.04	0.04
55	0.06	0.01	0.01	0	0.01	0.01	0.01	0.03	0.01	0.06	0.05
60	0.14	0.02	0.03	0.01	0.02	0.03	0.04	0.04	0.08	0.09	0.12
65	0.05	0.09	0.12	0.08	0.07	0.11	0.12	0.11	0.19	0.18	0.21
70	0.17	0.14	0.23	0.27	0.26	0.22	0.24	0.22	0.24	0.21	0.22
75	0.27	0.27	0.24	0.27	0.32	0.26	0.23	0.24	0.2	0.18	0.16
80	0.13	0.25	0.18	0.17	0.19	0.2	0.16	0.15	0.14	0.11	0.09
85	0.07	0.11	0.1	0.1	0.08	0.1	0.08	0.09	0.06	0.06	0.05
90	0.04	0.06	0.04	0.05	0.03	0.04	0.04	0.04	0.03	0.03	0.02
95	0.03	0.03	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01
100	0.01	0.02	0.01	0.01	0	0.01	0.01	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

length	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0.01	0	0	0.02	0.02
40	0	0	0.01	0	0	0	0.09	0.11	0.04	0.25	0.14
45	0.02	0	0.01	0.01	0	0	0.02	0.12	0.09	0.12	0.05
50	0.04	0.02	0.04	0.02	0.01	0.01	0.01	0.15	0.23	0.04	0.07
55	0.06	0.06	0.05	0.02	0.04	0.02	0.01	0.03	0.18	0.1	0.05
60	0.11	0.15	0.15	0.06	0.06	0.04	0.02	0.02	0.09	0.12	0.04
65	0.19	0.23	0.26	0.19	0.12	0.1	0.03	0.03	0.04	0.12	0.09
70	0.24	0.23	0.24	0.3	0.21	0.19	0.09	0.05	0.02	0.1	0.18
75	0.17	0.16	0.14	0.21	0.24	0.22	0.2	0.09	0.03	0.05	0.19
80	0.09	0.08	0.06	0.1	0.18	0.22	0.23	0.14	0.07	0.03	0.11
85	0.04	0.04	0.02	0.05	0.08	0.11	0.16	0.13	0.08	0.02	0.04
90	0.02	0.01	0.01	0.02	0.04	0.06	0.08	0.08	0.07	0.02	0.01
95	0.01	0.01	0	0.01	0.01	0.02	0.03	0.03	0.04	0.02	0.01
100	0	0	0	0	0.01	0	0.01	0.01	0.01	0.01	0.01
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

(Table 12.9 Continued)

length	1997	1998	1999	2000
10	0	0	0	0
15	0	0	0	0
20	0	0	0	0
25	0	0	0	0
30	0	0	0	0
35	0	0.04	0.02	0.16
40	0.01	0.09	0.11	0.36
45	0.01	0.03	0.15	0.06
50	0.04	0.04	0.12	0.11
55	0.03	0.02	0.04	0.09
60	0.05	0.03	0.04	0.06
65	0.08	0.04	0.06	0.03
70	0.19	0.1	0.09	0.04
75	0.27	0.18	0.13	0.04
80	0.21	0.21	0.12	0.03
85	0.08	0.14	0.07	0.02
90	0.02	0.05	0.03	0.01
95	0.01	0.01	0.01	0
100	0	0	0	0
105	0	0	0	0
110	0	0	0	0
115	0	0	0	0
120	0	0	0	0

Table 12.10. Female, retained, length-frequency data for the winter targeted spawning run fleet

length	1980	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
10	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0.03	0.02
45	0	0	0	0	0	0	0	0	0	0	0	0.02	0.01
50	0	0.01	0	0	0.01	0.02	0.01	0.01	0	0	0.01	0	0.01
55	0	0.01	0	0	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
60	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.03	0.01	0.02	0.01	0	0
65	0.04	0.03	0.08	0.07	0.12	0.08	0.12	0.17	0.07	0.04	0.02	0.01	0.01
70	0.14	0.14	0.22	0.23	0.24	0.29	0.28	0.32	0.32	0.13	0.11	0.04	0.02
75	0.28	0.32	0.27	0.28	0.25	0.27	0.26	0.26	0.29	0.3	0.24	0.2	0.05
80	0.26	0.23	0.22	0.19	0.17	0.16	0.14	0.11	0.16	0.27	0.3	0.3	0.17
85	0.15	0.14	0.11	0.11	0.1	0.07	0.07	0.05	0.09	0.13	0.17	0.22	0.31
90	0.07	0.07	0.05	0.05	0.04	0.04	0.03	0.02	0.04	0.06	0.09	0.12	0.23
95	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.04	0.05	0.11
100	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01	0.04
105	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0

(Table 12.10 Continued)

length	1994	1995	1996	1997	1998	1999	2000	2007
10	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
35	0	0.01	0	0	0	0	0.01	0.001
40	0.07	0.2	0	0.01	0	0.03	0.16	0.04
45	0.02	0.14	0	0	0	0.01	0.04	0.02
50	0.16	0.02	0.03	0.01	0.01	0.05	0.04	0.03
55	0.03	0.05	0.02	0.01	0.02	0.04	0.06	0.03
60	0.06	0.08	0.01	0	0.01	0.02	0.11	0.05
65	0.05	0.11	0.03	0.01	0.01	0.02	0.07	0.21
70	0.02	0.12	0.14	0.05	0.03	0.12	0.1	0.38
75	0.03	0.09	0.32	0.23	0.1	0.23	0.17	0.17
80	0.09	0.04	0.28	0.33	0.29	0.26	0.12	0.04
85	0.16	0.02	0.09	0.24	0.31	0.13	0.05	0.02
90	0.18	0.04	0.02	0.07	0.17	0.06	0.04	0.01
95	0.11	0.04	0.02	0.02	0.04	0.02	0.02	0.003
100	0.02	0.01	0.01	0.02	0.01	0	0	0.002
105	0	0	0	0	0	0	0	0.001
110	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0

Table 12.11. Male, retained, length-frequency data for the winter targeted spawning run fleet

length	1980	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
10	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0.03	0.01	0.02	0	0	0	0	0	0	0	0.02
40	0	0.01	0.01	0.01	0	0	0.01	0.02	0	0	0.01	0.21
45	0	0.02	0.03	0.03	0.04	0.03	0.01	0.01	0.02	0	0	0.03
50	0.02	0.04	0.04	0.09	0.08	0.06	0.03	0.07	0.05	0.02	0.02	0.02
55	0.01	0.05	0.02	0.12	0.09	0.12	0.1	0.07	0.03	0.08	0.04	0.02
60	0.06	0.08	0.17	0.16	0.21	0.21	0.26	0.26	0.13	0.12	0.09	0.06
65	0.18	0.2	0.32	0.29	0.3	0.32	0.34	0.34	0.36	0.22	0.24	0.1
70	0.32	0.32	0.25	0.19	0.19	0.19	0.19	0.18	0.28	0.31	0.31	0.21
75	0.25	0.16	0.11	0.07	0.07	0.05	0.06	0.04	0.1	0.16	0.18	0.22
80	0.12	0.07	0.04	0.02	0.02	0.02	0.01	0.01	0.02	0.06	0.09	0.08
85	0.03	0.02	0.01	0	0	0	0	0	0.01	0.01	0.02	0.03
90	0	0	0	0	0	0	0	0	0	0	0.01	0
95	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0

(Table 12.11 Continued)

length	1993	1994	1995	1996	1997	1998	1999	2000	2007
10	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0.02	0	0	0
35	0	0	0.03	0.01	0.01	0.04	0.01	0.05	0.01
40	0.07	0.02	0.29	0.03	0.04	0.22	0.05	0.19	0.05
45	0.09	0.13	0.09	0.02	0.01	0.1	0.07	0.06	0.06
50	0.18	0.27	0.06	0.05	0.04	0.02	0.07	0.14	0.26
55	0.05	0.26	0.13	0.05	0.02	0.02	0.05	0.18	0.23
60	0.05	0.11	0.15	0.08	0.03	0.02	0.07	0.09	0.21
65	0.07	0.04	0.13	0.19	0.06	0.03	0.12	0.1	0.15
70	0.11	0.03	0.07	0.31	0.25	0.09	0.16	0.08	0.03
75	0.18	0.04	0.02	0.18	0.32	0.16	0.22	0.06	0.01
80	0.15	0.06	0.01	0.05	0.16	0.2	0.13	0.02	0
85	0.05	0.04	0.01	0.02	0.03	0.07	0.04	0.02	0
90	0.01	0.01	0	0.01	0.03	0.01	0.01	0	0
95	0.01	0	0	0	0	0	0	0	0
100	0	0	0	0	0.01	0	0	0	0
105	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0

Table 12.12. Combined sex, retained, length-frequency data for the summer trawl fleet

length	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0
30	0	0.11	0.11	0	0	0.01	0.01	0.13	0.2	0.06	0.17
35	0.04	0	0.1	0.02	0.03	0.05	0.06	0.12	0.1	0.15	0.01
40	0.09	0.08	0.11	0.14	0.03	0.14	0.23	0.02	0.29	0.16	0.24
45	0.32	0.33	0.13	0.21	0.1	0.22	0.24	0.11	0.16	0.28	0.23
50	0.34	0.09	0.06	0.06	0.27	0.12	0.11	0.33	0.06	0.21	0.2
55	0.16	0.17	0.05	0.1	0.26	0.11	0.1	0.17	0.07	0.09	0.09
60	0.03	0.14	0.06	0.1	0.06	0.15	0.06	0.03	0.07	0.02	0.04
65	0.01	0.05	0.15	0.08	0.04	0.08	0.06	0.03	0.03	0.01	0.01
70	0.01	0	0.13	0.12	0.05	0.04	0.05	0.02	0.01	0	0
75	0.01	0.01	0.05	0.1	0.07	0.03	0.04	0.02	0.01	0	0.01
80	0	0.01	0.03	0.05	0.05	0.03	0.02	0.01	0	0	0
85	0	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0	0	0
90	0	0	0.01	0.01	0.01	0.01	0	0	0	0	0
95	0	0	0.01	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

(Table 12.12 Continued)

length	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
30	0	0.29	0	0	0	0	0.47	0.11	0.03	0.07
35	0.03	0	0.19	0.01	0	0	0.24	0.23	0.12	0.13
40	0.24	0.02	0.31	0.16	0.13	0	0.06	0.28	0.2	0.16
45	0.48	0.04	0.26	0.45	0.47	0.33	0.14	0.3	0.26	0.17
50	0.11	0.04	0.12	0.13	0.22	0.07	0.01	0.06	0.17	0.18
55	0.04	0.1	0.05	0.08	0.17	0.3	0.07	0	0.11	0.15
60	0.03	0.16	0.03	0.05	0.02	0.3	0.01	0	0.03	0.08
65	0.02	0.14	0.01	0.05	0	0	0	0	0.01	0.04
70	0.02	0.11	0.01	0.04	0	0	0	0	0.01	0.01
75	0.02	0.06	0	0.02	0	0	0	0	0.01	0.01
80	0.01	0.02	0.01	0.01	0	0	0	0.01	0.02	0
85	0	0.01	0.01	0	0	0	0	0	0.02	0
90	0	0	0	0	0	0	0	0	0.01	0
95	0	0	0	0	0	0	0	0	0.01	0
100	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0

length	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0.01	0.01	0.03	0	0	0
30	0.03	0.02	0.18	0	0.09	0.08	0.06	0.31	0	0.01	0
35	0.28	0.28	0.41	0.04	0.14	0.11	0.32	0.22	0.13	0.4	0
40	0.07	0.18	0.13	0.32	0.38	0.12	0.28	0.13	0.47	0.12	0.08
45	0.05	0.15	0.15	0.54	0.31	0.35	0.22	0.25	0.35	0.2	0.24
50	0.07	0.14	0.06	0.09	0.03	0.2	0.07	0.06	0.04	0.21	0.3
55	0.04	0.04	0.03	0.01	0.02	0.03	0.03	0	0.01	0.04	0.17
60	0.04	0.01	0.01	0	0	0.04	0.01	0	0	0.01	0.13
65	0.1	0.02	0.01	0	0	0.03	0	0	0	0	0.07
70	0.11	0.04	0.01	0	0	0.01	0	0	0.01	0	0
75	0.09	0.05	0	0	0	0.01	0	0	0	0	0
80	0.05	0.04	0.01	0	0	0	0	0	0	0	0
85	0.01	0.01	0	0	0	0	0	0	0	0	0
90	0.02	0	0	0	0	0	0	0	0	0	0
95	0.02	0	0	0	0	0	0	0	0	0	0
100	0.01	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0

Table 12.13. Female, retained, length-frequency data for the winter bycatch trawl fleet

length	2000	2001	2002	2003	2004	2005	2006	2007
10	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
35	0.01	0	0	0	0.03	0.01	0	0
40	0.16	0	0.12	0.07	0.38	0.03	0	0
45	0.04	0	0.08	0.02	0.17	0.06	0	0
50	0.04	0	0.01	0.08	0.06	0.27	0.02	0.12
55	0.06	0.02	0.04	0.08	0.11	0.14	0.04	0.12
60	0.11	0.04	0.1	0.06	0.05	0.04	0.14	0.33
65	0.07	0.28	0.08	0.16	0.04	0.1	0.27	0.35
70	0.1	0.34	0.15	0.27	0.06	0.11	0.21	0.06
75	0.17	0.17	0.2	0.14	0.04	0.1	0.16	0.02
80	0.12	0.06	0.13	0.08	0.03	0.08	0.08	0
85	0.05	0.04	0.06	0.02	0.02	0.03	0.05	0
90	0.04	0.04	0.01	0	0.01	0.03	0.02	0
95	0.02	0	0.01	0	0	0	0.01	0
100	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0
120	0	0	0	0	0			0

Table 12.14. Male, retained, length-frequency data for the winter bycatch trawl fleet

length	2000	2001	2002	2003	2004	2005	2006	2007
10	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
35	0.05	0	0.03	0.07	0.2	0.02	0.05	0
40	0.19	0	0.21	0.09	0.43	0.05	0.19	0
45	0.06	0.07	0.07	0.2	0.14	0.47	0.06	0
50	0.14	0.07	0.21	0.2	0.14	0.26	0.14	0
55	0.18	0.14	0.28	0.1	0.04	0.08	0.18	0.01
60	0.09	0.24	0.08	0.14	0.02	0.06	0.09	0.07
65	0.1	0.38	0.04	0.12	0.01	0.02	0.1	0.26
70	0.08	0.03	0.04	0.06	0.01	0.02	0.08	0.43
75	0.06	0	0.04	0.01	0.01	0.01	0.06	0.16
80	0.02	0.07	0	0	0.01	0.01	0.02	0.04
85	0.02	0	0.01	0	0	0	0.02	0.01
90	0	0	0	0	0	0	0	0.01
95	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0

Table 12.15. Discarded length-frequency data (combined sex) for the summer trawl fleet

length	2000	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0	0
15	0.09	0	0	0	0.01	0	0
20	0.9	0.04	0.03	0.32	0.04	0.59	0.26
25	0	0.26	0.04	0.32	0.06	0.04	0.1
30	0	0.63	0.78	0.3	0.22	0.16	0.32
35	0.01	0.07	0.15	0.06	0.5	0.14	0.21
40	0	0	0	0	0.16	0.04	0.08
45	0	0	0	0	0.01	0.02	0.02
50	0	0	0	0	0	0	0.01
55	0	0	0	0	0	0.01	0
60	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0

Table 12.16. Discarded length-frequency data (combined sex) for the winter targeted trawl fleet

length	1998	1999	2000	2007
10	0	0	0	0
15	0	0	0	0
20	0.01	0.16	0	0.36
25	0.75	0.51	0.09	0.55
30	0.07	0.32	0.03	0
35	0.01	0	0.19	0.02
40	0.12	0	0.64	0.06
45	0.02	0	0.04	0
50	0.01	0	0.01	0
55	0.01	0	0	0
60	0	0	0	0
65	0	0	0	0
70	0	0	0	0
75	0	0	0	0
80	0	0	0	0
85	0	0	0	0
90	0	0	0	0
95	0	0	0	0
100	0	0	0	0
105	0	0	0	0
110	0	0	0	0
115	0	0	0	0
120	0	0	0	0

Table 12.17. Discarded length-frequency data (combined sex) for the winter bycatch trawl fleet

length	2001	2002	2003	2004	2005	2006
10	0	0	0	0	0	0
15	0	0	0	0	0	0
20	0.09	0.01	0.08	0.02	0.03	0.44
25	0.6	0.58	0.64	0.01	0.04	0.52
30	0.16	0.4	0.21	0	0	0
35	0.01	0	0	0.17	0.07	0.01
40	0.1	0.01	0.01	0.67	0.63	0.02
45	0.03	0.01	0.01	0.1	0.19	0
50	0.01	0	0.02	0.01	0.03	0
55	0	0	0.01	0	0.01	0
60	0	0	0.01	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0
75	0	0	0	0	0	0
80	0	0	0	0	0	0
85	0	0	0	0	0	0
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0
105	0	0	0	0	0	0
110	0	0	0	0	0	0
115	0	0	0	0	0	0
120	0	0	0	0	0	0

Table 12.18. Male age-composition data of winter targeted trawl fleet

age	1980	1982	1984	1986	1988	1990	1991	1992
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0.02	0.02	0	0.02	0.01	0.01	0.22
3	0.02	0.04	0.07	0.06	0.07	0.02	0.04	0.04
4	0.07	0.13	0.26	0.22	0.16	0.16	0.28	0.04
5	0.28	0.24	0.34	0.39	0.47	0.17	0.31	0.11
6	0.33	0.36	0.22	0.23	0.22	0.36	0.15	0.22
7	0.19	0.13	0.06	0.08	0.05	0.21	0.07	0.21
8	0.08	0.06	0.02	0.01	0	0.05	0.09	0.08
9	0.02	0.02	0	0.01	0	0.02	0.03	0.05
10	0	0.01	0	0	0	0	0.01	0.02
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0

Table 12.19. Female age-composition data of winter targeted trawl fleet

age	1980	1982	1984	1986	1988	1990	1991	1992
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0.01
3	0	0.01	0	0.01	0.02	0	0.01	0.01
4	0.01	0.02	0.03	0.04	0.02	0.02	0.07	0.01
5	0.1	0.09	0.19	0.21	0.26	0.07	0.21	0.1
6	0.27	0.35	0.35	0.38	0.41	0.28	0.28	0.3
7	0.3	0.25	0.22	0.2	0.19	0.33	0.25	0.28
8	0.15	0.12	0.11	0.09	0.06	0.17	0.13	0.15
9	0.08	0.07	0.06	0.04	0.02	0.08	0.04	0.09
10	0.09	0.08	0.05	0.03	0.02	0.05	0.03	0.04
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0

Table 12.20. Aging error standard deviations.

age	st. dev.
0	0.046248
1	0.046248
2	0.393378
3	0.521081
4	0.568061
5	0.585344
6	0.591702
7	0.594041
8	0.594902
9	0.595218
10	0.595335
11	0.595335
12	0.595335
13	0.595335
14	0.595335
15	0.595335
16	0.595335
17	0.595335
18	0.595335
19	0.595335
20	0.595335
21	0.595335
22	0.595335
23	0.595335
24	0.595335
25	0.595335

12.8 Appendix A: Calculation of 2007 CPUE survey value

The 2007 CPUE survey value was calculated as follows.

The 6 day catch rate for the Shoalhaven (1 July to 16 July) was calculated as 1,280 kg per day. This value was considered by Shelf RAG to equate to the standardised catch rate for the Shoalhaven, as there was considered to be similarities between the Shoalhaven and the vessel previously used as the standard boat for the fleet. The standardised CPUE becomes 1,013 kg/standard day if the 8 day period (1 July to 23 July) is used.

The Giuseppa 6 day catch rate (8 July to 27 July) was calculated as 1,504 kg per day. Comparison with the 'standard' boat produces a Relative Fishing Power estimate for the Giuseppa of 1.78, which leads to a standardised CPUE of 845 kg/standard day. (Note this estimate includes large catches taken off Sydney grounds in the last week of July.)

The two values could be combined into a single standardised CPUE (in the absence of the 'modelling' method previously employed) in two ways:

1. Simple average: 1,063 kg/standard day.

2. Total Catch / Total Standard Days for both boats: (7,682 + 9,025) / (6 + 10.7) = 16,707 / 16.7 = 1,000.4 kg/std day.

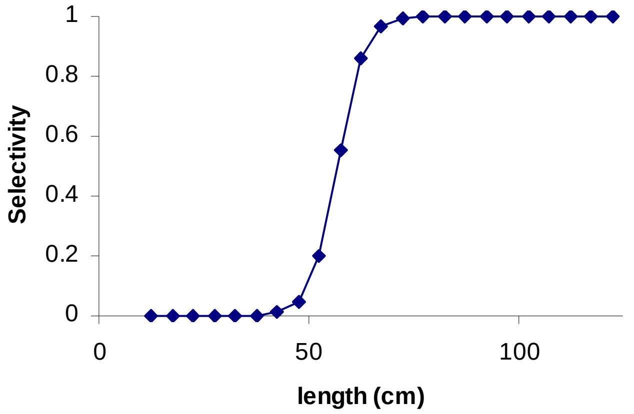
There is little difference between these two values, and for expediency we chose to use the higher of the values.

Sensitivities to this value can be explored by assuming the average standardised CPUE for Giuseppa and the value obtained using an RFP = 1.95 for Shoalhaven (based on the standardised catch rate of the same vessel before the name change to Shoalhaven) which gives (845+656)/2 = 750 kg/standard day.

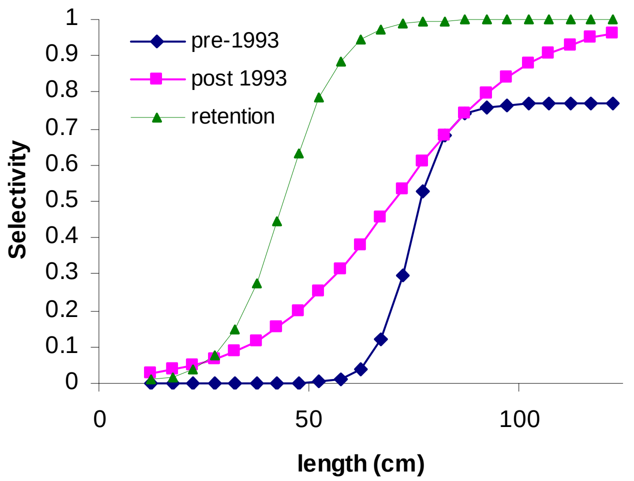
Alternatively, as an upper bound for the survey CPUE an average of the raw (unstandardised) catch rates for Giuseppa and Shoalhaven (no standardisations) would give (1504+1280)/2 = 1,392 kg per day.

12.9 Appendix B: Fleet selectivities

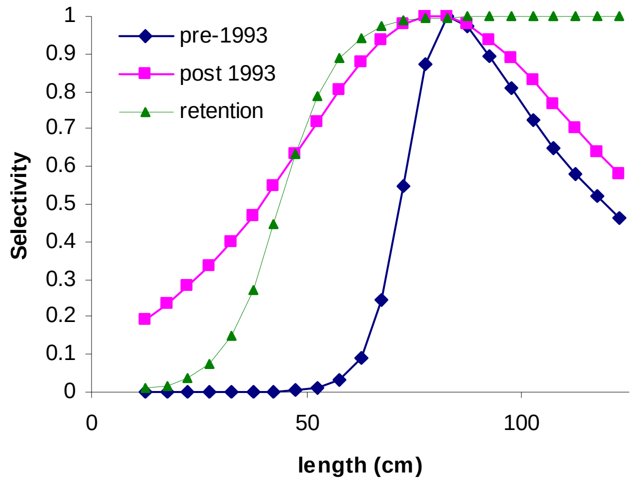
Non-trawl selectivity



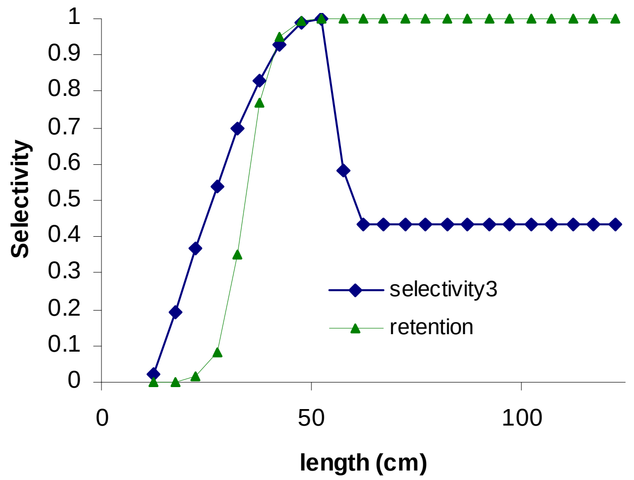
Female, winter targeted fleet



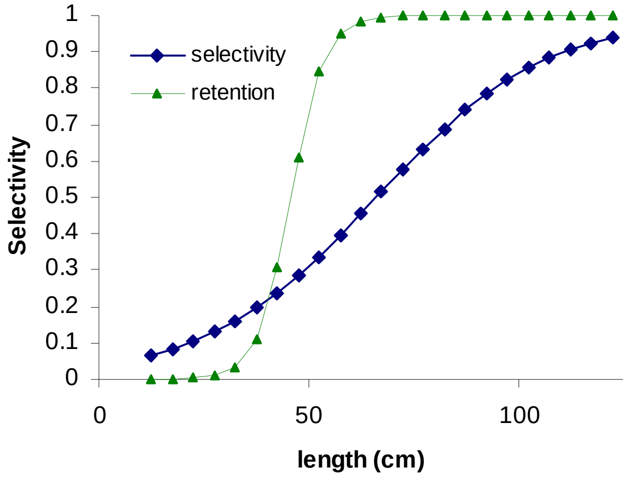
Male, winter targeted fleet



Summer trawl fleet

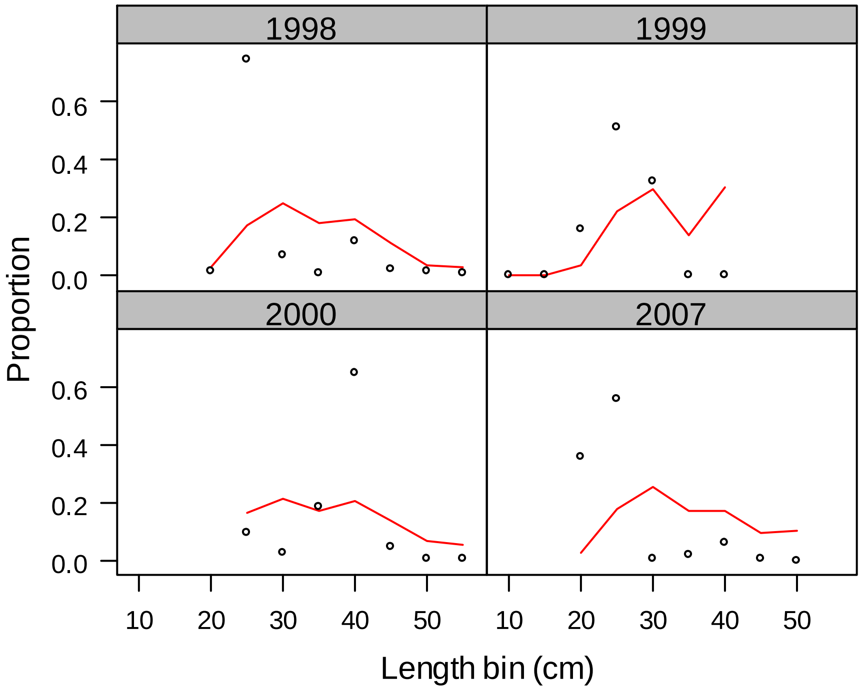


winter bycatch trawl fleet

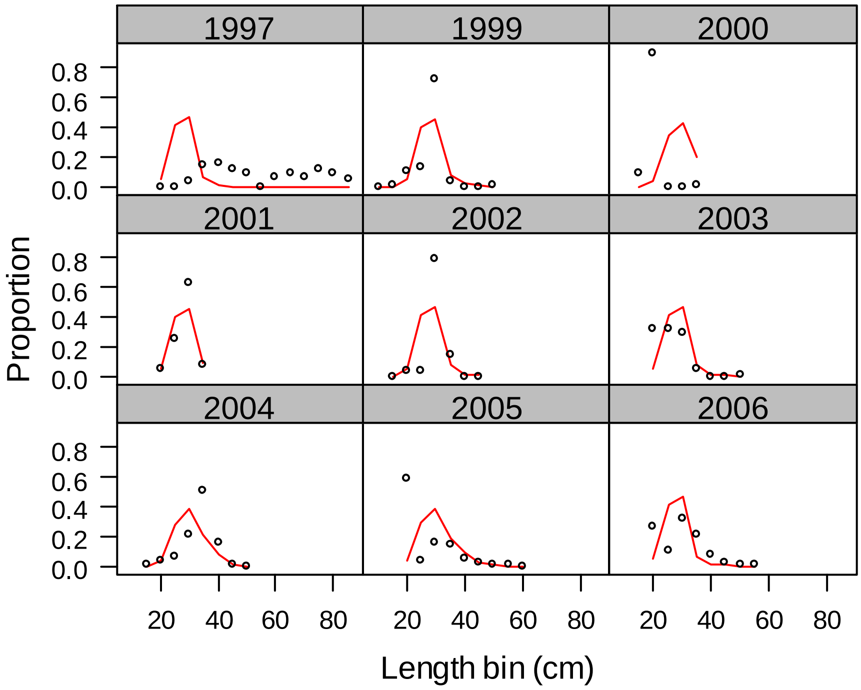


12.10 Appendix C: fits to the length-FREQUENCY data

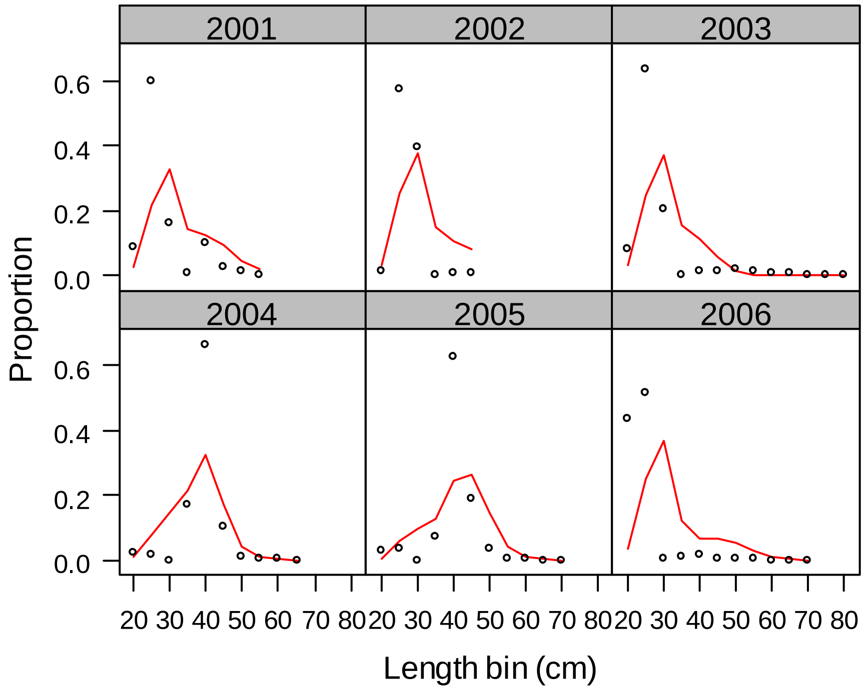
Discarded – combined sex, winter targeted trawl fleet



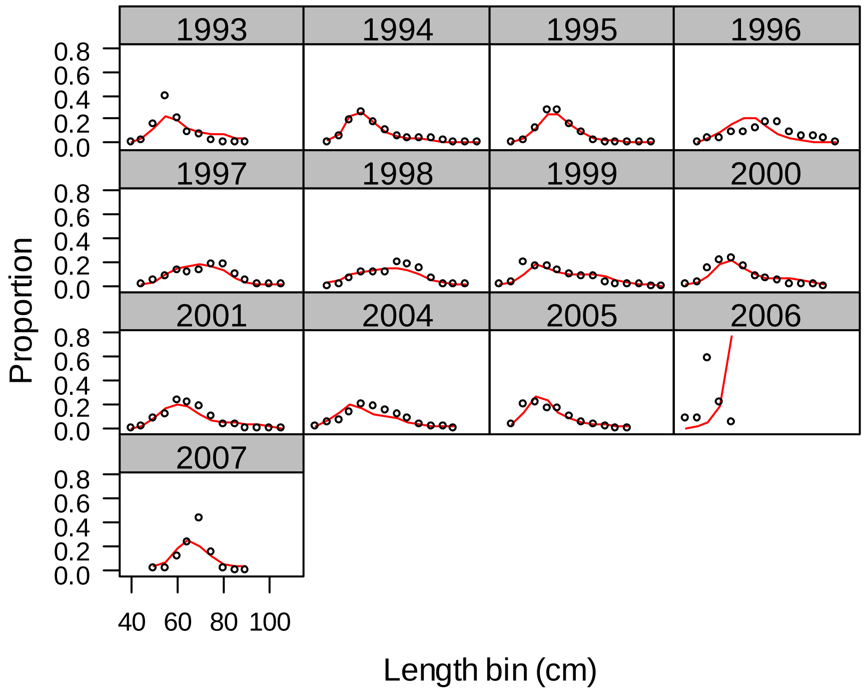
Discarded – combined sex, summer trawl fleet



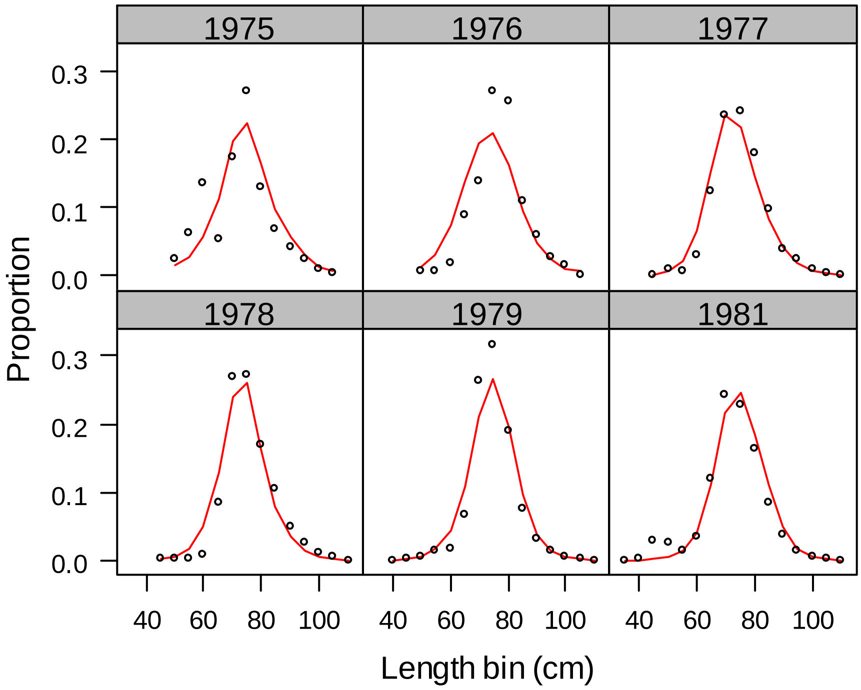
Discarded – combined sex, winter bycatch trawl fleet



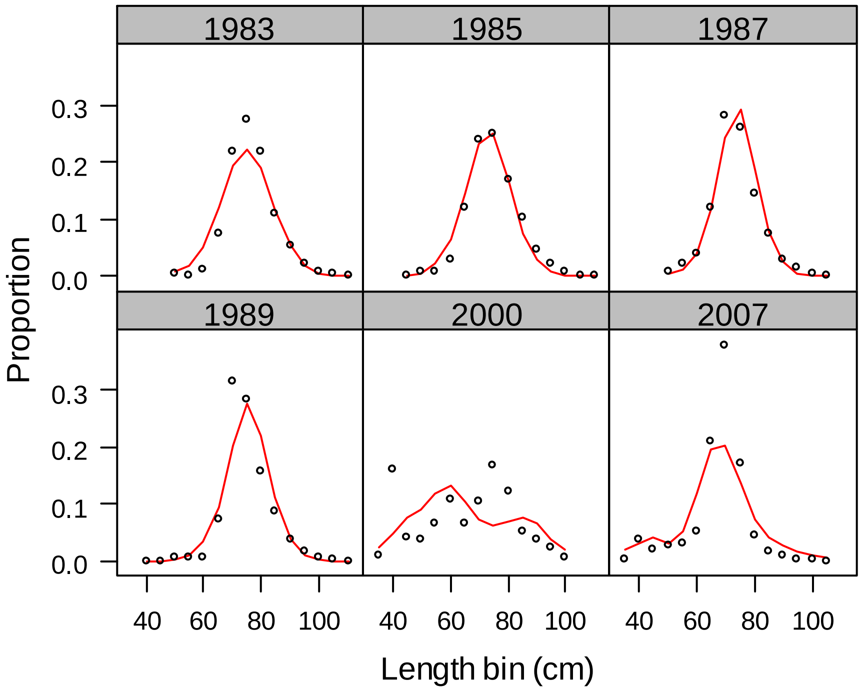
Retained – combined sex, non-trawl fleet



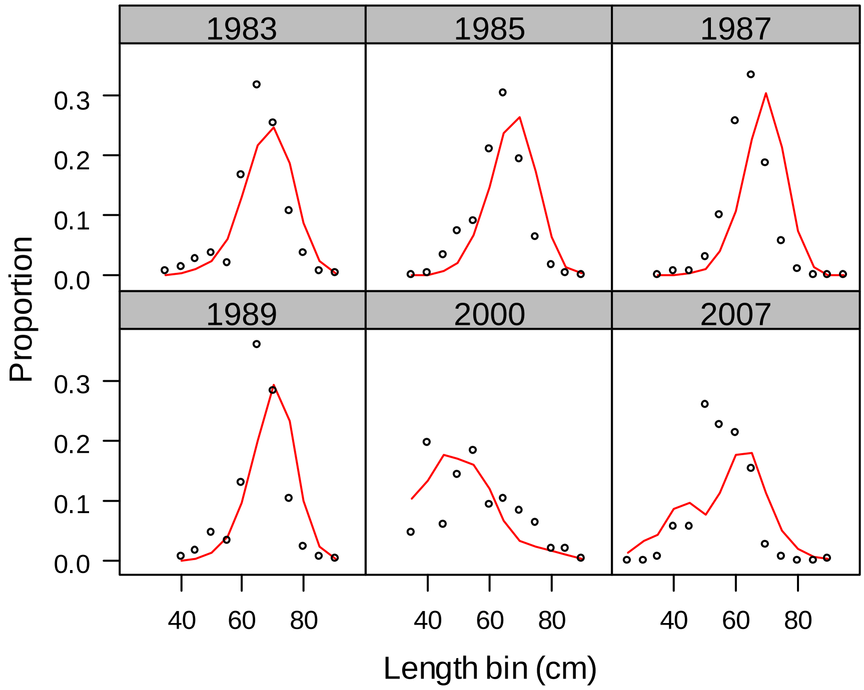
Retained – combined sex, winter targeted trawl fleet



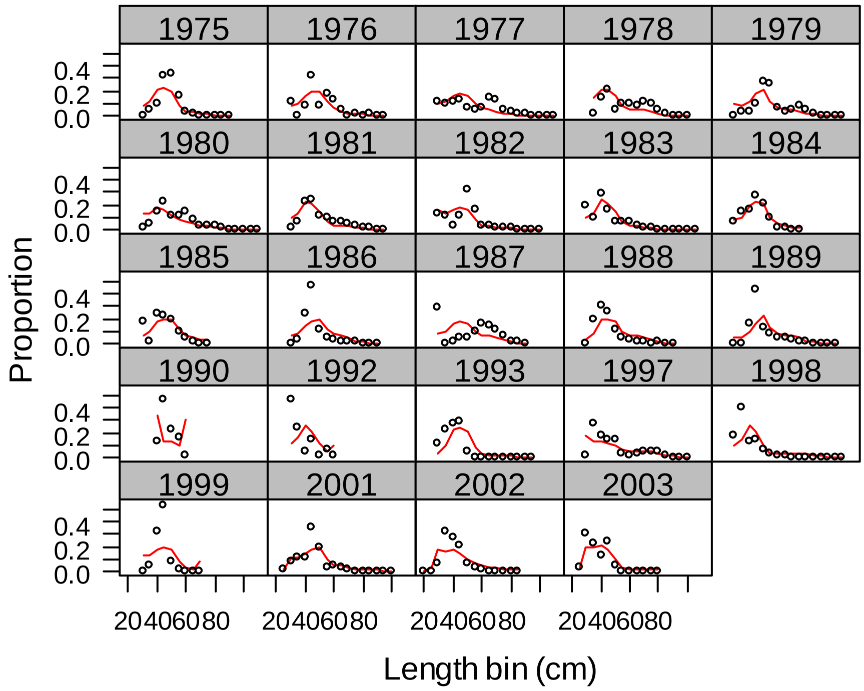
Retained – female, winter targeted trawl fleet



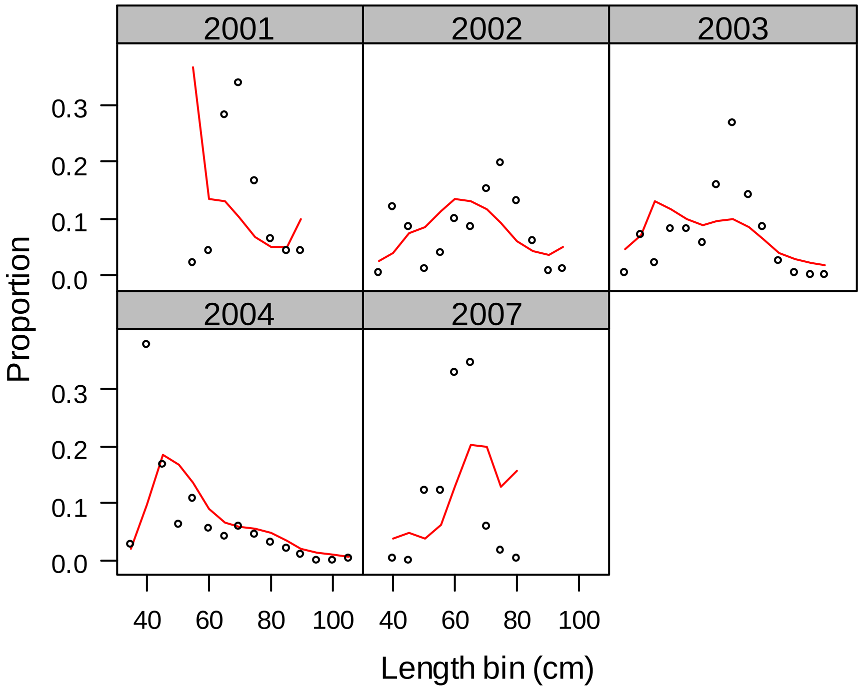
Retained – male, winter targeted trawl fleet



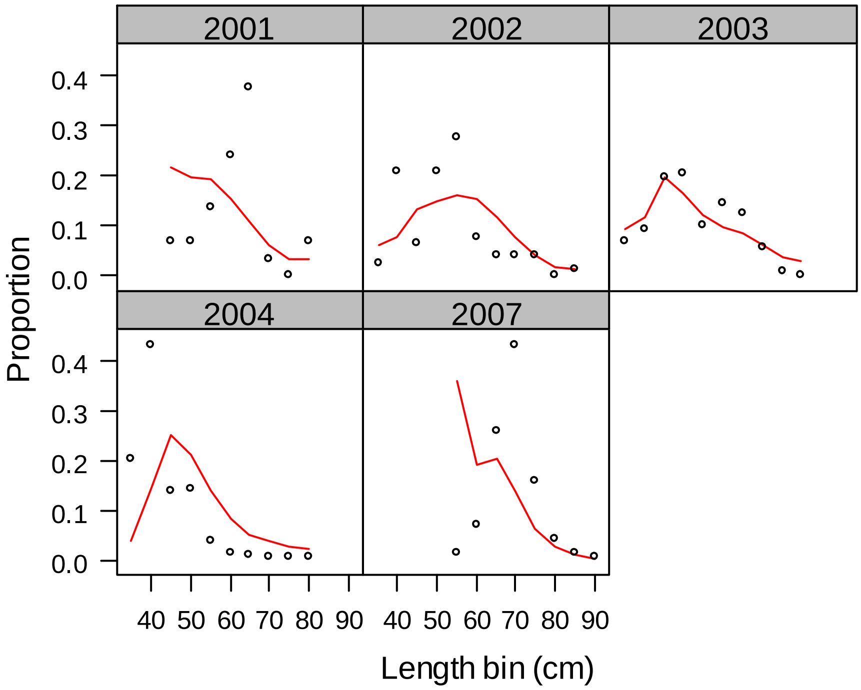
Retained – combined sex, summer trawl fleet



Retained –female, winter bycatch trawl fleet

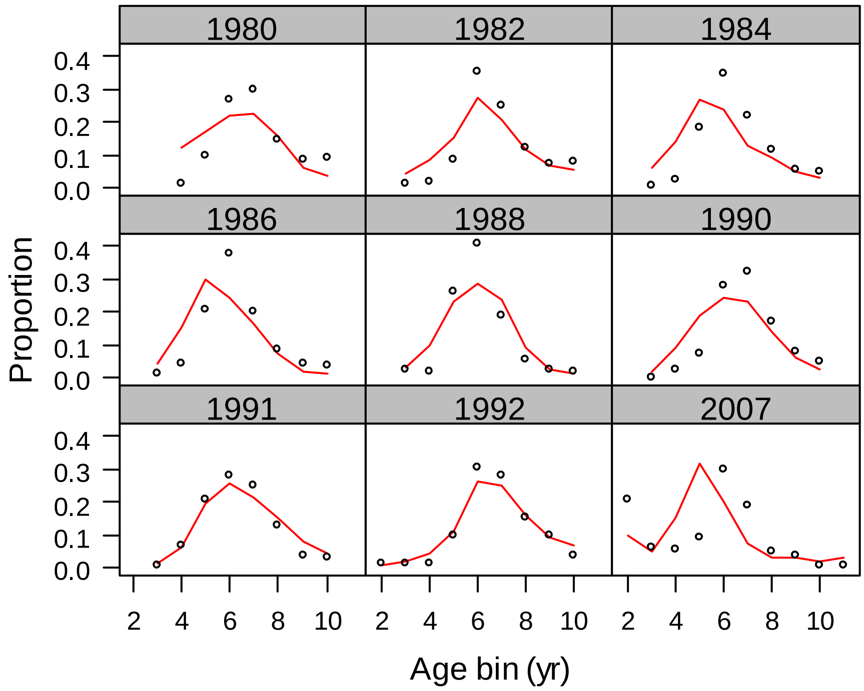


Retained –male, winter bycatch trawl fleet

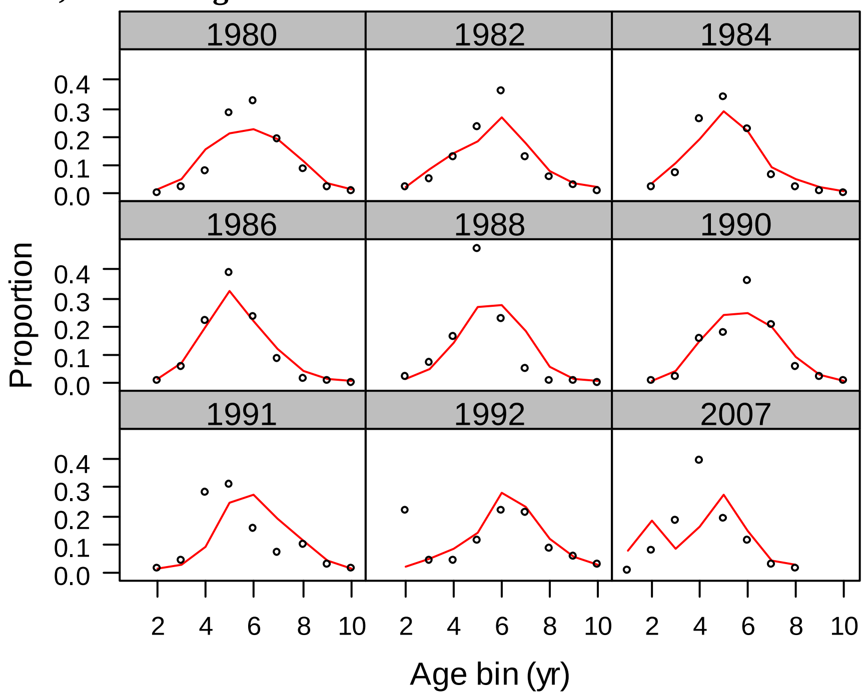


12.11 Appendix D: Fits to the age composition data

Female, winter targeted trawl

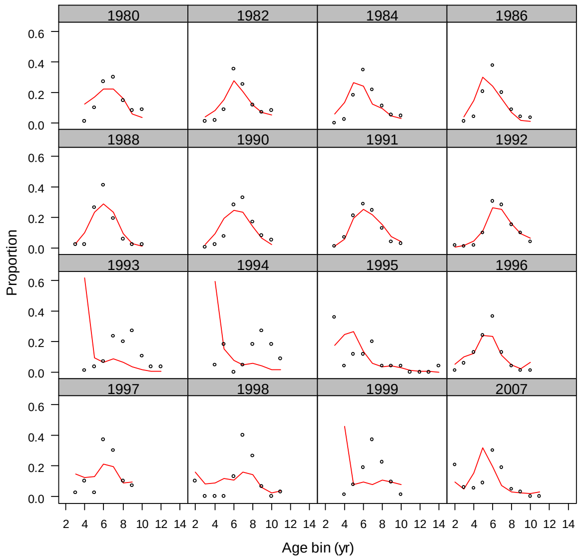


Male, winter targeted trawl

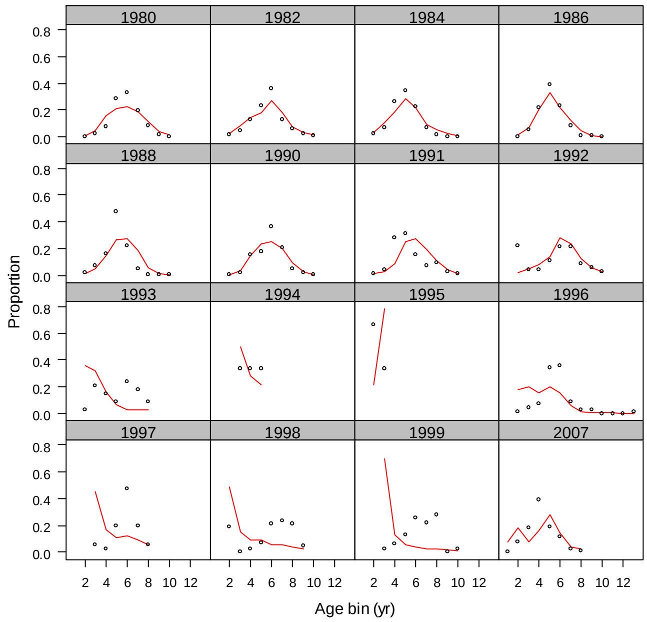


12.12 Appendix E: Fits to the implied age composition from the conditional age at length data

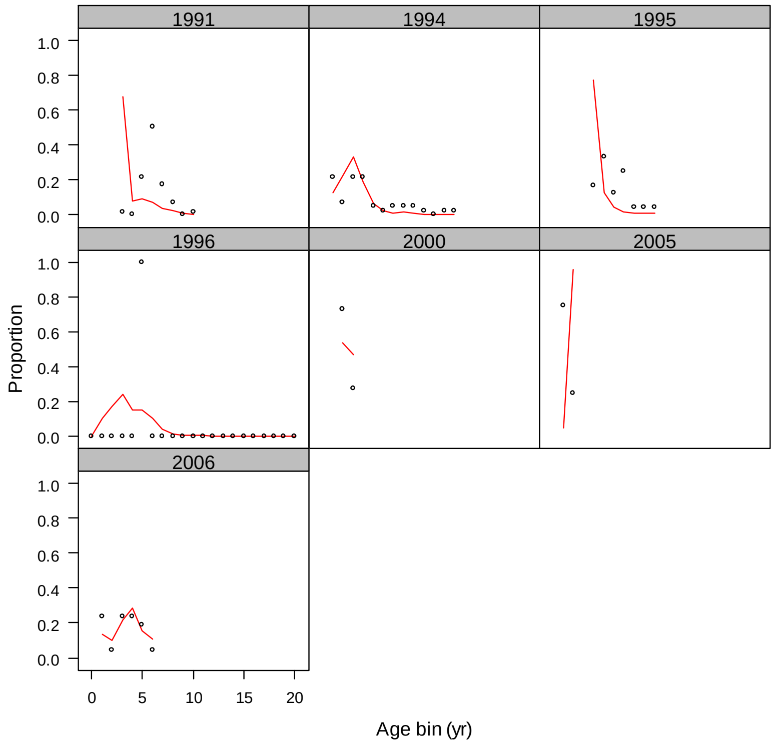
Female, winter targeted trawl (implied age-composition fits are for the years 1993-1999)



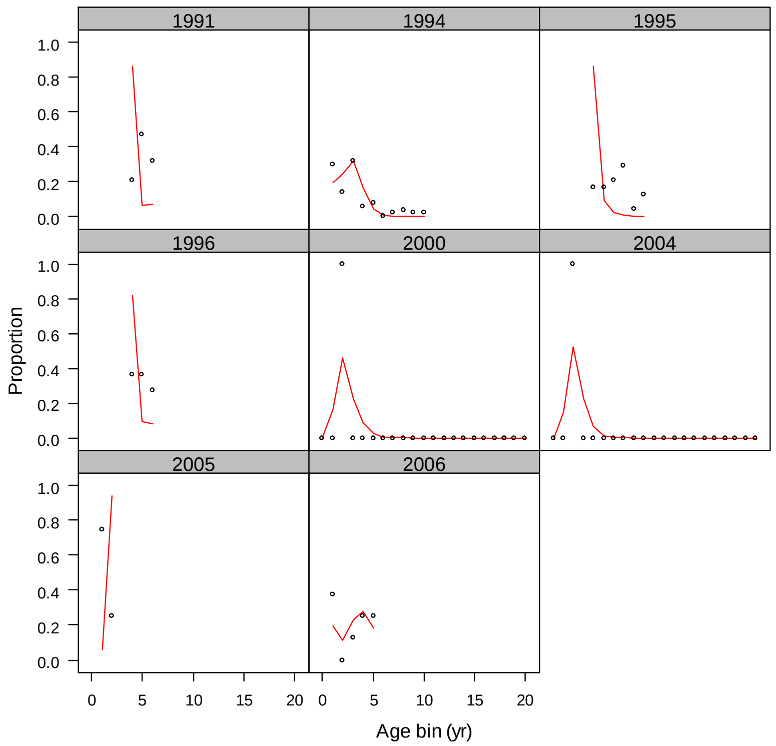
Male, winter targeted trawl (implied age-composition fits are for the years 1993-1999)



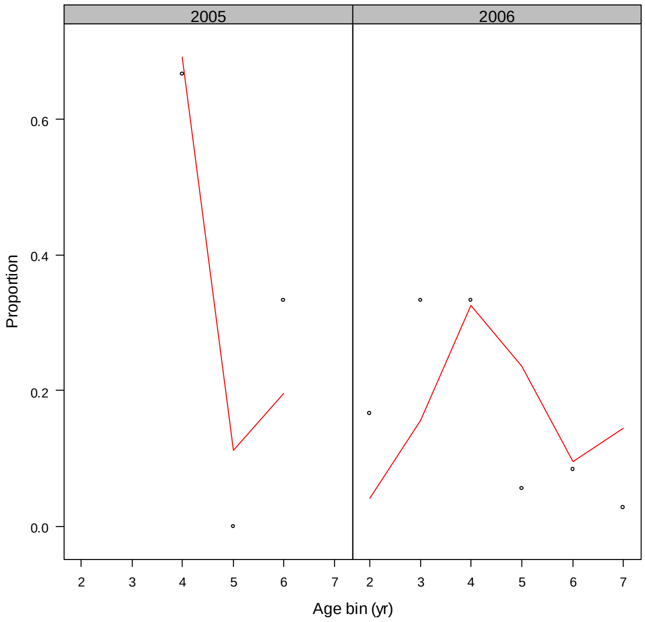
Female, summer trawl



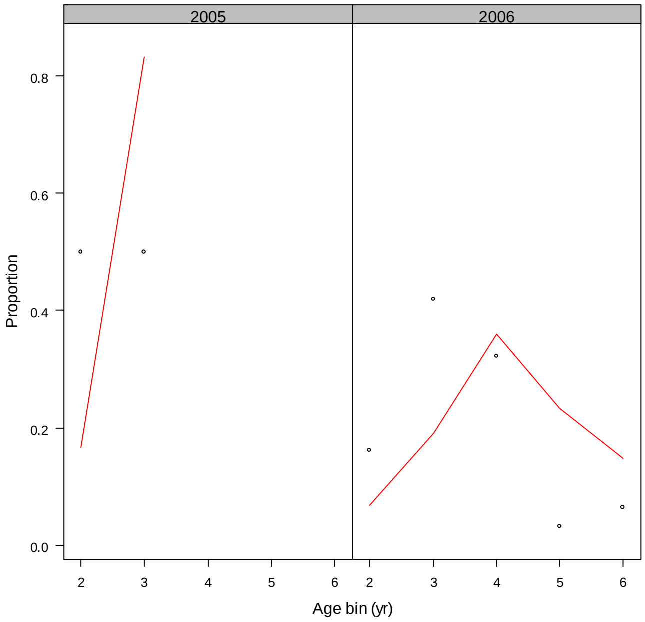
Male, summer trawl



Female, winter bycatch trawl



Male, winter bycatch trawl



13. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2006[10]

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13.1 Summary

This document updates the 2006 assessment of jackass morwong (*Nemadactylus macropterus*) in the eastern areas of the SESSF to provide estimates of stock status at the end of 2007. This assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to the previous assessment, such as the addition of discard information, and the estimation of growth parameters within the assessment. Other changes include the adddition of extra length-frequency information, and the addition of 2006 data.

A preliminary assessment of western zone jackass morwong using data from 1986-2006 is also presented.

The base-case assessment for the eastern areas estimates that current spawning stock biomass is 19 % of unexploited stock biomass. This assessment is largely driven by the recent catch rate indices, which indicate a 70 % decline in the stock over the last 20 years. The age and length data when fitted in the absence of the catch rate indices do not indicate the same magnitude of decline. In order to fit to the catch rate indices, the model has estimated that recruitments have largely been below average in the last 25 years, although there is some evidence for an above average recruitment in 2003.

Depletion across all sensitivities varied between 11% and 28%.

The preliminary assessment for the western stock indicates that the stock has declined in recent years as fishing pressure has increased, but spawning stock biomass is still considerably higher than the target level. The longterm RBCs estimated for the western stock are comparable with current catch levels.

13.2 Introduction

13.2.1 The Fishery

Jackass morwong have been landed in southern Australia since the inception of the steam trawl fishery off New South Wales in the early twentieth century (Fay 2004).

[10] Paper presented to the Shelf Resource Assessment Group on September 4 and 5, 2007

Jackass morwong were not favoured during the initial years of this fishery, when the main target species was tiger flathead (*Neoplatycephalus richardsoni*). Declines in flathead catches and improved market acceptance led to increased targeting of jackass morwong during the 1930s and later years of the steam trawl fishery (Klaer, 2001). Annual estimates of landings of jackass morwong from the steam trawl fishery between 1915 and 1957 reached a peak of about 2,000 t during the late 1940s (Table 13.1).

The fishery expanded greatly during the 1950s, with Danish seine vessels becoming the main vessels in the fishery. Landings of jackass morwong in NSW and eastern Victoria increased following WWII, and, at their peak in the 1960s, annual landings were of the order of 2,500 t (Table 13.1). The fishery shifted southwards during this time, with the majority of the landed catches coming from eastern Victoria. Landings of morwong then dropped to around 1,000 t by the mid-1980s, with landings in eastern Tasmania becoming an increasing proportion of catches. By the mid-1980s, the majority of jackass morwong were being landed by modern otter trawlers, with small landings by Danish seine vessels in eastern Victoria and eastern Bass Strait (Smith and Wayte, 2002).

Following the introduction of management measures into the South East Fishery in 1985, the recorded catch of jackass morwong ranged between 785 t (2003) to 1,650 t (1989). In 1992, an initial TAC was set at 1,500 t (Smith and Wayte, 2004). The agreed TAC was reduced to 1,200 t in 2000, to 960 t in 2001, increased to 1,200 t in 2006, and decreased to 750 t in 2007. Landings of jackass morwong in the eastern zones continued to decline during the 1990s, and annual catches in these areas are currently of the order of 600 t (Table 13.3). Catches from the western zones within the Southern and Eastern Scalefish and Shark Fishery (SESSF) have historically been minimal, with some trawling off Western Tasmania and West Victoria. However, catches in the western zones increased substantially in 2001, and now represent ~26% of the total landings of morwong in the SESSF (Table 13.3).

Morwong is also caught in small quantities in state waters off NSW and Tasmania, and by the non-trawl sector of the fishery, although these landings are not large. Reported non-trawl catches of morwong in 2006 were around 5.3 t. This assessment does not consider landings from vessels in the non-trawl sector. The state catches have been added to the Commonwealth catches in the appropriate zone.

13.2.2 Stock structure

Genetic studies conducted by the CSIRO have found no evidence of separate stocks in Australian waters. New Zealand and Australian stocks are however, distinct (Elliott *et al*., 1992). Analysis of otolith microstructure (Proctor *et al*., 1992) found differences between jackass morwong from southern Tasmania and those off NSW and Victoria, but it is unclear if such differences indicate separate stocks. Differences among jackass morwong in the western and eastern zones have been suggested (D.C. Smith, MAFRI, pers. commn. 2004; I. Knuckey, Fishwell, pers. commn. 2004), and it is assumed for the purposes of this assessment that there are separate stocks of jackass morwong in the eastern and western zones. This assessment concentrates on the eastern stock of jackass morwong, although a preliminary assessment for the western zone is presented. The landings and other data from the areas west of Bass Strait were also included in the eastern assessment as a sensitivity test.

13.2.3 Previous Assessments

Smith (1989) analysed catch and effort data for the Eden fishery (1971-72 to 1983-84), finding a significant decline in catch-per-unit-effort (CPUE) to 1980. Lyle (1989) analysed logbook data for Tasmania and western Bass Strait from 1976-84. No trends were apparent in these data.

The biomass of jackass morwong in the eastern zone was estimated using a combination of trawl surveys and VPA to be about 10,000 t in the mid-1980s, (Smith, 1989). Age-structured modelling of the NSW component of the fishery indicated that Maximum Sustainable Yield (*MSY*) is approached with a fishing mortality (*F*) between 0.2 and 0.3 yr^{-1}, and that the fishery was at optimum levels in the mid-1980s (Smith, 1989).

At the 1993 meeting of SEFSAG, then recent age data (from the Central Ageing Facility, CAF) and length data were presented together with new age and length data from southeastern Tasmania. Estimates of total mortality from catch curve analyses were similar to previous estimates in the early 1980s. Length and age data from southeastern Tasmania were characterised by a greater proportion of larger and older fish. Preliminary ageing data from sectioned otoliths were tabled at SEFAG in 1994 which suggested that morwong were longer lived (35 years) than previously thought (20 years).

In 1995, catch and unstandardised effort by major area in the fishery were derived from logbook records for the period 1986-94. Whereas the 1994 assessment stated that catch rates had remained relatively stable for the previous 4 years, GLM-standardized trawl catch rates exhibited a slow decline from 1987. Indeed, Smith and Wayte (2002) note that the mean unstandardised catch rate of jackass morwong has continued to decline, and, since 1996, has triggered AFMA’s catch rate performance criterion.

An assessment in 1997 was based on the collation and analysis of catch and effort data, combined with new biological information on growth rates of jackass morwong. Information on length frequencies and the retained and discarded catch of jackass morwong was obtained from SMP data and the FRDC report by Liggins (1996). Further length-frequency data were available from NSW and Tasmanian state projects. Catch curve analysis on fish between 5 and 26 years old produced an estimate for total mortality of 0.18 yr^{-1}. This was considerably lower than previous estimates of 0.6 to 0.77 yr^{-1} and was a direct result of the “new” maximum age. It is also lower than the values obtained by applying the 1993/94 age-length key (0.3 yr^{-1}) to length composition data. Using a value for *M* of 0.09 yr^{-1}, a fishing mortality (*F*) of 0.09 yr^{-1} was estimated.

Recently, Klaer (MS) used a stock reduction analysis (SRA) method to model the population of jackass morwong off NSW using catch history data from 1915-61. This analysis led to a point estimate of unexploited biomass of 21,600 tonnes, with a 1962 depletion level of 71%.

The first formal quantitative assessment of jackass morwong was conducted by Fay (2004) during 2004 based on 2002 data. It used a generalised age-structured modelling approach to assess the status and trends of the jackass morwong trawl fishery in the eastern zones, using data from the period 1915-2002. The 2004 assessment indicated that the spawning biomass of jackass morwong was between 25-45% of the 1915 unexploited biomass. The base-case model estimated the current spawning biomass was 37% of the unexploited biomass. The model could not adequately reconcile changes in catch rate in the late 1980s with catches during this period.

The 2004 assessment was updated in 2006 using the same software package with additional data that had become available since the previous assessment (Fay, 2006). Two recent (1986-2005) catch rate series were explored in the 2006 assessment. ShelfRAG originally chose to use a catch rate standardisation that was restricted to vessels which caught jackass morwong for at least 5 years and had a median annual catch of at least 5 t. Only shots in which at least 30 kg of jackass morwong were caught were included. The new standardized catch rate time series, which was chosen to be consistent with other SESSF species, also endeavoured to select targeted shots by selecting shots with ≥1kg of morwong from vessels that had reported catches of morwong for three or more years and whose median annual catch was greater than 2 tonnes.

Base-case estimates of 2006 spawning depletion when the model was fit to the ≥1kg catch rate series indicated that the stock was at low levels, around 15% of the unexploited equilibrium state. This led to 2007 recommended biological catches (RBCs) of zero under all Tier 1 and Tier 2 harvest control rules (HCRs). If the model was fitted to the new age and length data but used the ≥30 kg catch rate index, estimates of current stock status were more optimistic, with 2006 spawning depletion estimated to be 35% of the unexploited state.

The results of the 2006 assessment were clearly sensitive to the catch and effort data used to calculate a catch rate index that is representative of changes in biomass. As the estimated population trend is primarily driven by this catch rate index, the choice of data included is key to estimates of stock status for this population. For the 2004 assessment, it was considered that a ≥ 30 kg cut-off for catch and effort data was reasonable for morwong. However, the increasing trend in the number of shots catching small amounts of morwong from those vessels targeting the species (Day 2006) suggest that this might not be the case. The analysis by Day showed that the increase in small shots is not due to a change in reporting practices. In 2006 ShelfRAG decided to use the ≥ 1 kg catch rate as input to the base-case, as this was the more precautionary approach, no evidence against using this series was presented, and it is consistent with the approach used for other SESSF species.

13.2.4 Modifications to the previous assessment

A substantial number of modifications have been made to the previous assessment, based on recommendations made by Fay (2004), and updates to the data. The previous assessment was conducted using the software package Coleraine while the current assessment uses the package Stock Synthesis 2 (SS2) (Methot, 2005) which overcomes some of the technical shortcomings previously identified.

13.2.4.1 Data-related modifications

a) Discarding from the recent fleets has been included in the model through the use of onboard length frequency data from the ISMP.

b) Length-frequency data collected at the Sydney fish market from the mixed fleet (1971-85) have been included.

c) Length-frequency data collected at the Sydney fish market from the NSW/eastern Victoria otter trawl fleet (1986-90) have been included

d) The catch rate index produced by Smith (1989) for the overlap years between the steam trawl and early Danish seine fleet (1948-1966) has been included.

e) Conditional age-at-length information from the NSW/eastern Victoria otter trawl fleet, the eastern Tasmania trawl fleet and the Danish seine fleet have been included, instead of age compositions constructed from age-length keys and length-frequencies. This enables estimation of growth curve parameters within the assessment (rather than being set based on auxiliary information).

f) State catches have been added to catches from the appropriate fleet.

g) The plus-group for length-frequency information has been extended from 40 cm to 47 cm.

h) The ‘other boats’ fleet used in the previous assessment has been split into an ‘early Danish seine’ fleet (1944-1967) and a ‘mixed’ fleet (1968-1985), to better match the sources of length-frequency data.

i) Age-reading error has been included.

j) The weighting on the length frequency data (sample sizes) has been altered (in line with current agreed practice).

k) Catch, discard, length-composition, age-at-length, and catch rate data from 2006 have been added.

13.2.4.2 Model-related modifications

a) Estimation of recruitment residuals has been limited to those cohorts for which length-composition data are available.

b) Selectivity is modelled as being a function of length rather than of age (this is the default in SS2). Many other calculations in SS2 are length-based rather than age-based as in Coleraine.

c) Growth curve parameters ($L_{min,}$ L_{max} , K, and cv_L) are estimated within the assessment, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths.

d) The extent of variation in recruitment, σ_R, has been increased from 0.3 to 0.55 to better allow the model to match the data.

13.3 Methods

13.3.1 The data and model inputs

13.3.1.1 Biological parameters

A single-sex model (i.e. both sexes combined) has been used, as the length composition data for jackass morwong are not usually available by sex.

Previous assessments pre-specified the values for the parameters of the Von Bertalanffy growth equation, but as SS2 can accept age-at-length data as an input it has been possible in this assessment to estimate these parameters within the model-fitting procedure. This is a more appropriate approach because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

Estimates of the rate of natural mortality, *M*, reported in the literature vary from 0.09 to 0.2 yr^{-1}. This assessment follows recent assessments in using 0.15 yr^{-1} as the base-case estimate of *M*. Sensitivity to this value is tested. The base-case value for the steepness of the stock-recruitment relationship, *h*, is 0.7. A range of alternative values is examined in sensitivity tests.

Jackass morwong become sexually mature at about three years of age, which corresponds to a length of about 25 cm. Maturity is modelled as a logistic function, with 50% maturity at 24.5 cm and 95% maturity at 27 cm. Sensitivity to this value is tested. Fecundity-at-length is assumed to be proportional to weight-at-length. The morwong in the west are larger for their age than those in the east, so for the western zone assessment 50% maturity is set at 28 cm, and 95% maturity at 31 cm.

The parameters of the length-weight relationship are the same as those used in previous assessments (a=1.7 x 10^{-5}, b=3.031). These values are taken from Smith and Robertson (1995).

13.3.1.2 Fleets

The assessment data for jackass morwong have been separated into seven ‘fleets’, which represent one or more gear, regional, or temporal differences in the fishery. Landings data from eastern Tasmania were separated from the catches from the other regions in the east, because the length compositions of catches from this area indicate that it lands larger fish. Note that the fleets have been renumbered as compared to the previous assessment, for ease of data preparation.

1. Eastern trawl – otter trawlers from NSW, eastern Victoria and Bass Strait (1986 – 2006)

2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1986 – 2006)

3. Tasmanian trawl – otter trawlers from eastern Tasmania (1986 – 2006)

4. Steam trawl – steam trawlers (1915 – 61)

5. Early Danish seine – Danish seine (1929 – 67). These landings may include a small amount of motor trawl catches.

6. Mixed – mixed Danish seine and diesel trawl catch (1968 – 85).

7. Western trawl – otter trawlers from western Victoria and western Tasmania (1986 – 2006)

13.3.1.3 Landed catches

A landed catch history for jackass morwong, separated into the seven ‘fleets’, is available for all years from 1915 to 2006 (Figure 13.1).

Klaer (2006) used a compilation of catch data from historical steam trawlers (Klaer and Tilzey, 1996) to recreate a catch history for jackass morwong for this sector of the fishery from 1915 to 1961 (Table 13.1). Estimates of total annual landings of jackass morwong from the eastern zones by Danish seine vessels during 1929-67 (Table 13.1), and the mixed fleet during 1968-85 (Table 13.2) were compiled from Klaer (2006), Klaer (pers. commn. 2004) and Allen (1989).

The landings for the ‘early Danish seine’ fleet may include some catches from small motor trawlers which began to appear in the fishery in about 1954 (Blackburn, 1978), but it is believed that these catches are small in comparison to the Danish seine catches (N.Klaer, pers. comm. 2007).

The ‘mixed’ fleet consisted primarily of Danish seine vessels until the mid 1970s when the first modern otter diesel trawlers entered the fishery (Klaer, 2006), but no separation of landings by gear type is available for this period. For the purposes of this assessment, therefore, landings during 1968-85 were treated as coming from one fleet with a single selectivity pattern.

The landings for the more recent years (eastern trawl, Danish seine, Tasmanian trawl and western trawl) (Table 13.3) are extracted from the SESSF logbook database. Quotas were introduced into the fishery in 1992, and from then onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. For example, it is usually possible to separate logbook records, but not landing records, by fleet. The logbook catches for each fleet from 1992 onwards have been scaled up by the ratio of landed catches to logbook catches in each year (Thomson, 2002). Prior to 1992, the unscaled logbook catches are used.

Small amounts of morwong are caught in state waters. NSW trawl and trap catches have been added to the eastern trawl fleet, and Tasmanian state catches have been added to the Tasmanian fleet.

In order to calculate the Recommended Biological Catch (RBC) for 2008, it is necessary to estimate the catch for 2007. This was estimated assuming that Commonwealth catch will reduce from 2006 to 2007 according to the ratio of the TACs for those years (1,200 t and 750 t), and that state catches will remain at the same level.

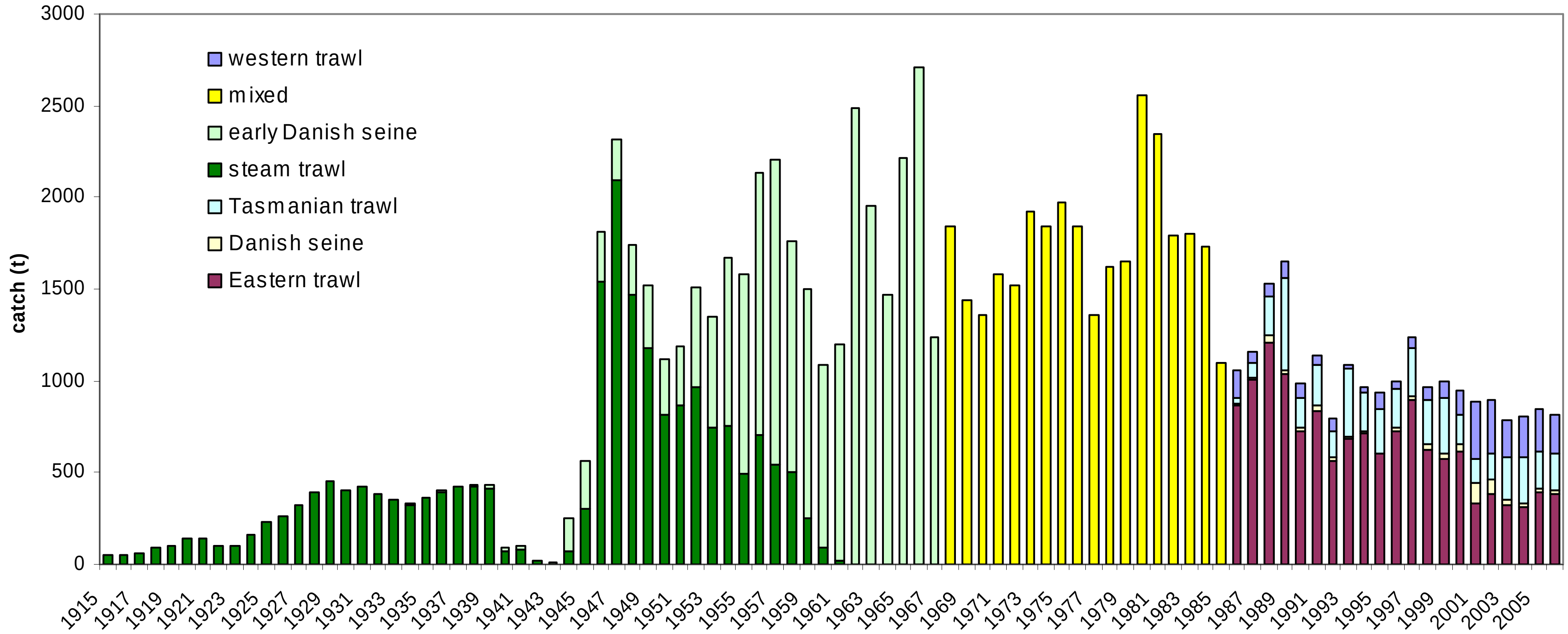


Figure 13.1. Catches of jackass morwong by fleet (including state catches), 1915 – 2006.

13.3.1.4 Discard rates

Information on the discarding rate of jackass morwong was available from the ISMP for 1993-2006. These data are summarised in Table 13.4. Generally, discards of jackass morwong in the eastern areas have been <10% of landings. However discards increased in 2006 to 12% in NSW and eastern Victoria and 14 % in eastern Tasmania.

There is limited information on discarding for the early steam trawl fleet (1915-61) and the early Danish seine fleet (1929-67). However, it is known that some discarding of morwong did occur in those years, due to a preference in the fishery for other species (Klaer, 2001). Discard amounts were available for some early steam trawl catches, and for other years and early Danish seine a constant rate of 20% of landed catches has been assumed (Klaer, 2006), and added to the landed catches. The same approach has been used for the mixed fleet.

Discarding has been extremely low in the west, and is not included in the assessment.

13.3.1.5 Catch rate indices

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1920-21, 1937-42, and 1952-57 (Klaer, 2006, Table 13.6). Smith (1989) presented a standardised catch rate index for jackass morwong for 1948-66 (Table 13.7). This index standardises for gear type during a period of overlap between the steam trawl fishery and the onset of Danish seine vessels. Smith (1989) also provided a standardised CPUE index for all vessels for the period 1977-84 (Table 13.8). This index corresponds to the mixed fleet.

Catch and effort information from the SEF1 logbook database from the period 1986-2006 were standardised using GLM analysis to obtain indices of relative abundance for the eastern, Tasmanian and western trawl fleets (Haddon, 2006; Table 13.9). The data restrictions used in selecting the data for the analysis of the catch and effort data were: vessels had to have been in the fishery for three or more years, zero catch rates were excluded, and the shot had to have taken place in depths between 70 and 300 m in the east, and 70 and 360 m in the west. An analysis of logbook data showed that this depth range includes close to or greater than 90% of the morwong catch in all years (Wayte, 2006).

13.3.1.6 Length composition data

The length data for jackass morwong are usually not disaggregated by sex, and so length data for fish of both sexes were lumped together for this assessment

Length composition information for the retained component of the eastern trawl fleet catch is available from the Sydney fish market for 1986-90, and from port sampling for 1991-2006. Port-sampled length compositions with adequate sample sizes were available for the Tasmanian trawl fleet for 1997-2006, for the recent Danish seine fleet for 1997-2002, and 2004, and for the western trawl fleet for 1996-97 and 1999-2006. Years for which the total number of fish measured was less than 100 were not used, as the length composition from such a small sample size is unlikely to be representative of the population. The length-composition data used in the assessment for the eastern trawl, Danish seine and Tasmanian trawl fleets are given in Table 13.13 to Table 13.15.

Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch (Table 13.5). Discard length frequencies of sample size greater than 100 were available in 1996-1998, 2001 and 2004-2006 for the Eastern trawl fleet, in 1997-2001 and 2005-2006 for the Tasmanian trawl fleet, and in 2002 and 2003 for the recent Danish seine fleet.

Length composition information from market sampling (Blackburn, 1978) is also available for the steam trawl fleet for 1947-58 (Table 13.10) and for the early Danish seine fleet for 1947-67 (Table 13.11). These data are assumed to be representative of the retained catch. Sample sizes were available for these data in terms of the total numbers of fish measured, which are frequently one or more orders of magnitude greater than those for the recent port-sampling data.

Length composition information for the mixed fleet is available from the Sydney fish market for 1971-1985 (Table 13.12).

13.3.1.7 Age composition data

Age-at-length measurements, based on sectioned otoliths, provided by the Central Ageing Facility (CAF), were available for the years 1993-2006 for the eastern trawl fleet; 1994-96 and 2006 for the Tasmanian trawl fleet; 1998, 2000-01, 2003 and 2005-06 for the recent Danish seine fleet; and 1995 and 2003-06 for the western trawl fleet. Years for which the total number of fish aged was less than 10 were not used. No age information was available for the earlier fleets.

An estimate of the standard deviation of age reading error was calculated by André Punt (pers. commn, 2007) from data supplied by Kyne Krusic-Golub of PIRVic (Table 13.16).

13.3.2 Stock Assessment method

13.3.2.1 Population dynamics model and parameter estimation

A single-sex stock assessment for jackass morwong was conducted using the software package SS2 (version 2; Methot 2007). SS2 is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for jackass morwong. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the SS2 technical description (Methot, 2005) and are not reproduced here. Some key features of the population dynamics model underlying SS2 which are pertinent to this assessment are discussed below.

A single stock of jackass morwong was assumed for the eastern assessment, with an assumption of an unexploited biomass and equilibrium (unexploited) age structure at the start of 1915 when the steam trawl fishery commenced. Catches from western Tasmania and western Victoria were assumed to come from a separate stock and are therefore not considered in the eastern assessment, except as a sensitivity test. For the western assessment, the stock was assumed to be unexploited at the start of 1986. Catches prior to this are thought to have been minimal.The eastern assessment modelled the impact of six fishing fleets on the morwong population. The input CVs of the catch rate indices for each fleet were set equal to the model-estimated standard errors of these indices (Table 13.6 – Table 13.9).

Selectivity was assumed to vary among fleets, but the selectivity pattern for each fleet was modelled as being time-invariant. Selectivity was modelled as a function of length. Separate logistic functions were used for the selectivity ogives for each fleet. The two parameters of the selectivity function for each fleet were estimated within the assessment. Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for those fleets where discard information was available (eastern trawl, Tasmanian trawl and Danish seine). Implicitly the probability of discarding was assumed to be independent of length for the other fleets.

The rate of natural mortality, M, was assumed to be constant with age, and also time-invariant. The natural mortality for the base-case analysis was set to 0.15 yr^{-1} following previous assessments.

Recruitment was assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis was set to 0.7. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) were estimated for 1942 to 2004 for the eastern assessment, and for 1986-2004 for the western assessment. Deviations were not estimated in the east prior to 1942, as there is not enough data prior to this date to estimate them. The value of the parameter determining the magnitude of the process error in annual recruitment,σ_R , was set equal to 0.55, so that the standard deviations of estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_R.

A plus-group was modelled at age 25. Growth of morwong was assumed to be time-invariant, that is there has been no change over time in the mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve within the assessment using the age-at-length data. No differences in growth by gender are modelled, as the stock was modelled as a single-sex.

All sample sizes for length frequency data greater than 200 were set to 200. This is because the appropriate sample size for length frequency data is probably more related to the number of shots sampled, rather than the number of fish measured. The length frequency data would be given too much weight relative to other data sources if the number of fish measured were used. The sample sizes for the recent fleets were also individually tuned so that the input sample size was equal to the effective sample size calculated by the model.

The estimated and pre-specified parameters of the model for the eastern assessment are shown in Table 13.17.

13.3.2.2 Sensitivity tests

For the eastern assessment a number of sensitivity tests were used to examine the sensitivity of the results of the model to some of the assumptions and data inputs:

1) M = 0.1, 0.2yr^{-1}, estimated.
2) h = 0.6, 0.8.
3) σ_R =0.3, 0.8
4) 50% maturity occurs at length 22 cm.
5) Double and halve the weighting on the recent CPUE series.
6) Double and halve the weighting on the length composition data.
7) Double and halve the weighting on the age-at-length data.
8) Omit early catch rate and length composition data.
9) Add the western zones as a separate fleet.

One sensitivity test was performed for the western assessment : growth parameters fixed to those estimated from the eastern stock.

The results of the sensitivity tests are summarized by the following quantities:

1) SB_0 the average unexploited female spawning biomass.
2) SB_{2008} the female spawning biomass at the start of 2008.
3) SB_{2008}/SB_0 the depletion level at the start of 2008, i.e. the 2008 spawning biomass expressed as a fraction of the unexploited spawning biomass.
4) $-lnL$ the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data, although this value is not comparable for all sensitivities).
5) *RBC 20:40:40* the 2008 RBC calculated using the 20:40:40 harvest rule.
6) *RBC 20:40:48* the 2008 RBC calculated using the 20:40:48 harvest rule.
7) Longterm *RBC 20:40:40* the longterm RBC calculated using the 20:40:40 harvest rule.
8) Longterm *RBC 20:40:48* the longterm RBC calculated using the 20:40:48 harvest rule.

13.4 Results and discussion

13.4.1 Eastern stock

13.4.1.1 The base-case analysis

Parameter estimates

Figure 13.2 (left) shows the estimated growth curve for the eastern stock of jackass morwong. All growth parameters are estimated in this model. The estimated values for each parameter are *Lmin*=14.7 cm, *Lmax*=35.3cm, *K*=0.212, cv of growth = 0.105 (standard errors 0.411, 0.154, 0.077 and 0.0019, respectively).

Selectivity is assumed to be logistic for all fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). With the exception of current Danish seine, the estimates of these parameters for the base-case model do not vary greatly between fleets (Table 13.18). Figure 13.2 (right) shows the selectivity functions.

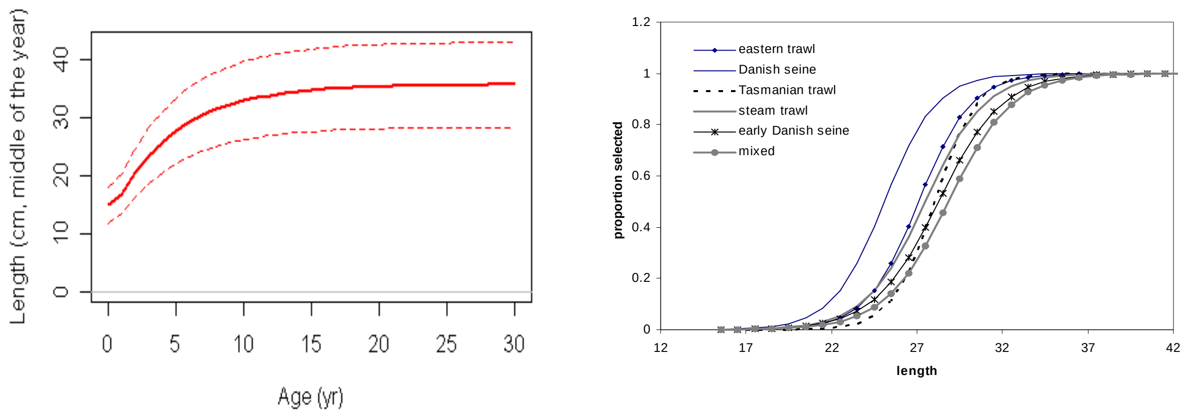


Figure 13.2. The model-estimated growth curve, and selectivity functions for the six fleets.

Fits to the data

The fits to the catch rate indices (Figure 13.3) are reasonable. For the steam trawl catch rate index, the data indicate a decline in the stock, but the model estimates that stock is increasing slightly after 1950. This is a result of the estimated high recruitment in 1948, which is well-supported by the length composition data. The mixed fleet catch rate index shows that abundance is relatively constant over 1977 to 1984, but the model has estimated that stock is declining. The fit to the eastern trawl fleet is good, although the model has not been able to mimic the increase in the most recent years. For the Tasmanian trawl fleet the model is unable to mimic the initial hump, or the recent increase.

The fits to the discard rate data (Figure 13.4) are reasonable for the eastern and Tasmanian trawl fleets, but poor for the Danish seine fleet. However this fleet provides a very small proportion of the total catch.

The base-case model is able to mimic the retained length-frequency distributions adequately (Appendix A, Section 13.7), with the exception of the recent Danish seine fleet, for which sample sizes are very small and on which the model places little emphasis. The fits to the historical steam trawl and early Danish seine fleets are better than those for the more recent data. The number of fish measured for the historical data is generally very high, which leads to smoother observed distributions. The fits to the discarded length compositions are variable (Appendix A, Section 13.7). This is not surprising, as the observed discard length frequencies are quite variable from year to year, and sample sizes are small.

The fits to the age composition data are shown in Appendix B (Section 13.8). The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of outputting the fits to these data even though they are not included directly in the assessment.The model mimics the observed age data well.

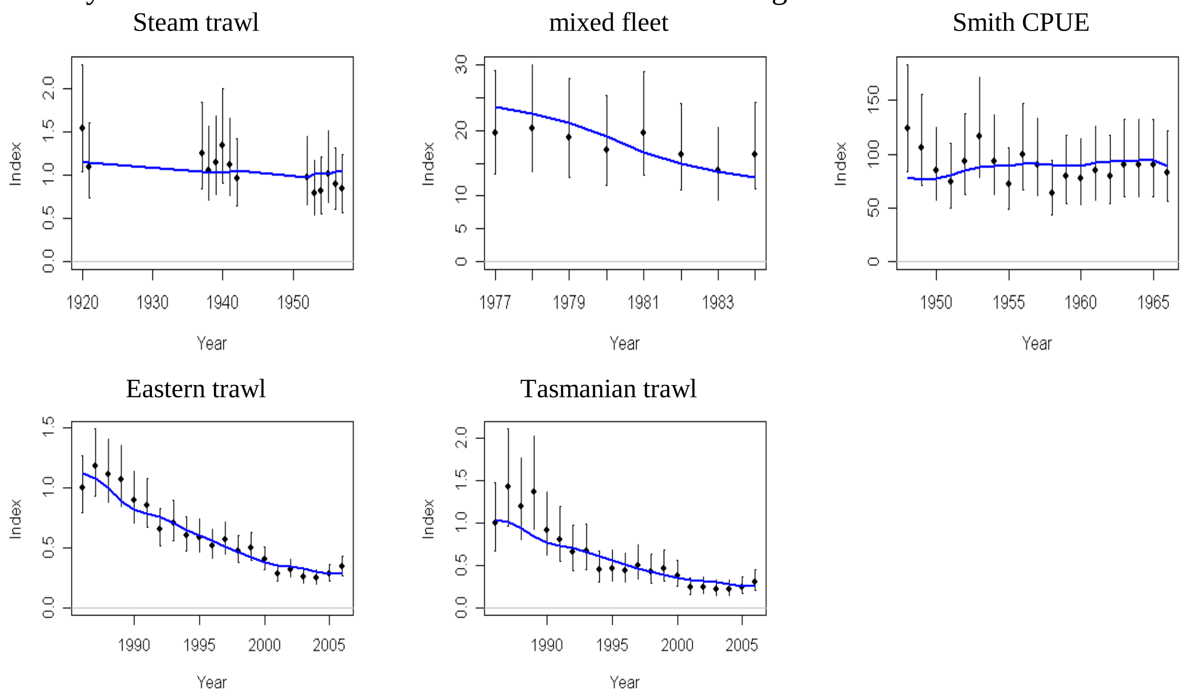


Figure 13.3. Observed (solid dots) and model-estimated (lines) catch rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

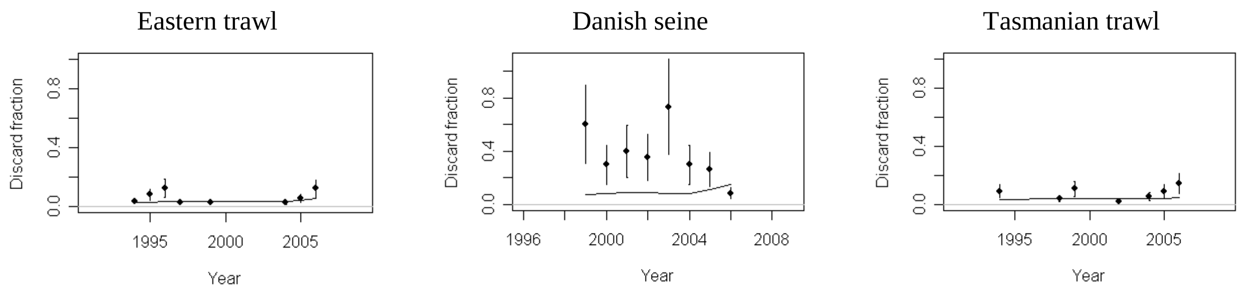


Figure 13.4. Observed (solid dots) and model-estimated (lines) discard rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

Assessment outcomes

The left panel of Figure 13.5 shows the time trajectory of female spawning stock biomass corresponding to the mode of the posterior density (MPD) estimates of the base-case model, and the right hand panel shows the spawning stock depletion. The stock declines slowly from the beginning of the fishery in 1915, fluctuates during the 1940s, 50s and 1960s, before a sharp decline in the mid-1960s, after a period of low recruitments and high catches. The recovery in the late 1960s is driven by the very high recruitment in 1968 (Figure 13.6), which appears to be well-supported by both the age and length data. After this, the stock continues to decline until 2006 when it increases slightly, in response to increased recruitments in 2003 and 2004.

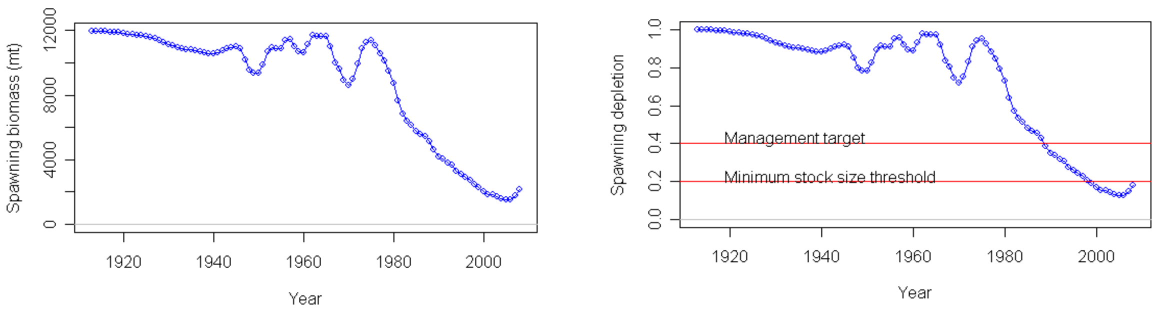


Figure 13.5. Time-trajectories of female spawning biomass, and spawning biomass depletion corresponding to the MPD estimates for the base-case analysis for the eastern stock.

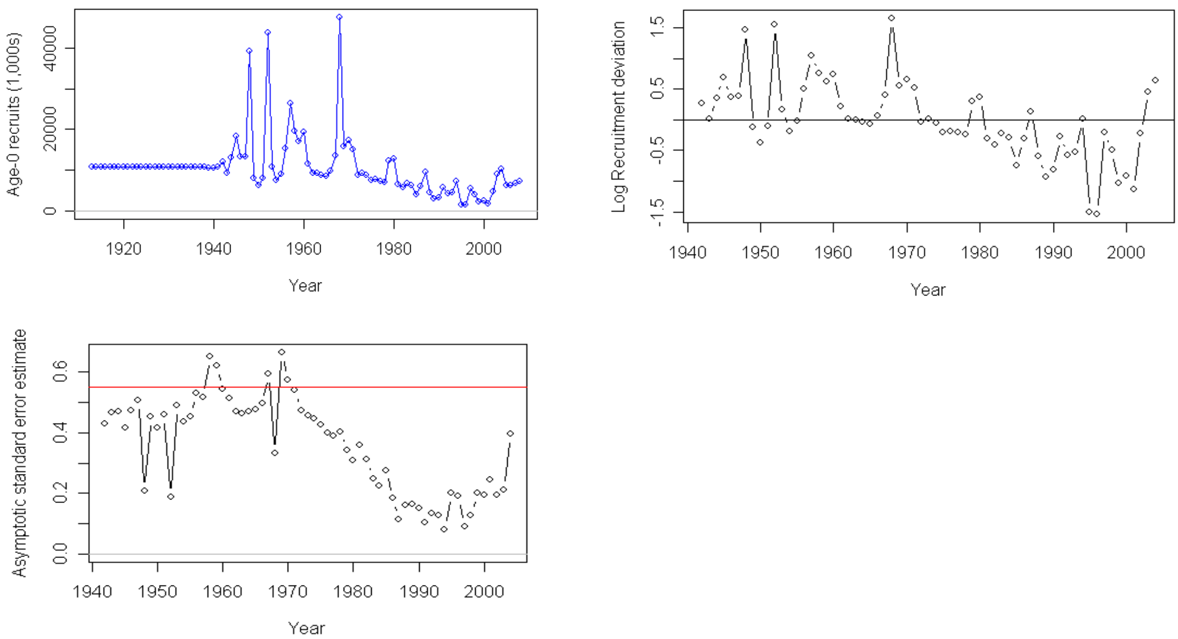


Figure 13.6. Time-trajectories of recruitment, recruitment deviation and recruitment deviation standard error corresponding to the MPD estimates for the base-case analysis.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 13.6. The model estimates that most of the recruitments in the last 25 years have been below average. This contrasts with the earlier period from 1940-70 where recruitment is highly variable, but largely above average. All data sources provide evidence for an above average recruitment in 2003. The evidence for a high 2004 recruitment is not as strong.

The current spawning stock biomass is estimated by the base-case model to be 19 % of unexploited stock biomass, and therefore the 2008 recommended biological catch (RBC) under both harvest control rules is 0 t (Table 13.19) because the stock is below the minimum stock size threshold. The longterm RBC (assuming average recruitment in the future) is 1,354 t under the 20:40:40 rule and 1,238 t under the 20:40:48 rule (Figure 13.7 and Table 13.20).

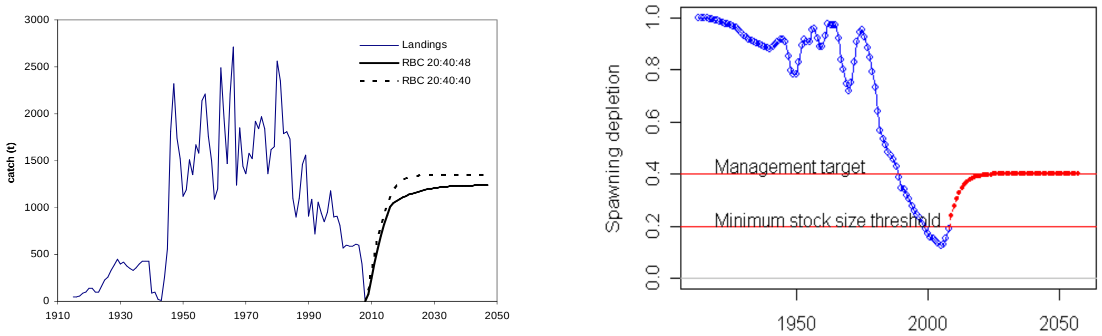


Figure 13.7. Time trajectories of landings and the projection of RBCs under the assumption that future recruitment is average, for two versions of the harvest control rule (dotted – 20:40:40; solid – 20:40:48) (left), and the relative spawning biomass under the 20:40:40 rule (right).

Model exploration

The recent declining catch rates during a period of relatively low catches are not consistent with the earlier period when catches were much higher, yet the catch rates were not declining. To reconcile this information the model estimates that annual recruitments have been mostly below average between 1980 and 2002, thus allowing spawning biomass to decline even though catches are relatively low.

To investigate the contributions of various data sources to the model estimates of stock status, the model was run with different combinations of the recent data (1986-2006). Removal of the length and age data does not have a large effect on model results (Figure 13.8). If the recent catch rate indices are omitted from the analysis, the model estimates that the stock has more than doubled from 2000 to the end of 2006. This increase is driven by very high recruitment estimates for 2002, 2003 and 2004 (Figure 13.9). While the catch rate indices for both the recent trawl fleets have increased slightly from 2001 to 2006, they certainly show no evidence for such a dramatic increase in stock biomass. In other words, it is the recent catch rate indices that are driving the assessment results, but the stock increase predicted by length and age data alone is implausible.

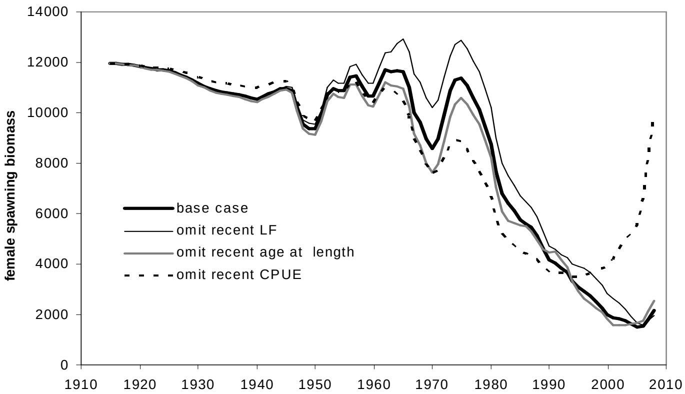


Figure 13.8. Female spawning biomass when the model is fitted to different combinations of recent data.

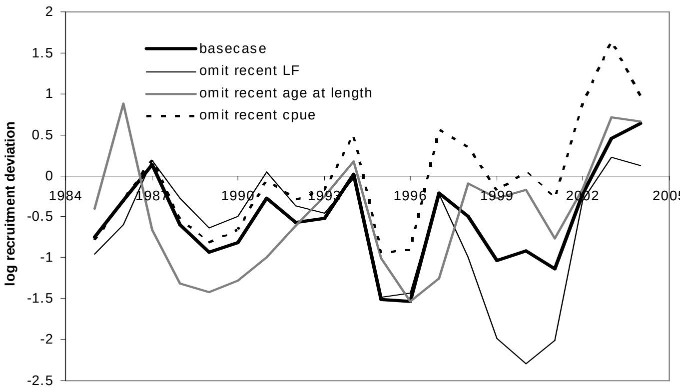


Figure 13.9. Recent recruitment deviations when the model is fitted to different combinations of recent data.

13.4.1.2 Sensitivity tests

Results of the sensitivity tests are shown in Table 13.19. The results are sensitive to the assumed value for natural mortality (*M*), but less so to steepness and $\sigma_{R.}$ The base-case assessment used a value of 0.15 yr^{-1} for *M*, and this gives a better overall fit to the data than *M* = 0.1 or 0.2 yr^{-1} (the log-likelihood is lower). The estimated value of *M* is 0.12 yr^{-1} . Decreasing the age at 50% maturity leads to a slightly more optimistic assessment.

Changing the weighting on various data sources changes the estimated biomass trajectory, but has little effect on the current depletion estimate. The exception to this is doubling the weighting on the length composition data, which leads to a more optimistic assessment, largely due to higher estimates of recruitment in the final two years.

Omission of catch rate and length composition data prior to 1986 leads to little difference in results, suggesting that the model is driven by the recent information.

Not surprisingly, inclusion of the western zones as a separate fleet leads to a more optimistic assessment. However, the RBCs estimated from this model are of the same order as current catches in the west.

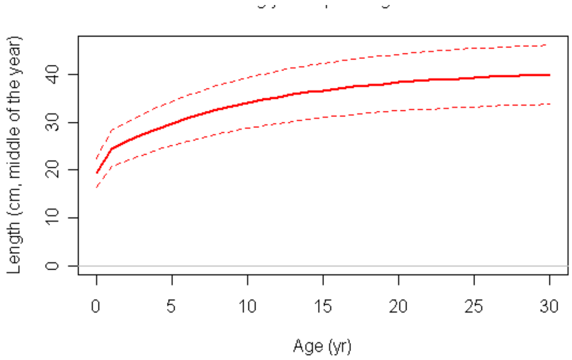
13.4.2 Western stock

The assessment for the western stock is considered to be preliminary, as it has not been subjected to as close a scrutiny as the eastern stock assessment, and is based on much less information. Only one sensitivity test has been run.

13.4.2.1 The base-case analysis

Parameter estimates

Figure 13.10 (left) shows the estimated growth curve for the western stock of jackass morwong. All growth parameters are estimated in this model. The estimated values for each parameter are *Lmin*=23.7 cm, *Lmax*=38.2 cm, *K*=0.096, cv of growth = 0.079 (standard errors 0.624, 0.32, 0.0093 and 0.0025, respectively). These parameters are less precisely estimated than those in the eastern stock assessment. There are 901 age-at length observations, as compared to 3,261 observations in the east. Selectivity is assumed to be logistic. The parameters that define the selectivity function are the length at 50% selection which is estimated to be 34.5 cm and the spread which is estimated to be 8 cm. Figure 13.10 (right) shows the selectivity function.



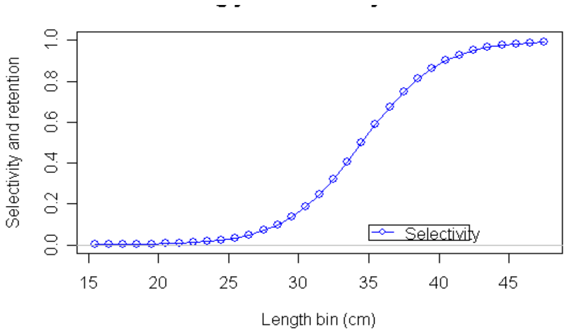


Figure 13.10. The model-estimated growth curve, and selectivity functions for the western stock.

Fits to the data

The fit to the catch rate index (Figure 13.11) is reasonable in later years, but not particularly good in the early years. The model is unable to mimic the initial hump. The model mimics the length-frequency distributions adequately for most years (Appendix A, Section 13.7). The model fits to the noisy age-composition data are adequate (Appendix B, Section 13.8).

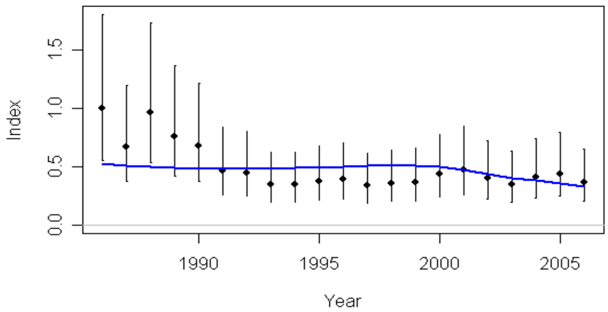


Figure 13.11. Observed (solid dots) and model-estimated (lines) catch-rate versus year for the western stock. The vertical lines indicate approximate 95% confidence intervals for the data.

Assessment outcomes

The left panel of Figure 13.12 shows the time trajectory of female spawning stock biomass corresponding to the MPD estimates, and the right hand panel shows the spawning stock depletion. The stock has remained constant from 1986 to 2001, when it begins to decline in response to increased fishing pressure.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 13.13.

The current spawning stock biomass is estimated to be 63% of unexploited stock biomass. The RBC is 410 t under the 20:40:40 control rule, and 297 t under the 20:40:48 control rule. The longterm RBCs are 208 t and 191 t (Figure 13.14), about the same level as current catches.

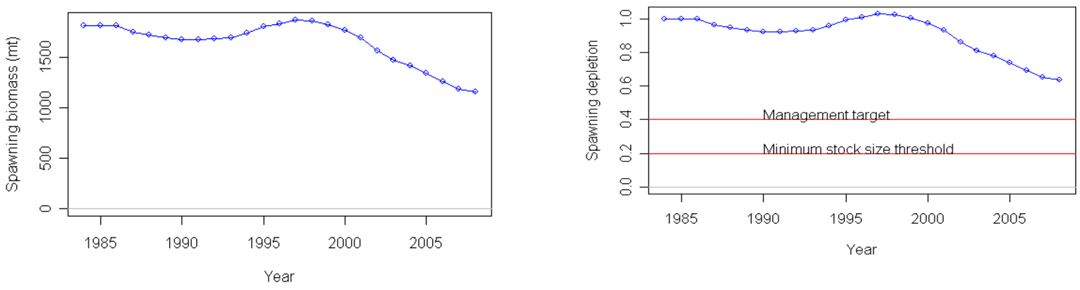


Figure 13.12. Time-trajectories of female spawning biomass, and spawning biomass depletion corresponding to the MPD estimates for the western stock.

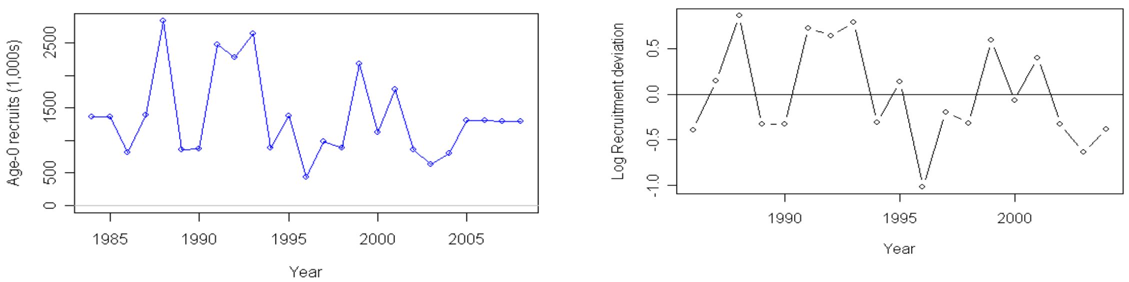


Figure 13.13. Time-trajectories of recruitment and recruitment deviation corresponding to the MPD estimates for the western zone analysis.

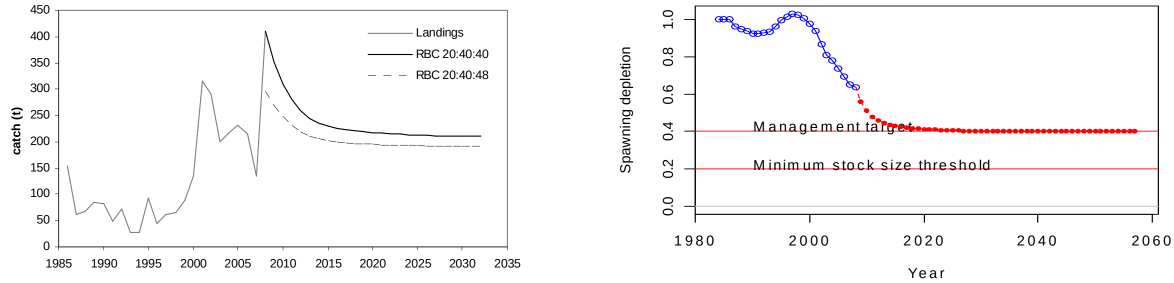


Figure 13.14. Time trajectories of landings and the projection of RBCs under the assumption that future recruitment is average, for two versions of the harvest control rule (dotted – 20:40:40; solid – 20:40:48) (left), and the relative spawning biomass under the 20:40:40 rule (right).

13.4.2.2 Sensitivity tests

Only one sensitivity test has been run for the western stock – assuming the same growth parameters as estimated in the east, rather than estimating the parameters from the western data (Table 13.19). This gives an even more optimistic assessment of current stock status. Unsurprisingly, it produces a considerably worse fit to the age and length composition data.

13.4.3 Discussion

The base-case analysis for the eastern stock estimates that 2008 spawning stock biomass will be 19% of unexploited stock biomass. Fits to the length, age, and catch rate data are all reasonable. The RBCs for the base-case model for 2008 are 0 t as the stock is below the minimum stock size threshold. The long-term yields under the 20:40:40 and 20:40:48 harvest control rules are 1,355 t and 1,240 t respectively.

Depletion across all sensitivities varied between 11% (M=0.1 yr^{-1}) and 28% (M=0.2 yr^{-1}). Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, M, however the model fits the data better with the base-case value than with either of the values used in the sensitivity analyses. The results are less sensitive to the values assumed for steepness and σ_R. Changing the weighting on various data sources changes the estimated biomass trajectory, but has little effect on the current estimate of stock size relative to unexploited stock size.

The results of this assessment are largely driven by the recent catch rate indices, which indicate a 70 % decline in the stock over the last 20 years. There is no obvious consistent trend in the age and length composition data. The recent declining catch rates during a period of relatively low catches are not consistent with the earlier period when catches were much higher, yet the catch rates were not declining. To reconcile this information the model estimates that annual recruitments have been mostly below average between 1980 and 2002, thus allowing spawning biomass to decline even though catches are relatively low.

If the recent catch rate indices are omitted from the analysis, the model estimates that the stock has more than doubled from 2000 to the end of 2006. Such an increase is implausible and is not reflected in the catch rate indices. All data sources provide evidence for an above average recruitment in 2003.

The longterm RBCs estimated by the base-case model are higher than the recent catches, which due to the long period of lower than average recruitments have driven the stock down. This implies that these targets based on average future recruitment may not be appropriate given the recruitment uncertainty.

The preliminary assessment for the western stock indicates that stock has declined in recent years as fishing pressure has increased, but spawning stock biomass is still considerably higher than the target level. The longterm RBCs estimated for the western stock are comparable with current catch levels.

Morwong is one of the most connected species in the southeast Australian ecosystem. As such it is directly and indirectly affected by pressures on many parts of the system. An ecosystem model developed for the region (Fulton *et al.*, 2007) suggests that while fishing pressure is the major force on deep water species, shelf species are under substantial ecological as well as fisheries pressure. Morwong in particular is under a strong combination of the two kinds of pressure, with fishing pressure not always dominating. For instance, the Atlantis ecosystem model suggests that until the mid 1990s ecological pressures were the major structuring force for the stock, but since then fishing pressure has become increasingly dominant.

While there is a good deal of uncertainty regarding this ecosystem model output it can give insight into important factors to consider when assessing the species. This does not mean that multispecies or ecosystem models must be used, but it does imply that ecological pressures may need to be considered in some form. This can potentially be done through alternative natural mortality forcing – for example, by estimating changes in natural mortality over time using an ecological model, and applying these changes in a stock assessment model.

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Table 13.1. Total catches (landed plus discards) (tonnes) of jackass morwong by steam trawlers, early Danish seine vessels and the mixed fleet of Danish seine and diesel trawlers, 1915 – 67.

Year	steam trawl	early Danish seine
1915	49	0
1916	50	0
1917	58	0
1918	89	0
1919	99	0
1920	145	0
1921	143	0
1922	102	0
1923	98	0
1924	162	0
1925	235	0
1926	259	0
1927	327	0
1928	391	0
1929	449	1
1930	398	4
1931	420	0
1932	380	5
1933	352	0
1934	326	4
1935	361	3
1936	390	12
1937	419	8
1938	421	9
1939	413	17
1940	74	18
1941	79	21
1942	20	0
1943	2	5
1944	67	189
1945	305	260
1946	1538	275
1947	2096	221
1948	1472	273
1949	1182	334
1950	819	299
1951	867	322
1952	971	535
1953	740	612
1954	754	920
1955	489	1088
1956	709	1430
1957	540	1668
1958	501	1257
1959	253	1249
1960	95	993
1961	16	1185
1962	0	2489
1963	0	1950
1964	0	1472
1965	0	2210
1966	0	2709
1967	0	1237

Table 13.2. Total catches (landed plus discards) (tonnes) of jackass morwong by the mixed fleet of Danish seine and diesel trawlers, 1968 – 85

Year	mixed
1968	1846
1969	1442
1970	1362
1971	1582
1972	1525
1973	1925
1974	1843
1975	1969
1976	1841
1977	1361
1978	1624
1979	1649
1980	2556
1981	2347
1982	1789
1983	1806
1984	1733
1985	1096

Table 13.3. Landed catches (tonnes) of jackass morwong for the eastern trawl fleet (Commonwealth catches in NSW/east Victoria plus NSW state catches), the Tasmanian trawl fleet (Commonwealth catches in eastern Tasmania plus Tasmanian state catches, the Danish seine fleet in Bass Strait/eastern Victoria and NSW, and the western trawl fleet (western Victoria and Tasmania), 1986 – 2006. The latter are not included in the assessment.

Year	eastern trawl	Tasmanian trawl	Danish seine	western trawl
1986	861	30	12	153
1987	1006	80	13	60
1988	1209	214	36	67
1989	1039	505	21	85
1990	722	159	27	83
1991	839	226	23	47
1992	564	140	18	72
1993	687	372	4	27
1994	717	213	7	27
1995	599	249	0	91
1996	729	210	13	44
1997	892	269	21	62
1998	620	245	32	65
1999	578	298	30	89
2000	611	154	48	134
2001	331	133	108	316
2002	387	139	76	289
2003	318	237	31	199
2004	310	256	21	216
2005	389	193	27	232
2006	387	198	19	215

Table 13.4. Proportion of total catch that was discarded. Years where proportions were less than 0.02 were not used in the analysis. The value of 1.0 for Danish seine in 2001 was replaced by the average ratio from the other years.

Year	eastern trawl	Tasmanian trawl	Danish seine
1993	0.016	-	0.024
1994	0.036	0.092	-
1995	0.079	-	-
1996	0.124	-	-
1997	0.029	0.012	-
1998	0.017	0.043	-
1999	0.026	0.107	0.600
2000	0.011	0.002	0.298
2001	0.013	0.014	1.000
2002	0.004	0.022	0.351
2003	0.012	0.010	0.732
2004	0.027	0.054	0.298
2005	0.056	0.092	0.261
2006	0.121	0.142	0.083

Table 13.5. Length composition for the discarded component of the catch for the eastern otter trawl, Danish seine and Tasmanian otter trawl fleets. The row ‘Number’ indicates the number of fish sampled in the discard data for that year.

Length	Eastern otter trawl							Danish seine		Tasmanian otter trawl					
(cm)	1996	1997	1998	2001	2004	2005	2006	2002	2003	1997	1998	1999	2001	2005	2006
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0044	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0128	0.0000	0.0000	0.0037	0.0000	0.0000	0.0000
18	0.0013	0.0000	0.0000	0.0000	0.0038	0.0000	0.0000	0.0195	0.0095	0.0000	0.0000	0.0037	0.0000	0.0000	0.0083
19	0.0016	0.0000	0.0000	0.0000	0.0311	0.0000	0.0000	0.0085	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0621	0.0000	0.0000	0.0000	0.2029	0.0080	0.0044	0.0501	0.0203	0.0000	0.0000	0.0037	0.0126	0.0000	0.0111
21	0.1518	0.0008	0.0007	0.0077	0.2990	0.0737	0.0226	0.0679	0.0377	0.0000	0.0120	0.0020	0.0123	0.0214	0.0083
22	0.3034	0.0037	0.0000	0.0732	0.3224	0.1716	0.1061	0.0950	0.0765	0.0077	0.0133	0.0047	0.0204	0.0418	0.0055
23	0.2368	0.0170	0.0000	0.1596	0.1269	0.3078	0.2817	0.0908	0.1052	0.0000	0.0388	0.0167	0.0544	0.0831	0.0111
24	0.1151	0.0500	0.0996	0.3137	0.0140	0.3077	0.3333	0.1281	0.1488	0.0087	0.0671	0.0369	0.0819	0.1340	0.0530
25	0.0688	0.0456	0.0410	0.4367	0.0000	0.1012	0.1737	0.1943	0.1889	0.0163	0.1721	0.0540	0.1105	0.1539	0.0774
26	0.0330	0.0733	0.1428	0.0091	0.0000	0.0217	0.0685	0.1553	0.1863	0.0231	0.1858	0.0720	0.1970	0.1649	0.1208
27	0.0246	0.0735	0.1747	0.0000	0.0000	0.0046	0.0078	0.1205	0.0999	0.0288	0.1853	0.1119	0.2249	0.1772	0.0900
28	0.0016	0.0903	0.1797	0.0000	0.0000	0.0014	0.0018	0.0679	0.0576	0.0317	0.1706	0.1391	0.1723	0.1390	0.0673
29	0.0000	0.0894	0.3615	0.0000	0.0000	0.0022	0.0000	0.0008	0.0253	0.0279	0.1007	0.1757	0.1107	0.0511	0.0739
30	0.0000	0.0811	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.0769	0.0418	0.1711	0.0032	0.0238	0.0915
31	0.0000	0.0847	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0126	0.0865	0.0073	0.1450	0.0000	0.0098	0.0655
32	0.0000	0.0731	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1019	0.0052	0.0453	0.0000	0.0000	0.0881
33	0.0000	0.0751	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.1048	0.0000	0.0106	0.0000	0.0000	0.1066
34	0.0000	0.0650	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0510	0.0000	0.0028	0.0000	0.0000	0.0688
35	0.0000	0.0627	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0692	0.0000	0.0010	0.0000	0.0000	0.0352
36	0.0000	0.0408	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1279	0.0000	0.0000	0.0000	0.0000	0.0176
37	0.0000	0.0291	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0490	0.0000	0.0000	0.0000	0.0000	0.0000
38	0.0000	0.0212	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0519	0.0000	0.0000	0.0000	0.0000	0.0000
39	0.0000	0.0088	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0596	0.0000	0.0000	0.0000	0.0000	0.0000
40	0.0000	0.0099	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0346	0.0000	0.0000	0.0000	0.0000	0.0000
41	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0163	0.0000	0.0000	0.0000	0.0000	0.0000
42	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0087	0.0000	0.0000	0.0000	0.0000	0.0000
43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0087	0.0000	0.0000	0.0000	0.0000	0.0000
44	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0087	0.0000	0.0000	0.0000	0.0000	0.0000
45	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number	244	2470	147	118	374	692	458	131	284	170	427	588	419	431	227

Table 13.6. Standardised catch rates for the steam trawl fleet.

Year	catch rate	cv
1920	1.54	0.2
1921	1.09	0.2
1937	1.25	0.2
1938	1.06	0.2
1939	1.14	0.2
1940	1.35	0.2
1941	1.12	0.2
1942	0.96	0.2
1952	0.98	0.2
1953	0.79	0.2
1954	0.82	0.2
1955	1.02	0.2
1956	0.89	0.2
1957	0.84	0.2

Table 13.7. Standardised catch rates calculated by Smith (1989) for the overlap years of the early Danish seine fleet and the steam trawl fleet.

Year	catch rate	cv
1948	123.7	0.2
1949	105.4	0.2
1950	84.4	0.2
1951	74.2	0.2
1952	92.8	0.2
1953	116.1	0.2
1954	92.6	0.2
1955	71.6	0.2
1956	99.2	0.2
1957	90.1	0.2
1958	63.3	0.2
1959	79.3	0.2
1960	77.6	0.2
1961	85	0.2
1962	79.7	0.2
1963	89.5	0.2
1964	89.8	0.2
1965	89.6	0.2
1966	82.4	0.2

Table 13.8. Standardised catch rates for the mixed fleet.

Year	catch rate	cv
1977	19.7	0.2
1978	20.3	0.2
1979	18.9	0.2
1980	17.1	0.2
1981	19.6	0.2
1982	16.3	0.2
1983	13.9	0.2
1984	16.4	0.2

Table 13.9. Standardised catch rates for the eastern, Tasmanian and western trawl fleets.

	Eastern trawl		Tasmanian trawl		Western trawl	
Year	catch rate	cv	catch rate	cv	catch rate	cv
1986	1	0.12	1	0.2	1	0.3
1987	1.1781	0.12	1.4261	0.2	0.6661	0.3
1988	1.1118	0.12	1.194	0.2	0.962	0.3
1989	1.0732	0.12	1.367	0.2	0.7581	0.3
1990	0.899	0.12	0.9204	0.2	0.6757	0.3
1991	0.8519	0.12	0.8047	0.2	0.4631	0.3
1992	0.655	0.12	0.6566	0.2	0.445	0.3
1993	0.7058	0.12	0.6667	0.2	0.3461	0.3
1994	0.6008	0.12	0.4526	0.2	0.346	0.3
1995	0.584	0.12	0.4648	0.2	0.3755	0.3
1996	0.5197	0.12	0.4398	0.2	0.3927	0.3
1997	0.5679	0.12	0.5017	0.2	0.3404	0.3
1998	0.4773	0.12	0.4256	0.2	0.3569	0.3
1999	0.4989	0.12	0.4594	0.2	0.3661	0.3
2000	0.4008	0.12	0.381	0.2	0.4309	0.3
2001	0.2848	0.12	0.2364	0.2	0.4689	0.3
2002	0.3215	0.12	0.2479	0.2	0.3988	0.3
2003	0.2588	0.12	0.2191	0.2	0.3485	0.3
2004	0.2491	0.12	0.2187	0.2	0.4104	0.3
2005	0.2873	0.12	0.2475	0.2	0.4387	0.3
2006	0.3395	0.12	0.3031	0.2	0.3606	0.3

Table 13.10. Length composition for the retained component of the catch for the early steam trawl fleet. ‘Number’ indicates the number of fish measured.

Length	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
19	0.0000	0.0005	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
20	0.0000	0.0024	0.0002	0.0048	0.0027	0.0003	0.0000	0.0001	0.0002	0.0001	0.0000	0.0000
21	0.0004	0.0095	0.0005	0.0119	0.0089	0.0022	0.0003	0.0009	0.0007	0.0015	0.0011	0.0000
22	0.0039	0.0183	0.0044	0.0181	0.0207	0.0075	0.0021	0.0035	0.0029	0.0025	0.0014	0.0012
23	0.0124	0.0190	0.0131	0.0334	0.0375	0.0182	0.0072	0.0067	0.0152	0.0106	0.0044	0.0043
24	0.0215	0.0269	0.0263	0.0368	0.0509	0.0345	0.0165	0.0105	0.0321	0.0261	0.0170	0.0089
25	0.0184	0.0397	0.0393	0.0406	0.0523	0.0588	0.0324	0.0174	0.0460	0.0394	0.0328	0.0188
26	0.0217	0.0529	0.0436	0.0518	0.0523	0.0721	0.0559	0.0254	0.0567	0.0570	0.0542	0.0210
27	0.0345	0.0577	0.0631	0.0860	0.0509	0.0796	0.0779	0.0504	0.0553	0.0742	0.0786	0.0336
28	0.0616	0.0686	0.0858	0.0835	0.0610	0.0885	0.0886	0.0764	0.0545	0.0818	0.1110	0.0515
29	0.0844	0.0780	0.0943	0.0881	0.0698	0.0838	0.0983	0.1089	0.0735	0.0769	0.1140	0.0913
30	0.0962	0.0920	0.0974	0.1050	0.0800	0.0838	0.1024	0.1252	0.0901	0.1024	0.1227	0.1119
31	0.1125	0.1072	0.1062	0.0969	0.0884	0.0807	0.0997	0.1173	0.0984	0.0913	0.0846	0.1129
32	0.1185	0.0957	0.1092	0.0816	0.0898	0.0803	0.0845	0.1038	0.0932	0.0883	0.0729	0.1048
33	0.1181	0.0895	0.0857	0.0719	0.0741	0.0710	0.0792	0.0774	0.0829	0.0789	0.0701	0.0891
34	0.0935	0.0753	0.0754	0.0647	0.0767	0.0632	0.0652	0.0665	0.0747	0.0639	0.0587	0.0792
35	0.0765	0.0595	0.0558	0.0478	0.0549	0.0520	0.0546	0.0534	0.0602	0.0528	0.0532	0.0697
36	0.0548	0.0431	0.0394	0.0318	0.0417	0.0390	0.0417	0.0457	0.0495	0.0446	0.0477	0.0567
37	0.0314	0.0285	0.0283	0.0211	0.0301	0.0312	0.0322	0.0324	0.0391	0.0324	0.0313	0.0518
38	0.0196	0.0175	0.0145	0.0124	0.0224	0.0207	0.0229	0.0304	0.0276	0.0293	0.0189	0.0373
39	0.0112	0.0098	0.0077	0.0067	0.0137	0.0129	0.0160	0.0178	0.0187	0.0164	0.0118	0.0247
40	0.0043	0.0054	0.0057	0.0024	0.0111	0.0102	0.0121	0.0124	0.0133	0.0124	0.0069	0.0148
41	0.0021	0.0021	0.0022	0.0017	0.0052	0.0054	0.0063	0.0083	0.0055	0.0076	0.0044	0.0068
42	0.0008	0.0007	0.0010	0.0006	0.0025	0.0022	0.0020	0.0054	0.0043	0.0050	0.0014	0.0062
43	0.0008	0.0002	0.0002	0.0002	0.0011	0.0010	0.0011	0.0020	0.0030	0.0025	0.0003	0.0022
44	0.0004	0.0000	0.0003	0.0002	0.0005	0.0004	0.0006	0.0010	0.0014	0.0015	0.0003	0.0006
45	0.0002	0.0000	0.0001	0.0000	0.0004	0.0001	0.0003	0.0006	0.0007	0.0003	0.0002	0.0006
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0001	0.0002	0.0000
47	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Number	4836	13960	8577	8823	9721	9456	7956	8033	12010	7997	6351	3243

Table 13.11. Length composition for the retained component of the catch for the early Danish seine fleet. ‘Number’ is the number of fish measured.

Length	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0008	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0030	0.0000	0.0025	0.0016	0.0005	0.0000	0.0000	0.0009	0.0000	0.0000	0.0006	0.0004	0.0010	0.0000	0.0000	0.0005	0.0000	0.0001	0.0000	0.0000
21	0.0019	0.0150	0.0003	0.0176	0.0031	0.0024	0.0004	0.0036	0.0032	0.0010	0.0002	0.0034	0.0029	0.0023	0.0009	0.0006	0.0008	0.0003	0.0001	0.0006	0.0002
22	0.0082	0.0179	0.0028	0.0294	0.0057	0.0124	0.0015	0.0108	0.0082	0.0056	0.0023	0.0066	0.0069	0.0093	0.0043	0.0026	0.0040	0.0021	0.0011	0.0028	0.0012
23	0.0208	0.0178	0.0057	0.0299	0.0207	0.0161	0.0033	0.0143	0.0180	0.0187	0.0066	0.0118	0.0117	0.0194	0.0123	0.0062	0.0079	0.0043	0.0030	0.0078	0.0060
24	0.0220	0.0176	0.0098	0.0359	0.0450	0.0270	0.0098	0.0282	0.0281	0.0335	0.0137	0.0184	0.0193	0.0296	0.0254	0.0099	0.0183	0.0126	0.0062	0.0118	0.0117
25	0.0088	0.0278	0.0165	0.0367	0.0569	0.0519	0.0200	0.0193	0.0552	0.0536	0.0257	0.0269	0.0319	0.0379	0.0375	0.0160	0.0304	0.0226	0.0111	0.0169	0.0204
26	0.0182	0.0393	0.0332	0.0463	0.0564	0.0598	0.0298	0.0278	0.0636	0.0762	0.0501	0.0342	0.0383	0.0453	0.0490	0.0328	0.0470	0.0378	0.0241	0.0303	0.0221
27	0.0157	0.0448	0.0402	0.0601	0.0569	0.0773	0.0600	0.0327	0.0588	0.0838	0.0837	0.0511	0.0463	0.0582	0.0547	0.0548	0.0539	0.0580	0.0458	0.0511	0.0349
28	0.0384	0.0460	0.0659	0.0862	0.0678	0.0804	0.0902	0.0605	0.0566	0.0885	0.0939	0.0719	0.0665	0.0625	0.0579	0.0735	0.0697	0.0810	0.0714	0.0680	0.0498
29	0.0579	0.0499	0.0768	0.0904	0.0812	0.0881	0.0924	0.0852	0.0476	0.0759	0.1028	0.0972	0.0682	0.0658	0.0598	0.0897	0.0896	0.0929	0.1035	0.0859	0.0771
30	0.0824	0.0874	0.1242	0.0925	0.0776	0.0929	0.1251	0.1134	0.0785	0.0885	0.1150	0.1299	0.0990	0.0836	0.0862	0.0941	0.1022	0.1018	0.1173	0.1069	0.1072
31	0.0912	0.1030	0.1273	0.0980	0.0916	0.0900	0.1073	0.1206	0.0962	0.0755	0.0881	0.1143	0.1037	0.0897	0.0877	0.0870	0.0971	0.1033	0.1246	0.1169	0.1156
32	0.1296	0.1239	0.1311	0.0791	0.0874	0.0969	0.0899	0.1130	0.1099	0.0770	0.0872	0.1028	0.1134	0.0938	0.0910	0.0936	0.0956	0.0993	0.1235	0.1177	0.1313
33	0.1327	0.1209	0.1066	0.0722	0.0843	0.0820	0.0928	0.0986	0.1068	0.0748	0.0829	0.0822	0.1002	0.0923	0.0910	0.0904	0.0885	0.0975	0.1077	0.1064	0.1167
34	0.1094	0.0996	0.0984	0.0664	0.0797	0.0707	0.0840	0.0802	0.0865	0.0655	0.0717	0.0690	0.0804	0.0852	0.0921	0.0889	0.0764	0.0792	0.0805	0.0855	0.0915
35	0.0906	0.0708	0.0598	0.0528	0.0647	0.0532	0.0604	0.0677	0.0625	0.0590	0.0605	0.0588	0.0621	0.0694	0.0774	0.0769	0.0649	0.0664	0.0608	0.0653	0.0699
36	0.0774	0.0456	0.0438	0.0363	0.0517	0.0434	0.0422	0.0498	0.0461	0.0456	0.0416	0.0453	0.0541	0.0577	0.0598	0.0629	0.0496	0.0531	0.0447	0.0457	0.0508
37	0.0390	0.0310	0.0268	0.0259	0.0279	0.0241	0.0360	0.0278	0.0334	0.0328	0.0286	0.0301	0.0350	0.0386	0.0443	0.0461	0.0392	0.0356	0.0309	0.0309	0.0361
38	0.0239	0.0201	0.0152	0.0174	0.0176	0.0143	0.0251	0.0148	0.0190	0.0193	0.0203	0.0180	0.0247	0.0253	0.0302	0.0303	0.0258	0.0212	0.0180	0.0219	0.0227
39	0.0157	0.0093	0.0064	0.0103	0.0088	0.0071	0.0146	0.0134	0.0112	0.0119	0.0120	0.0118	0.0177	0.0143	0.0148	0.0183	0.0153	0.0139	0.0110	0.0114	0.0130
40	0.0082	0.0047	0.0036	0.0089	0.0052	0.0053	0.0091	0.0094	0.0061	0.0080	0.0060	0.0081	0.0081	0.0098	0.0117	0.0115	0.0102	0.0081	0.0061	0.0078	0.0110
41	0.0050	0.0022	0.0021	0.0027	0.0026	0.0024	0.0018	0.0058	0.0021	0.0026	0.0039	0.0048	0.0050	0.0045	0.0063	0.0067	0.0064	0.0040	0.0035	0.0043	0.0052
42	0.0031	0.0008	0.0015	0.0016	0.0016	0.0008	0.0029	0.0018	0.0010	0.0014	0.0017	0.0018	0.0023	0.0028	0.0029	0.0033	0.0037	0.0028	0.0023	0.0022	0.0030
43	0.0000	0.0004	0.0005	0.0005	0.0016	0.0005	0.0015	0.0013	0.0003	0.0009	0.0010	0.0006	0.0015	0.0008	0.0019	0.0024	0.0011	0.0011	0.0014	0.0011	0.0010
44	0.0000	0.0000	0.0008	0.0000	0.0010	0.0000	0.0000	0.0000	0.0001	0.0003	0.0002	0.0005	0.0004	0.0005	0.0009	0.0009	0.0009	0.0006	0.0007	0.0006	0.0007
45	0.0000	0.0002	0.0005	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0003	0.0002	0.0004	0.0002	0.0002	0.0002	0.0002	0.0003
46	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0002	0.0001	0.0000	0.0000	0.0003
47	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0002
Number	1590	5070	3882	5511	1933	3779	2749	2231	8627	8769	4826	6205	8569	10660	10038	15498	17887	24744	16586	19328	5980

Table 13.12. Length composition for the retained component of the catch for the mixed fleet. ‘Number’ is the number of fish measured.

Length	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0013	0.0000	0.0001	0.0000	0.0001	0.0008	0.0003	0.0004	0.0000	0.0000	0.0000	0.0013
22	0.0008	0.0000	0.0000	0.0019	0.0007	0.0018	0.0001	0.0009	0.0031	0.0013	0.0017	0.0008	0.0000	0.0000	0.0019
23	0.0110	0.0032	0.0065	0.0143	0.0013	0.0065	0.0010	0.0034	0.0111	0.0073	0.0056	0.0110	0.0032	0.0065	0.0143
24	0.0388	0.0158	0.0056	0.0358	0.0050	0.0105	0.0043	0.0078	0.0206	0.0196	0.0199	0.0388	0.0158	0.0056	0.0358
25	0.0287	0.0602	0.0185	0.0654	0.0145	0.0104	0.0143	0.0092	0.0306	0.0453	0.0319	0.0287	0.0602	0.0185	0.0654
26	0.0489	0.0713	0.0463	0.0934	0.0403	0.0133	0.0219	0.0138	0.0362	0.0708	0.0649	0.0489	0.0713	0.0463	0.0934
27	0.0835	0.0602	0.0944	0.0821	0.0596	0.0238	0.0319	0.0268	0.0446	0.0927	0.0997	0.0835	0.0602	0.0944	0.0821
28	0.0885	0.0729	0.1176	0.0753	0.0852	0.0480	0.0372	0.0393	0.0561	0.0986	0.1270	0.0885	0.0729	0.1176	0.0753
29	0.0658	0.0808	0.1315	0.0810	0.1086	0.0714	0.0385	0.0588	0.0672	0.0847	0.1078	0.0658	0.0808	0.1315	0.0810
30	0.0616	0.0713	0.1167	0.0786	0.1073	0.0977	0.0490	0.0667	0.0832	0.0791	0.0893	0.0616	0.0713	0.1167	0.0786
31	0.0632	0.0523	0.1065	0.0829	0.1036	0.1044	0.0802	0.0738	0.1002	0.0715	0.0736	0.0632	0.0523	0.1065	0.0829
32	0.0641	0.0555	0.0870	0.0737	0.0973	0.1110	0.1031	0.1039	0.0988	0.0796	0.0707	0.0641	0.0555	0.0870	0.0737
33	0.0717	0.0681	0.0481	0.0651	0.0904	0.1031	0.1110	0.1147	0.1002	0.0749	0.0603	0.0717	0.0681	0.0481	0.0651
34	0.0885	0.0586	0.0463	0.0527	0.0696	0.0882	0.1210	0.1162	0.0891	0.0692	0.0528	0.0885	0.0586	0.0463	0.0527
35	0.0658	0.0713	0.0417	0.0517	0.0663	0.0777	0.0994	0.1107	0.0765	0.0620	0.0549	0.0658	0.0713	0.0417	0.0517
36	0.0565	0.0681	0.0435	0.0377	0.0514	0.0626	0.0833	0.0844	0.0586	0.0483	0.0448	0.0565	0.0681	0.0435	0.0377
37	0.0573	0.0523	0.0278	0.0320	0.0360	0.0468	0.0575	0.0616	0.0450	0.0364	0.0342	0.0573	0.0523	0.0278	0.0320
38	0.0312	0.0444	0.0213	0.0223	0.0269	0.0341	0.0446	0.0403	0.0317	0.0242	0.0207	0.0312	0.0444	0.0213	0.0223
39	0.0261	0.0317	0.0176	0.0151	0.0161	0.0276	0.0319	0.0255	0.0195	0.0139	0.0162	0.0261	0.0317	0.0176	0.0151
40	0.0211	0.0174	0.0083	0.0105	0.0084	0.0186	0.0228	0.0176	0.0121	0.0101	0.0070	0.0211	0.0174	0.0083	0.0105
41	0.0059	0.0111	0.0074	0.0083	0.0046	0.0166	0.0165	0.0087	0.0071	0.0055	0.0081	0.0059	0.0111	0.0074	0.0083
42	0.0084	0.0111	0.0019	0.0040	0.0030	0.0133	0.0123	0.0071	0.0036	0.0023	0.0035	0.0084	0.0111	0.0019	0.0040
43	0.0025	0.0095	0.0019	0.0040	0.0024	0.0058	0.0089	0.0033	0.0023	0.0015	0.0023	0.0025	0.0095	0.0019	0.0040
44	0.0034	0.0016	0.0028	0.0046	0.0009	0.0035	0.0052	0.0033	0.0010	0.0006	0.0015	0.0034	0.0016	0.0028	0.0046
45	0.0000	0.0032	0.0000	0.0016	0.0004	0.0014	0.0022	0.0010	0.0004	0.0002	0.0006	0.0000	0.0032	0.0000	0.0016
46	0.0000	0.0032	0.0009	0.0013	0.0002	0.0013	0.0012	0.0006	0.0000	0.0000	0.0002	0.0000	0.0032	0.0009	0.0013
47	0.0067	0.0000	0.0000	0.0013	0.0000	0.0001	0.0006	0.0004	0.0000	0.0001	0.0002	0.0067	0.0000	0.0000	0.0013
Number	1186	631	1080	3716	5388	7971	8893	7911	13608	11552	4825	1186	631	1080	3716

Table 13.13. Length composition for the retained component of the catch for the eastern trawl fleet. ‘Number’ is the number of fish measured.

Length	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0020
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0040
21	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0010	0.0019	0.0002	0.0033	0.0000	0.0078
22	0.0015	0.0018	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0006	0.0012	0.0004	0.0063	0.0113	0.0012	0.0132	0.0003	0.0135
23	0.0065	0.0049	0.0036	0.0022	0.0044	0.0022	0.0003	0.0016	0.0000	0.0012	0.0051	0.0001	0.0097	0.0025	0.0010	0.0115	0.0320	0.0130	0.0135	0.0017	0.0275
24	0.0160	0.0078	0.0123	0.0056	0.0122	0.0022	0.0129	0.0026	0.0003	0.0070	0.0154	0.0010	0.0176	0.0066	0.0023	0.0207	0.0434	0.0329	0.0210	0.0066	0.0436
25	0.0310	0.0186	0.0227	0.0123	0.0311	0.0142	0.0193	0.0083	0.0006	0.0136	0.0274	0.0104	0.0416	0.0163	0.0099	0.0244	0.0491	0.0454	0.0568	0.0179	0.0732
26	0.0488	0.0271	0.0351	0.0302	0.0488	0.0478	0.0346	0.0157	0.0095	0.0082	0.0436	0.0173	0.0872	0.0386	0.0250	0.0396	0.0681	0.0758	0.0823	0.0475	0.0865
27	0.0632	0.0533	0.0444	0.0476	0.0910	0.1132	0.1078	0.0187	0.0216	0.0491	0.0616	0.0523	0.0921	0.0669	0.0612	0.0622	0.0874	0.0764	0.1163	0.0744	0.0936
28	0.0774	0.0778	0.0715	0.0526	0.1221	0.1803	0.1409	0.0306	0.0610	0.0749	0.0767	0.0804	0.0974	0.1047	0.0972	0.1056	0.1102	0.0759	0.0977	0.1024	0.0910
29	0.0906	0.1027	0.0880	0.0661	0.1487	0.1947	0.1104	0.0517	0.0737	0.0837	0.0997	0.1072	0.1163	0.1393	0.1413	0.1141	0.1748	0.0780	0.0974	0.1148	0.0797
30	0.1079	0.1127	0.1072	0.0840	0.1188	0.1838	0.1272	0.0591	0.1325	0.1105	0.1025	0.0843	0.1116	0.1337	0.1337	0.1337	0.0984	0.0960	0.0963	0.1121	0.0794
31	0.1157	0.1257	0.1126	0.1053	0.0766	0.1174	0.1097	0.0689	0.1349	0.1446	0.1101	0.1023	0.0897	0.1311	0.1337	0.1175	0.0841	0.1040	0.0857	0.1241	0.0974
32	0.0998	0.1102	0.1209	0.1327	0.0777	0.0698	0.0774	0.0858	0.1197	0.0967	0.1050	0.1028	0.0872	0.1025	0.1120	0.0958	0.0658	0.1088	0.0710	0.0969	0.0934
33	0.0862	0.1043	0.0995	0.1114	0.0610	0.0428	0.0357	0.0982	0.1125	0.0691	0.0850	0.0937	0.0545	0.0771	0.0908	0.0794	0.0507	0.0893	0.0597	0.0689	0.0747
34	0.0748	0.0796	0.0806	0.1305	0.0666	0.0131	0.0808	0.1023	0.0763	0.1031	0.0742	0.0863	0.0470	0.0565	0.0568	0.0532	0.0372	0.0597	0.0423	0.0611	0.0428
35	0.0575	0.0590	0.0702	0.0784	0.0311	0.0081	0.0673	0.0907	0.0510	0.0686	0.0570	0.0853	0.0375	0.0398	0.0406	0.0418	0.0294	0.0459	0.0444	0.0462	0.0320
36	0.0434	0.0457	0.0512	0.0549	0.0366	0.0028	0.0281	0.0738	0.0450	0.0726	0.0469	0.0615	0.0293	0.0290	0.0282	0.0274	0.0181	0.0336	0.0221	0.0362	0.0232
37	0.0333	0.0312	0.0375	0.0375	0.0266	0.0026	0.0274	0.0693	0.0303	0.0431	0.0324	0.0451	0.0214	0.0192	0.0213	0.0203	0.0122	0.0218	0.0205	0.0250	0.0139
38	0.0206	0.0188	0.0175	0.0174	0.0111	0.0021	0.0112	0.0673	0.0434	0.0234	0.0148	0.0275	0.0175	0.0153	0.0142	0.0159	0.0086	0.0142	0.0163	0.0230	0.0097
39	0.0122	0.0098	0.0112	0.0101	0.0178	0.0012	0.0051	0.0476	0.0250	0.0200	0.0119	0.0211	0.0108	0.0090	0.0122	0.0123	0.0080	0.0121	0.0169	0.0215	0.0041
40	0.0071	0.0053	0.0069	0.0106	0.0055	0.0012	0.0021	0.0486	0.0226	0.0037	0.0086	0.0118	0.0075	0.0053	0.0090	0.0090	0.0041	0.0085	0.0100	0.0106	0.0022
41	0.0035	0.0012	0.0030	0.0056	0.0033	0.0002	0.0007	0.0292	0.0171	0.0060	0.0040	0.0052	0.0061	0.0024	0.0049	0.0045	0.0025	0.0028	0.0070	0.0052	0.0014
42	0.0013	0.0016	0.0014	0.0034	0.0011	0.0003	0.0008	0.0153	0.0087	0.0004	0.0018	0.0029	0.0042	0.0017	0.0028	0.0023	0.0009	0.0020	0.0030	0.0013	0.0008
43	0.0010	0.0004	0.0005	0.0006	0.0022	0.0001	0.0001	0.0094	0.0080	0.0004	0.0021	0.0005	0.0031	0.0005	0.0011	0.0011	0.0006	0.0014	0.0032	0.0020	0.0005
44	0.0004	0.0004	0.0000	0.0006	0.0044	0.0000	0.0003	0.0019	0.0024	0.0000	0.0012	0.0005	0.0039	0.0003	0.0003	0.0004	0.0002	0.0000	0.0000	0.0002	0.0002
45	0.0000	0.0000	0.0000	0.0006	0.0011	0.0000	0.0000	0.0014	0.0022	0.0000	0.0014	0.0005	0.0021	0.0000	0.0001	0.0002	0.0003	0.0000	0.0000	0.0000	0.0002
46	0.0001	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0013	0.0016	0.0000	0.0018	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
47	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0023	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number	13441	4900	3649	1786	901	1181	1355	2359	1124	667	2990	3190	8060	12659	8062	5603	5757	4066	3544	5747	13604

Table 13.14. Length composition for the retained component of the catch for the Danish seine fleet. 'Number' is the number of fish measured

length	1997	1998	1999	2000	2001	2002	2004
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0027	0.0000	0.0000	0.0000	0.0015	0.0000
22	0.0039	0.0074	0.0000	0.0009	0.0000	0.0020	0.0000
23	0.0155	0.0162	0.0000	0.0000	0.0000	0.0165	0.0000
24	0.0620	0.0356	0.0000	0.0031	0.0000	0.0476	0.0093
25	0.1162	0.0698	0.0000	0.0201	0.0045	0.0812	0.0648
26	0.1158	0.0863	0.0000	0.0346	0.0077	0.1075	0.1388
27	0.1260	0.2097	0.0544	0.0360	0.0482	0.1018	0.1388
28	0.1248	0.1270	0.1473	0.1535	0.0507	0.1189	0.2593
29	0.1429	0.1499	0.1460	0.1734	0.1459	0.1487	0.0834
30	0.0863	0.1233	0.1967	0.1589	0.1491	0.0820	0.0927
31	0.0544	0.0770	0.2145	0.1845	0.1707	0.1223	0.1112
32	0.0410	0.0623	0.1053	0.0372	0.1795	0.0682	0.0370
33	0.0358	0.0142	0.0626	0.1390	0.0915	0.0430	0.0371
34	0.0353	0.0082	0.0285	0.0390	0.0742	0.0362	0.0000
35	0.0134	0.0046	0.0254	0.0079	0.0310	0.0131	0.0093
36	0.0167	0.0027	0.0073	0.0054	0.0270	0.0022	0.0093
37	0.0037	0.0018	0.0057	0.0026	0.0096	0.0035	0.0093
38	0.0034	0.0006	0.0031	0.0020	0.0061	0.0000	0.0000
39	0.0030	0.0003	0.0016	0.0016	0.0022	0.0007	0.0000
40	0.0000	0.0001	0.0016	0.0004	0.0003	0.0020	0.0000
41	0.0000	0.0001	0.0000	0.0000	0.0019	0.0013	0.0000
42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number	340	1088	295	286	315	487	108

Table 13.15. Length composition for the retained component of the catch for the Tasmanian otter trawl fleet. ‘Number’ is the number of fish measured

length	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0001	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0019	0.0015	0.0007	0.0001	0.0068	0.0071	0.0008	0.0000	0.0000
24	0.0000	0.0158	0.0017	0.0023	0.0009	0.0205	0.0107	0.0005	0.0011	0.0000
25	0.0000	0.0603	0.0073	0.0074	0.0024	0.0343	0.0356	0.0085	0.0005	0.0042
26	0.0169	0.0448	0.0307	0.0290	0.0052	0.0775	0.0593	0.0273	0.0194	0.0055
27	0.0210	0.0859	0.0539	0.0545	0.0179	0.0936	0.0802	0.0575	0.0566	0.0693
28	0.0647	0.1197	0.1188	0.0897	0.0334	0.1262	0.1106	0.0709	0.1254	0.0528
29	0.1089	0.2207	0.1267	0.0963	0.0591	0.1161	0.1241	0.0873	0.0644	0.0559
30	0.1094	0.1343	0.1269	0.1142	0.0936	0.1231	0.1216	0.0924	0.1919	0.0758
31	0.1042	0.1256	0.1400	0.1258	0.1053	0.1113	0.1165	0.0773	0.1866	0.1231
32	0.1135	0.0454	0.1256	0.1890	0.0810	0.0896	0.0698	0.0817	0.1077	0.1187
33	0.1090	0.0530	0.0877	0.0985	0.0989	0.0529	0.1127	0.0551	0.0841	0.1344
34	0.0915	0.0354	0.0513	0.0608	0.1237	0.0418	0.0756	0.0447	0.0409	0.0877
35	0.0799	0.0213	0.0411	0.0460	0.1225	0.0251	0.0305	0.0377	0.0346	0.0857
36	0.0435	0.0143	0.0305	0.0325	0.0774	0.0261	0.0256	0.0436	0.0403	0.0712
37	0.0433	0.0062	0.0221	0.0209	0.0392	0.0185	0.0067	0.0569	0.0176	0.0314
38	0.0388	0.0086	0.0117	0.0192	0.0590	0.0117	0.0067	0.0721	0.0145	0.0394
39	0.0186	0.0026	0.0092	0.0049	0.0199	0.0105	0.0027	0.0620	0.0087	0.0100
40	0.0171	0.0012	0.0062	0.0051	0.0248	0.0045	0.0027	0.0505	0.0058	0.0217
41	0.0048	0.0006	0.0032	0.0012	0.0121	0.0040	0.0013	0.0384	0.0000	0.0132
42	0.0050	0.0003	0.0017	0.0007	0.0185	0.0016	0.0000	0.0274	0.0000	0.0000
43	0.0050	0.0000	0.0005	0.0007	0.0007	0.0012	0.0000	0.0050	0.0000	0.0000
44	0.0023	0.0020	0.0008	0.0000	0.0000	0.0024	0.0000	0.0020	0.0000	0.0000
45	0.0025	0.0000	0.0000	0.0000	0.0044	0.0007	0.0000	0.0002	0.0000	0.0000
46	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
Number	282	835	2384	762	664	2116	424	1248	1391	520

Table 13.16. Standard deviation of age reading error.

Age	std dev
0	0.4215
1	0.4215
2	0.4367
3	0.4533
4	0.4713
5	0.4909
6	0.5122
7	0.5354
8	0.5607
9	0.5881
10	0.6180
11	0.6505
12	0.6858
13	0.7243
14	0.7661
15	0.8116
16	0.8611
17	0.9150
18	0.9736
19	1.0374
20	1.1067
21	1.1822
22	1.2643
23	1.3536
24	1.4508
25	1.5565

Table 13.17. Estimated and pre-specified parameters of the model for the eastern assessment (base-case values are in bold)

Estimated parameters	number
unexploited recruitment	1
recruitment deviations 1942 – 2004	63
growth	4
selectivity (2 for each fleet)	12
retention	6
Pre-specified parameters	**values**
rate of natural mortality, *M*	0.1, **0.15**, 0.2
steepness, *h*	0.6, **0.7**, 0.8
recruitment variability , σ_r	0.3, **0.55**, 0.8
length at 50% maturity (east)	22,**24.5** cm
length at 95% maturity (east)	27 cm
length-weight scale, *a*	1.7 x 10^{-5}
length-weight power, *b*	3.031

Table 13.18. Estimated selectivity parameters for all fleets for the base-case (spread is the difference between length at 50% and length at 95% selection).

Fleet	length at 50%	spread (cm)
eastern trawl	27.1	4.5
Danish seine	25.1	4.4
Tasmanian trawl	28.0	3.6
steam trawl	27.5	5.1
early Danish	28.3	5.5
mixed	28.8	5.5

Table 13.19. Summary of results for the base-case and sensitivity tests (log-likelihood (-ln L) values that are comparable are in bold).

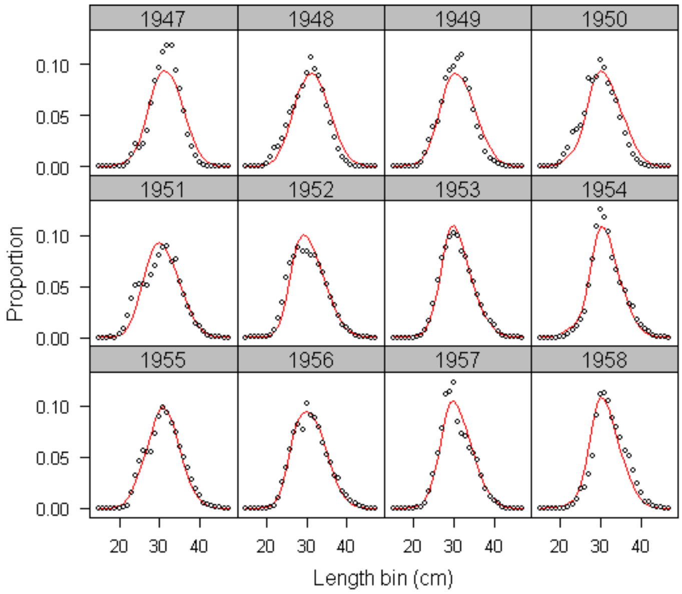
Model	female SB_0	female SB_{2008}	SB_{2008}/SB_0	2008 RBC 20:40:40	2008 RBC 20:40:48	longterm RBC 20:40:40	longterm RBC 20:40:48	-ln L
Eastern stock								
base-case	11,961	2,255	0.19	0	0	1,355	1,240	**3104.7**
M = 0.1 yr^{-1}	14,539	1,616	0.11	0	0	1,125	1,027	**3105.0**
M = 0.2 yr^{-1}	11,608	3,239	0.28	470	353	1,773	1,618	**3114.1**
estimate M (estimate=0.12 yr^{-1})	13,602	1,880	0.14	0	0	1,216	1,113	3102.4
h = 0.6	12,893	2,158	0.17	0	0	1,276	1,184	**3099.8**
h = 0.8	11,315	2,343	0.21	25	18	1,419	1,282	**3108.9**
σ_R = 0.3	10,850	2,332	0.21	47	35	1,229	1,125	3188.9
σ_R = 0.8	14,510	2,294	0.16	0	0	1,646	1,507	3077.0
50% maturity at 22 cm	12,639	2,773	0.22	67	50	1,408	1,292	**3105.1**
Double weighting on CPUE	11,599	2,378	0.21	16	12	1,323	1,211	3202.2
Halve weighting on CPUE	12,546	2,682	0.21	50	38	1,420	1,299	3071.2
Double weighting on LF data	11,826	3,200	0.27	293	221	1,333	1,221	6250.8
Halve weighting on LF data	11,946	1,915	0.16	0	0	1,335	1,222	2214.7
Double weighting on age data	11,747	1,834	0.16	0	0	1,304	1,194	8332.7
Halve weighting on age data	12,134	2,363	0.19	0	0	1,354	1,240	1817.5
Omit early catch rate and	11,987	2,194	0.18	0	0	1,365	1,249	2916.9
Include western zones as a	14,298	3,710	0.26	323	227	1,661	1,525	3990.9
Western stock								
base-case	1,811	1,150	0.63	410	297	208	191	1030.7
use eastern growth parameters	1,385	1,196	0.86	477	335	190	174	1156.2

Table 13.20. Base-case future time trajectory of RBCs (tonnes) under two harvest control rules, assuming average recruitment.

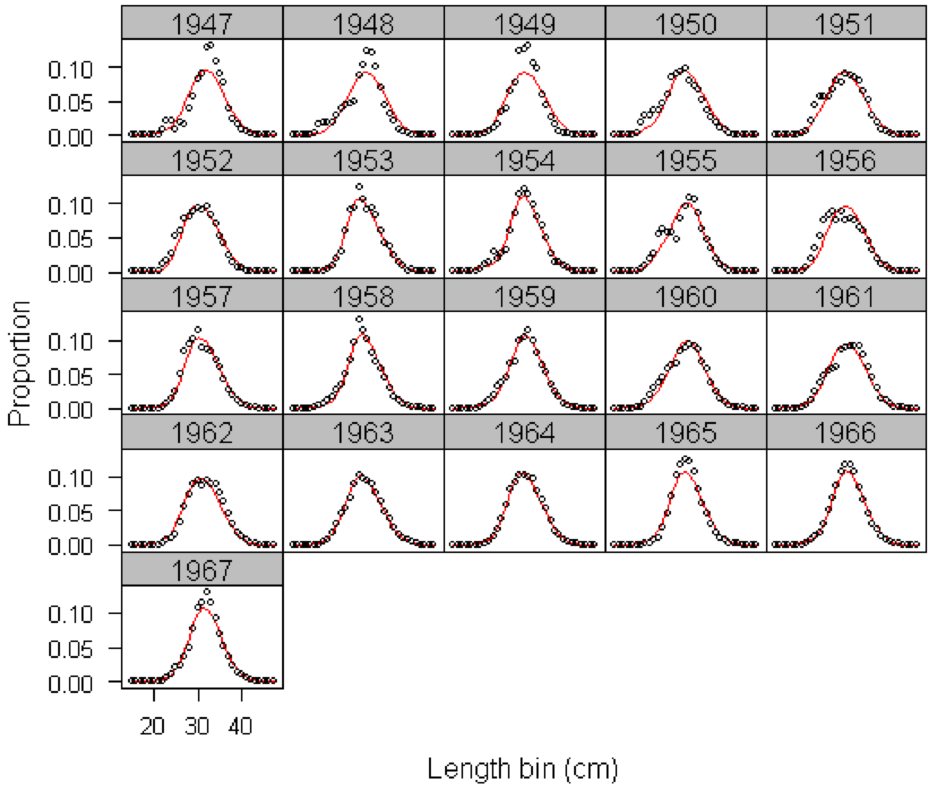
Year	RBC 20:40:40	RBC 20:40:48
2008	0	0
2009	112	85
2010	319	245
2011	515	408
2012	683	559
2013	824	696
2014	943	818
2015	1041	923
2016	1121	1012
2017	1182	1046
2018	1229	1068
2019	1264	1089
2020	1289	1107
2021	1307	1124
2022	1321	1139
2023	1330	1153
2024	1337	1164
2025	1342	1174

13.7 Appendix A: Fits to the length composition data

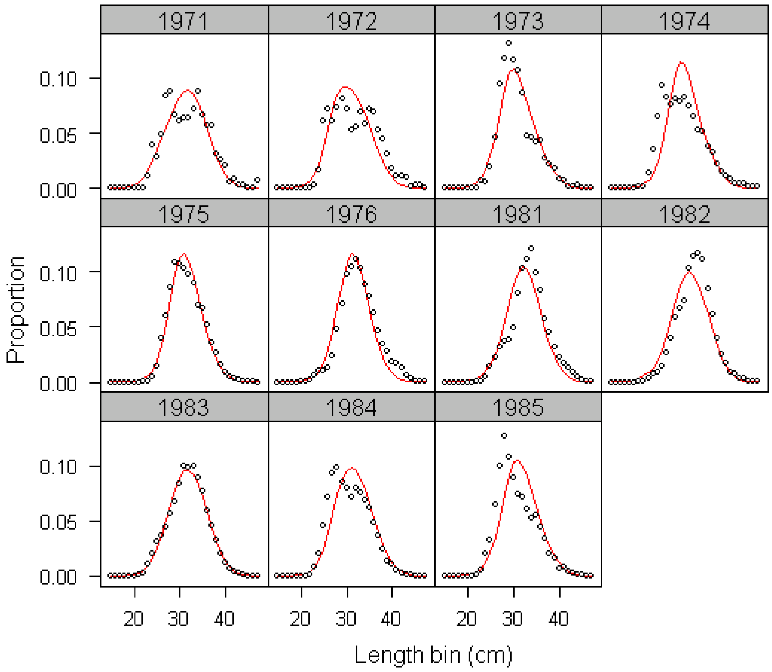
Retained – steam trawl



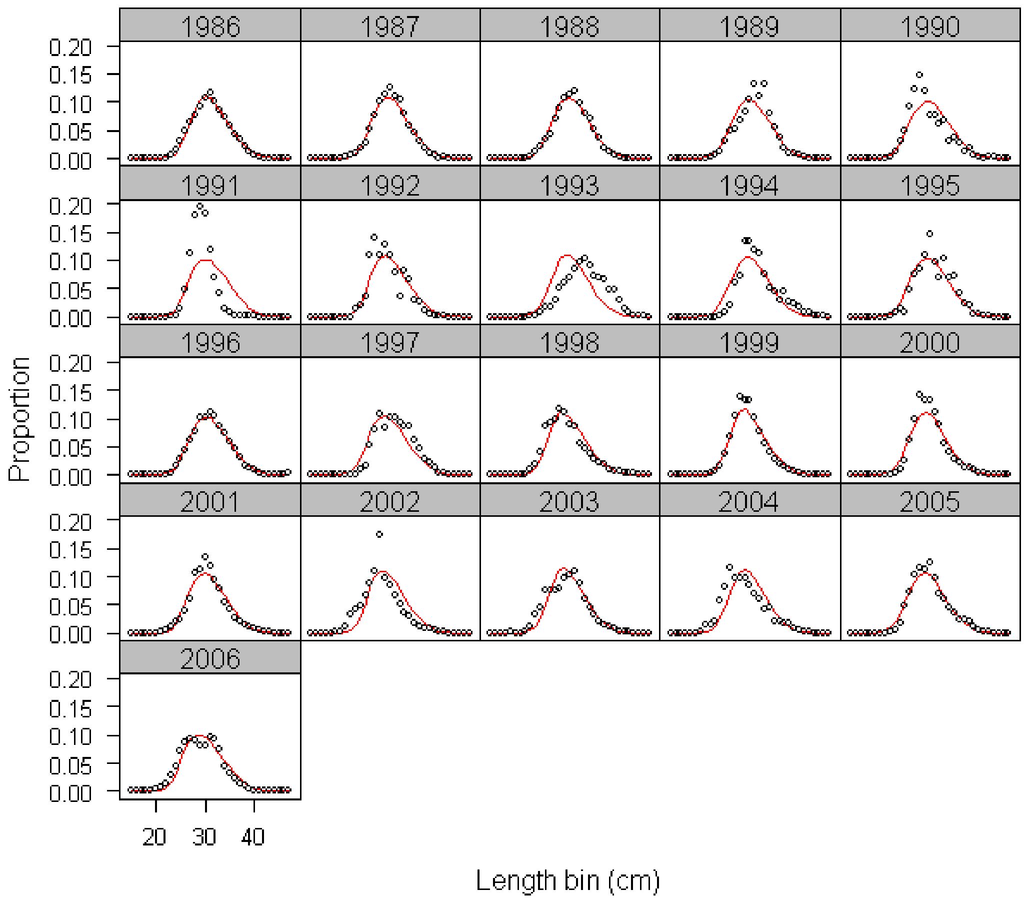
Retained – early Danish seine



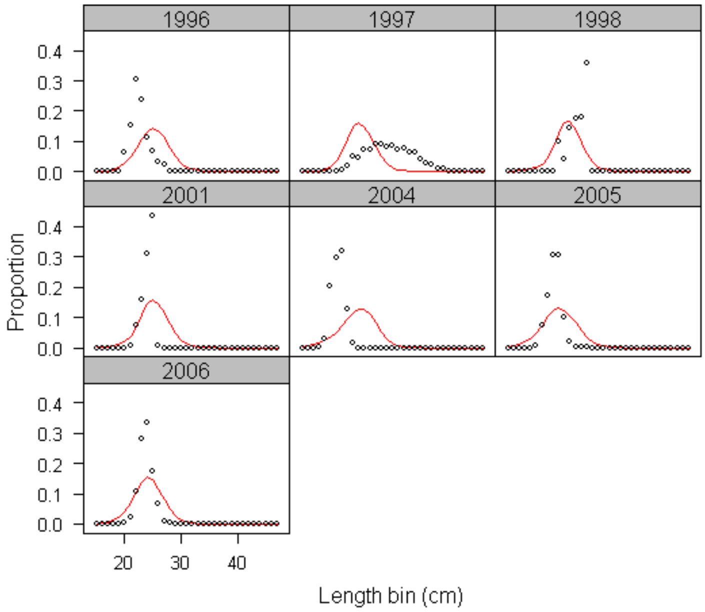
Retained – mixed fleet



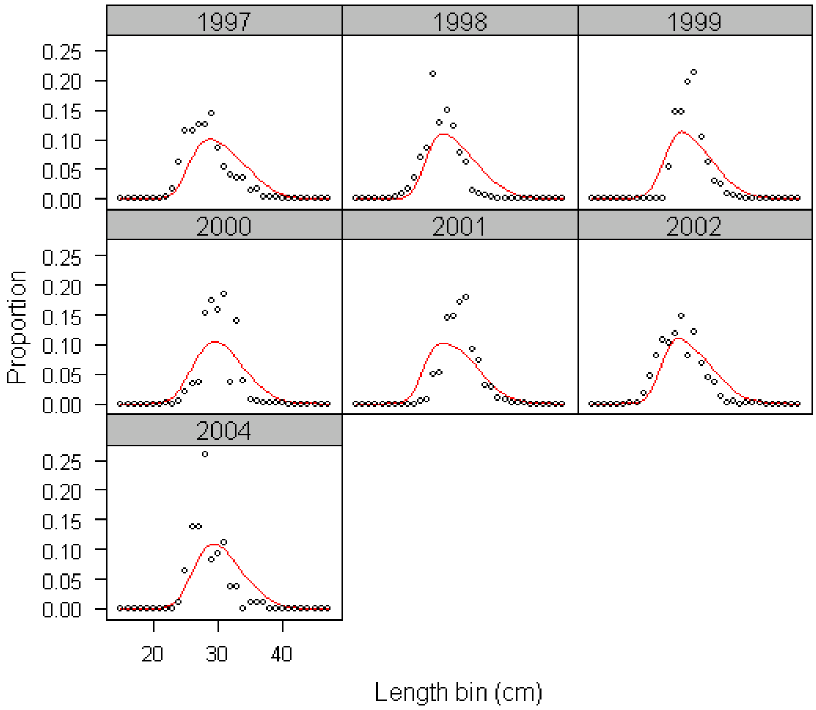
Retained – eastern trawl



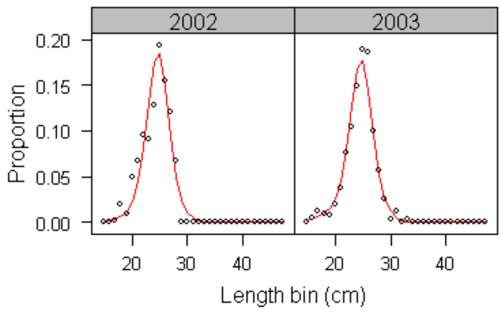
Discarded- eastern trawl



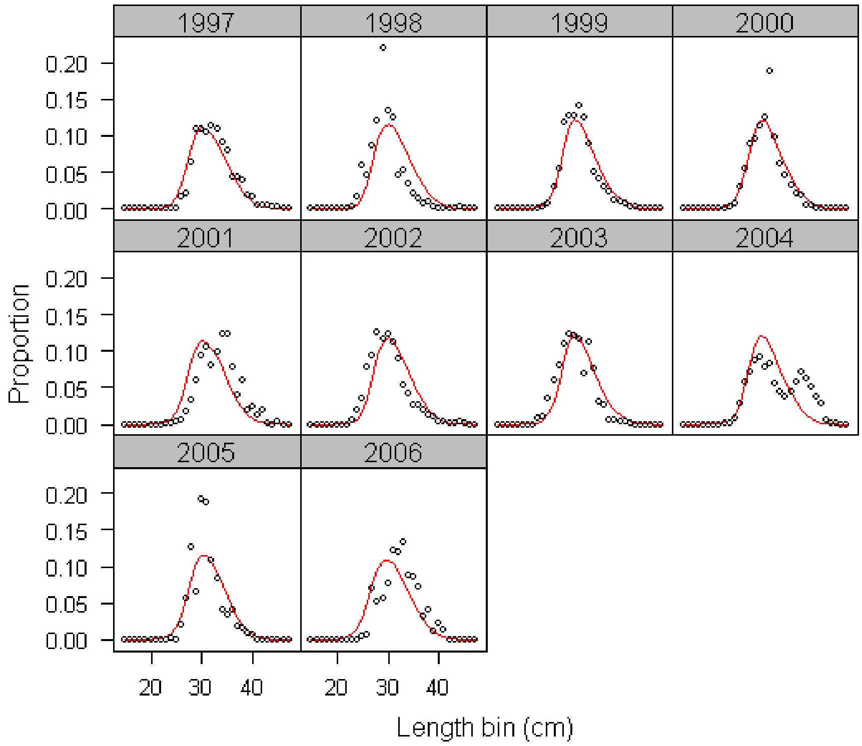
Retained – Danish seine



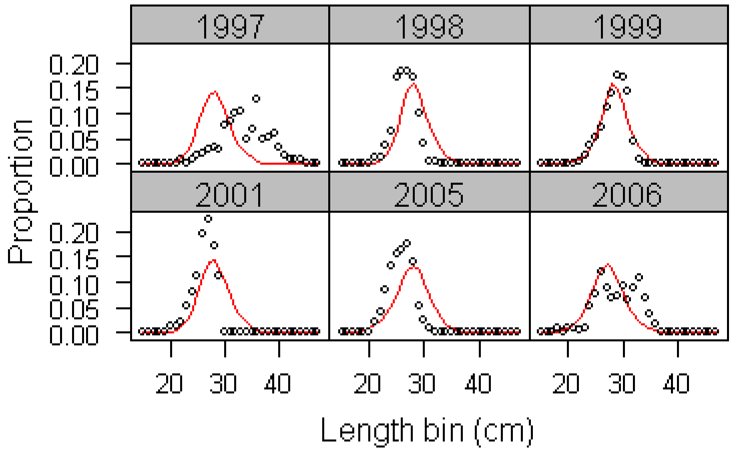
Discarded – Danish seine



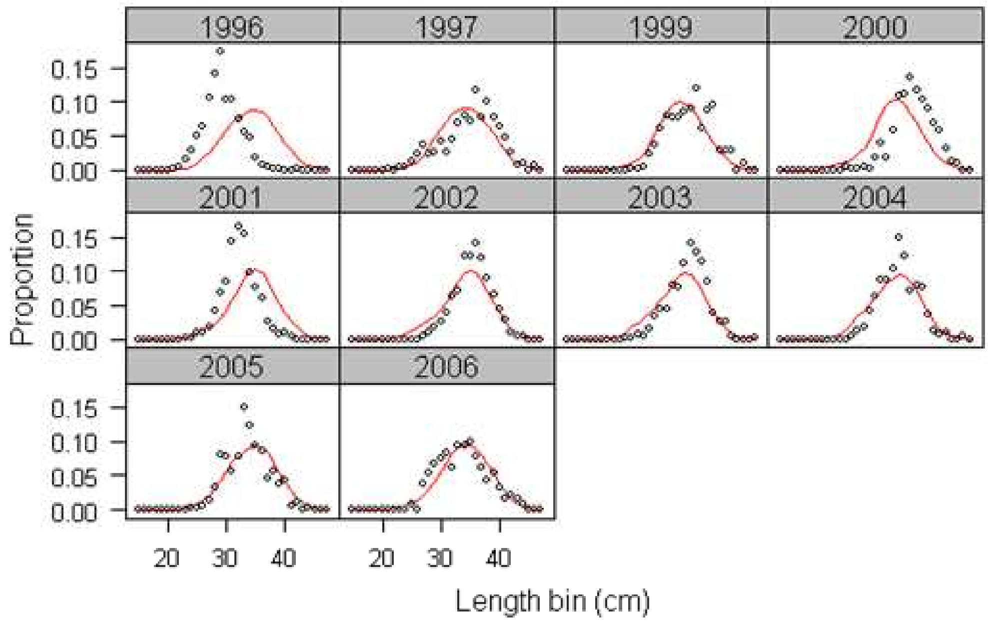
Retained – Tasmanian trawl



Discarded – Tasmanian trawl

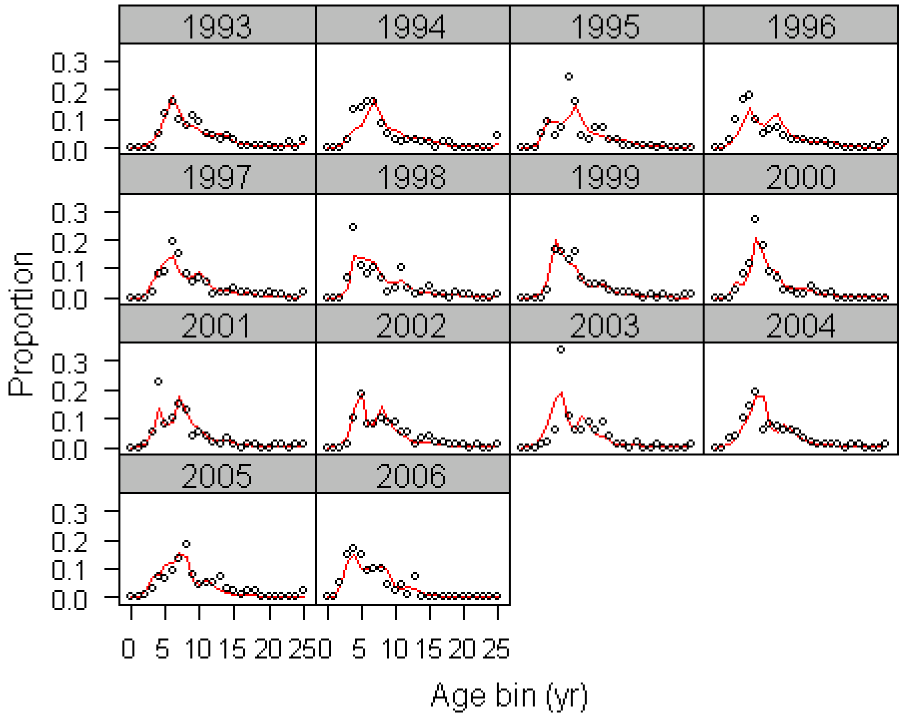


Retained – Western trawl

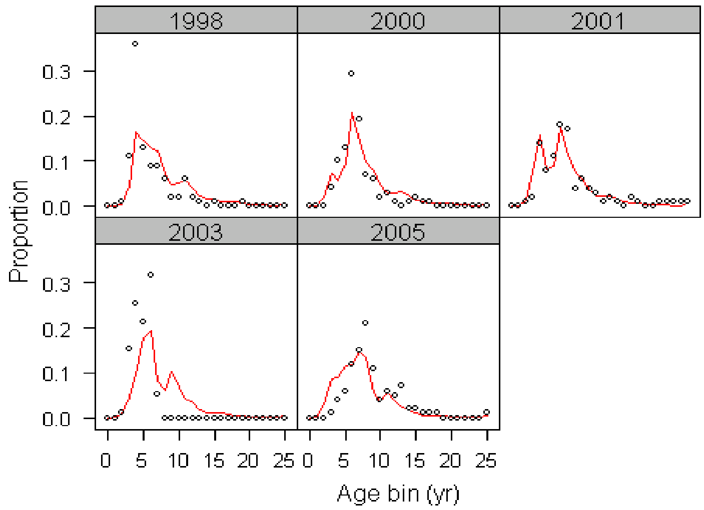


13.8 Appendix B: Fits to the age composition data

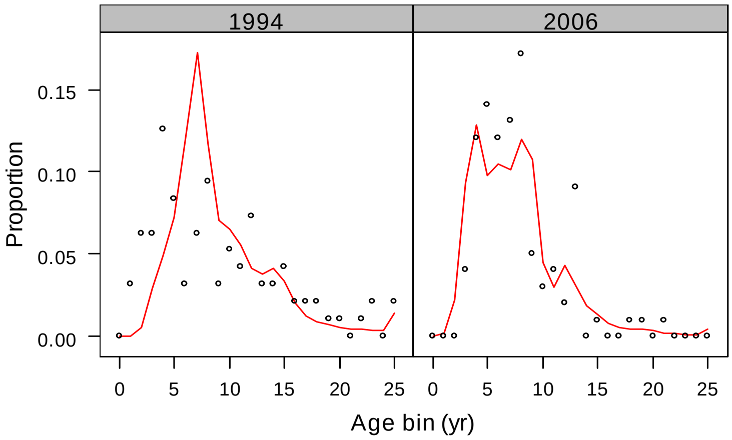
Eastern trawl



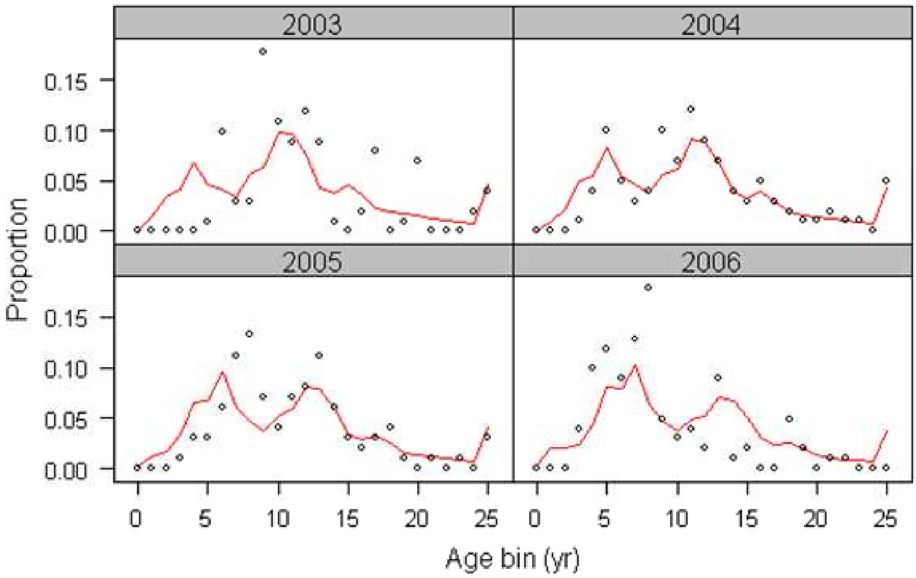
Danish seine



Tasmanian trawl



Western trawl



14. Projected Stock Assessment of Tiger Flathead (*Neoplatycephalus richardsoni*) Based on Data up to 2006

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14.1 Background

This document updates the assessment for tiger flathead (*Neoplatycephalus richardsoni*) produced in 2006 (Klaer, 2006). It has been decided that a full assessment was not required for this species in 2007, and RBC estimates be made using updated projections from the 2006 assessment.

14.1.1 Modifications for the 2007 projected assessment

The only changes made to the 2006 assessment have been the updating of estimated total catch per fleet for 2006 and the provision of an estimate of the 2007 catch (Table 14.1). The 2006 catch estimate was made using recent total catch information produced by PirVIC (2006 total landings 3,037t, M. Koopman pers comm). An estimate of the 2007 catch was made assuming that Commonwealth catch will reduce from 2006 to 2007 according to the ratio of the TACs for those years (2850t/3000t), and that State catches will remain at the same level.

The case chosen for management purposes from the 2006 assessment was that which included the Tasmanian region as part of the eastern stock, and had the Tasmanian fishing fleet treated separately in terms of selectivity. Only results using that case are presented here.

An estimate of the relationship of B_{mey}=1.03xB_{msy} for tiger flathead has been provided by ABARE (T. Kompas pers comm, via A. Morison pers comm). Application of this calculation to the target B_{msy} in our RBC calculations results in a target B_{msy} of 40%x1.03=41.2% (A. Morison, pers comm), which here has been rounded to 41%. Therefore, an additional B_{targ} level of 41% has been included in the RBC calculations (Table 14.2).

Table 14.1. Reported catches (tonnes) by fleet and zone 1986–2006, estimated catch 2007.

	Danish seine					Diesel trawl					Tasmania		
		SEF1											
Year	Zone 10	Zone 20	Zone 60	State	Total	Zone 10	Zone 20	Zone 60	State	Total	SEF1	State	Total
1986	1.3	246.8	663.3	0.0	911.4	483.6	476.8	29.3	37.0	1026.7	25.9	0.0	25.9
1987	0.0	823.7	478.3	84.0	1385.9	494.4	549.3	24.2	64.0	1131.8	6.0	0.0	6.0
1988	11.3	471.9	589.8	127.0	1200.0	641.0	528.6	48.5	71.0	1289.1	38.7	77.0	115.7
1989	10.6	708.6	375.0	119.0	1213.2	548.9	662.8	67.2	67.0	1345.8	47.3	81.0	128.3
1990	12.9	281.2	201.1	107.0	602.2	665.9	678.8	50.7	60.0	1455.4	25.2	153.0	178.2
1991	10.8	332.5	317.6	99.0	759.9	710.5	639.7	71.0	71.0	1492.2	39.6	126.0	165.6
1992	34.0	621.7	348.4	147.0	1151.1	568.6	529.7	99.2	40.0	1237.5	40.0	130.0	170.0
1993	20.3	206.3	156.9	132.0	515.6	496.5	336.0	74.3	55.0	961.9	72.7	121.0	193.7
1994	9.7	192.6	273.9	150.0	626.2	506.3	330.5	83.7	61.0	981.5	57.0	121.0	178.0
1995	0.1	229.6	232.2	102.0	563.9	504.0	542.9	82.8	59.0	1188.7	68.3	71.0	139.3
1996	0.0	351.4	226.8	133.0	711.3	565.6	520.6	95.7	83.0	1264.9	62.8	51.0	113.8
1997	0.0	592.2	303.1	128.0	1023.3	374.1	914.4	142.3	111.0	1541.8	112.9	62.0	174.9
1998	0.0	679.8	179.1	46.0	904.9	462.5	911.2	145.1	180.8	1699.7	131.6	54.0	185.6
1999	0.0	1241.6	618.0	13.8	1873.4	582.4	698.2	28.5	211.3	1520.4	195.2	53.0	248.2
2000	0.0	1018.2	265.8	2.0	1286.0	1059.7	737.0	25.3	184.2	2006.3	92.5	110.0	202.5
2001	14.0	827.0	459.0	23.5	1323.6	878.3	518.0	31.9	124.2	1552.4	115.9	0.2	116.1
2002	27.9	868.5	440.2	20.5	1357.2	873.1	680.1	16.5	107.9	1677.6	237.1	0.3	237.4
2003	0.1	839.7	469.7	5.8	1315.3	1026.7	863.7	17.7	169.2	2077.3	276.5	0.2	276.8
2004	0.1	903.6	425.2	6.9	1335.7	822.7	669.1	15.2	198.6	1705.6	546.1	8.6	554.7
2005	0.5	716.9	530.1	2.4	1250.0	492.6	806.9	16.8	172.3	1488.5	437.4	23.3	460.7
2006	0.3	772.1	327.7	0.8	1100.9	583.7	724.8	17.5	236.7	1562.7	328.1	45.1	373.3
2007	0.3	733.5	311.4	0.8	1045.9	554.6	688.6	16.6	236.7	1496.4	311.7	45.1	356.9

Table 14.2. Projected assessment results for the Tas fleet scenario.

Model	SSB_0 (t)	SSB_{cur}/SSB_0	B_{targ}	B_{kink}	RBC 2008 (Commonwealth + State) (t)		
					Landings	Plus discards	
Tas fleet	25,546	0.43	40	40	2,707	2,832	(with Tas)
Tas fleet	25,546	0.43	48	40	2,093	2,190	(with Tas)
Tas fleet	25,546	0.43	41	40	2,622	2,743	(with Tas)

14.2 Reference

Klaer, N. 2006. Updated stock assessment of tiger flathead (*Neoplatycephalus richardsoni*) based on data up to 2005. Report to ShelfRAG, Canberra, August 2006.

15. School whiting (*Sillago flindersi*) stock assessment based on data up to 2006[11]

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15.1 Summary

This document presents an assessment of school whiting (*Sillago flindersi*) in the SESSF using data up to 31 December 2006. A partial stock assessment for school whiting was last performed in 2004 by Cui *et al.* (2004) using data from 1991 through until 2003. Given a lack of reliable age- and length-composition data, this assessment just used data from the Commonwealth logbook, and ignored catches taken under state jurisdictions and all catches before 1991. As a result, Cui *et al.* (2004) were only able to give information about biomass levels relative to 1991 in this assessment. The 2007 assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to be made. Further, catch data were incorporated from 1947, state catches were included and additional length composition data were used dating back to 1983. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data (c) the addition of updated length frequencies, catches and catch-rates, (d) the inclusion of discards and (e) including ageing error in the model.

The updated base-case assessment estimates that current (2008) spawning stock biomass is 35% of unfished stock biomass. Fits to the length, age, and catch-rate data are reasonable. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*, the length at 50% maturity and the projected catch used in 2007. Likelihood profiles support the use of a base case value for *M* of 0.6yr^{-1}.

Depletion across all sensitivities varied between 22% (age at 50% mortality=18cm) and 47% (age at 50% mortality=14cm). Exploration of model sensitivity also shows that the model outputs are sensitive to the value assumed for the 2007 catch.

At the September 2007 Shelf Resource Assessment Group meeting, the NSW state catch component of the 2006 catch data used in the base case was revised. The RBCs for the updated base-case model for 2008 are 1,185 t and 904 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,848 t and 1,685 t respectively. Results are presented here for both the base case and the updated base case.

School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very

[11] Paper presented to the Shelf Resource Assessment Group on September 4 and 5, 2007

rapid impact on the fish stock. As a result there will always be some uncertainty about the status of the stock. Further exploration of some biological parameters, such as age and length at maturity may help reduce this uncertainty, but the high mortality rate and short expected life time for this species mean that rapid changes are always possible and projections will always be subject to uncertainty relating to very recent recruitment events which are poorly informed until these cohorts fully enter the fishery.

15.2 Introduction

15.2.1 The Fishery

School whiting occur in the eastern regions of the SESSF and Bass Strait (zones 10, 20, 30 and 60) and are commonly found on sandy substrates to depths of about 60m. School whiting are benthic feeders and they mainly spawn during summer. They grow rapidly, reach a maximum age of about 6 years and become sexually mature at about 2 years of age.

In the SESSF full recruitment to the fishery occurs at 2-3 years of age although 1 year olds are also taken. The majority of the catch from 1947-1995 has been taken using Danish seine (mainly in zone 60 of the SESSF - Bass Strait) although the fraction of the catch taken by otter trawl has increased recently, and has averaged more than 65% of the total catch since 1995. In contrast to the Danish seine catches, catches by otter trawl occur predominantly in SESSF zone 10, with most of this catch taken by state registered trawlers. Much of the school whiting caught by the Lakes Entrance Danish seine fleet since 1993 has been sent to an export market, although issues with quality of whiting caught in the summer months has reduced catches for the export market during this time.

Annual catches (landings and discards) of school whiting are shown (for the updated base case) in Table 15.2 and in Figure 15.2. Large catches of school whiting were first taken in the 1980’s (Smith, 1994) and catches increased to over 2,000 t in 1986. Catches have remained over 1,000t since then, with 1,800 t caught in 2006. Discard percentages are variable and appear market driven.

The TAC for calendar years 2005 and 2006 was 1,500 t and for 2007 this was reduced to 750t. The actual catches (for the updated base case) in these years were 1,193t in 2004, 1,080t in 2005 and 1,634t in 2006, but a significant proportion of this catch was from state waters. The state catches in this period were 732t in 2004, 540t in 2005 and 1,056t in 2006 with an average of over 800 t of state catch over the last 10 years.

15.2.2 Stock structure

School whiting is assumed to be a single stock off the east coast of Australia and in Bass Strait, which is largely encompassed by the SESSF but does continue further north above Barrenjoey Point to Ballina. Stout whiting (*Silllago robusta*) is caught off northern New South Wales and the range of these two species overlaps between Ballina and Clarence River, with the northern limit for school whiting at Ballina. NSW catches of stout whiting and school whiting were split equally between the two whiting species in this region where they both occur.

15.2.3 Previous Assessments

A partial stock assessment for school whiting was last performed in 2004 by Cui *et al.* (2004) using data from 1991 through until 2003. This followed an earlier assessment (Punt 1999). Given a lack of reliable age- and length-composition data, the 2004 assessment just used data from the Commonwealth logbook, and ignored catches taken under state jurisdictions and all catches before 1991. As a result, Cui *et al.* (2004) were only able to give information about biomass levels relative to 1991 in this assessment. Cui *et al.* (2004) looked at the probabilities of falling below the 1991 spawning biomass and half the 1991 spawning biomass for 5 different levels of future catch. This assessment predicted large recruitments in 2002 and 2003 but with high uncertainty. As a result the 2003 estimate of spawning biomass was higher than the 1991 spawning biomass, but was also highly uncertain.

15.2.4 Modifications to the previous assessments

A substantial number of modifications have been made to the previous assessment, including updating data to 2006. The previous assessment Cui *et al.* (2004) was based on integrated analysis written using the software package ADMB. The current assessment uses the package SS2 which overcomes some of the technical shortcomings previously identified.

Cui *et al.* (2004) recommended the following modifications to their assessment:

1. The support for the assessment result that there were more animals aged 6 and older in 1991 would be increased if length-frequency data were available for the earlier years.
2. Future assessments should take account of ageing error when fitting the model.
3. Although no age-length keys are available for 1999 and 2000, some length-frequency data are available. The assessment model should be modified to so that use can be made of these data.
4. Sensitivity should be explored to, inter alia, the value assumed for M and the weights assigned to be various data sources.
5. Future assessments should take account of discards.

All of these improvements are incorporated into the current assessment and a range of additional improvements to the data collected and incorporated into the assessment.

15.2.4.1 Data-related issues

a) The discard mass has been included in the model through the use of onboard length frequency data from the ISMP.
b) Length-frequency data collected at the Sydney fish market from the NSW Danish seine and otter trawl fleets (1983-89) have been included.
c) Length frequencies from 1991 from the Lakes Entrance Danish seine fleet (Anonymous, 1992) have been included.
d) Port-based length-frequency data up to 2006 have been included in the assessment.
e) The catch-rate time series has been calculated for the Victorian Danish seine fleet (Haddon, 2007).

f) Conditional age-at-length information has been included in the assessment instead of age compositions constructed from age-length keys and length-frequencies. This enables estimation of growth curve parameters within the assessment (rather than being set based on auxiliary information).
g) State catches have been added to catches from the appropriate fleets.
h) Age-reading error (Table 15.3) has been accounted for when fitting to the conditional age-at-length data.
i) Catch, discard, length-composition, age-at-length, and catch rate data from 2004-2006 have been added.
j) The weighting on the length frequency and the conditional age-at-length data has been altered in line with current agreed practice.

15.2.4.2 Model-related issues

a) Three growth curve parameters (L_{min}, L_{max}, and cv_L) are estimated within the assessment, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths. The fourth growth curve parameter, *K*, had to be fixed to get a reasonable growth curve.
b) Estimation of recruitment residuals has been limited to those cohorts for which length-composition data are available.

15.3 Methods

15.3.1 The data and model inputs

15.3.1.1 Biological parameters

A single-sex model (i.e. both sexes combined) was used, as the length composition data for school whiting are not available by sex.

Previous assessments pre-specified the values for the parameters of the von Bertalanffy growth equation, but as SS2 can accept age-at-length data as an input it has been possible in this assessment to estimate most of these parameters within the model-fitting procedure. This is a more appropriate approach because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

Previous work has suggested a range of values for the mortality parameter *M*, for school whiting ranging from 0.37 (Bax and Knuckey, 2001), 0.5 (Klaer and Thomson 2006), and 0.9 (Cui *et al.* (2004), Punt *et al.* (2005)). A sensitivity analysis across a range of values of *M* is conducted in this assessment and used to construct a likelihood profile for *M*. This resulted in selecting *M*=0.6 for the base case. The base-case value for the steepness of the stock-recruitment relationship, *h*, is 0.75.

School whiting become sexually mature at a length of about 16 cm, when the fish are around 2 years of age. Fecundity is assumed to be proportional to spawning biomass. The parameters of the length-weight relationship are obtained from Klaer and Thomson (2006) (a=1.32 × 10^{-5}, b=2.93).

15.3.1.2 Fleets

The assessment for school whiting is based on three fleets: two Danish seine fleets (with NSW and Victorian fleets treated separately) and a single otter trawl fleet. Time-invariant logistic selectivity is assumed for all three fleets.

1. Victorian Danish seine – Danish seine based around Lakes Entrance in eastern Victoria and Bass Strait (1947 – 2006). Length frequency data are available for this fleet from Victorian Fisheries in 1991 and from ISMP records in the years 1994-2005.

2. Otter trawl – otter trawlers from NSW, eastern Victoria and Bass Strait and Eastern Tasmania (1947 – 2006). Length frequency data are available for this fleet for two years from the Sydney fish market, 1983 and 1988, and from ISMP records from 1997-2006. In addition there are length frequency data from 1971 and 1974 for otter trawl from the northern limit of the school whiting range.

3. NSW Danish seine – Danish seine fleet operating in state waters in NSW (1957 – 1994). Length frequency data are available for this fleet from the Sydney fish market from 1983 -1989.

15.3.1.3 Landed catches

The model uses a calendar year for all catches. Landings data came from a number of sources. Early Victorian school whiting catches are available from 1947-1978 (Wankowski, 1983) and later Victorian state catches, from 1979-2006, were provided by Matt Koopman. Information enabling these Victorian state catches to be separated by fleet was not available so it was assumed that 3% of these catches were from the otter trawl fleet and 97% were from Danish seine for the whole period. Matt Koopman supplied a catch history separated into state and Commonwealth catches for the period 1957-2006, none of these catches were separated by fleet.

At the September 2007 Shelf Resource Assessment Group meeting, the NSW state catch component of the 2006 catch data used in the original base case was revised. The NSW state catch comprises a mixture of stout whiting (*S. robusta*) and school whiting (*S. flindersi*). A correction was applied to all state catches to remove the stout whiting component of this catch. The initial dataset supplied for this assessment (used for the base case) included an incomplete 2006 NSW state catch, and no correction had been made to this 2006 incomplete catch figure for stout whiting catches. This figure was updated during the September 2007 Shelf Resource Assessment Group meeting, including all 2006 state catches from NSW and with the stout whiting component of the catch removed. This resulted in an “updated base case”. While the changes appeared minimal, this new catch history resulted in a different fit to the model and differences in the analysis and RBCs. The catch figures presented in this paper have been revised to incorporate the updated base case catch data. The sensitivity analyses are comparable to the base case, but results for the updated base case are also included

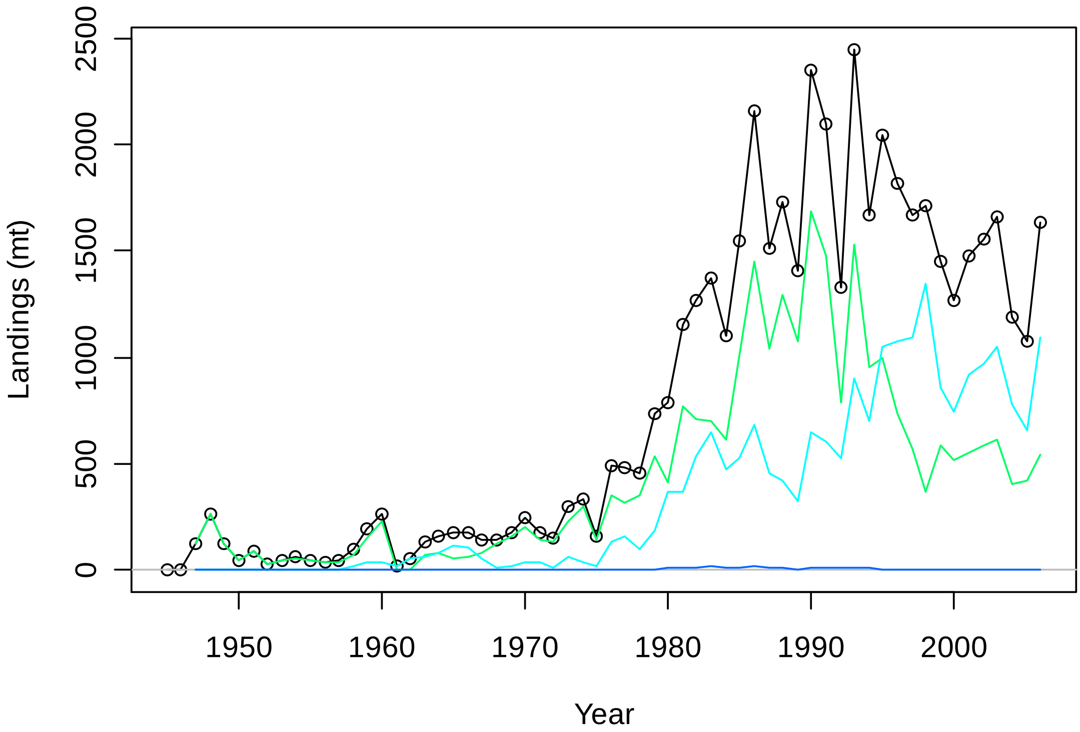


Figure 15.1. The total landed catch of school whiting (using the updated base case catch data) in the SESSF from 1947-2006 (black with circles). These catches are also separated by fleet. The Victorian Danish seine fleet (fleet 1, green) took the majority of the catch until 1995. The otter trawl fleet (fleet 2, aqua) was the other major fleet, with this fleet taking more than half the total catch since 1995. The NSW Danish seine fleet (fleet 3, blue) catches are listed from 1957-1994: the catch from this fleet is always less than 5% of the total catch.

The original data for the NSW component of this catch from the period from 1957-1992 is from Pease and Grinberg (1995). Corrections were made to these catches to remove the stout whiting component from the catch, with these corrections based on how far north the catch was landed along the NSW coast. Due to limited availability of catch data in the period 1957-1984, 66% of the NSW catches reported by Pease were assigned to school whiting in this period. The corrected NSW state catches of school whiting were incorporated into the NSW state catch history provided by Matt Koopman. The total NSW state catch was then allocated in the ratio of 97% to the otter trawl fleet and 3% to the NSW Danish seine fleet from 1957-1994. From 1995 to 2006 all of the NSW state catch was assumed to be otter trawl. Tasmanian state catches were available from 1995-2006 and all of this catch was assigned to the "Victorian Danish seine" fleet.

Commonwealth catches from 1985-2006 were separated into otter trawl and Danish seine (assumed to be the "Victorian Danish seine" fleet). This data came from the log book and was supplied by Neil Klaer. Note that there is still some uncertainty about the Commonwealth catch history as the version that Matt Koopman has of the Commonwealth catch (which is not split up by fleet) differs from the version that Neil Klaer has over the period 1986-2006 with the average difference of 93t per year, between the two catch series (which is around 10% of the Commonwealth catch over this time period). This difference was unable to be resolved, but hopefully it will be resolved in the future with the data project which will produce a single database of agreed catches. As there was no information to split the Koopman Commonwealth series into fleet types, this assessment uses the Klaer Commonwealth catch series (which has the higher of the two Commonwealth catch series).

Annual landed catches for the three fleets used in this assessment (Victorian Danish seine, otter trawl and NSW Danish seine) are shown in Figure 15.1 and listed in Table 15.2. The same catch history split into state and Commonwealth components is shown Figure 15.2. These tables and figures show the catch history for the updated base case.

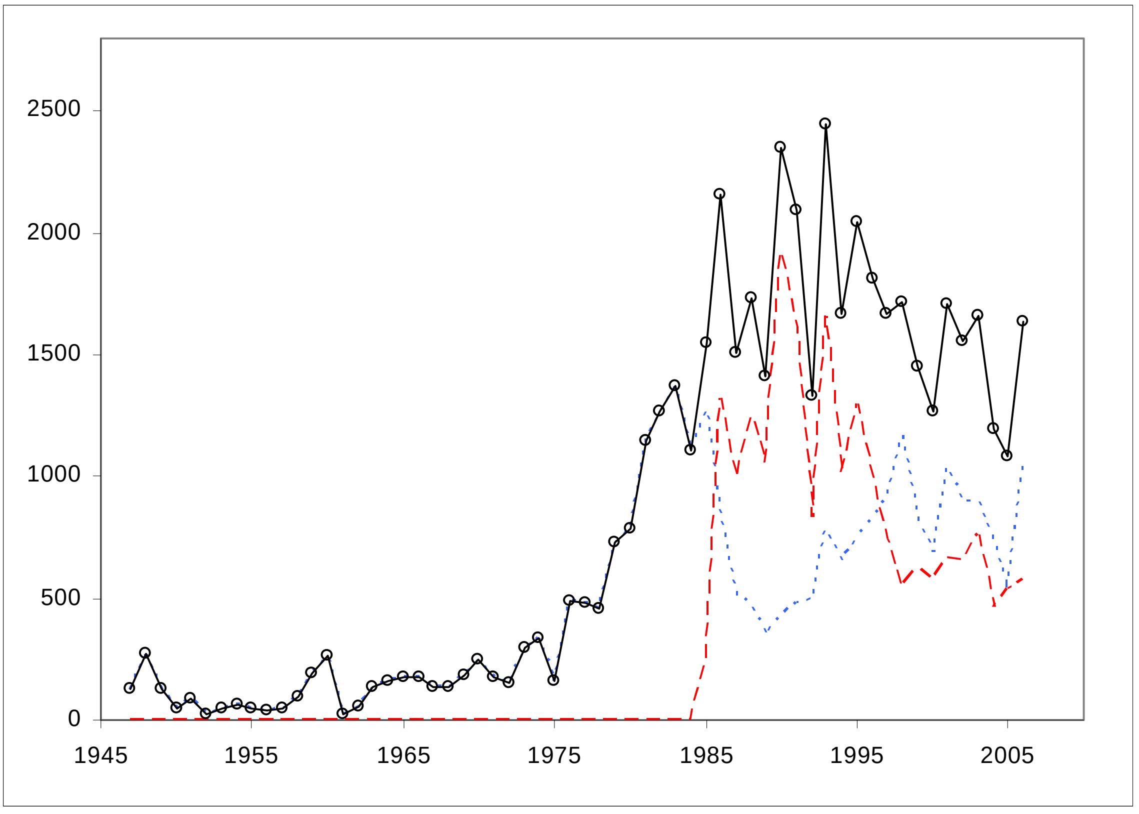


Figure 15.2. The total landed catch (using the updated base case catch data) of school whiting in the SESSF from 1947-2006 (black line with circles) and this same catch separated into state catches (dotted line, blue) and Commonwealth catches (dashed line, red). The Commonwealth catch was larger than the state catch in the period 1986-1996. The state catches (blue) comprise the whole catch until 1985. The Commonwealth catch starts in 1985.

The state catch is a significant proportion of the total catch for school whiting (Figure 15.2). From 1986-1996 the state catch averaged around 30% of the total catch, but from 1997-2006, the state catch has increased and the Commonwealth catch has decreased and as a result the state catch has averaged around 60% of the total catch in this period. The difference between catches in state and Commonwealth jurisdictions does not affect this assessment directly, but it does affect how catches are allocated to the different fleets, and it will have an impact on the allocation of the RBC. The NSW trawl fleet makes up around 80% of the state catches in the period 1986-2006. The Commonwealth catch starts in 1985 and the Victorian Danish seine fleet comprises around 80% of the Commonwealth catch. Note that the Commonwealth catch has been less than the state catch since 1997.

Information on the discard rate of school whiting is available from the ISMP for 1993-2006. These data are summarised in Table 15.2, Figure 15.3 and Figure 15.4. Discard rates vary amongst years, and have been up to 38% (in 1998). Members of the fishing industry have indicated that discarding of small school whiting can vary rapidly in response to demands from the export market.

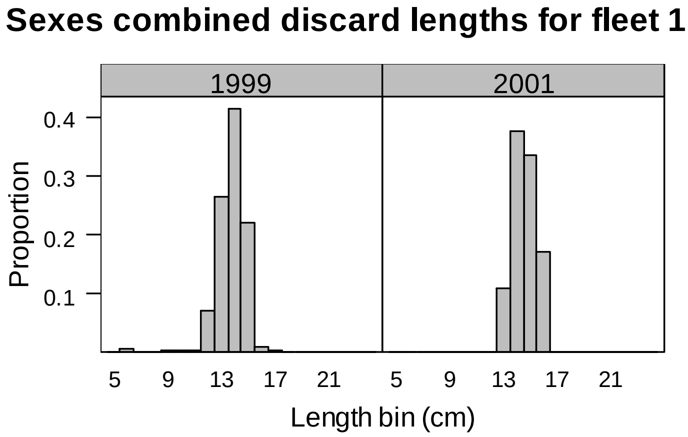


Figure 15.3. The discard length frequencies for school whiting for the Victorian Danish seine fleet.

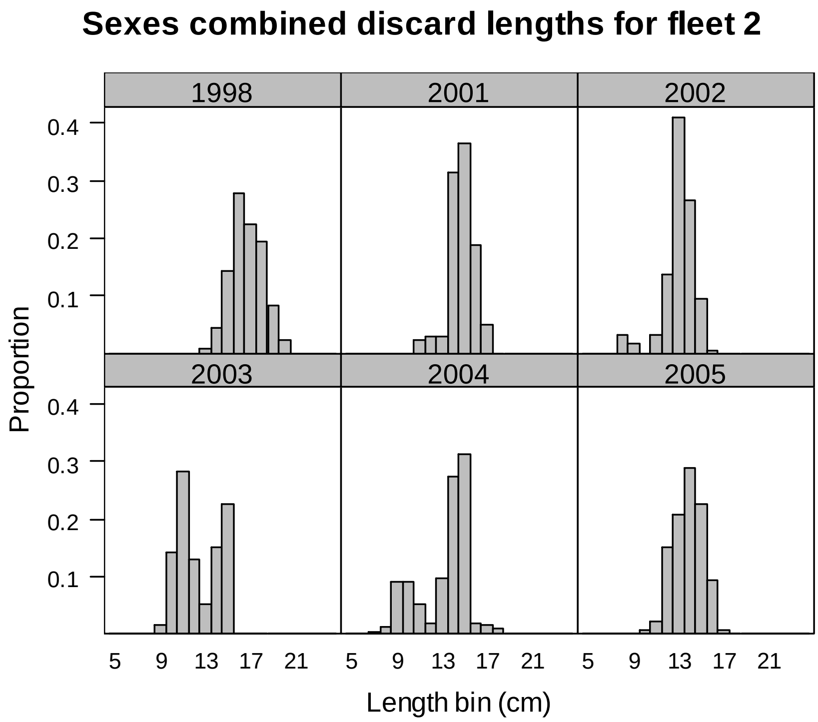


Figure 15.4. The discard length frequencies for school whiting for the otter trawl fleet.

15.3.1.4 Catch rate indices

Catch and effort data from the SEF1 logbook database from the period 1986 -2006 were standardised using GLMs to obtain indices of relative abundance (Haddon, 2007; Table 15.2). The restrictions used in selecting data for analysis were: (a) vessels had to have been in the trawl fishery for three or more years, (b) the catch rate had to be larger than zero, (c) catches in zone 60 only (d) catches in less than 100m depth and (e) effort is considered as catch per shot rather than as catch per hour, to allow for missing records of total time for each shot for data early in the fishery.

15.3.1.5 Length composition data

Length composition information for the retained component of the catch by the Victorian Danish seine fleet is available from port sampling for the period 1994-2005 (Figure 15.5). Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch from this fleet in this same period (Figure 10.2). An additional year of length frequency data for the retained component of the catch by the Victorian Danish seine fleet was obtained by Victorian Fisheries (Anonymous, 1992) in 1991.

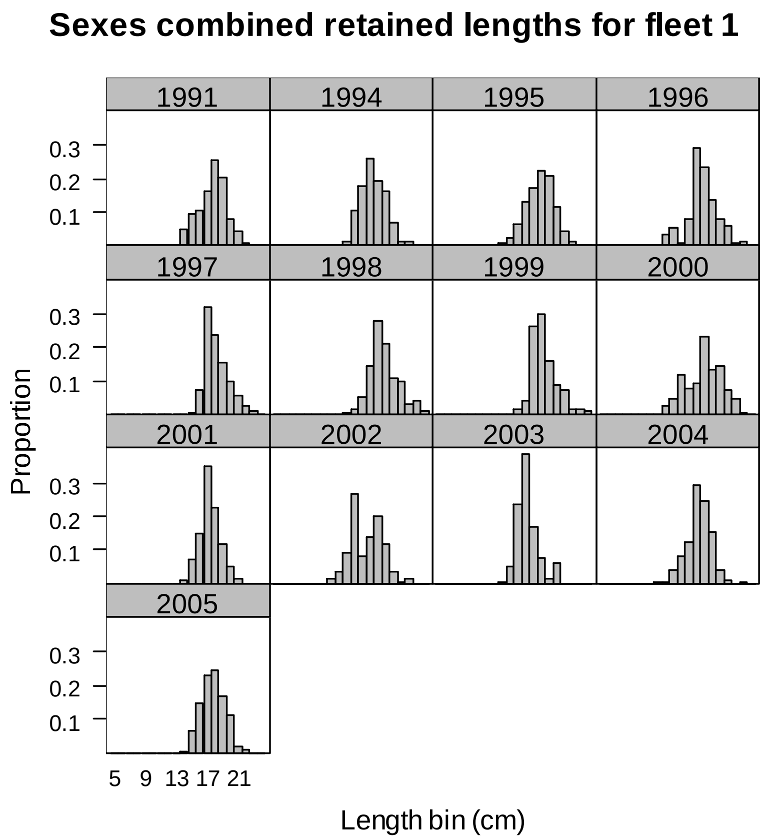


Figure 15.5. The retained length frequencies for school whiting for the Victorian Danish seine fleet.

Length composition information for the retained component of the catch by the Commonwealth trawl fleet is available from port sampling for 1997-2006 (Figure 15.6). Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch (Figure 15.4).

Length composition information for the retained component of the catch by the NSW Danish seine fleet is available from Sydney fish market measurements for the period 1983-1989 (Figure 15.7).

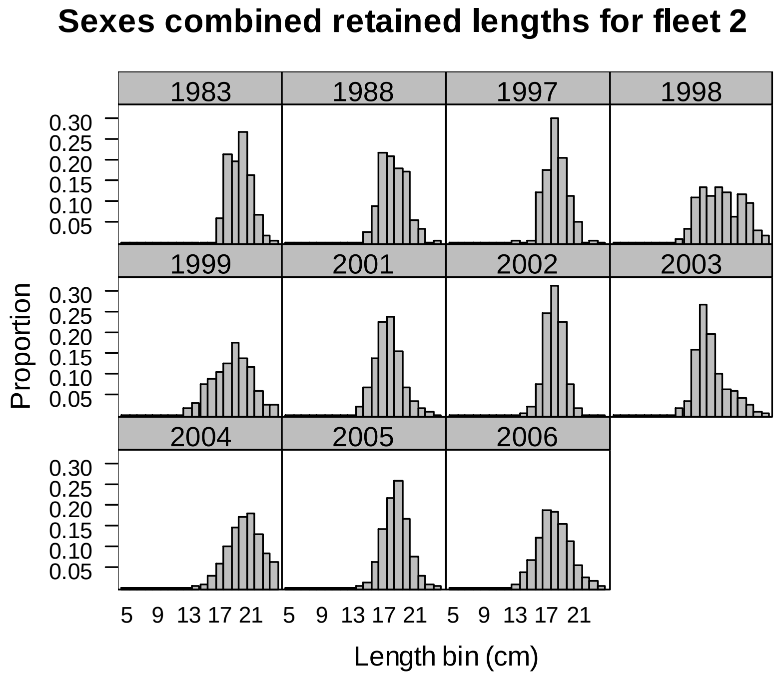


Figure 15.6. The retained length frequencies for school whiting for the otter trawl fleet.

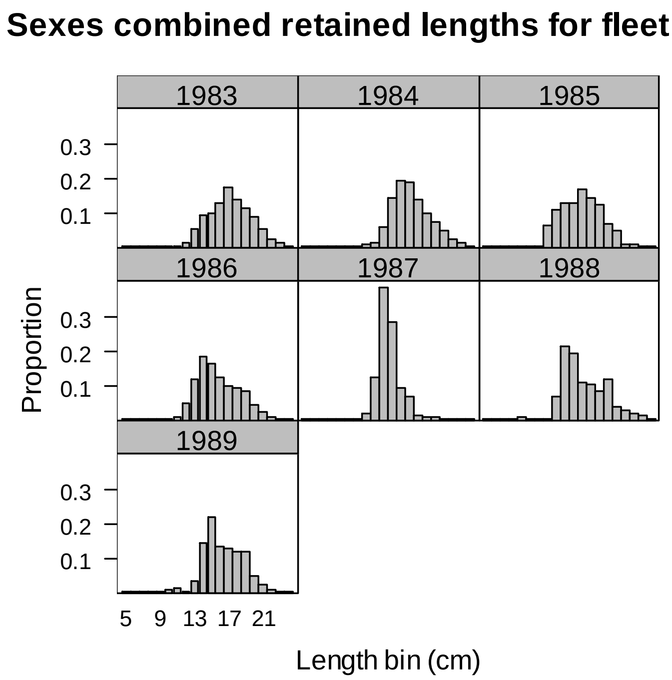


Figure 15.7. The retained length frequencies for school whiting for the Victorian Danish seine fleet.

15.3.1.6 Age composition data

Age-at-length measurements, based on sectioned otoliths provided by the CAF, are available from 1994-2005 for the Victorian Danish seine fleet and from 1997-2006 for the otter trawl fleet. An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2007) using data supplied by Kyne Krusic Golub of PIRVic and a variant of the method of Richards *et al.* (1992).

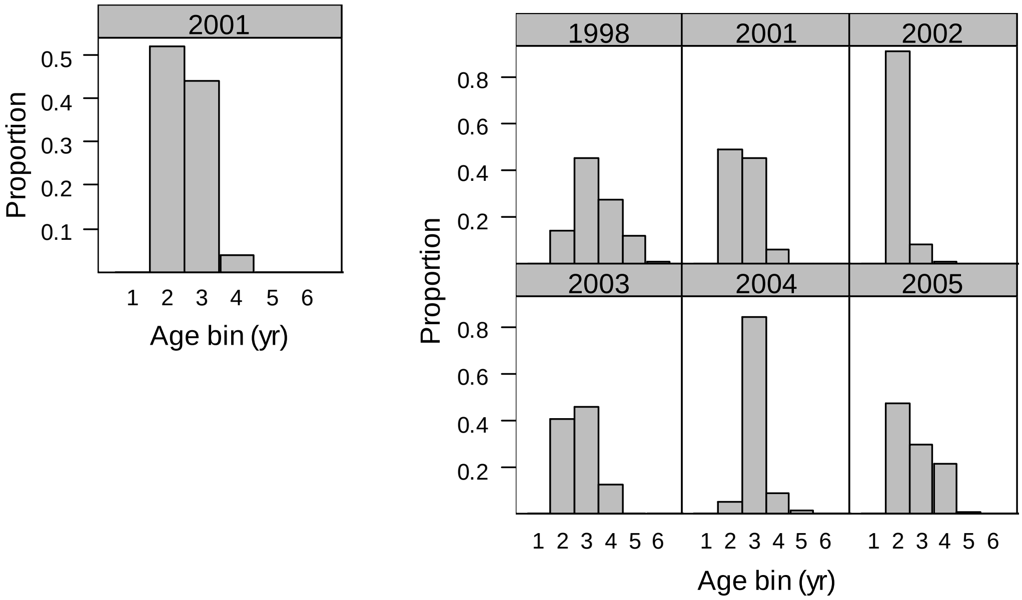


Figure 15.8. The discarded age frequencies for school whiting for one year only for the Victorian Danish seine fleet (left) and for 6 years for the Commonwealth otter trawl fleet (right).

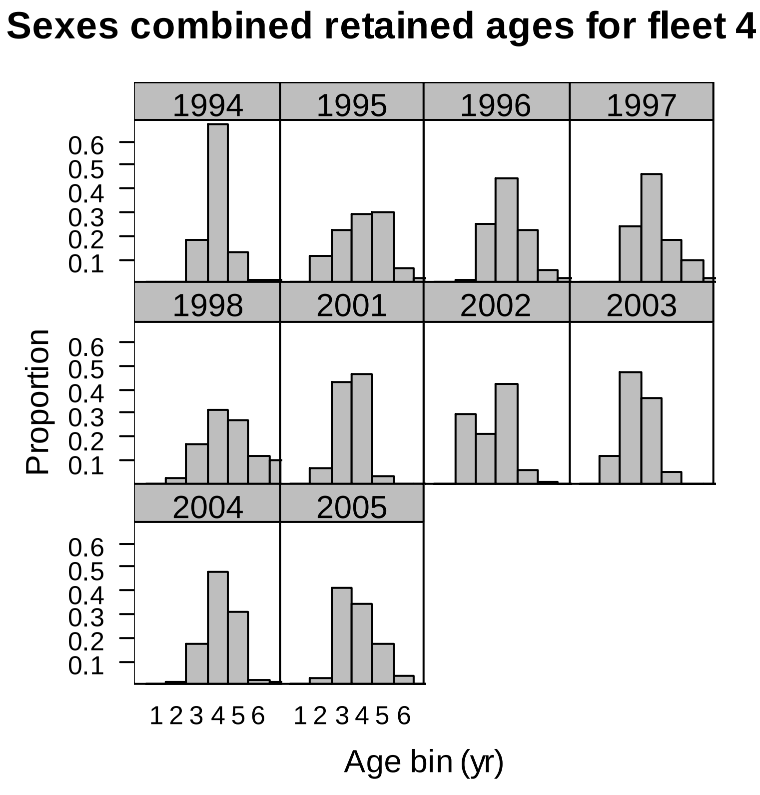


Figure 15.9. The retained age frequencies for school whiting for the Victorian Danish seine fleet.

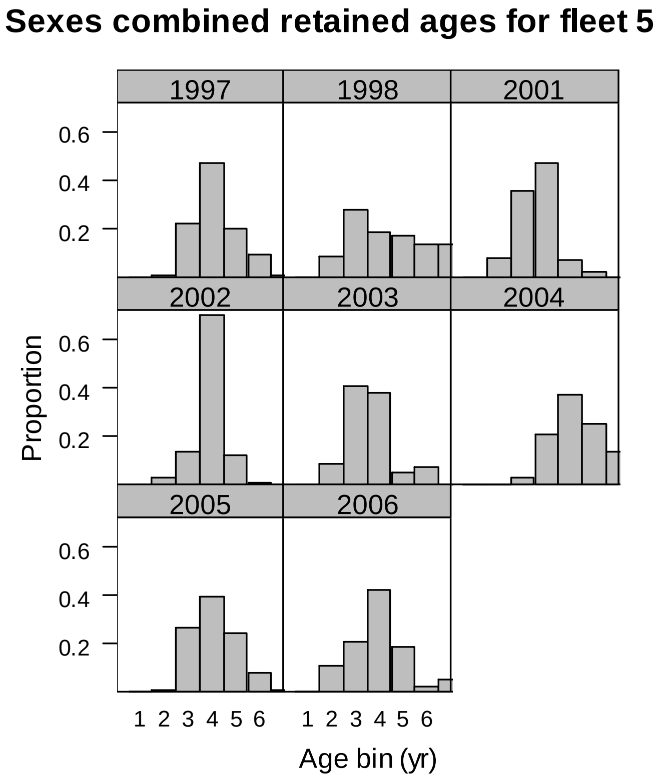


Figure 15.10. The retained age frequencies for school whiting for the otter trawl fleet.

Age-at-length data for discarded fish are available in 2001 only for the Victorian Danish seine fleet and for 6 years in the period 1998-2005 for the otter trawl fleet (Figure 15.8). Retained age-at-length data for the Victorian Danish seine fleet (Figure 15.9) and the Commonwealth otter trawl fleet (Figure 15.10) are available for a range of years in the period 1994-2006.

15.3.2 Stock Assessment method

15.3.2.1 Population dynamics model and parameter estimation

A single-sex stock assessment for school whiting was conducted using the software package SS2 (version 2.00h; Methot 2007). SS2 is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for school whiting. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are fully described in the SS2 technical description (Methot, 2005) and are not reproduced here. Some key features of the base-case model are:

a) School whiting constitute a single stock within the area of the fishery (Smith and Wayte, 2005).
b) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1947. This corresponds to a break in fishing during World War II, and given the facts that the species is short lived and was only lightly exploited prior to World War II, this seems a reasonable assumption.
c) The CVs of the CPUE indices for the Victorian Danish seine fleet were set equal to the model-estimated standard errors (0.3 for the base case and 0.33 for the updated base case).

d) Three fishing fleets are modelled. Sensitivity to the number of fleets modelled was explored.
e) Selectivity was assumed to vary among fleets, but the selectivity pattern for each separate fleet was modelled as length-specific, logistic and time-invariant. The two parameters of the selectivity function for each fleet were estimated within the assessment. Sensitivity to the assumption of time invariant selectivity was also explored.
f) Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for the two fleets where discard information was available (Victorian Danish seine and otter trawl). Retention for the NSW Danish seine fleet was implicitly assumed to be independent of length as no length frequency composition data is available on discards for this fleet.
g) The rate of natural mortality, *M*, is assumed to be constant with age, and also time-invariant. The base-case value for *M* is 0.6 yr^{-1}.
h) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1981 to 2004. Deviations are not estimated prior to 1981 or after 2004 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.
i) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 0.4 in the base case (and 0.37 for the updated base case), so that the standard deviations of estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_r.
j) A plus-group is modelled at age 6 years.
k) Growth of school whiting is assumed to be time-invariant, in that there is no change over time in mean size-at-age, with the distribution of size-at-age being estimated along with the remaining growth parameters within the assessment. No differences in growth related to gender are modelled, because the stock is modelled as a single-sex.
l) The sample sizes for length and age frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Following this retuning by fleet, any sample sizes with an effective sample size greater than 200 were further individually down-weighted to give a maximum effective sample size of 200. This is because the appropriate sample size for length frequency data is probably more related to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured were used.

15.3.2.2 Sensitivity tests

A number of sensitivity tests are used to examine the sensitivity of the results of the model to some of the assumptions and data inputs:

a) $M = 0.5$ and $0.7\ yr^{-1}$.
b) $h = 0.65$ and $0.85\ yr^{-1}$.
c) $\sigma_r = 0.3$ and 0.5.
d) 50% maturity occurs at length 14 and 18cm.
e) The von Bertalanffy *k* parameter = 0.2 and 0.3.
f) Double and halve the weighting on the CPUE series.
g) Double and halve the weighting on the length composition data.
h) Double and halve the weighting on the age-at-length data.
i) Change the projected catch for 2007 – use the average catch for the last 10 years for each fleet - a total catch of 1541 t (instead of projecting the 2006 catch of 1798 t).
j) Change the projected catch for 2007 – use the average catch for 2004 and 2005 for each fleet - a total catch of 1161 t (instead of projecting the 2006 catch of 1798 t).
k) At the September 2007 Shelf RAG meeting a revised catch history was adopted and this updated base case is included as a sensitivity. Note that the sensitivities are compared to the original base case, not to the updated base case.

In addition to these sensitivities a number of model and data exploration options were investigated. These models were ruled out as possible base case models for a range of different reasons:

l) Include the low discard rates data: the years previously omitted with discarding rates (<4%):1995, 2003 and 2004 for Danish seine and 2002 and 2006 for otter trawl. (Including these data results in unrealistically low model estimates of discarding rates).
m) Add 1971 and 1974 length frequency data from northern NSW (these length frequencies were from the northern end of the range and including them produced spurious recruitment events).
n) Combine the Victorian and NSW Danish seine fleets into a single fleet, resulting in a two fleet model (length frequency composition data looks different for these two components of the Danish seine fleet)
o) Two fleet model with 1971 and 1974 length frequency data from northern NSW added.
p) Two fleet model with time varying selectivity for Danish seine before and after 1990 (this imposes the NSW selectivity on the Victorian Danish seine fleet).
q) Two fleet model and omit the NSW Danish seine length frequencies (1983-1989).
r) Two fleet model and omit the NSW Danish seine and NSW otter trawl length frequencies (1983-1989).
s) Two fleet model and omit the NSW Danish seine and NSW otter trawl length frequencies and the single year of Victorian Danish seine length frequency (1991 only).
t) Remove all 2006 data except for catch data.
u) Remove all 2005-6 data except for catch data.
v) Remove all 2004-6 data except for catch data.

w) Remove 2006 CPUE data.
x) Remove 2006 length data.
y) Remove 2006 age data.

The results of the base-case analysis, the updated base case and the sensitivity tests and model and data exploration options are summarized in Table 15.5 and Table 15.6 using the following quantities:

a) SB_0 the average unexploited spawning biomass,
b) SB_{2008} the spawning biomass at the start of 2008,
c) SB_{2008}/SB_0 the depletion level at the start of 2008, i.e. the 2008 spawning biomass expressed as a percentage of the unexploited spawning biomass
d) $-lnL$ the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data),
e) *2008 RBC 20:40:40* the 2008 RBC calculated using the 20:40:40 harvest rule,
f) *2008 RBC 20:40:48* the 2008 RBC calculated using the 20:40:48 harvest rule.
g) *Long term RBC 20:40:40* the long term RBC calculated using the 20:40:40 harvest rule,
h) *Long term RBC 20:40:48* the long term RBC calculated using the 20:40:48 harvest rule.

15.4 Results and discussion

15.4.1 The base-case analysis

15.4.1.1 Parameter estimates

Figure 15.11 shows the estimated growth curve for school whiting for the base case. It was only possible to estimate 3 out of the 4 growth parameters. The estimates of the growth parameters are: (a) *Lmin*=8.77cm, (b) *Lmax*=20.4cm and (c) cv of growth = 0.064, with the 4th parameter fixed at k=0.25yr^{-1}.

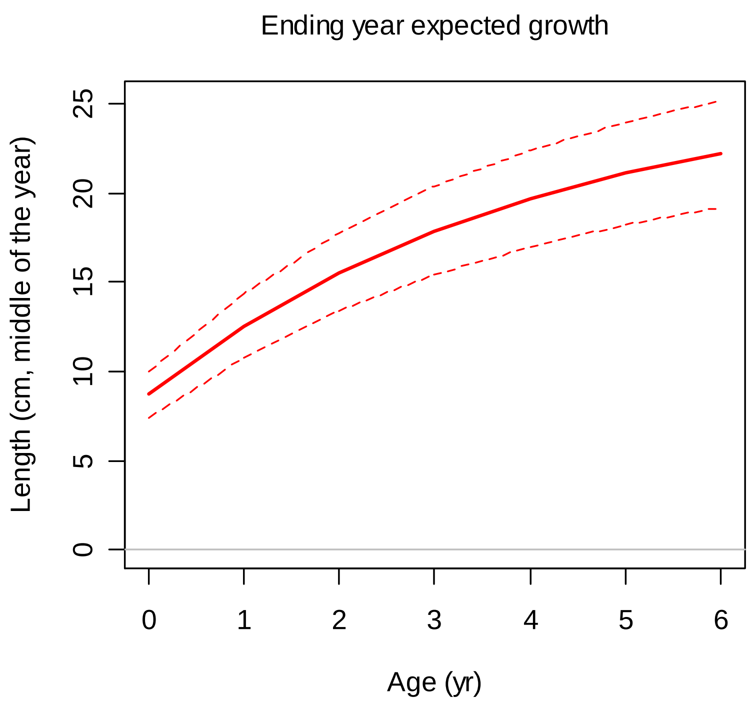


Figure 15.11. The model estimated growth function for school whiting for the base case analysis.

The parameters that define the selectivity function are the length at 50% selection and the spread. The selectivity functions for each of the three fleets are shown in Figure 15.12 for the base case. The estimates of these parameters for the Victorian Danish seine fleet are 17.1cm and 2.96cm, for otter trawl are 19.3cm and 5.05cm and for NSW Danish seine are 14.2cm and 1.70cm. The selectivity functions for each of the three fleets are shown in Figure 15.12. Note that these fitted selectivities show that otter the trawl fleet catches larger fish than either of the two Danish seine fleets and that the NSW Danish seine fleet catches smaller fish than the Victorian Danish seine fleet. Retention for the NSW Danish seine fleet was implicitly assumed to be independent of length as no length frequency composition data is available on discards for this fleet. The estimate of the parameter that defines the initial numbers (and biomass), ln(R_0), is 12.7 for the base case.

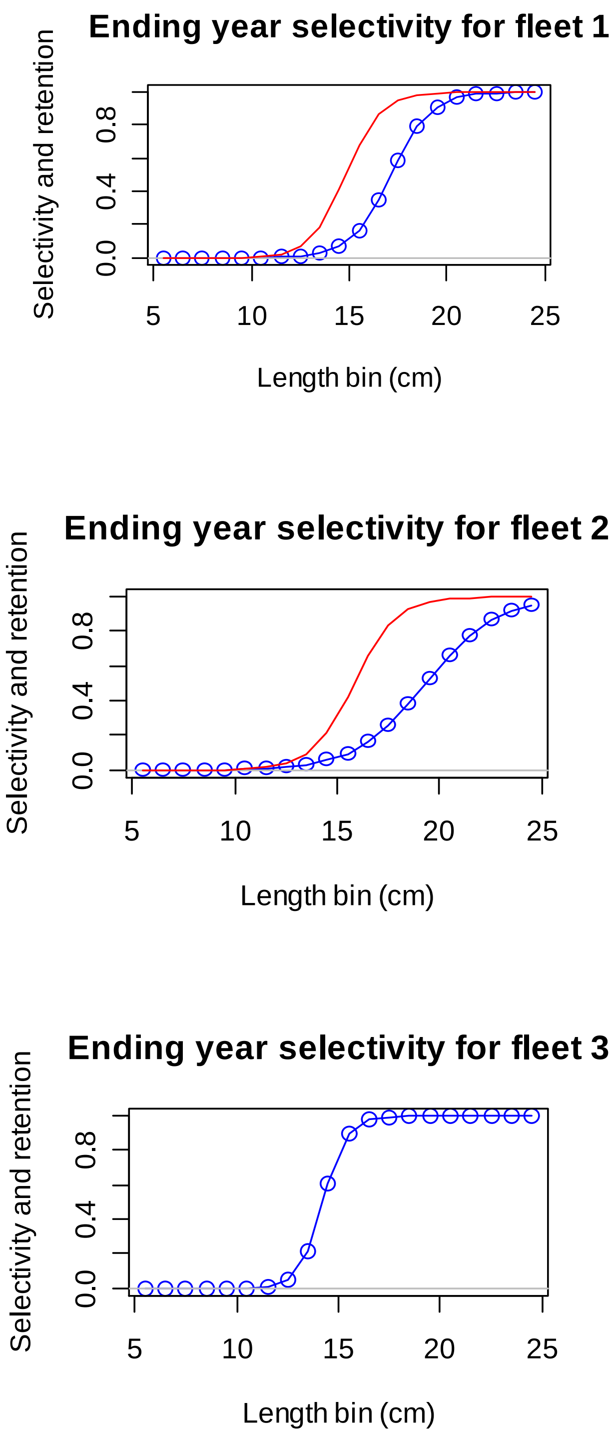


Figure 15.12. The model estimated selectivity (blue line with circles) and retention (red line) patterns for Victorian Danish seine (top), otter trawl (middle) and NSW Danish seine (bottom) fleets respectively for the base case analysis.

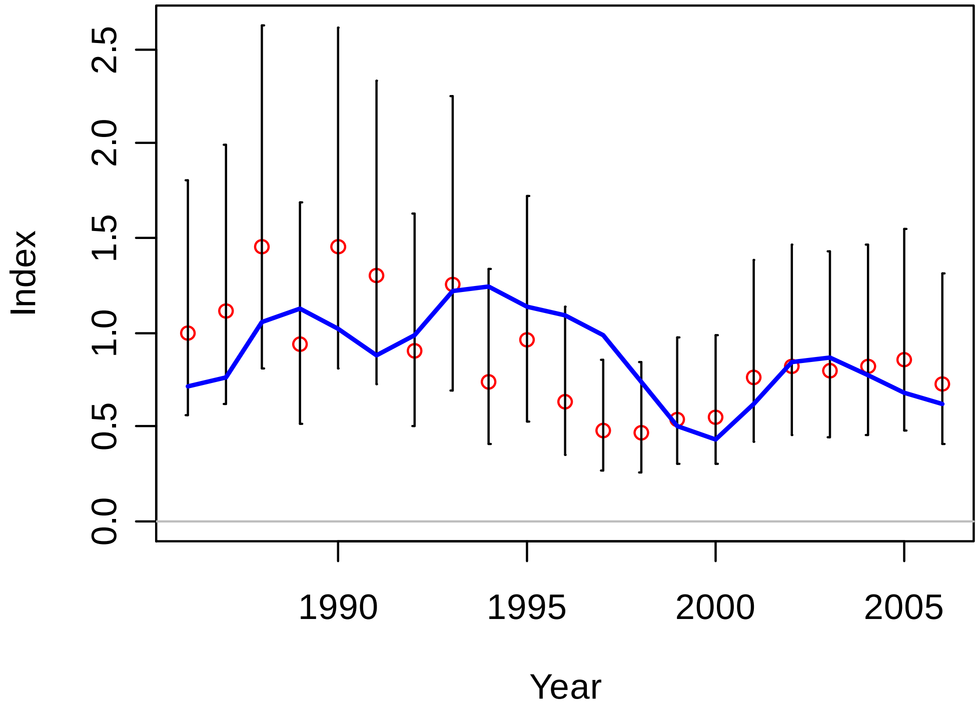


Figure 15.13. Observed (red circles) and model-predicted (blue lines) catch-rate for the Victorian Danish seine fleet versus year for the base case analysis. The vertical lines indicate approximate 95% confidence intervals for the data.

15.4.1.2 Fits to the data

The fits to the catch rate indices for the base case (Figure 15.13) are tolerable, showing a general increase in trend through until the mid 1990s followed by a decline through to the year 2000, with an increase followed by a plateau through until 2006. The predicted CPUE is consistently higher than the observed CPUE for 5 consecutive years from 1994 to 1998. Note also that the first 10 years of catch rate data is quite variable, which makes it difficult to get a good fit to these catch rate indices.

The fits to the discard rate data (Figure 15.14) are reasonable for the Victorian Danish seine and otter trawl fleets for the base case. To achieve reasonable levels of predicted discards, 5 years of very low (<4%) discard rate data was excluded (1995, 2003 and 2004 for Victorian Danish seine and 2002 and 2006 for otter trawl). If these very low discard rates are included in the model, the fitted discard rates match these very low rates well but give very poor fits to all other years with discard rates >4%. Including these low discard rates results in much lower overall predicted discard rates compared to the mean of the discard rates over all years with discard data for each fleet. To achieve predicted discard rates which have a better match to the overall discard rates, these 5 data points were excluded. Fits to the age and length composition data for discarded catches are shown in the appendix, Section 15.7.

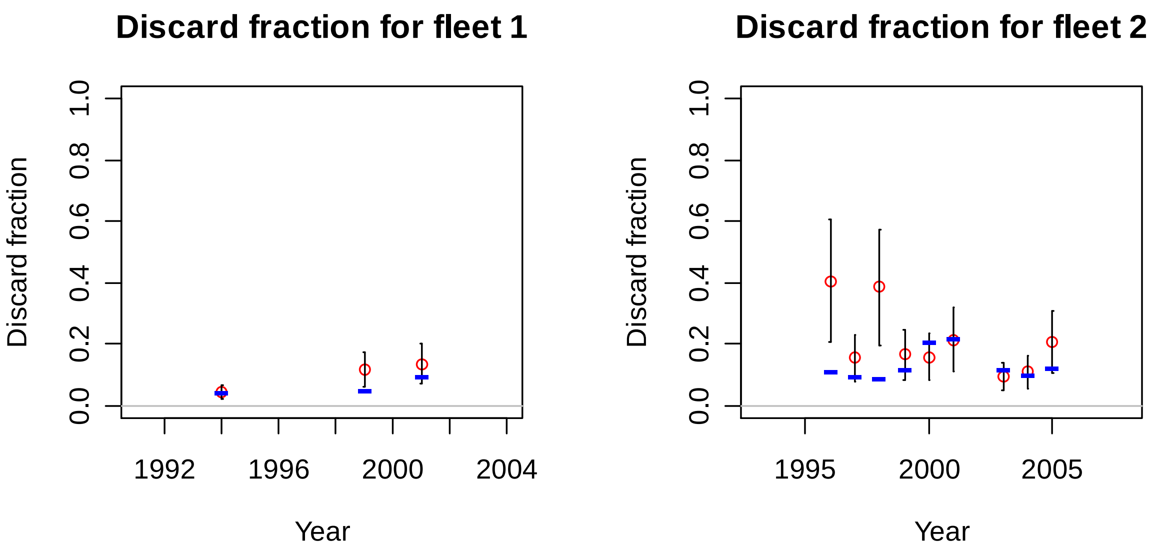
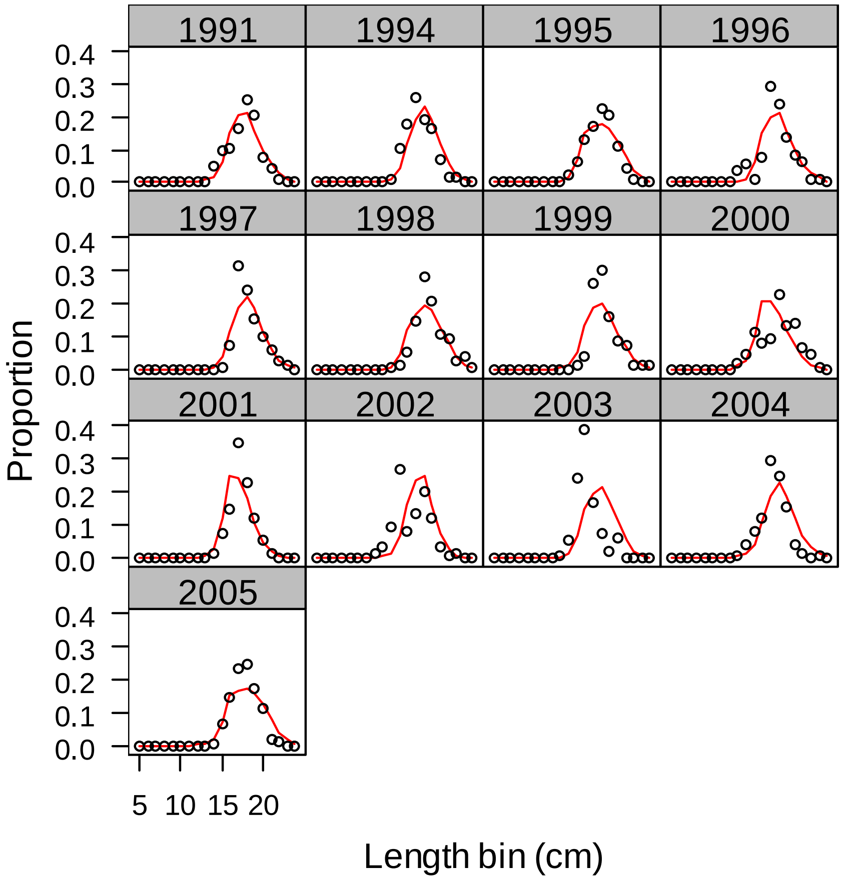


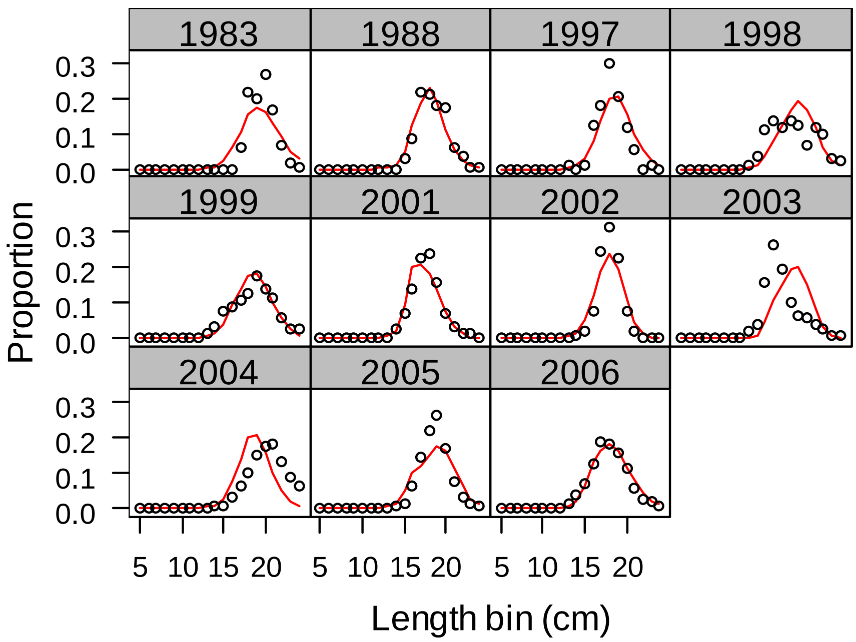
Figure 15.14. Observed (red circles) and model-predicted (blue dashes) discard rates versus year for the Victorian Danish seine (left) and otter trawl (right) fleets for the base case analysis. The vertical lines indicate approximate 95% confidence intervals for the data.

The base-case analysis is able to fit the retained length-frequency distributions adequately (Figure 15.15). The years 2003 and 2004 provide a challenge for fits to length composition data for the otter trawl fleet as 2003 has a peak of small fish and 2004 has a peak of large fish, and the fitted growth rate does not allow these peaks to represent the same cohort of fish. The predicted length frequencies are unable to reflect such a sharp change to the length-composition in one year. The age-composition data are shown in Figure 15.16 for the base case and the fits to this data are good. It should be noted that these age-compositions were not fitted directly, as conditional age-at-length data were used instead. However, the fits to the age-compositions provide a means of checking the adequacy of the model; the model fits the observed age data very well.

Combined sex retained length fits for fleet 1



Combined sex retained length fits for fleet 2



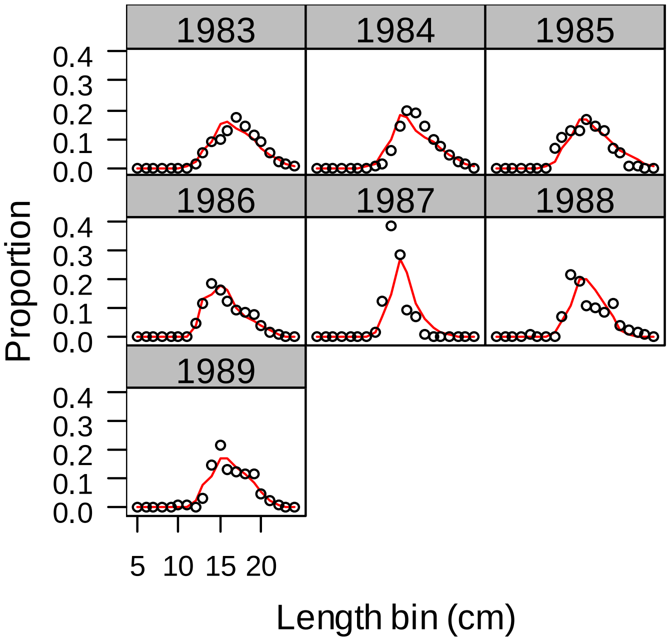


Figure 15.15. The observed and model-predicted fits to the length composition data for Victorian Danish seine (top), otter trawl (middle) and NSW Danish seine (bottom) data for school whiting for the base case analysis.

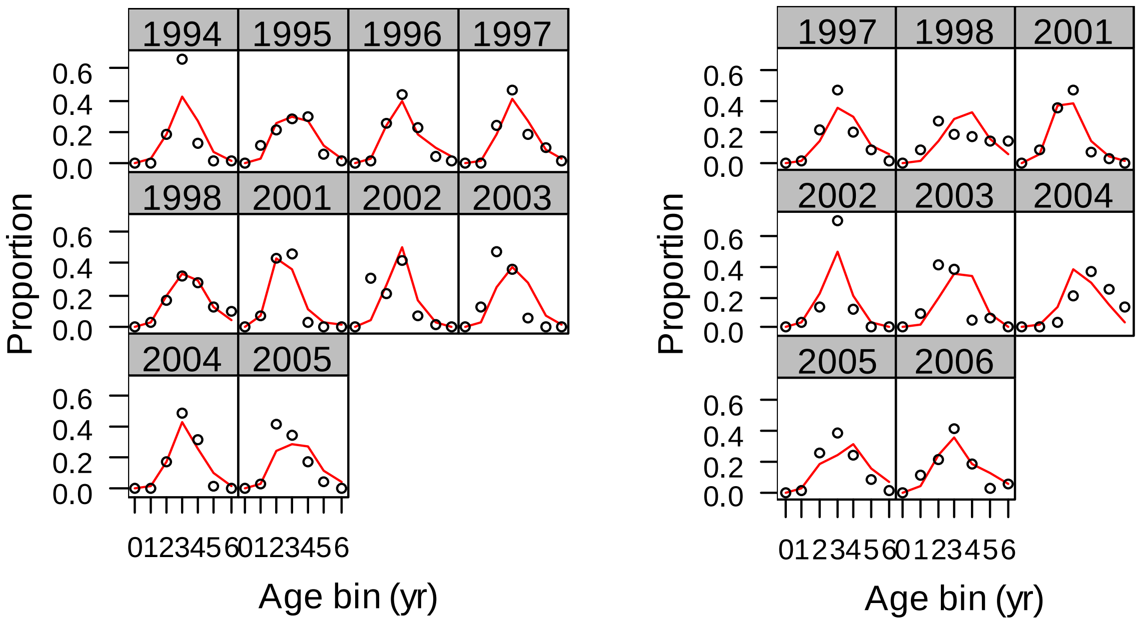


Figure 15.16. The observed and model-predicted fits to age for Victorian Danish seine (left) and otter trawl (right) data for school whiting for the base case analysis.

15.4.1.3 Assessment outcomes

The current spawning stock biomass is estimated to be 36% of unfished stock biomass (i.e. 2008 spawning biomass relative to unfished spawning biomass) for the base case and 35% for the updated base case. The left panel of Figure 15.17 shows the time trajectory of female spawning stock biomass corresponding to the updated base-case analysis, and the right hand panel shows the relative spawning stock depletion with the limit and target reference points at 20% ands 40 % respectively. The stock declines slowly from the beginning of the fishery in 1947, before a sharp decline in the1980s corresponding to an increase in catch. The recovery in the late-1980s and again in the late 1990s is driven by high recruitment events (Figure 15.18, left panel). Following these good recruitment events, the stock typically declines following poor recruitments and continued harvesting and as a result the stock shows considerable short term sensitivity to recruitment.

15.4.1.4 Application of the harvest control rule

An estimate of the catch for biological year 2007 is needed to run the model forward to calculate the 2008 spawning biomass and depletion. For the base case analysis, based on the 2006 catch data, the Victorian Danish seine catch in 2007 is assumed to be 542t and the otter trawl catch is assumed to be 1,256t, with no catch for the NSW Danish seine fleet. The total catch is then 1,798t. The depletion in 2008 under the base-case parameterisation is estimated to be 36%. An application of the Tier 1 harvest control rules under each of the two target level scenarios (40% and 48%) leads to the following 2008 and long-term RBCs:

Control Rule	**2008 RBC**	**Long-term RBC**
20:40:48 (base case)	1,032t	1,753t
20:40:40 (base case)	1,352t	1,922t

For the updated base case, the Victorian Danish seine catch in 2007 is assumed to be 542t and the otter trawl catch is assumed to be 1,092t, with no catch for the NSW Danish seine fleet. The total catch is 1,635t. The depletion in 2008 under the updated base-case parameterisation is estimated to be 35%. An application of the Tier 1 harvest control rules under each of the two target level scenarios (40% and 48%) leads to the following 2008 and long-term RBCs:

Control Rule	**2008 RBC**	**Long-term RBC**
20:40:48 (updated base case)	904t	1,685t
20:40:40 (updated base case)	1,185t	1,848t

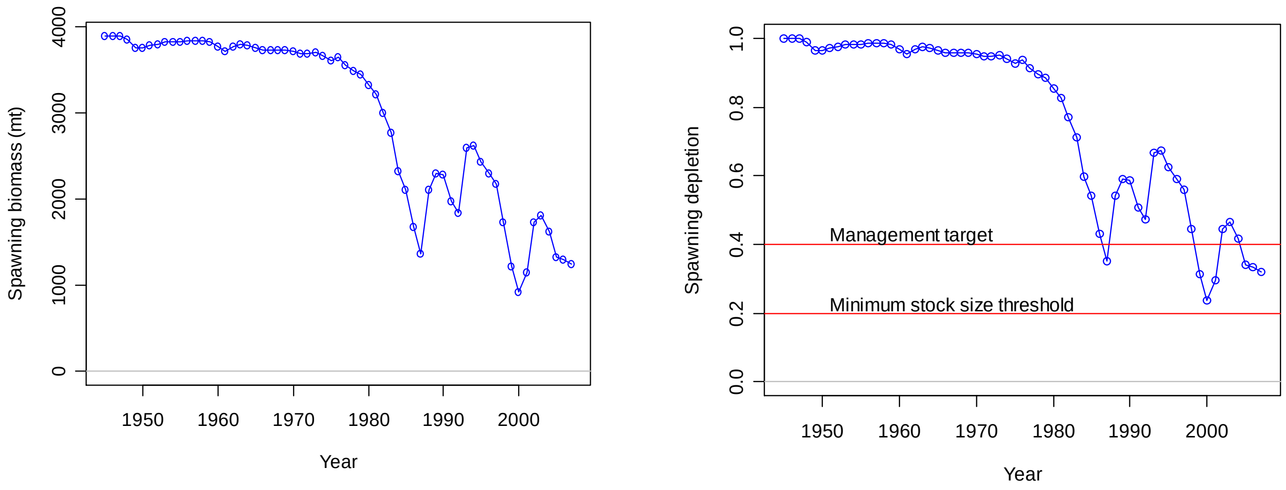


Figure 15.17. Time-trajectories of female spawning biomass, and spawning biomass depletion corresponding to the MPD estimates for the updated base-case analysis.

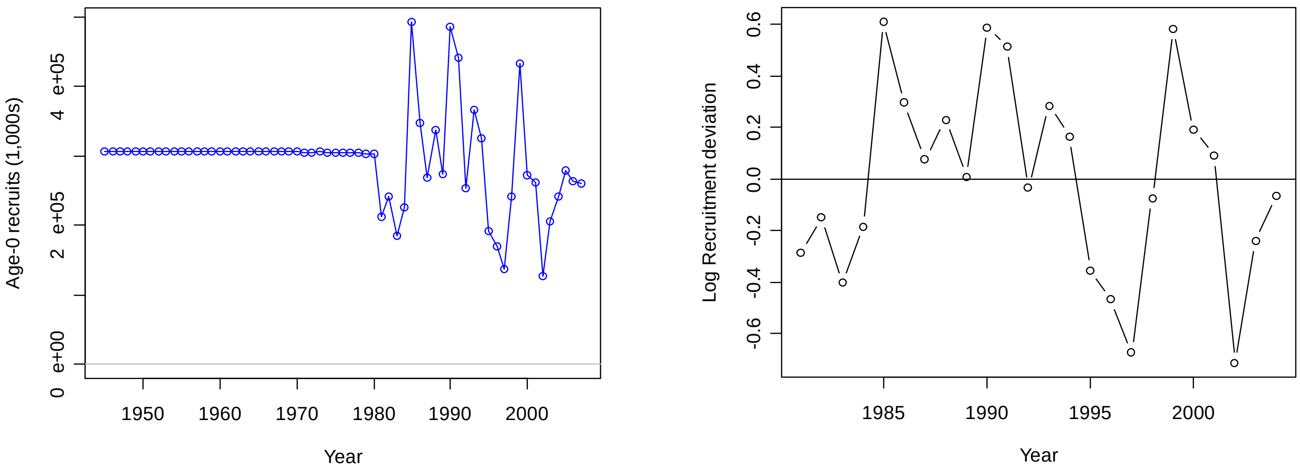
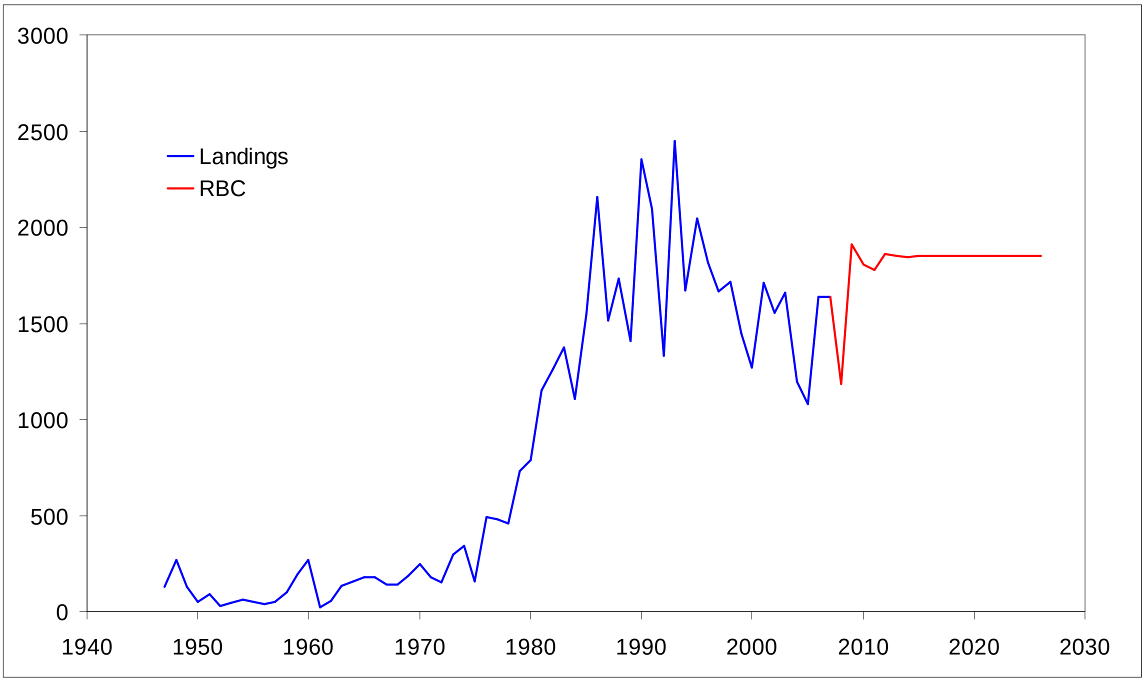


Figure 15.18. Time-trajectories of recruitment (left) and recruitment deviations (right) for the updated base-case analysis.



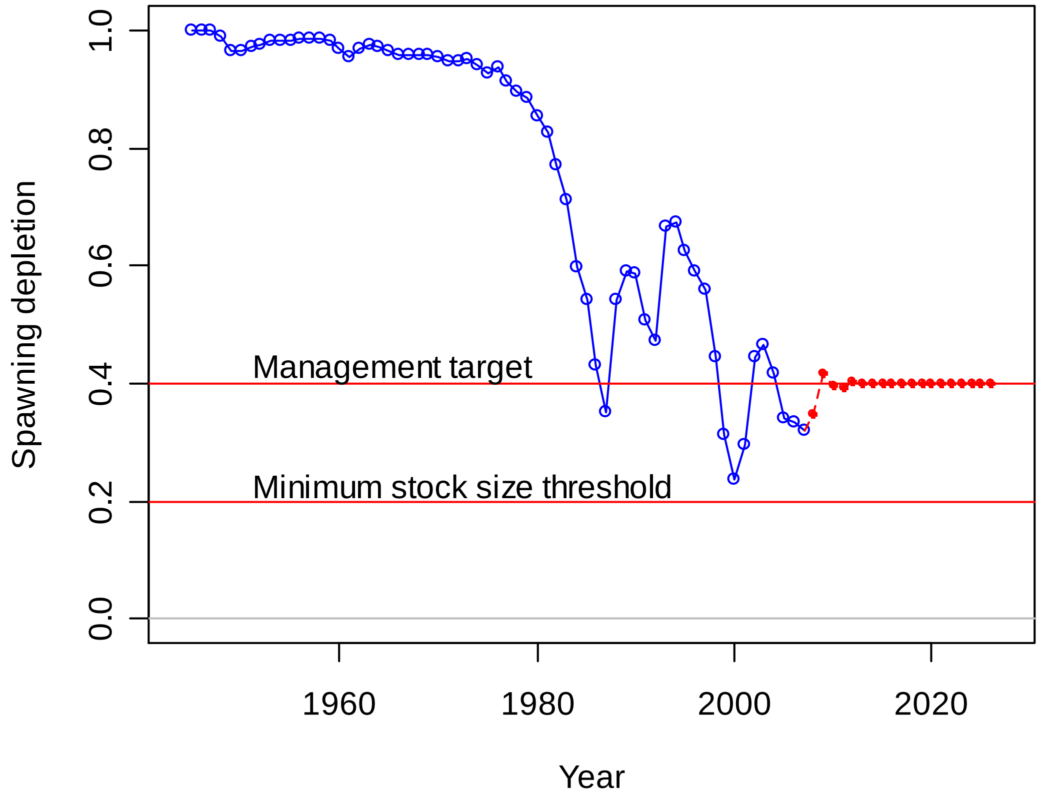


Figure 15.19. The projection of RBCs (top) and its corresponding relative spawning biomass (bottom) under the 20:40:40 rule for school whiting for the updated base case analysis.

An example of the time-series of RBCs and corresponding spawning biomass for the 20:40:40 harvest control rule is shown for the updated base case in Figure 15.19. Approximate 95% asymptotic confidence intervals for the spawning biomass are shown in Figure 15.20 including the forecast values for spawning biomass. These give an indication of the uncertainty in the estimates of the spawning biomass and for the forecast spawning biomass. In particular, it is worth noting the long term forecast for spawning biomass ranges from just over 20% to just under 60% of the unfished biomass. During the forecast period, mean recruitment levels are assumed for all forecast years.

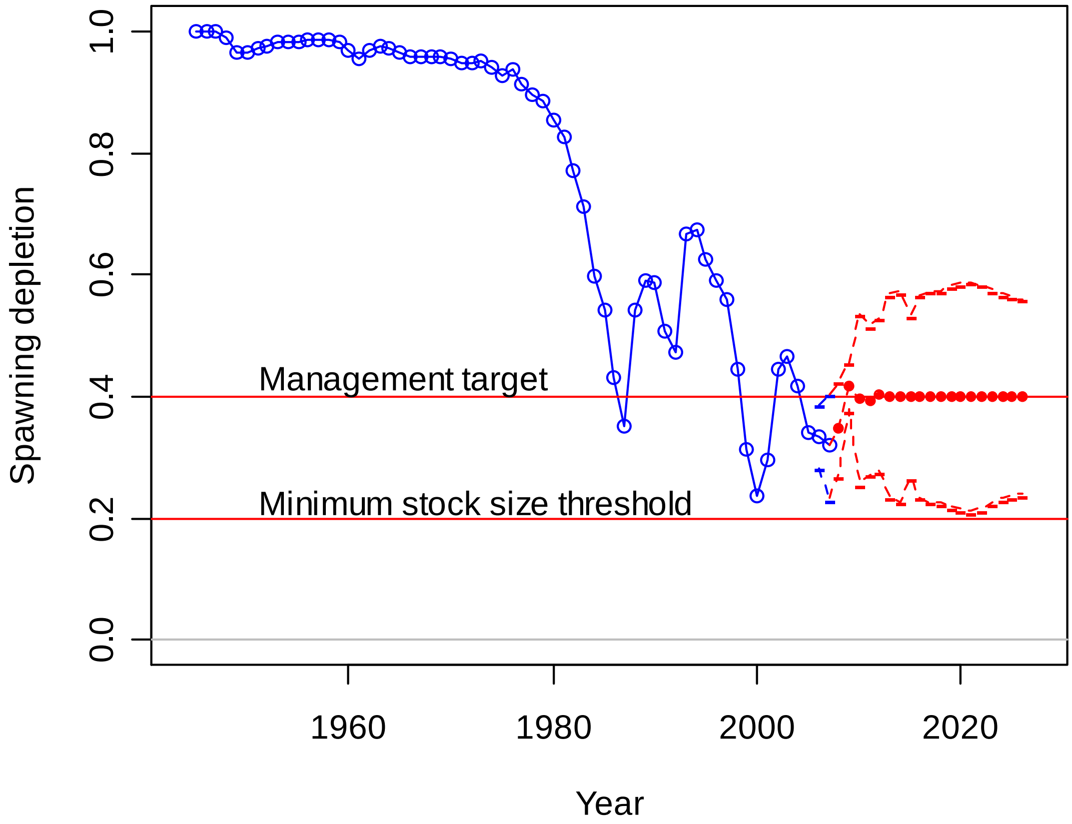


Figure 15.20. The projection of RBCs and spawning biomass under the 20:40:40 rule for school whiting with 95% confidence intervals for the updated base case analysis.

15.4.2 Sensitivity tests

Results of the sensitivity tests are shown in Table 15.5. The results are sensitive to the assumed value for natural mortality, but less so to steepness and σ_R (relative to the base-case). Various components of the likelihood function are plotted as a function of M in Figure 15.21 to explore the sensitivity of the model outcomes to the assumed value for natural mortality for the base case. Figure 15.21 shows that higher values of natural mortality than a value of 0.5yr^{-1} are supported by the data. Likelihood components relating to recruitment age and length data show minima around M = 0.6yr^{-1}, whereas

the best fits to the CPUE data occur for larger values of *M*. As a result the base case value chosen for *M* is 0.6 yr^{-1}, with sensitivities considered for values of 0.5 and 0.7.
The results are also very sensitive to the age at 50% maturity. School whiting become sexually mature at two years of age (Smith and Wayte, 2005), which corresponds to a length of around 16cm. Three year olds are about 18cm long and school whiting reach 14cm at about 1½ years old. One year old fish are around 11-12 cm and are unlikely to be sexually mature.

Analysis of the sensitivity to the projected catch in 2007 shows that this value is also important, especially for setting the value of the 2008 RBC. The total catch in 2006 of 1798t for the base case was considerably higher than in 2004 and 2005 (1228t and 1094t respectively). This also applies for the updated base case (with 2006 total catch of 1635t). Given that the state catches are unregulated in NSW, where the majority of the state catch is taken, the reduced TAC in 2006 will not affect the state catches. The most plausible result was that the 2006 catch would be repeated in 2007, but the alternatives scenarios with smaller values for the projected catch in 2007 resulted in higher values for the 2008 RBC.

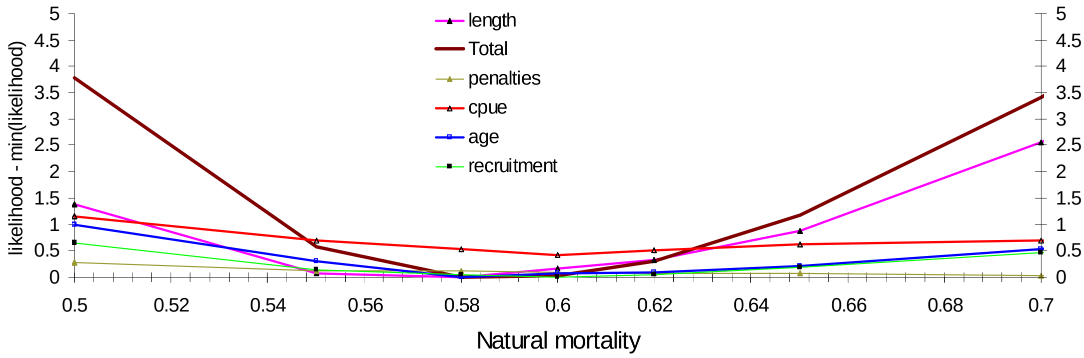
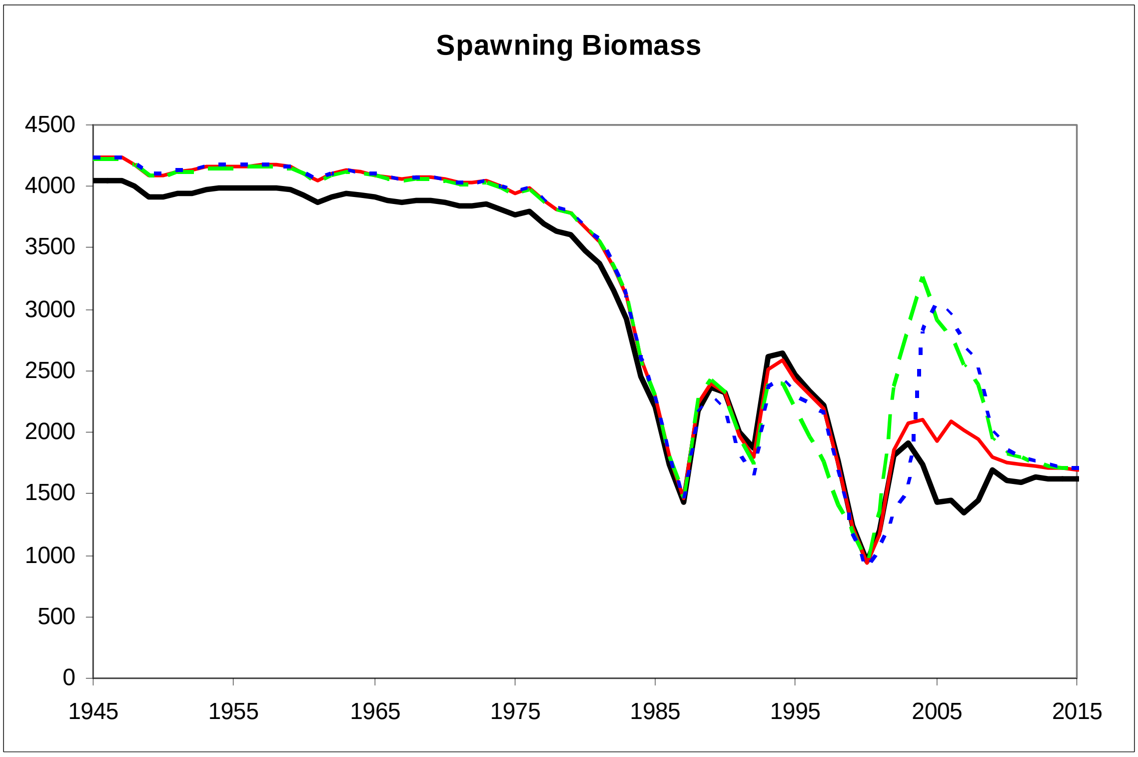


Figure 15.21. A plot of the various likelihood components as a function of natural mortality. The plotted value is the contribution to the likelihood function at each value of *M* less the minimum likelihood (across all values of *M*).

Results of the exploration of data and model structure are given in Table 15.6. While these alternatives are not candidates for adoption as a base case, they do illustrate the impact of various aspects of the data. A two fleet model, with the Victorian and NSW Danish seine fleets combined into a single Danish seine fleet seems to be a sensible alternative, but the fits to the length data suggested that there were either spatial or temporal changes in selectivity.

Removing all the 2006 data, except for catch data, results in an increase in the spawning biomass and in the 2008 RBC values. There is a further increase in both spawning biomass and 2008 RBC when the 2005 data, excluding catch data, is also removed, but a relatively small additional change when the 2004 data is removed as well.

These changes to the spawning biomass and recruitment series are illustrated in Figure 15.22. As years of data are successively removed, the model allows for larger recruitment events in the period 1999-2003, which results in the prediction of an increased spawning biomass. As the data from 2004, 2005 and 2006 is successively added to the model, these large recruitments which appear towards the end of the period containing data are successively removed, as data is added which is more informative on recruitment in these periods. This suggests these large recruitment events at the end of the time series are spurious and are not supported by data, as later data indicates that these recruitment events were not this large. Note that the 2003 series shows a single recruitment event in 2001 which is much larger then any previous recruitment event. The impact of these large recruitments on the spawning biomass is seen a few years after the recruitment event (Figure 15.22). This analysis supports the base case assumption that recruitment deviations are turned off in 2005 and 2006, to prevent spurious large recruitments at the end of the time series.



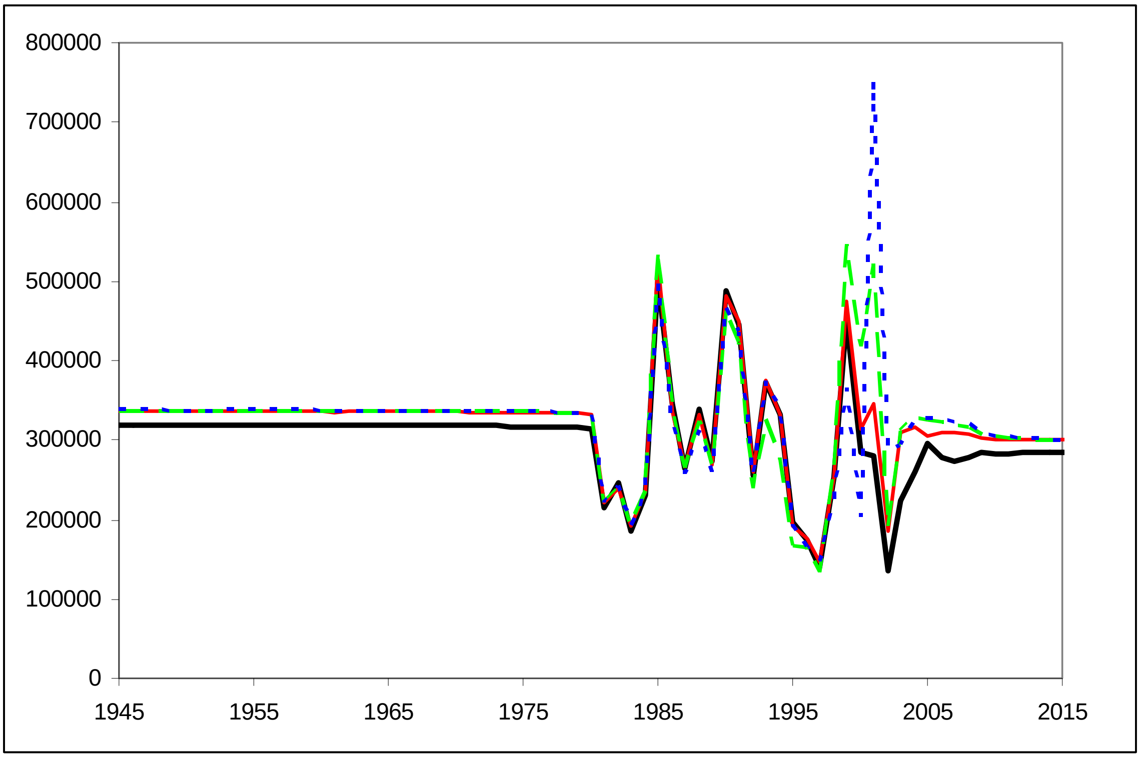
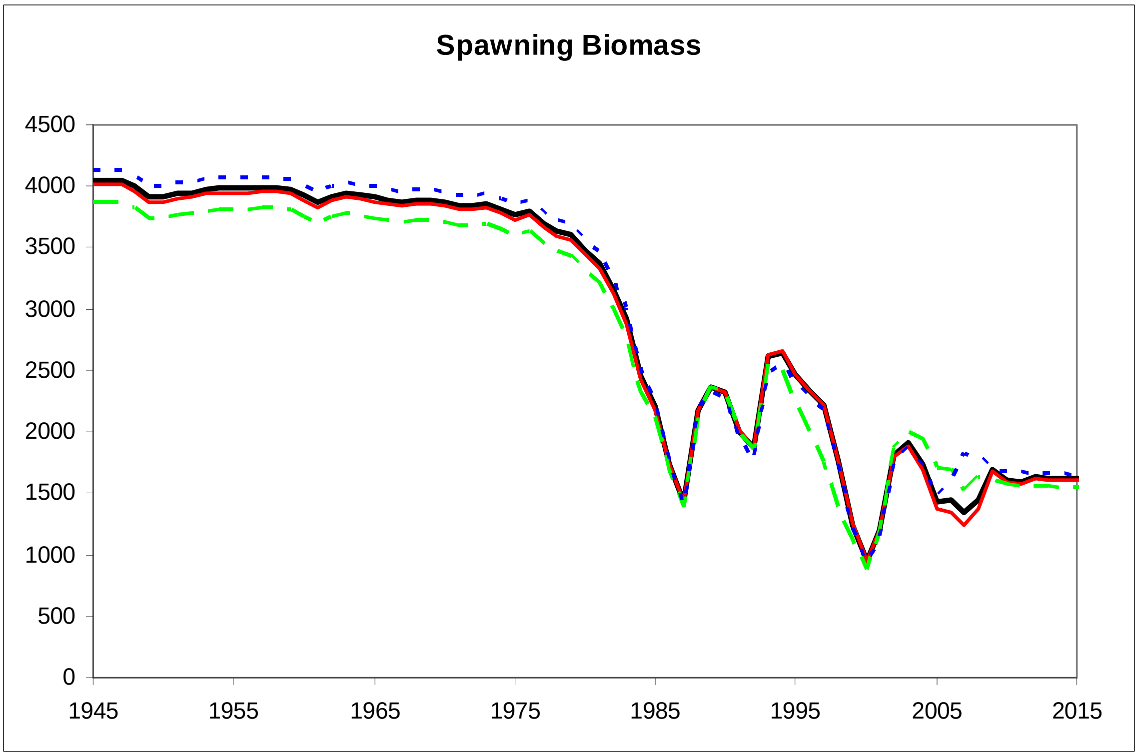


Figure 15.22. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 - 2015 using all the data to the end of 2006 (bold line, black), data to 2005 (solid line, red), data to 2004 (dashed line, green) and data to 2003 (dotted line, blue).

To explore this further, the 2006 CPUE, length and age data was removed separately, to examine the influence of these different 2006 data sources on the result. Removing the 2006 CPUE data point alone resulted in a small decrease in the spawning biomass in 2008 and the 2008 RBC. In contrast, omitting either the 2006 age or the 2006 length data resulted in an increase in 2008 spawning biomass and 2008 RBC, so it is the inclusion of the length and age data in the 2006 data set which is pulling the 2008 biomass estimates down. Without either the 2006 age or 2006 length data, the 2008 spawning biomass is greater than 40% of the unfished biomass. Figure 15.23 shows the impact on the spawning biomass and recruitment of omitting the various 2006 components of the data. Removing the 2006 length data allows a slightly larger recruitment event in 2001 and removing the 2006 age data allows a larger recruitment event in 2004. As with the retrospectives where all the data was removed for particular years, the 2006 data informs the model. In this case the 2006 age data informs the 2004 recruitment and the 2006 length data informs the 2001 recruitment.



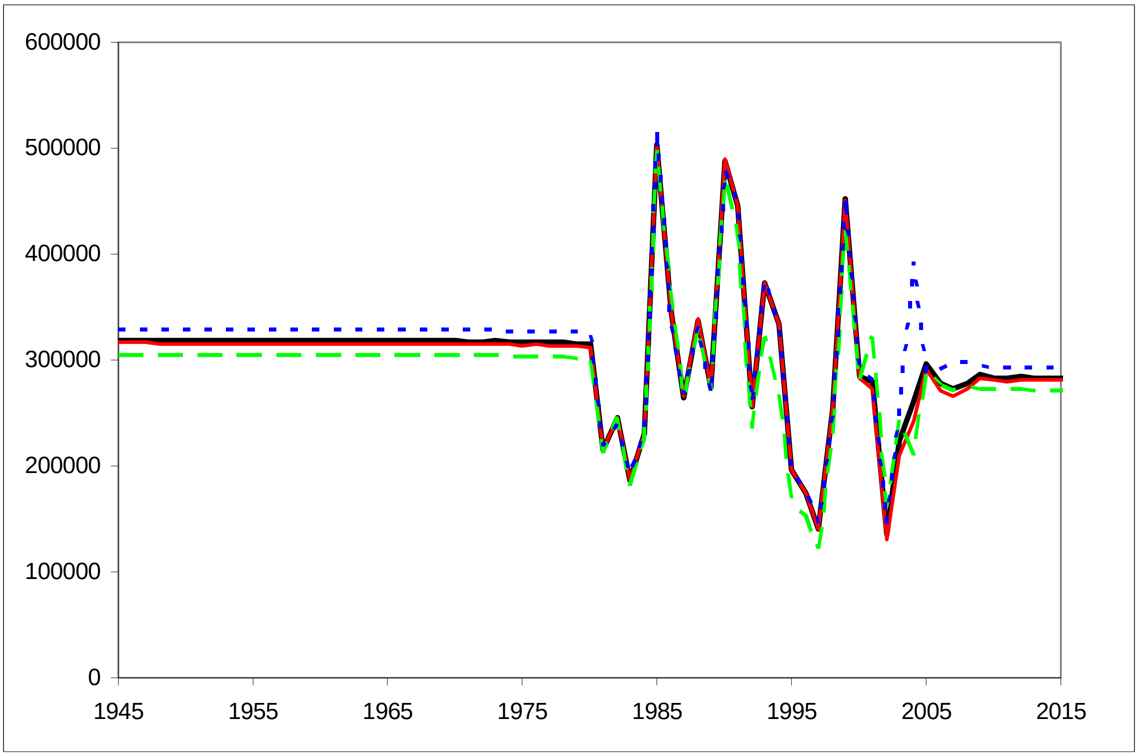


Figure 15.23. The modelled female spawning biomass (top) and recruitment series (bottom) from 1945 - 2015 using all the data to the end of 2006 (bold line, black), omitting the 2006 CPUE data only (solid line, red), omitting the 2006 length data only (dashed line, green) and omitting the 2006 age data only (dotted line blue).

15.4.3 Modified RBC calculations

Due to the rapid response in spawning biomass associated with variation in recruitment or fishing mortality for school whiting, applying the harvest control rules results in a short term (one year) reduction in RBC, compared to the 2006 total catch. This reduction in RBC is followed by an immediate return to values which are higher than the total 2006 catch and values which are close to the long term average value for the RBC. This rapid fluctuation in RBC is demonstrated in Figure 15.19. Such instability in RBCs is undesirable from a management perspective.

Alternative management options were explored to see if this fluctuation in expected RBC can be moderated. For these scenarios it is assumed that the state portion of the catch is fixed at the 2007 state catch (1056t) and the Commonwealth portion of the catch is set at one of four values 750t, 600t, 450t and 300t for either one, two or three years into the future. The change in RBC can be seen at the end of this period of fixed catch (Figure 15.24 and Table 15.1). With the Commonwealth catch fixed at 750t or 600t, there is a similar 1 year reduction in RBC in all cases, with the reduction occurring immediately after the period of fixed catch. In this case, delaying the reduction in RBC does not result in moderation of the size in the reduction in RBC. For a fixed Commonwealth catch of 450 t, the reduction in RBC is smaller than the reduction for the larger fixed Commonwealth catches, and this is further reduced by fixing the Commonwealth catch for 2 or 3 years. If the Commonwealth catch is fixed at 300t, there is an increase rather than a reduction in the RBC (compared to the 2007 total catch) at the end of the fixed catch period. Table 15.1 also lists the projected depletion for 2012 and the maximum changes in either RBC or TAC.

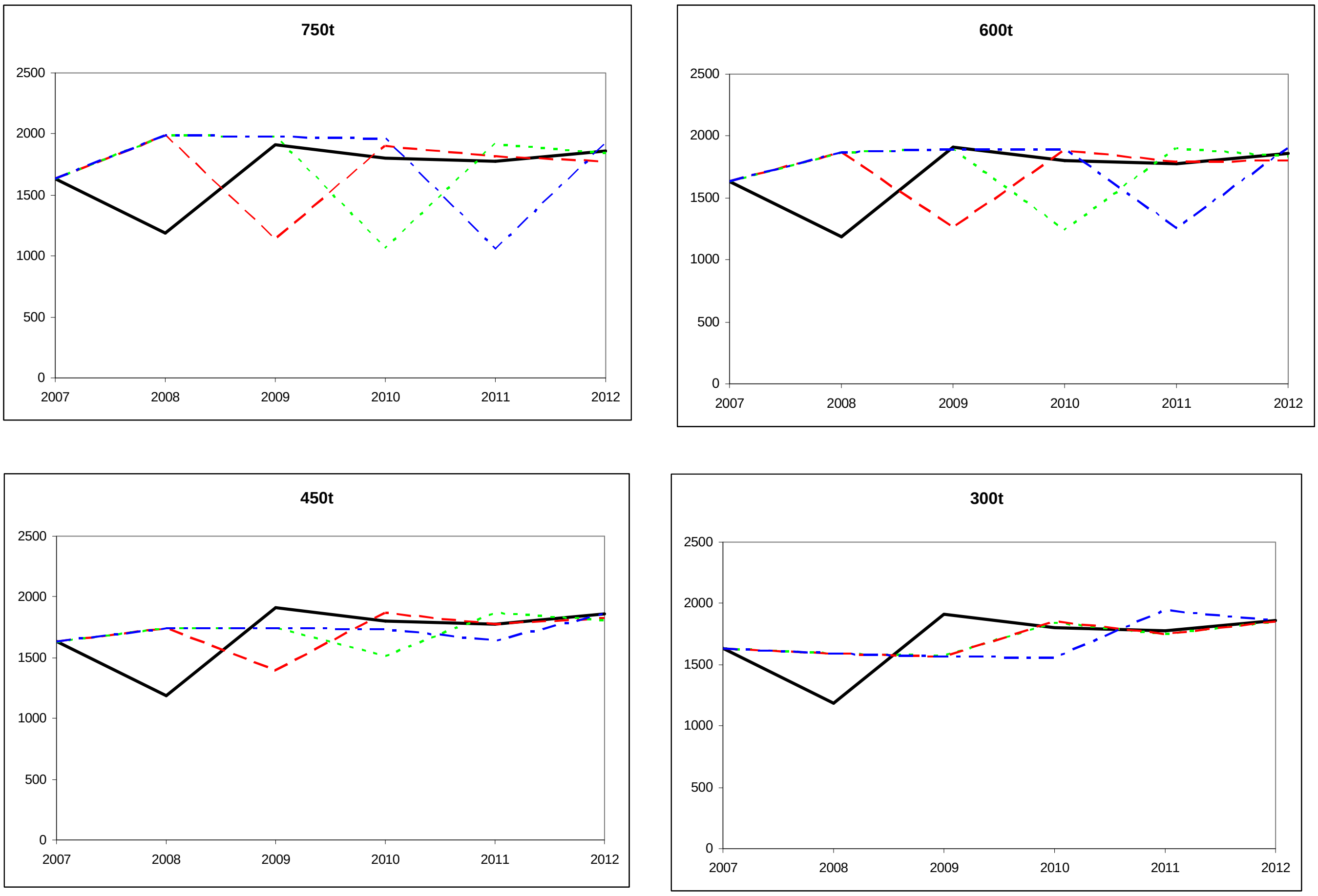


Figure 15.24. Plots of the projected catch and RBC for four different levels of fixed projected Commonwealth catch (750t, 600t, 450t and 300t). In each figure the updated base case (black line, bold) projection is identical, showing the projected catch set equal to the RBC from 2008 onwards. The other lines show the projected catch for a fixed period followed by the projected RBC, for the following periods of fixed catches: 2008 (dashed line, red); 2008 and 2009 (dotted line, green); and 2008, 2009 and 2010 (dot-dashed line, blue).

These results should be treated with some caution, as they are all based on the assumption of a fixed annual state catch (1,056t) for 5 years and mean recruitment over this same period. If the actual state catches vary from this assumed catch and if recruitment is either higher or lower than the mean (or variable) the actual RBCs obtained may be very different to the projections obtained through making these assumptions. State catches have been quite variable over the last 10 years with a mean state catch of 877t and a standard deviation of 190. The variation in recruitment modelled is illustrated in Figure 15.18, with the standard deviations of estimated recruitment about the stock-recruitment relationship, σ_r = 0.37. Note also that the change in the sum of the projected catch over the 5 year period to 2012 varies by a maximum of 4% over all of the scenarios considered in Table 15.1, although the individual variation between the low and high RBC/TAC from one year to the next is much larger.

Table 15.1.The fixed catch and projected RBC for 4 different levels of projected Commonwealth catch (750t, 600t, 450t and 300t), with catches fixed for 1, 2 or 3 years into the future. The bold figure indicates the first year of projected RBC. The projected 2012 depletion is also listed, along with the maximum one year changes in RBC, the maximum one year change in TAC, and maximum one year change in either RBC or TAC.

	2008	2009	2010	2011	2012	2012 depletion	Max ΔRBC	Δ TAC	Max ΔRBC or ΔTAC
base case	1185	1909	1802	1776	1858	0.40	724	0	724
1 year, 750t	1987	**1135**	1901	1814	1776	0.39	852	0	852
2 years, 750t	1987	1978	**1059**	1917	1846	0.40	928	0	928
3 years, 750t	1987	1978	1958	**1052**	1918	0.42	935	0	935
1 year, 600t	1866	**1263**	1888	1796	1801	0.41	625	150	625
2 years, 600t	1866	1896	**1237**	1901	1835	0.43	664	150	664
3 years, 600t	1866	1896	1894	**1252**	1905	0.54	653	150	653
1 year, 450t	1745	**1396**	1872	1775	1826	0.41	476	300	476
2 years, 450t	1745	1739	**1512**	1868	1806	0.44	356	300	356
3 years, 450t	1745	1739	1735	**1640**	1861	0.55	221	300	300
1 year, 300t	1588	**1577**	1847	1749	1852	0.41	275	450	450
2 years, 300t	1588	1566	**1853**	1753	1851	0.44	287	450	450
3 years, 300t	1588	1566	1556	**1942**	1864	0.56	385	450	450

15.4.4 Discussion

This document presents an assessment of school whiting (*Sillago flindersi*) in the SESSF using data up to 31 December 2006. A partial stock assessment for school whiting was last performed in 2004 by Cui *et al.* (2004) using data from 1991 through until 2003. Given a lack of reliable age- and length-composition data, this assessment just used data from the Commonwealth logbook, and ignored catches taken under state jurisdictions and all catches before 1991. As a result, Cui *et al.* (2004) were only able to give information about biomass levels relative to 1991 in this assessment. The 2007 assessment is performed using the stock assessment package SS2, which has enabled some technical improvements to be made. Further, catch data were incorporated from 1947, state catches were included and additional length composition data were used dating back to 1983. Changes from the 2004 assessment include: (a) the estimation of the growth parameters within the assessment, (b) the use of conditional age-at-length data (c) the addition of updated length frequencies, catches and catch-rates, (d) the inclusion of discards and (e) including ageing error in the model.

The updated base-case assessment estimates that current (2008) spawning stock biomass is 35% of unfished stock biomass. Fits to the length, age, and catch-rate data are reasonable. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*, the length at 50% maturity and the projected catch used in 2007. Likelihood profiles support the use of a base case value for *M* of $0.6 yr^{-1}$.

Depletion across all sensitivities varied between 22% (age at 50% mortality=18cm) and 47% (age at 50% mortality=14cm). Exploration of model sensitivity also shows that the model outputs are sensitive to the value assumed for the 2007 catch.

At the September 2007 Shelf Resource Assessment Group meeting, the NSW state catch component of the 2006 catch data used in the base case was revised. The RBCs for the updated base-case model for 2008 are 1,185 t and 904 t respectively under the 20:40:40

and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,848 t and 1,685 t respectively.
School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very rapid impact on the fish stock.

School whiting is a short lived species. Spawning biomass is particularly sensitive to variation in recruitment events and good and bad recruitment years can have a very rapid impact on the fish stock. As a result there will always be some uncertainty about the status of the stock. Further exploration of some biological parameters, such as age and length at maturity may help reduce this uncertainty, but the high mortality rate and short expected life time for this species mean that rapid changes are always possible and projections will always be subject to uncertainty relating to very recent recruitment events (from the most recent year or two), which are poorly informed until these cohorts fully enter the fishery.

15.5 Acknowledgements

The members of the SESSF stock assessment group – Neil Klaer, André Punt, Sally Wayte, Geoff Tuck, Rich Little, Fred Pribac and Tony Smith – are thanked for their generous advice and comments during the development of this assessment. Thanks also to the providers of data for this assessment – Matt Koopman (PIRVic) and Neil Klaer for the provision of stock assessment data (in a very useful format), Kevin Rowling (NSW Fisheries) for providing NSW length frequency compositions, Wayne Cheers and Peter Clarke for providing information on the Victorian Danish seine fleet, Malcolm Haddon (TAFI) for the calculation of the catch-rate indices and Kyne Krusic-Golub (PIRVic) for the provision of ageing data. Thanks also to other members of Shelf RAG for their helpful discussion and input to the assessment process throughout the year.

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Table 15.2.The annual catch for Victorian Danish seine, otter trawl and NSW Danish seine, the proportion discarded for Victorian Danish seine and otter trawl fleets and the standardised catch rate (Haddon, 2007) for the Victorian Danish seine fleet for school whiting. These figures are for the updated base case catch history.

Year	Victorian Danish seine	otter trawl	NSW Danish seine	Vic Danish seine discard proportion	trawl discard proportion	Catch rate
1947	122	4	0			
1948	262	8	0			
1949	125	4	0			
1950	47	1	0			
1951	89	3	0			
1952	26	1	0			
1953	46	1	0			
1954	59	2	0			
1955	49	2	0			
1956	39	1	0			
1957	41	7	0			
1958	76	22	1			
1959	154	38	1			
1960	230	37	1			
1961	0	23	1			
1962	0	52	2			
1963	73	61	2			
1964	78	79	2			
1965	59	117	4			
1966	69	107	3			
1967	81	57	2			
1968	128	12	0			
1969	164	18	0			
1970	204	40	1			
1971	143	36	1			
1972	135	14	0			
1973	233	64	2			
1974	301	37	1			
1975	139	17	0			
1976	351	138	4			
1977	322	157	5			
1978	352	104	3			
1979	538	188	5			
1980	412	367	11			
1981	772	368	11			
1982	714	535	16			
1983	705	650	19			
1984	614	476	14			
1985	1005	525	15			
1986	1451	684	20			1.0000
1987	1041	457	13			1.1095
1988	1293	427	12			1.4580
1989	1079	324	8			0.9355
1990	1691	651	10			1.4555
1991	1477	609	12			1.2970
1992	791	530	12			0.9027

Year	Victorian Danish seine	otter trawl	NSW seine Danish	Vic seine Danish discard proportion	trawl discard proportion	Catch rate
1993	1529	905	15			1.2524
1994	953	702	15	0.0427		0.7415
1995	997	1046	0	0.0036		0.9547
1996	739	1077	0		0.4060	0.6324
1997	571	1096	0		0.1544	0.4765
1998	372	1342	0		0.3849	0.4662
1999	590	859	0	0.1163	0.1669	0.5419
2000	520	749	0		0.1568	0.5479
2001	557	1154	0	0.1359	0.2142	0.7654
2002	585	968	0		0.0218	0.8141
2003	615	1047	0	0.0118	0.0915	0.7939
2004	409	784	0	0.0001	0.1080	0.8142
2005	423	657	0		0.2058	0.8568
2006	542	1092	0		0.0310	0.7288

Table 15.3. The standard deviation of age reading error.

age	st. dev.
0	0.352062
1	0.352062
2	0.399611
3	0.417104
4	0.423539
5	0.425907
6	0.426778

Table 15.4. Estimated and pre-specified parameters of the model.

Estimated parameters	Number of parameters
Unexploited recruitment	1
Recruitment deviations 1981 – 2004	24
Growth	3
Selectivity	6
Retention	4
Pre-specified parameters	**Values**
Rate of natural mortality, *M*	0.5, 0.6, 0.7
Von Bertalanffy *k*	0.2, 0.25, 0.3
Recruitment variability , σ_r	0.3, 0.4,0.5
Maturity inflection	14, 16, 18
Steepness, *h*	0.75
Maturity slope	-2
Length-weight scale, a	1.32×10^{-5}
Length-weight power, b	2.93

Table 15.5. Summary of results for the base-case analysis, updated base case and the sensitivity tests (log-likelihood (-ln L): values that are comparable are in bold face).

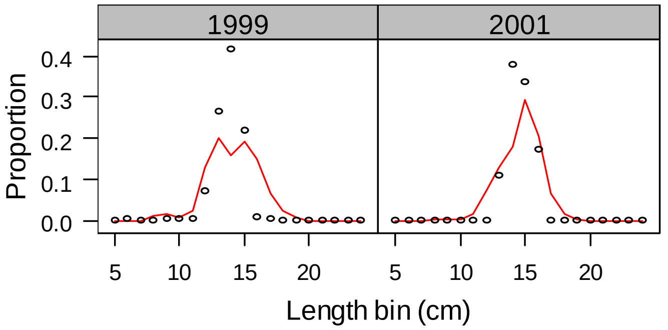
Model	female SB_0	female SB_{2008}	SB_{2008}/SB_0	2008 RBC 20:40:40	2008 RBC 20:40:48	Longterm RBC 20:40:40	Longterm RBC 20:40:48	-ln L
base case (*M*=0.6, *h*=0.75, σ_R=0.4)	4,048	1,448	0.36	1,352	1,032	1,922	1,753	**1,066.14**
M = 0.5	3,951	1,221	0.31	655	499	1,565	1,434	**1,074.91**
M = 0.7	3,978	1,758	0.44	2,460	1,871	2,251	2,044	**1,069.65**
h = 0.65	4,041	1,478	0.37	1,295	997	1,724	1,597	**1,073.56**
h = 0.85	3,886	1,480	0.38	1,729	1,305	2,017	1,816	**1,066.26**
σ_R = 0.3	3,923	1,417	0.36	1,356	1,034	1,862	1,699	**1,074.77**
σ_R = 0.5	4,209	1,469	0.35	1,295	988	2,000	1,824	**1,061.08**
50% maturity at 14cm	5,009	2,363	0.47	2,735	1,969	2,206	2,033	**1,066.40**
50% maturity at 18cm	3,056	662	0.22	91	72	1,658	1,494	**1,065.46**
Von Bertalanffy *k* = 0.2	4,048	1,405	0.35	1,211	921	1,905	1,738	**1,055.30**
Von Bertalanffy *k* = 0.3	4,061	1,502	0.37	1,534	1,173	1,952	1,779	**1,083.40**
Include all discarding data	3,755	1,316	0.35	1,182	892	1,810	1,649	1,131.83
Double weighting on CPUE	3,864	1,760	0.46	2,090	1,585	1,852	1,691	1,095.00
Halve weighting on CPUE	3,896	1,259	0.32	923	705	1,848	1,685	1,055.57
Double weighting on LF data	3,956	1,900	0.48	2,330	1,761	1,965	1,789	1,906.90
Halve weighting on LF data	4,155	1,198	0.29	631	484	1,929	1,759	825.77
Double weighting on age data	3,689	894	0.24	225	173	1,705	1,554	3,096.58
Halve weighting on age data	4,133	1,892	0.46	2,317	1,756	2,043	1,861	547.33
Projected catch: avg last 10	4,048	1,519	0.38	1,571	1,199	1,922	1,753	1,066.14
Projected catch: avg 2004/5	4,048	1,640	0.41	1,928	1,471	1,922	1,753	1,066.14
Updated base case	3,890	1,352	0.35	1,185	904	1,848	1,685	**1,065.66**

Table 15.6. Summary of results for the base-case analysis, updated base case and the model exploration (log-likelihood (-ln L): values that are comparable are in bold face).

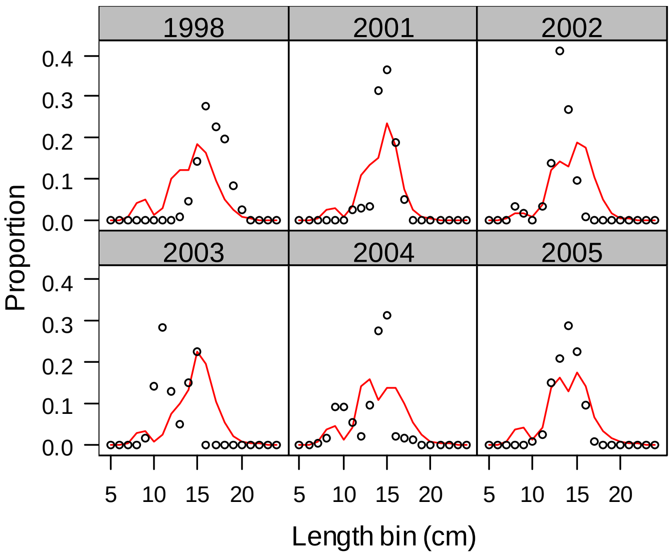
Model	female SB_0	female SB_{2008}	SB_{2008}/SB_0	2008 RBC 20:40:40	2008 RBC 20:40:48	Longterm RBC 20:40:40	Longterm RBC 20:40:48	-ln L
base case (*M*=0.6, *h*=0.75, σ_R=0.4)	4,048	1,448	0.36	1,352	1,032	1,922	1,753	**1,066.14**
Updated base case	3,890	1,352	0.35	1,185	904	1,848	1,685	**1,065.66**
Include all discarding data	3,755	1,316	0.35	1,182	892	1,810	1,649	1,131.83
Add 1970s LF data	3,823	1,551	0.41	1,847	1,399	1,837	1,677	1,099.33
2 fleet model	3,570	1,143	0.32	814	624	1,687	1,539	1,133.04
2 fleet model + 1970s LF data	3,629	1,243	0.34	1,045	799	1,711	1,561	1,140.56
2 fleet model: time varying selectivitv	4,201	1,444	0.34	1,227	937	1,987	1,812	1,038.12
2 fleet model: omit NSW Danish seine LF data	4,137	1,347	0.33	1,001	766	1,944	1,773	1,013.59
2 fleet mode: omit NSW Danish seine and trawl LF data	4,210	1,355	0.32	976	747	1,975	1,802	1,004.70
2 fleet mode: omit NSW LF data and 1991 Victorian LF	4,243	1,346	0.32	933	715	1,987	1,813	995.36
Remove 2006 data except for catch data	4,232	1,950	0.46	2,291	1,750	1,996	1,821	1,009.33
Remove 2005/6 data except for catch data	4,220	2,382	0.56	2,869	2,171	2,001	1,832	941.95
Remove 2004/5/6 data except for catch data	4,237	2,453	0.58	2,886	2,202	2,009	1,829	188.31
Remove 2006 CPUE data	4,013	1,372	0.34	1,155	882	1,904	1,736	1,065.92
Remove 2006 length data	3,879	1,636	0.42	1,959	1,485	1,855	1,695	1,066.12
Remove 2006 age data	4,136	1,801	0.44	2,107	1,608	1,955	1,589	1,015.62

15.7 Appendix: Discard age and length composition fits

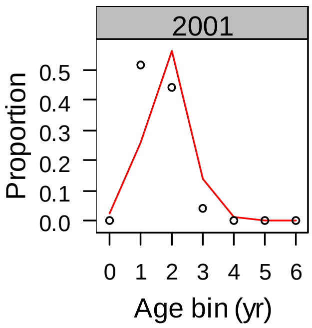
Discard length fits – Victorian Danish seine



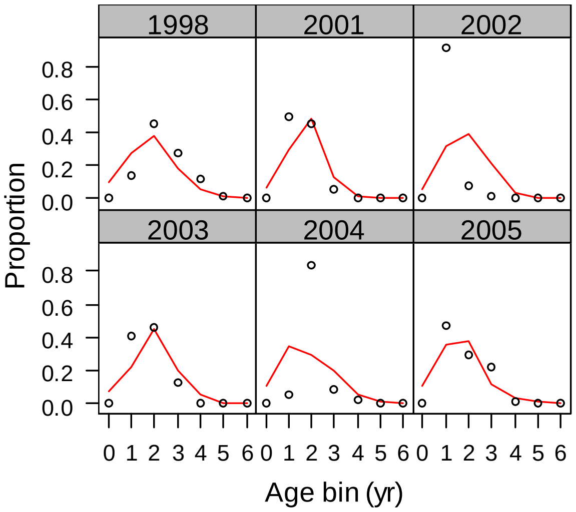
Discard length fits – otter trawl



Discard age fits – Victorian Danish seine



Discard age fits – Victorian Danish seine



16. Updated stock assessment for deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) in the Great Australian Bight trawl fishery using data to June up 2007

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16.1 Background

Deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) have been trawled sporadically in the Great Australian Bight (GAB) since the early 1900s (Kailola *et al.*, 1993). The GAB trawl fishery (GABTF) was set up and managed as a developmental fishery in 1988, and since then a permanent fishery has been established with steadily increasing catches of both species. Deepwater flathead are endemic to Australia and inhabit waters from NW Tasmania, west to north of Geraldton in WA in depths from 70m to more than 490m (Kailola *et al.*, 1993). Bight redfish are also endemic to southern Australia, occurring from off Lancelin in WA to Bass Strait in depths from 10m to 500m (www.fishbase.org).

16.1.1 Previous assessments

An initial stock assessment workshop for the GABTF held in 1992 focused on the status of deepwater flathead and Bight redfish. Sources of information for the workshop included historical data, logbook catch data, observer data and biological information. At this time, the short history of the managed fishery precluded any stock assessment based on a time series of catch and effort data. Therefore, logbook data were examined on a shot-by-shot basis to make biomass estimates using an 'area-swept' approach. Catch per unit area (kg/km^2) was calculated for quarter-degree squares and then scaled up by the total area in which the species had been recorded. The approximate exploitable biomass estimates for deepwater flathead and Bight redfish obtained by this crude method were 32000 t and 12000 t respectively (Tilzey and Wise, 1999). Large uncertainties in the method prevented calculation of error bounds. Using growth and mortality data together with these biomass estimates, sustainable yields were estimated to be 1500-3000 t for deepwater flathead and 200-400 t for Bight redfish.

Wise and Tilzey (2000) summarised the data for the GABTF focusing on deepwater flathead and Bight redfish, the two principle commercial species in shelf waters. They produced the first attempt to assess the status of these deepwater flathead and Bight redfish populations using age- and sex-structured stock assessment models. The virgin total biomass estimates for the base case model were 53760 tonnes (95% confidence interval is 2488-105032 tonnes) for deepwater flathead and 9095 tonnes (95% confidence interval is 4924-13266 tonnes) for Bight redfish. In 2002 an updated assessment was carried out including data up to 2001. The unexploited biomass estimates for the base case model were 12876 (95%CI=11928-13824) tonnes and 9563 (95%CI=8368-10759) tonnes for deepwater flathead and Bight redfish, respectively.

GABTF assessments in 2005 (Wise and Klaer, 2005; Klaer, 2005) continued to use a custom-designed integrated assessment model developed using the AD Model Builder software (Otter Research Ltd., 2000). A series of fishery-independent resource surveys was also commenced in 2005, providing a single annual biomass estimate for Bight redfish and deepwater flathead (Knuckey *et al.,* 2005). Although it was recognized that the survey was designed to provide relative abundance estimates after several years of operation, at this early stage preliminary absolute abundance estimates were made using swept area methods from the survey data. The unexploited biomass levels estimated for the base case models were 20,418t and 13,932t for deepwater flathead and Bight redfish, respectively. Current depletion levels were estimated at over 100% for deepwater flathead due to recent large recruitments and 75% for Bight redfish. The absolute biomass estimate from the survey was consistent with other fishery data for deepwater flathead, but was much greater than the biomass modelled without the survey for Bight redfish.

The intention for the 2006 assessment was initially to duplicate as far as possible the assessment results from 2005 (Wise and Klaer, 2005; Klaer, 2005). Although it was possible to replicate 2005 results reasonably well, there were a few differences in the model structure implemented in SS2 including calculation of recruitment residuals independently and allowing recruitment residuals to occur prior to the commencement of the fishery.

16.1.2 Modifications to the 2007 assessment

This 2007 assessment has attempted to incorporate much available data collected from the fishery that has not been previously used - particularly length-frequencies. Age-frequencies are no longer used explicitly. The model now uses original age-at-length measurements to fit growth curves within the model, which better allows for the interaction between selectivity and the growth parameters. These improvements greatly increase the amount of data available to the assessment, and allow an integrated approach to modelling growth.

16.2 Data available for assessment purposes

Sources of available data for deepwater flathead and Bight redfish include values for biological parameters, landed catches, catch-rates, age-frequencies and fishery-independent biomass surveys.

16.2.1 Biological parameters

Analyses of biological samples collected during the 2004 GAB reproductive study (1), length and age samples collected between 2000-2003 (2) and length samples collected during the 2001 FRDC project (3) were used to update the biological parameters (Table 16.1).

Table 16.1. Biological parameters.

	Source	Parameter	Parameter values			
			Deepwater flathead		Bight redfish	
			Female	Male	Female	Male
Years		y	1988-2007		1988-2007	
Age classes		a	0-30 years		0-65 years	
Sex ratio		p_s	0.5 (1:1)		0.5 (1:1)	
Natural mortality		M	0.2 per year		0.1 per year	
Female maturity	1		40 cm (TL)		25 cm (LCF)	
Growth	2	L_∞	69.82 cm (TL)	50.56 cm (TL)	38.45 cm (LCF)	
		K	0.195 per year	0.346 per year	0.108 per year	
		t_0	-0.637 years	-0.468 years	0 years	
Length-weight	3	ϕ_1	0.002 cm (TL)/gm	0.002 cm (TL)/gm	0.128 cm (LCF)/gm	0.144 cm (LCF)/gm
		ϕ_2	3.332	3.339	2.559	2.522

Note: these growth parameters now provide starting values for growth fitted within the assessment model.

16.2.2 Catches

Recent catches for deepwater flathead and Bight redfish were taken directly from CDR landings data for the GABTF maintained by AFMA. All values from 01/02 onwards have been updated compared to last year, and are generally slightly higher than reported previously for that period. Catch estimates for the period 1988/89 to 2006/07 are given in Table 16.2.

Table 16.2. Financial year catch of deepwater flathead and Bight redfish.

	Catch (kg)	
	Deepwater flathead	Bight redfish
88/89	312,491	85,651
89/90	394,672	170,833
90/91	420,152	281,808
91/92	608,128	265,612
92/93	508,162	120,698
93/94	585,072	107,472
94/95	1,254,803	157,803
95/96	1,551,593	173,922
96/97	1,459,341	327,177
97/98	1,010,348	372,617
98/99	680,659	437,788
99/00	544,992	323,641
00/01	776,912	387,879
01/02	963,613	262,613
02/03	1,866,026	424,672
03/04	2,482,093	946,477
04/05	2,264,119	937,456
05/06	1,545,604	789,704
06/07	1,039,690	1,023,908

16.2.3 Catch rates

Catch rates were previously standardised using Generalised Additive Models (GAMs) (Hobsbawn *et al*. 2002a; 2002b) and a log-linear model (Klaer, 2006). Standardisations for a range of SESSF species are carried out each year by the University of Tasmania (see Haddon, 2006). It is anticipated that standardisations for deepwater flathead and Bight redfish will be added to the list of SESSF species processed in a standard manner. However, for the assessement this year the standardisation was carried out for GAB species in the same manner as last year (Klaer, 2006). Data filtering and factors to be examined were chosen to match with the methods of Haddon (2006).

Only data that conformed to the following filtering criteria were examined:

- Boats included if median annual catch greater than 4t and have caught the species for 3 or more years;
- Depth<1000m;
- Non-zero species catch;
- Shot length >1.0 hr <10.0 hr.

The following factors were included for examination of their effects on catch rate:

- Year (Financial)
- Month
- Zone: int(Longitude/5.0)
- Depth: int(Depth/50)
- Vessel

The form of the model used in the R statistical package was:

```
sSP.glm <- lm(datSP.CPUE~datSP.year+
           datSP.month+datSP.zone+
           datSP.depth+datSP.vessel, data= datSP)
```

where CPUE for each fishing operation is log (catch/hours trawled).

Table 16.3. Year factor values from GAB log-linear model.

	Standardised CPUE	
	Deepwater flathead	Bight redfish
88/89	0.54	0.43
89/90	1.14	0.44
90/91	1.05	0.33
91/92	1.15	0.28
92/93	1.02	0.28
93/94	1.23	0.21
94/95	1.61	0.21
95/96	2.16	0.14
96/97	2.09	0.16
97/98	1.42	0.19
98/99	0.99	0.20
99/00	0.73	0.24
00/01	0.87	0.22
01/02	0.95	0.19
02/03	1.11	0.15
03/04	1.58	0.17
04/05	1.47	0.25
05/06	1.16	0.23
06/07	0.74	0.22

A comparison of LM model results with those presented last year is shown in Figure 16.1 and Figure 16.2.

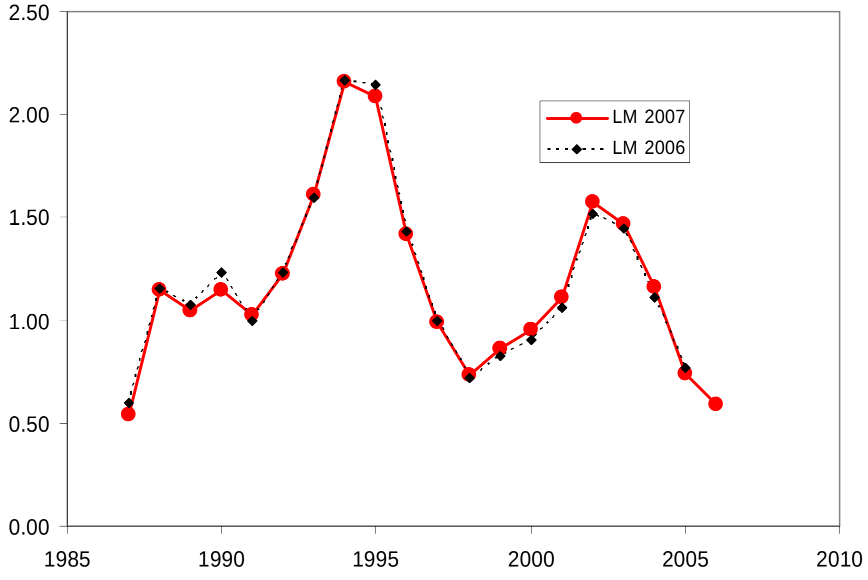

Figure 16.1. Deepwater flathead comparison of LM 2007 results with LM 2006.

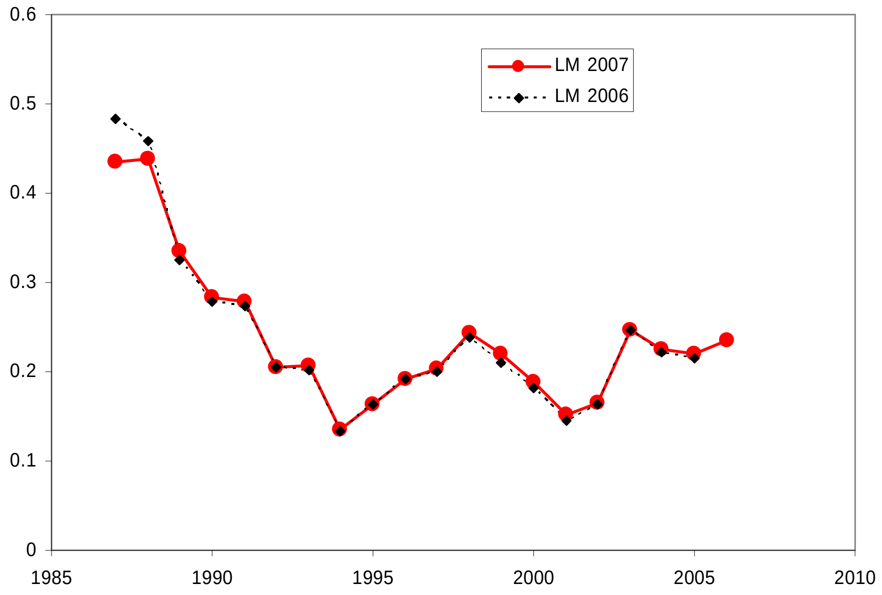

Figure 16.2. Bight redfish comparison of LM 2007 results with LM 2006.

16.2.4 Fishery-independent survey

Absolute biomass estimates have been taken from Knuckey *et al.* (2005), Knuckey (2006), Knuckey and Hudson (2007).

Table 16.4. Estimated exploitable biomass (t) with coefficient of variation (cv) of deepwater flathead and Bight redfish in each stratum and across all strata. Estimates in bold are used in the analyses.

2005	Day and night (hauls=76)				Day time (hauls=37)				Night time (hauls=39)			
Door spread	103.4 m		16.3 m		103.4 m		16.3 m		103.4 m		16.3 m	
Species	t	cv	t	cv	t	cv	t	cv	t	cv	t	cv
deepwater flathead	1,916	0.05	**12,152**	**0.05**	1,903	0.09	12,070	0.09	1,899	0.06	12,046	0.06
Bight redfish	2,128	0.14	13,498	0.14	847	0.36	5,375	0.36	3,293	0.13	**20,887**	**0.13**

2006	Day and night (hauls=75)				Day time (hauls=38)				Night time (hauls=37)			
Assumed swept width	108.0 m		16.3 m		108.0 m		16.3 m		108.0 m		16.3 m	
Species	t	cv	t	cv	t	cv	t	cv	t	cv	t	cv
Deepwater flathead	1,297	0.05	**8,230**	**0.05**	1,312	0.08	8,322	0.08	1,308	0.08	8,299	0.08
Bight redfish	2,228	0.16	14,517	0.16	610	0.26	3,869	0.26	3,902	0.16	**24,753**	**0.16**

2007	Day and night (hauls=75)				Day time (hauls=38)				Night time (hauls=37)			
Assumed swept width	*		16.3 m		*		16.3 m		*		16.3 m	
Species	t	cv	t	cv	t	cv	t	cv	t	cv	t	cv
Deepwater flathead	1,379	0.05	**8,540**	**0.05**	1,349	0.07	8,282	0.07	1,399	0.08	8,892	0.08
Bight redfish	2,734	0.18	16,575	0.17	1,190	0.37	7,134	0.36	4,198	0.17	**25,713**	**0.16**

* Door width measured as 84m (shots 1-18) and 99m (shots 19-39) during March and 109m during April 2007.

16.2.5 Length and age composition data

The number of length samples used in the assessment per financial year and source is given in Table 16.5 and Table 16.6. In any year, the source with the greatest number of available samples was used. Length frequencies were reweighted according to the size of the catch sampled.

Table 16.5. Length samples and source for deepwater flathead

Year	Samples	Source
1993	1,242	Port
1994	584	Port
1997	601	Port
1998	3,782	Port
1999	5,368	Port
2000	6,885	Onboard
2001	6,401	Onboard
2002	2,273	Onboard
2003	4,205	Port
2004	4,464	Port
2005	3,477	Onboard
2006	937	Onboard

Table 16.6. Length samples and source for Bight redfish

Year	Samples	Source
1992	252	Port
1993	516	Port
1997	400	Port
1998	1,000	Port
1999	5,824	Port
2000	3,003	Port
2001	2,618	Onboard
2002	1,173	Onboard
2003	2,706	Port
2004	3,343	Onboard
2005	2,257	Onboard
2006	404	Onboard

Table 16.7 Otolith age at length samples used in the assessment

Year	Deepwater flathead	Bight redfish
1992		95
1993	407	247
1994	178	
1997	972	996
1998	1,163	
1999		321
2000	600	420
2001		483
2002	640	
2003		627
2004	563	576
2005	555	576
2006	248	241

16.3 Analytical framework

16.3.1 Model and parameter estimation

The population dynamics model implemented in SS2 is documented in Methot (2005). Parameters estimated are initial recruitment levels, trawl selectivity and annual recruitment deviations.

16.3.2 Sensitivity tests

A series of sensitivity test is used to examine the sensitivity of the results of the model to some of its assumptions / the data inputs:

Model-related sensitivity tests

1) Vary *M* to values lower and higher than those of the base case.
2) Steepness = 0.65, Steepness =0.75 and Steepness=0.85.
3) Model the biomass survey as relative rather that absolute values.

Data-related sensitivity tests

1) Double and halve the residual standard deviations for the catch-rate indices.
2) Double and halve the effective sample sizes for the age-composition data.
3) Double and halve the effective sample sizes for the length-composition data.
4) Exclude the fishery-independent biomass survey.

16.3.3 Projection and calculation of the Recommended Biological Catch

The SS2 model includes the ability to calculate RBC values based on assessment scenario results and the Australian Tier 1 and 2 rule (see Wayte (2006) for details of how the Tier rules are implemented).

16.4 Results

16.4.1 Diagnostic fits to input data for the deepwater flathead base case

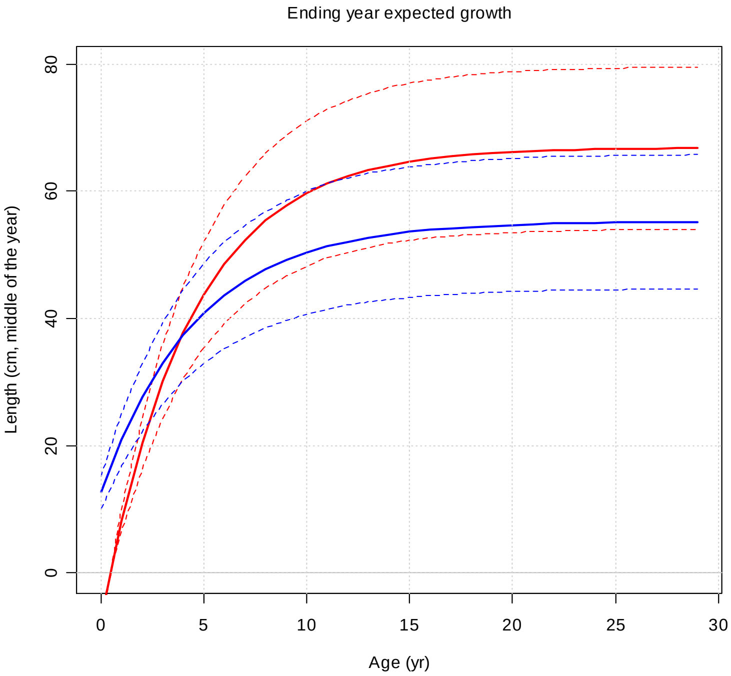

Figure 16.3. Fitted growth curves based on age-at-length data.

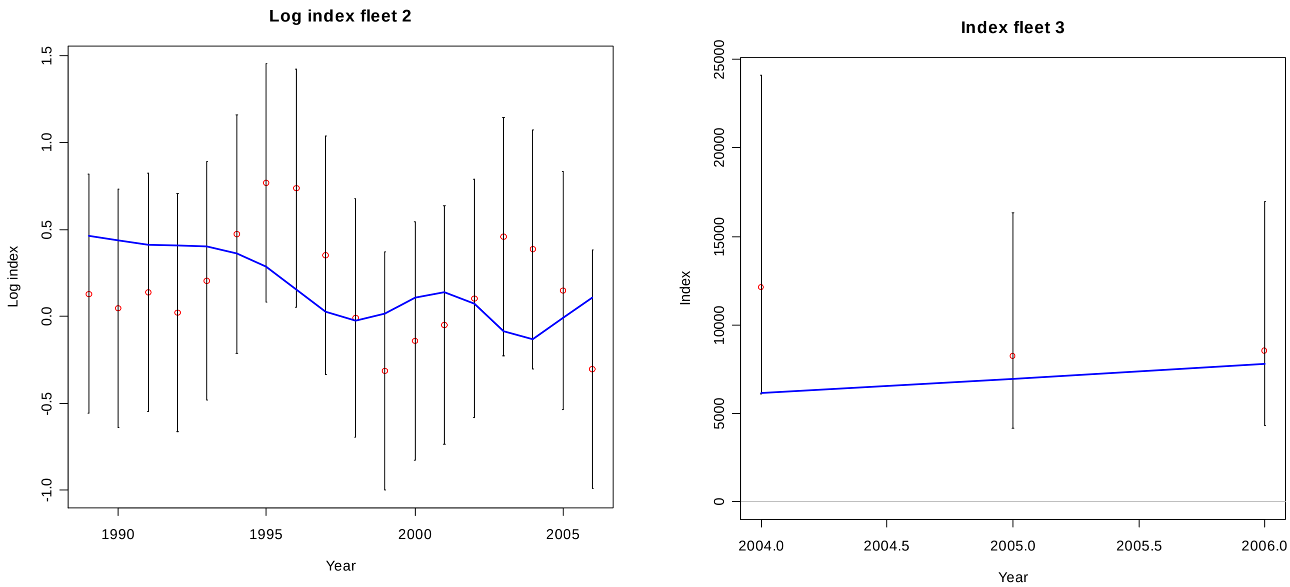

Figure 16.4. Model fits to CPUE and survey.

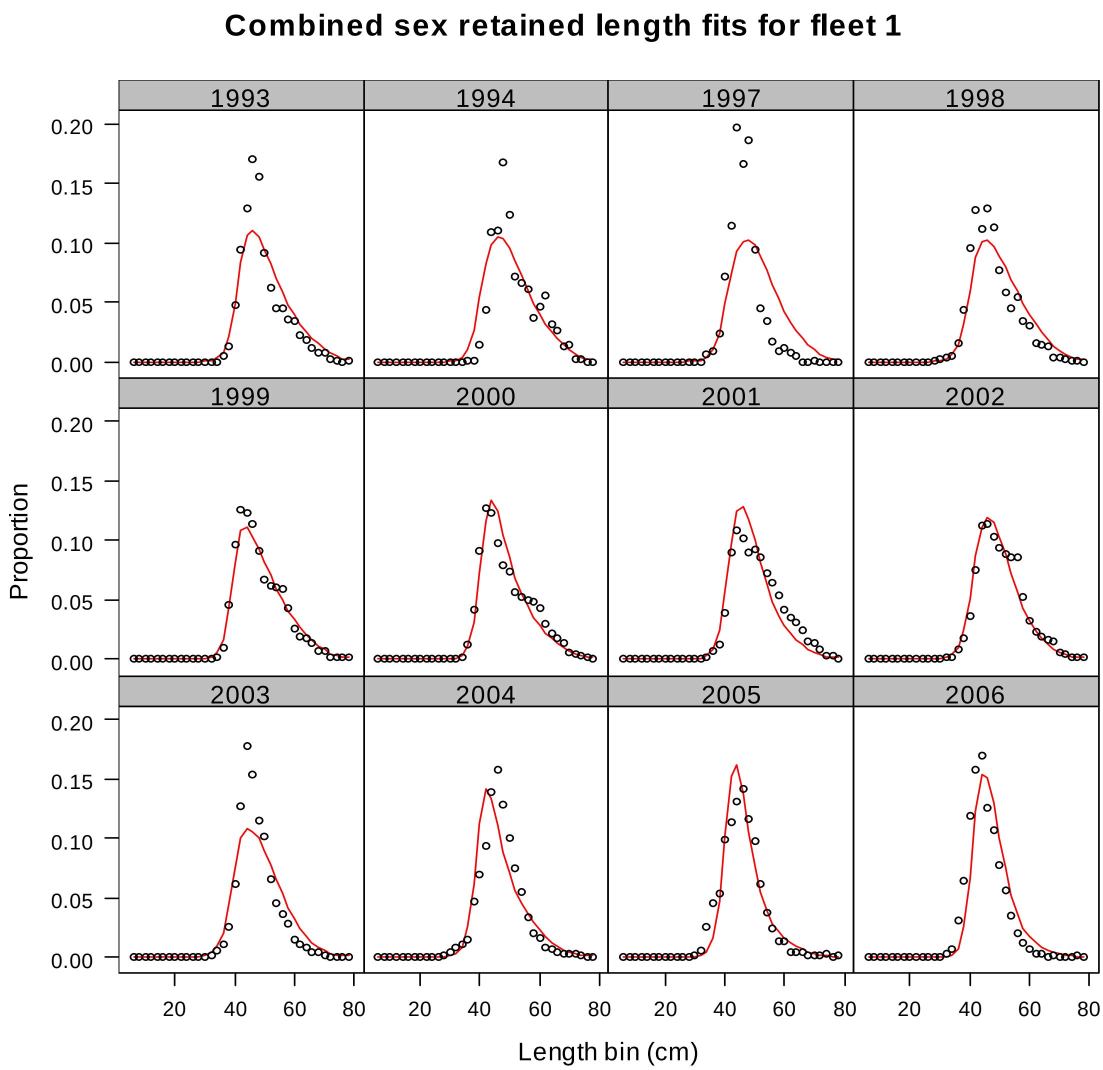

Figure 16.5. Model fits to combined length frequency.

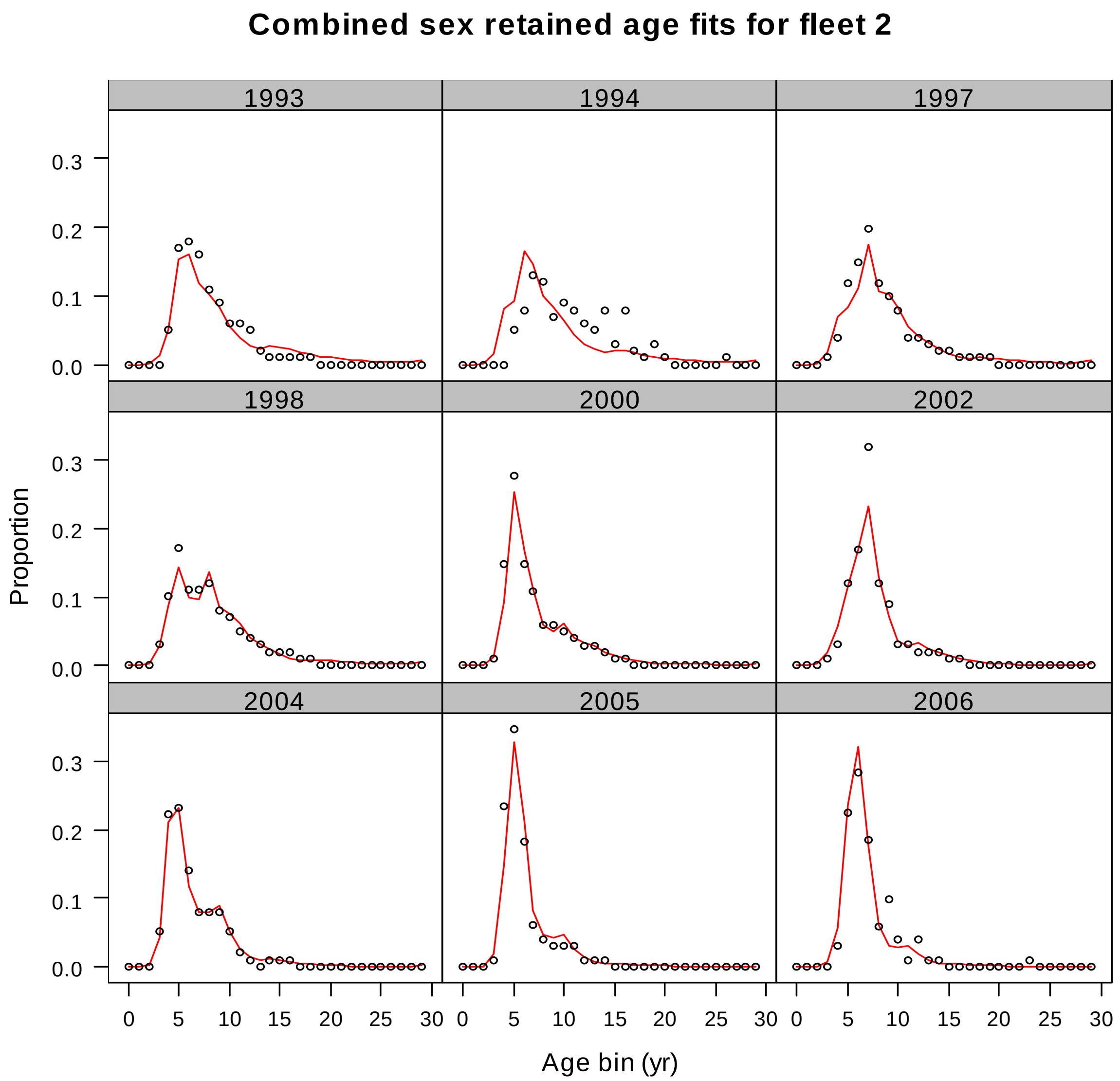

Figure 16.6. Indicative model fits to combined age frequency.

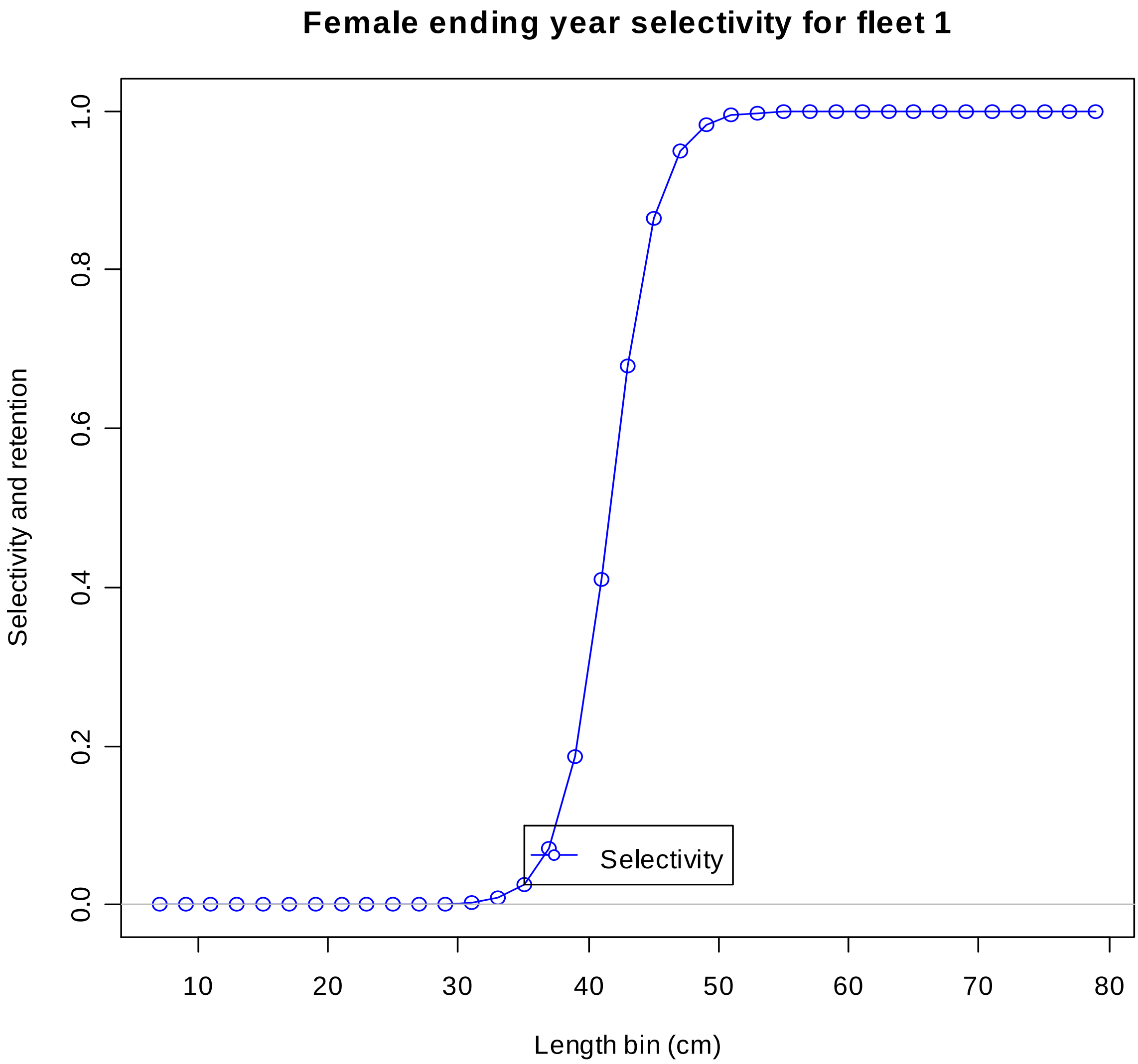

Figure 16.7. Size selectivity fit (female shown) for trawl.

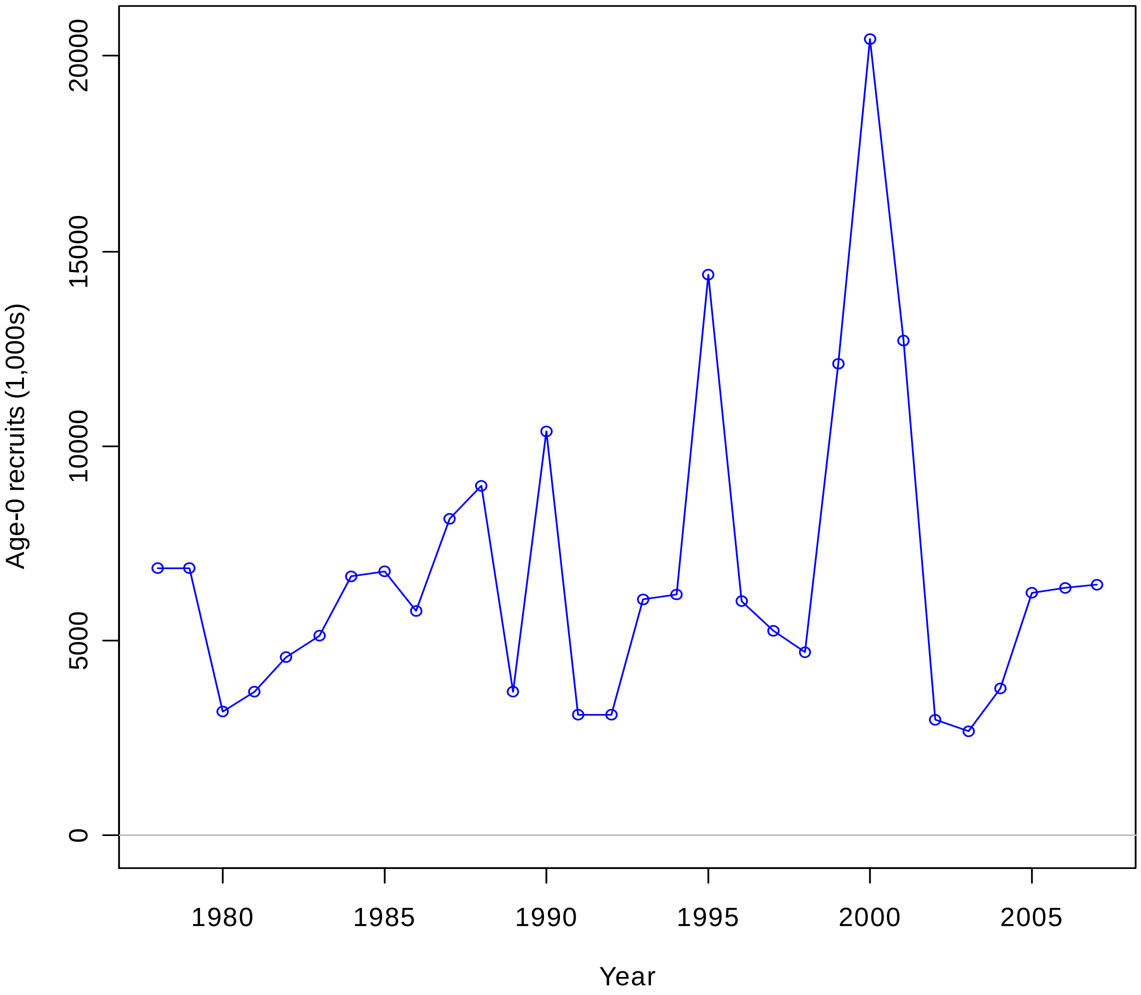

Figure 16.8. Recruitment time series for the base case.

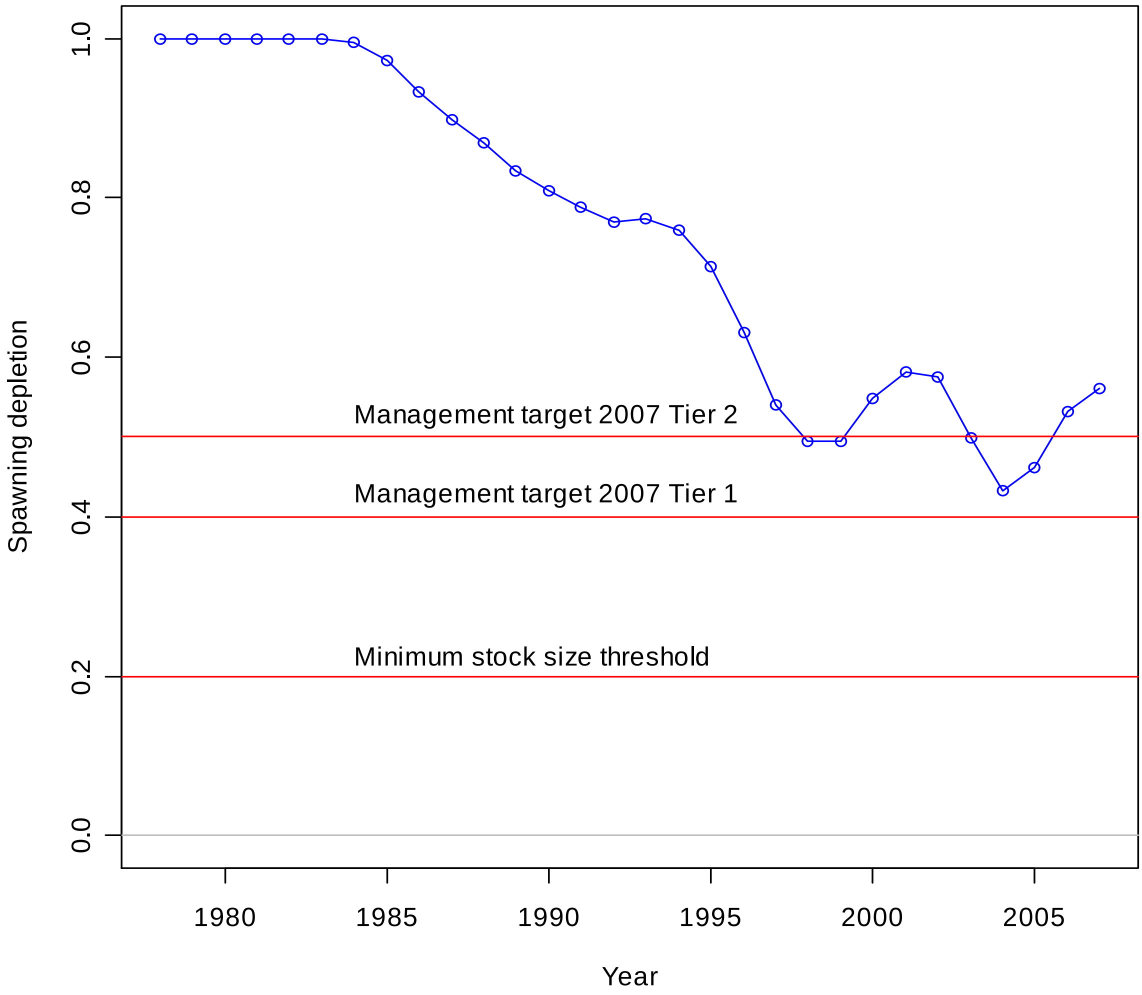

Figure 16.9. Spawning biomass depletion level per year for the base case.

16.4.2 Diagnostic fits to input data for the Bight redfish base case

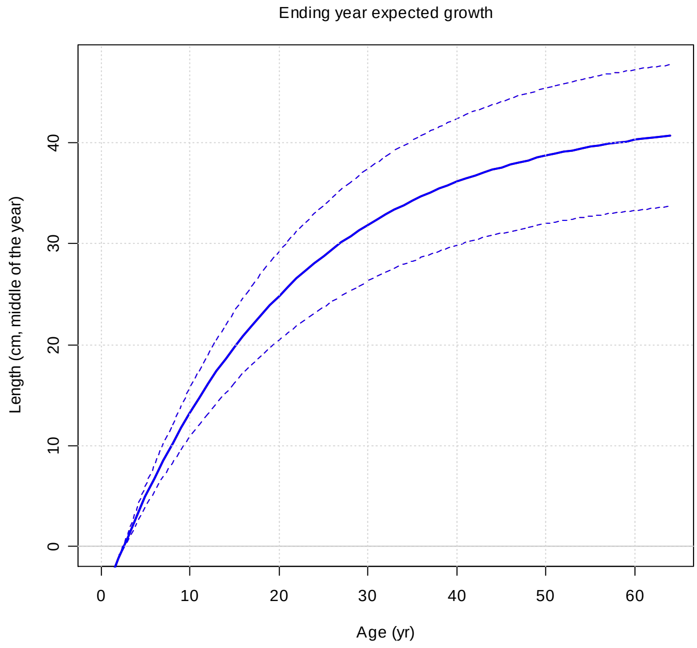

Figure 16.10. Fitted growth curves based on age-at-length data.

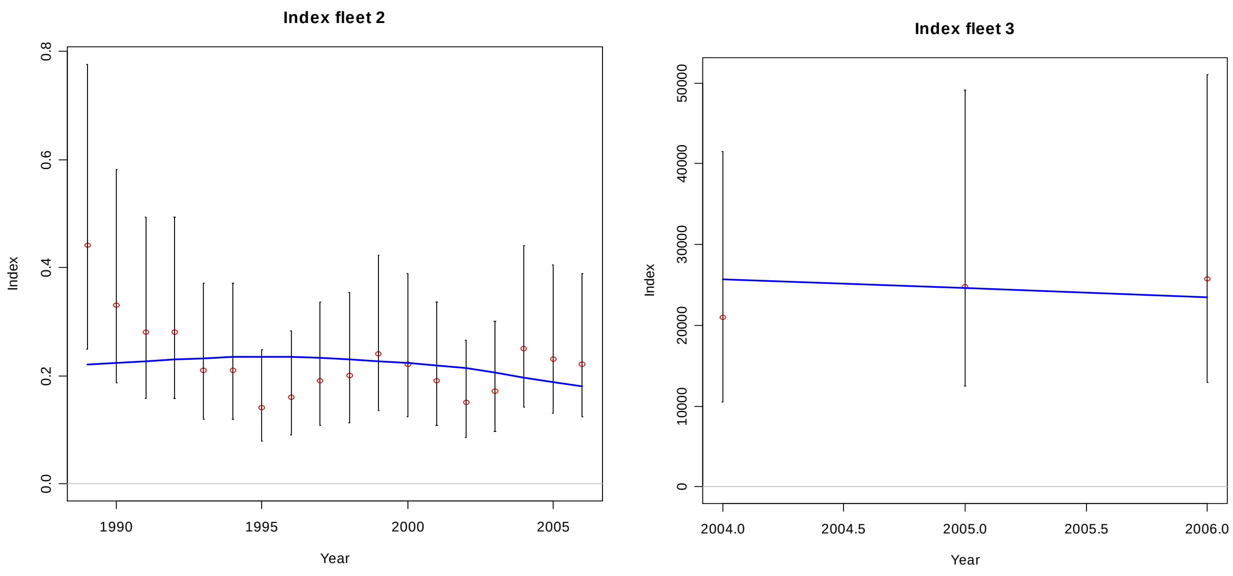

Figure 16.11. Model fits to CPUE and survey.

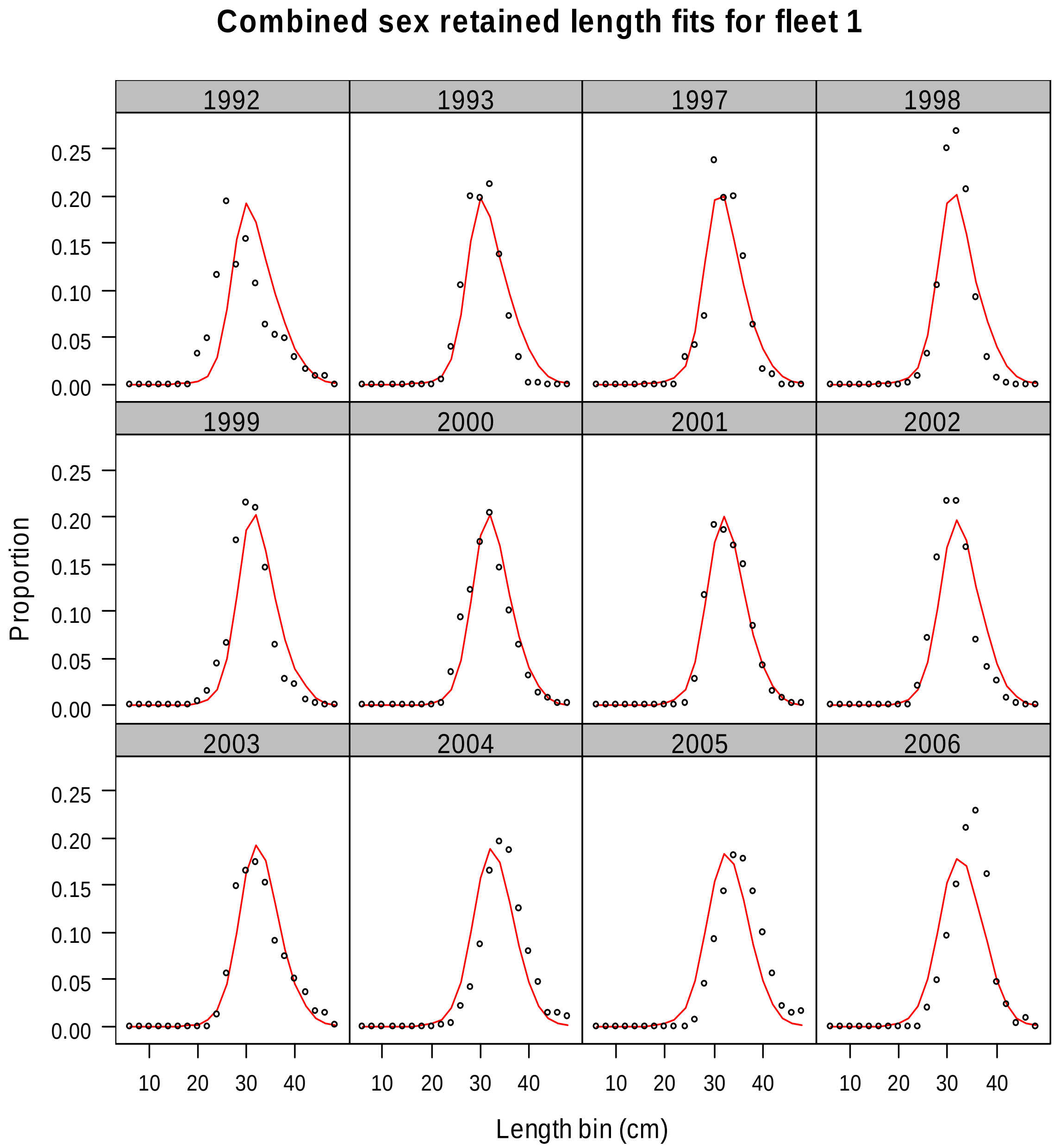

Figure 16.12. Model fits to combined length frequency.

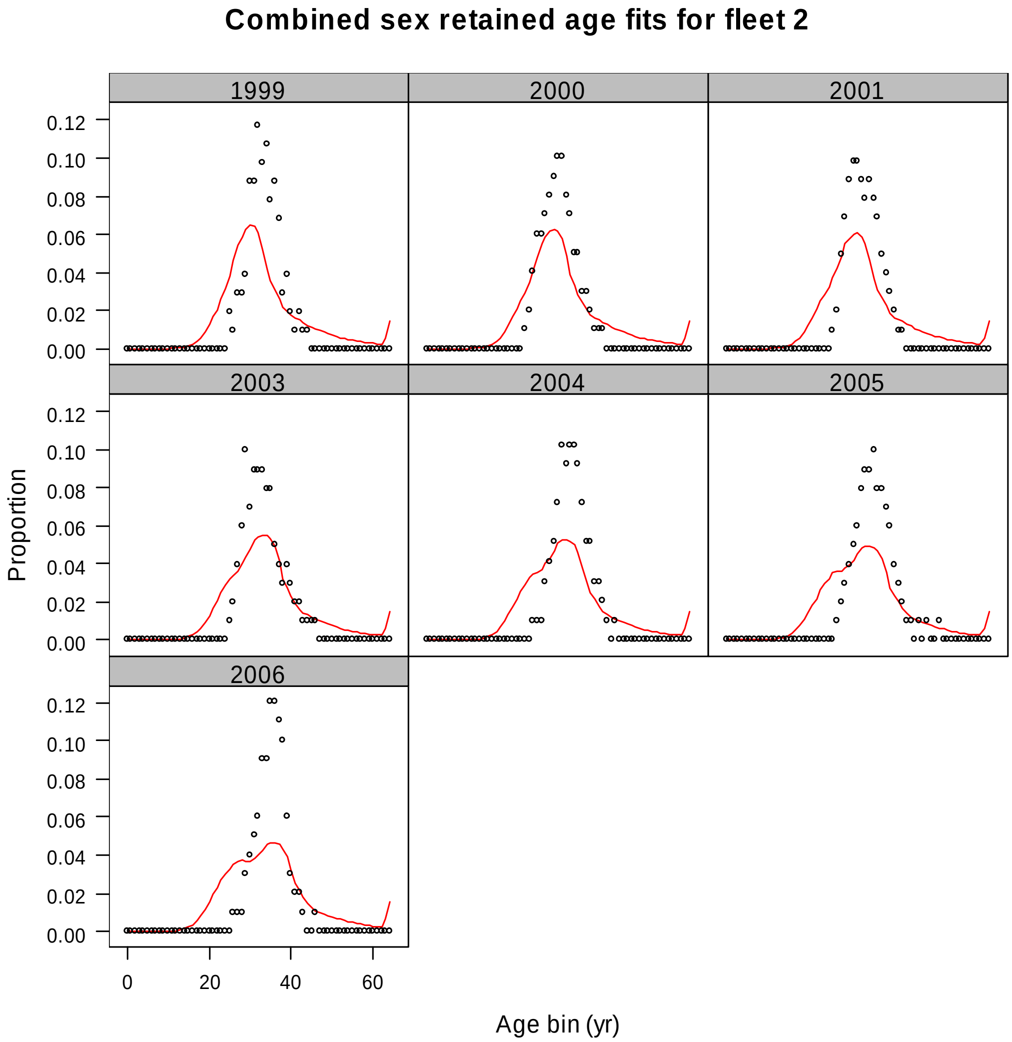

Figure 16.13. Indicative model fits to combined age frequency.

There is a trade-off between good fits of length or age frequencies for Bight redfish. It is possible to much improve the apparent fit to age frequency by ignoring length-only data. Further work is required to improve the ability of the Bight redfish model to fit both age and length-frequency data. A symptom of the conflict is that the expected numbers of fish older than about 50 are much greater than observed. Allowing the model to fit the natural mortality rate, and changing the selectivity model to allow a dome-shape did not provide a remedy.

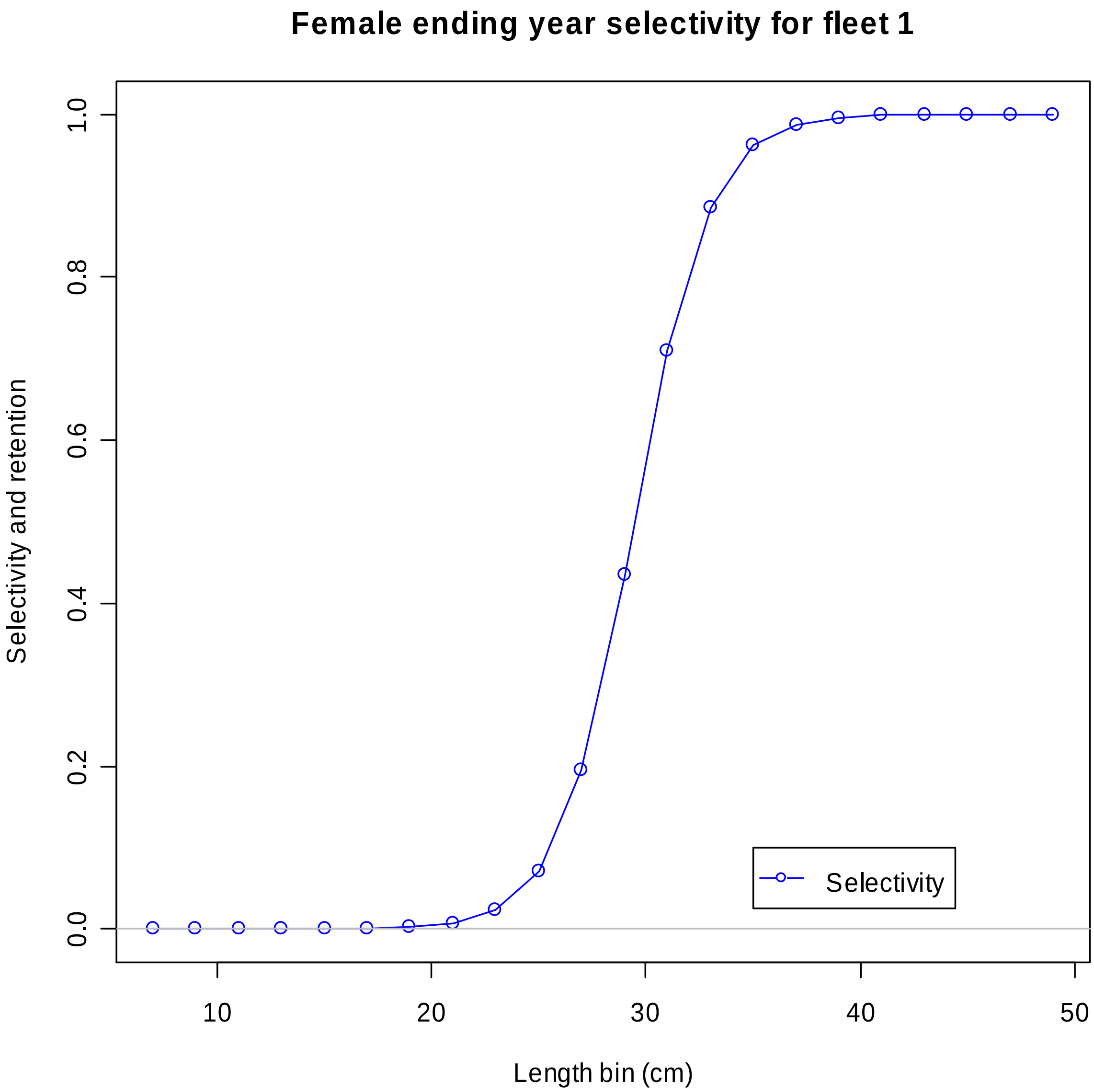

Figure 16.14. Size selectivity fits by fleet (female shown) for trawl.

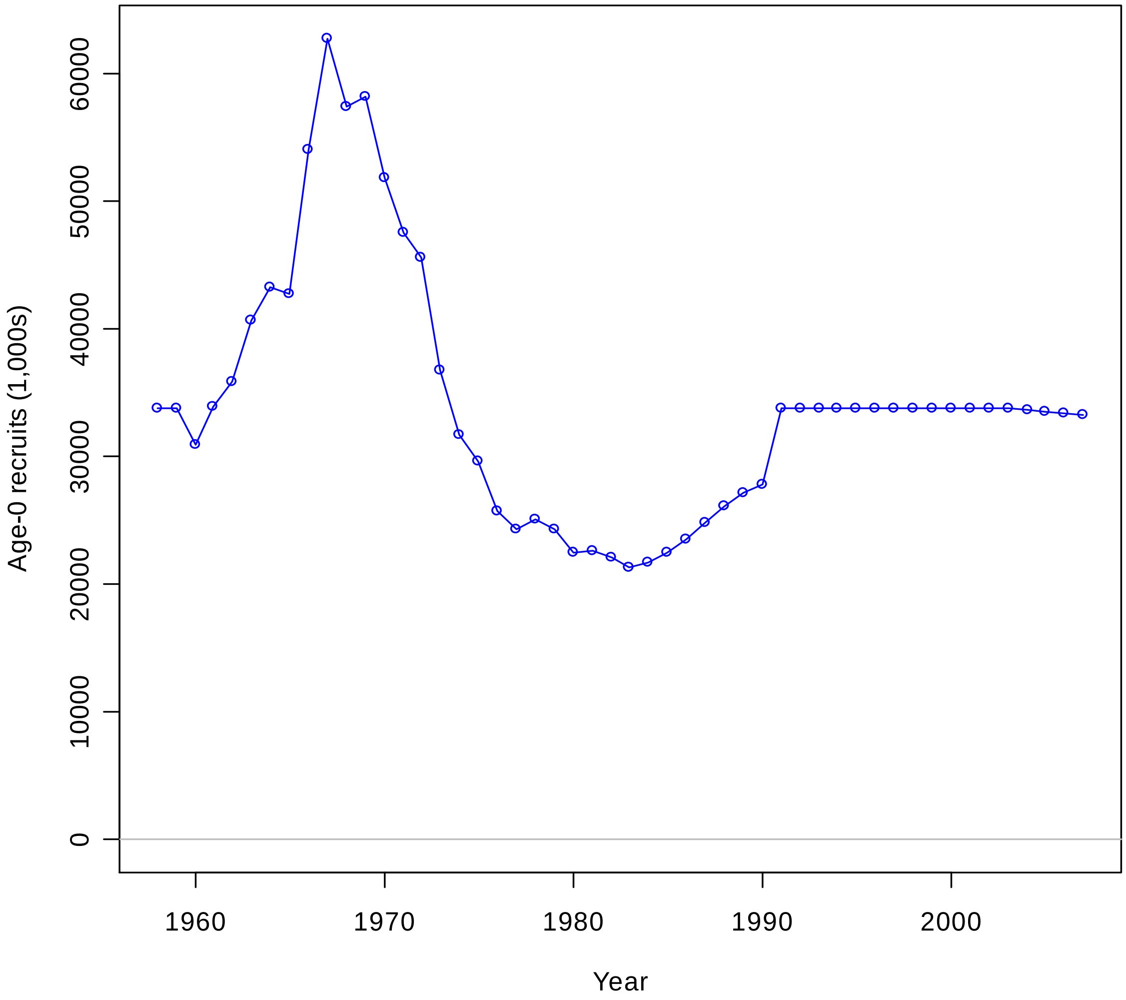

Figure 16.15. Recruitment time series for the base case.

The pattern in historical recruitments is created by the model to best fit recent indices and age/length frequencies. Further work to resolve the age and length-frequency data conflict could also influence this historical recruitment pattern.

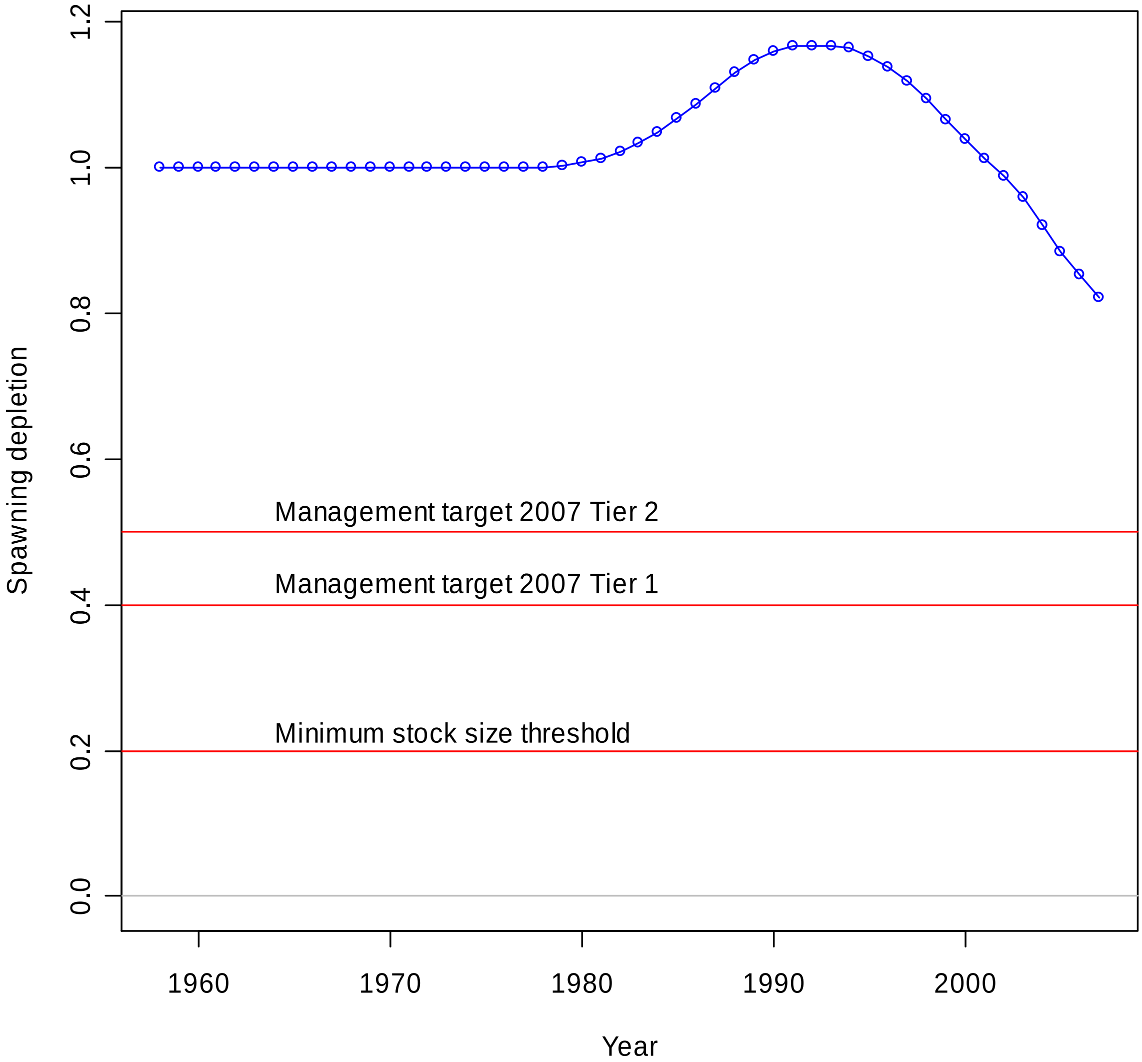

Figure 16.16. Spawning biomass depletion level per year for the base case.

Table 16.8. Summary statistics for the base-case analysis and the sensitivity tests for deepwater flathead. Values for the negative log-likelihood are only listed for those sensitivity tests that are comparable with the base-case analysis.

Scenario	SSB_{1980}	SSB_{2007}	% Depletion	RBC4040	RBC4840	RBC5050	-lnL
Base-case	8,836	4,951	56.03	1,524	1,154	1,076	1327.44
M =0.15yr^{-1}	8,107	3,514	43.35	855	647	604	1365.46
M =0.25yr^{-1}	9,989	6,583	65.90	2,459	1,859	1,733	1312.41
Steepness = 0.65	8,936	4,866	54.46	1,497	1,134	1,057	1328.32
Steepness = 0.85	8,759	5,016	57.26	1,545	1,169	1,091	1326.80
Halve CPUE σs	8,833	5,040	57.06	1,548	1,172	1,093	
Double CPUE σs	8,828	4,865	55.11	1,501	1,136	1,059	
Half age sample sizes	9,243	4,678	50.61	1,462	1,107	1,033	
Double age samples	*8,448	5,341	63.22	1,633	1,236	1,152	
Half length samples	9,215	5,380	58.38	1,624	1,231	1,148	
Double length samples	8,549	4,384	51.27	1,371	1,037	967	
Relative biomass survey	*8,255	3,718	45.04	1,162	880	820	
Ignore biomass survey	8,280	3,834	46.30	1,197	906	845	

* to calculate these results it was necessary to fix the growth parameters to the fitted base case values

Table 16.9. Summary statistics for the base-case analysis and the sensitivity tests for Bight redfish. Values for the negative log-likelihood are only listed for those sensitivity tests that are comparable with the base-case analysis.

Scenario	SSB_{1980}	SSB_{2007}	% Depletion	RBC4040	RBC4840	RBC5050	-lnL
Base-case	18,685	15,362	82.22	5,383	3,607	3,278	638.35
M =0.05yr^{-1}	*13,626	11,350	83.29	1,254	920	852	720.26
M =0.15yr^{-1}	17,750	13,569	76.44	>10,000	9,341	8,262	619.07
Steepness = 0.65	18,685	15,362	82.22	5,383	3,607	3,278	638.35
Steepness = 0.85	18,685	15,363	82.22	5,383	3,607	3,278	638.35
Halve CPUE σs	18,924	15,528	82.05	5,404	3,624	3,294	
Double CPUE σs	18,567	15,284	82.31	5,373	3,598	3,270	
Half age sample sizes	*19,640	16,099	81.97	5,745	3,819	3,465	
Double age samples	17,035	14,347	84.22	4,339	2,986	2,730	
Half length samples	18,862	15,531	82.34	5,708	3,798	3,446	
Double length samples	18,817	15,518	82.47	5,258	3,544	3,226	
Relative biomass survey	*89,882	82,964	92.30	>10,000	>10,000	>10,000	
Ignore biomass survey	2,506	1,370	54.66	864	435	459	

* to calculate these results it was necessary to fix the growth parameters to the fitted base case values

16.5 Future work

The following are some ways in which future assessments of deepwater flathead and Bight redfish could or should be improved.

- Continue investigation of appropriate ways to weight survey values versus other fishery data, and also relative weightings among indices and frequency data.
- Investigate why Bight redfish growth parameters are on lower bounds for l_{min} and K.
- Investigate improved ways to model the conflict between Bight redfish age and length distributions.
- Determine whether early age frequencies also include length data and include them if possible.

16.6 Acknowledgements

Matt Koopman, Anne Gason and Kyne Krusic Golub (PIRVic) are thanked for the provision of data. Ageing error values for both species were modelled and provided by André Punt (CMAR). I also thank Jemery Day, Sally Wayte, Geoff Tuck and Rich Little for our fruitful discussions during our regular SS2 modelling workshops, and brief review of the assessment base cases.

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17. Yield and total mortality values and Tier 3 estimates for selected shelf and slope species in the SESSF 2007[12]

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17.1 Introduction

This document updates yield analyses presented in Klaer and Thomson (2006) for major commercial species caught in the Southern and Eastern Scalefish and Shark Fishery (SESSF) on the shelf and slope. Much of the data processing and analysis has been automated, following procedures documented particularly in Thomson (2002a).

17.2 Methods

The fishery region and zones referred to here are as shown in Figure 17.1.

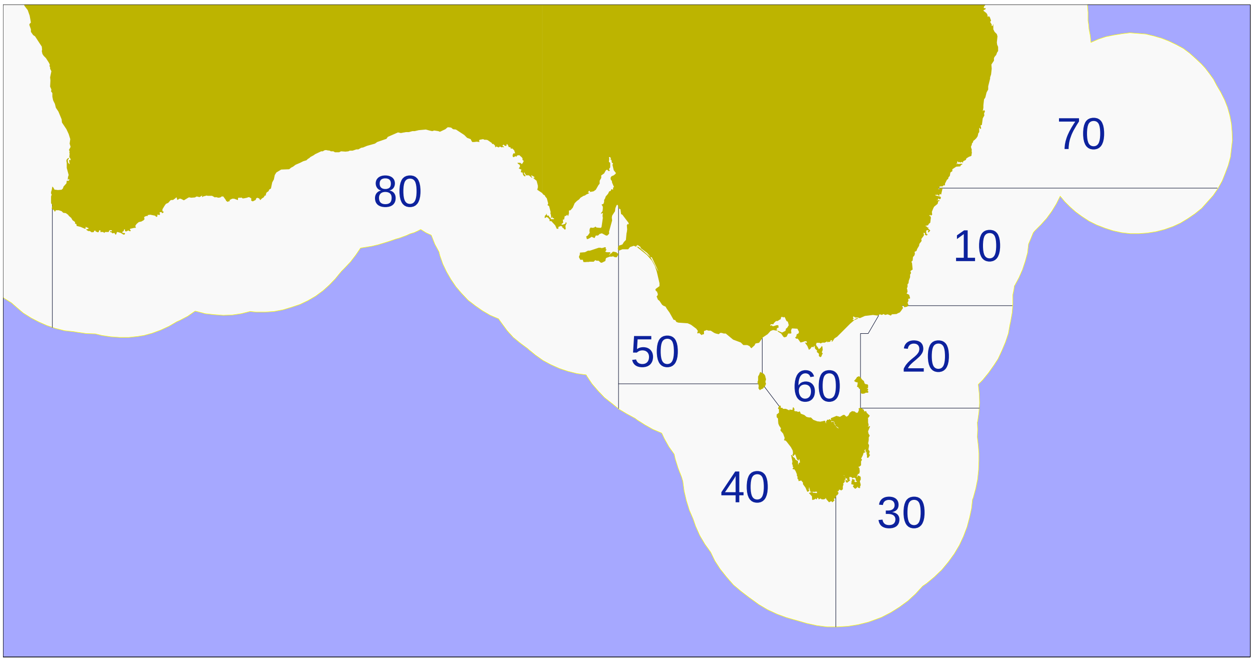


Figure 17.1. Map of the SESSF showing 8 statistical zones used in analyses here

[12] Paper presented to the Shelf Resource Assessment Group in September, 2007

17.2.1 Yield analysis

The information required for this calculation was: selectivity-at-age, length-at-age, weight-at-age; age-at-maturity; and natural mortality. The parameters used are shown in Table 17.1. A mix of shelf and slope quota species have been considered, and results are presented where the automated process appears to have produced sensible results, and where sufficient data were available. The AFMA abbreviations for the names of the quota species are also shown in Table 17.1.

Table 17.1. Population parameters used for yield analysis

	Flathead	Redfish		Morwong	Silver trevally	Spotted warehou	Blue warehou	John dory	School whiting	Mirror dory	Pink ling	Blue grenadier	Ribaldo
Code	FLT	RED	RES	MOW	TRE	TRS	TRT	DOJ	WHS	DOM	LIG	GRE	RIB
Pop	1	1	2	1	1	1	1	1	1	1	1	1	1
a_{max}	25	40	40	30	20	23	25	20	15	20	30	20	50
l_{max}	70	60	60	50	70	70	70	70	50	70	140	140	90
Fleets	2	1	1	2	2		2	2	2	2	2	2	2
a	0.0249	0.0577	0.0577	0.0429	0.0443	0.0153	0.03	0.046	0.013	0.0164	0.00293	0.00375	0.0024
b	3.31	2.77	2.77	3	2.7864	3	2.9	2.9	2.93	3	3.139	3.013	3.37
l_∞	76.6	25.278	27.37	36.39	44.5	51.25	54.65	53.2	23.9	65.25	103.355	101	59
k	0.178	0.224	0.2	0.34	0.34	0.464	0.37	0.15	0.513	0.16	0.166	0.18	0.11
t_0	-0.65	-0.719	-1.29	-0.45	-1	-0.65	-0.67	-1	-0.3	-0.38	3.139	0.58	0.0
M	0.2	0.1	0.1	0.11	0.1	0.25	0.45	0.36	0.5	0.3	0.2	0.2	0.084
S_{50}	27.93	15.94	15.94	21.94	22.31	31.05	17.61	15.54	15.29	15.54	39.9	37.8	40
S_{95}	31.02	17.25	17.25	21.95	22.32	40	35	30	15.3	40	43	50.73	42
l_{mat}	30	19	19	22	28	37	33.4	31.5	16	35	67	70	40
h	0.85	0.75	0.75	0.75	0.8	0.75	0.75	0.45	0.95	0.75	0.75	0.9	0.75

For species for which a recent stock assessment has been performed by the SEF community, the population parameters used in the assessment were used here. Otherwise, the primary source of information on population parameters was Smith and Wayte (2002) or, failing that, the Fishbase website (http://www.fishbase.com). A meta-analysis performed by Koopman *et al.* (2001) was used to provide a value for steepness.

The S95 value for spotted warehou, blue warehou, John dory and mirror dory were changed this year to maintain consistency between the yield and catch curve analyses. Catch curves indicated that the length at full selection in the fishery was too low to produce reasonable catch curve results.

17.2.1.1 Length- and weight-at-age

Length-at-age was calculated using the von Bertalanffy growth equation (parameters are l_∞, K and t_0) and the weight-at-age using the allometric length-weight relationship (parameters are a and b). The von Bertalanffy was calculated using length and age data supplied by the Central Ageing Facility (CAF, John Ackerman pers com). The type of length measurement (e.g. standard length or total length) used was specified in the data. It is assumed the parameters of the length-weight relationship (Smith and Wayte, 2002) use the same measures. The units for these parameters are not specified and do not all appear to use the same units. These were manipulated until the results appeared to be in kg per cm. Parameters that were not available from Smith and Wayte (2002) were obtained from the Fishbase website (http://www.fishbase.org), using values that had been calculated from Australian fish or, if necessary, New Zealand fish.

17.2.1.2 Female length-at-maturity

Length-at-maturity for females (which is converted into a knife-edged function of age using the calculated lengths-at-age) was obtained, where possible, from Wayte and Smith (2002). If separate figures were not available for males and females, that for both sexes combined was used. In some cases several different figures were available and an arbitrary selection was made - when there were three of more figures the median figure was chosen.

17.2.1.3 Natural mortality

Natural mortality figures were obtained from Smith and Wayte (2002) or by calculating the median of the figures presented by Bax and Knuckey (2001). The value of M for John dory was updated by the Shelf Research Assessment Group in 2005 based on an additional meta-analysis performed by Matt Koopman.

17.2.1.4 Selectivity

A logistic selectivity curve is assumed for all species. Selectivity parameters were drawn from Bax and Knuckey's calculated selectivity factors. All parameters used in the present investigation apply to a 90mm trawl mesh (except for school whiting where 42mm has been assumed) and non-trawl gear types are not considered. Figures were not available, from Bax and Knuckey, for John dory or silver trevally. Those for mirror dory were applied to John dory because, of all the quota species, mirror dory are most like John dory in shape.

The selectivity parameters used in this study have been estimated from an empirical relationship between fish size and mesh size derived from covered cod end (or trouser haul) experiments on a subset of the species. These pertain purely to gear selectivity, which is not the function often referred to in stock assessments as "selectivity". Fishers are able to target fish of a particular size by fishing in particular areas and in particular different depths -- all SEF quota shelf-associated species show a pattern of larger fish being caught at greater depths. No account is taken in this study of how trawl selectivity changes as a function of gear design or gear deployment (e.g. changing door separation with depth) that have been shown to exert large influences on overall selectivity in other studies.

It has been suggested that practices such as double bagging might reduce the selectivity of commercial trawls below that expected for a 90 mm mesh cod end, however there was no evidence for this, with the possible exception of school whiting and redfish off Eastern Victoria.

The “selectivity” estimated in stock assessment models is a function of both gear selectivity, targeting by the fishery and availability of fish to being caught.

17.2.1.5 Stock-recruit relationship

A Beverton-Holt stock-recruit relationship is assumed using the single-parameter formulation suggested by Francis (1992a). The value of this parameter (steepness) was investigated by Koopman *et al*. (2001) using meta-population analysis. The histograms presented by Koopman *et al*. (2001) were examined and likely figures for steepness chosen. The default figure of 0.75 suggested by Francis (1992b) is used when the results of Koopman *et al*. (2001) do not suggest a clear pattern.

17.2.2 Catch curve analysis

17.2.2.1 Data

This investigation used length frequency data from three sources: the NSW Sydney Fish Market measurement program; the Kapala slope cruises of 1976/7 and 1996/7 (Andrew *et al.,* 1997); and the ISMP port measurement data (eg Knuckey *et al.,* 2001). For a given year, fleet and population (see below for further detail) length frequencies from each zone by season cell are catch-weighted and summed to give annual length frequencies. The methodology is described in detail in Thomson (2002).

Age and length data were obtained from the Central Ageing Facility. Some ALK data were available for all species.

These age and length data were used to calculate the parameters of a von Bertalanffy growth curve for each species (again, see Thomson; 2002b for details). Age-length keys (ALKs) were also constructed from these data.

Two methods were used to convert length frequencies data into age frequencies: ALKs and chopping. The ALK method was used, where possible, to generate age frequencies data by multiplying the length frequency for a given year by the ALK for that same year. No allowances were made for inadequate sampling of an ALK so that, if no age samples were taken from a particular length class then all samples from this length class in the length frequency were ignored. This occurs because the ALK has a zero for all ages for that length class so that the length frequency is always multiplied by zero. ‘Chopping’ involves using the von Bertalanffy to chop the length frequency into age classes. Catch curve analysis was applied to all resulting age frequencies. Chopping is a crude methodology, used only because time did not permit greater sophistication. In the future it would be desirable to use a method that allows variance in length-at-age about the von Bertalanffy curve.

17.2.2.2 Fleets and Populations

The difference between a fleet and a population is that although the length frequency data are separated for both, the ALK data are separated into populations but are combined across fleets.

For species except tiger flathead, redfish, spotted warehou and blue grenadier, the length frequency data were separated into trawl and non-trawl (including Danish seine) fleets. Tiger flathead was separated into trawl and Danish seine. Non-trawl data for redfish was ignored so that there was only one fleet - a trawl fleet. Spotted warehou was divided into trawl and non-trawl fleets but any Danish seine records were ignored. These fleets were numbered in the order in which they are listed above e.g. for most species Fleet 1 is trawl fleet and Fleet 2 non-trawl. For blue grenadier the fleets were separated into the summer non-spawning trawl fishery and the winter spawning trawl fishery.

Redfish was divided into two populations – north and south of 36^{o}S. Population 1 is north and Population 2 south of this latitude.

17.2.2.3 Automated catch curve analysis

Catch curve analysis involves fitting a straight line to log-transformed data from age classes that are thought to be fully selected by the fishery. The underlying principle is that cohorts diminish in number, over time, through a process that can be described by exponential decay:

$$N_{y+1} = N_y e^{-Z_y} \qquad (1)$$

where N_y is the number of animals in a cohort at the start of year y, Z_y is the overall instantaneous mortality rate - incorporating natural mortality (M_y) and fishing mortality (F_y) multiplied by selectivity (S which is a function of age and or length):

$$Z_y = M + F_y\ S \qquad (2)$$

Log-transforming equation 1 gives:

$$\ln(N_{y+1}) = \ln(N_y) - Z_y \qquad (3)$$

Therefore the slope of a straight line fitted to log-transformed age frequency data for a single cohort for consecutive years would be equal to -Z_y. However, data are seldom sufficiently accurate to allow the calculation of Z_y for each pair of N_y, N_{y+1} figures. The assumption is usually made that the Z_y (and therefore F_y) has been constant for the lifetime of each cohort. A straight line is fitted to the age data for several cohorts in a single year. The line is confined to ages that are thought to be fully selected (so that S in equation 2 can be taken to be 1 for all ages). This usually involves choosing, by eye, a section of the log-transformed data for which the plotted points seem to lie in a straight line. The youngest ages are assumed to be affected by selectivity and the oldest by a breakdown in the assumption of a constant F_y and possibly also by selectivity.

Catch curves were fitted to the next age class following the length of 95% selection to the second-last age class available. The last age class is used as an accumulator bin, so should not be fitted. This method ensures that the age of full selection into the fishery is consistent with the yield per recuit analysis. Further work is perhaps required to select a more appropriate final age to fit based on characteristics of the data.

17.3 Results

17.3.1 Yield per recruit analysis

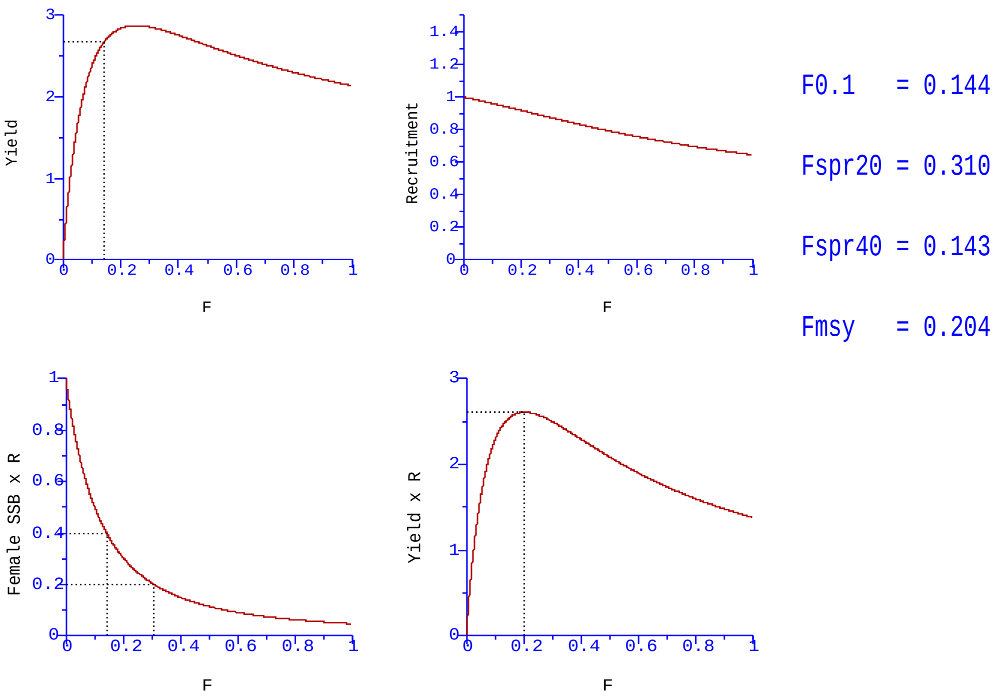


Figure 17.2. Flathead yield per recruit reference point calculations

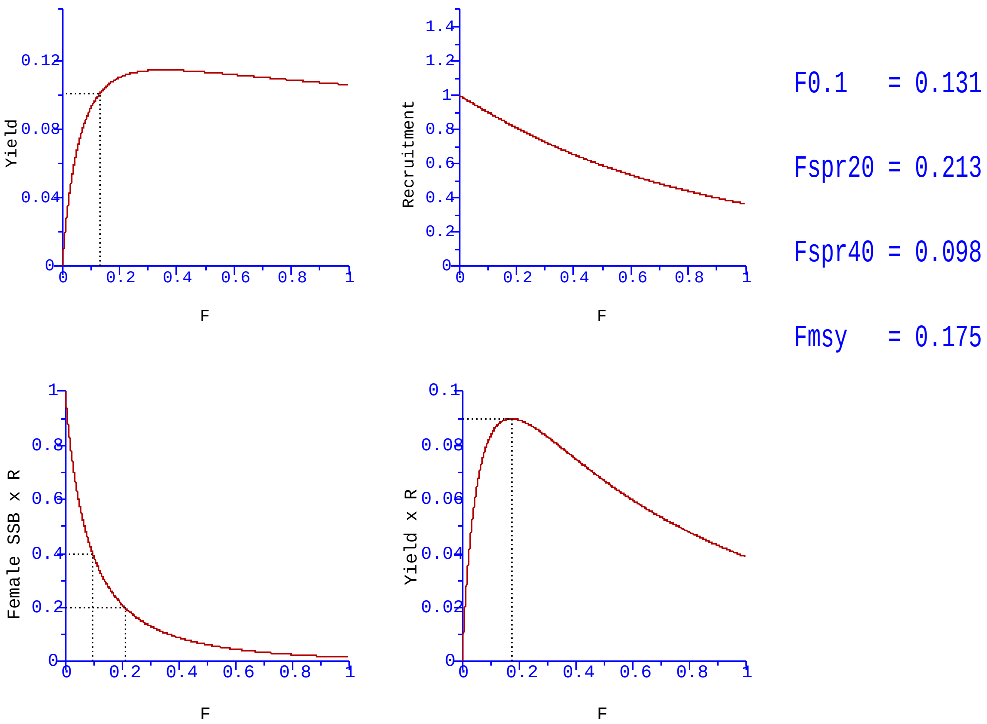


Figure 17.3. Redfish yield per recruit reference point calculations

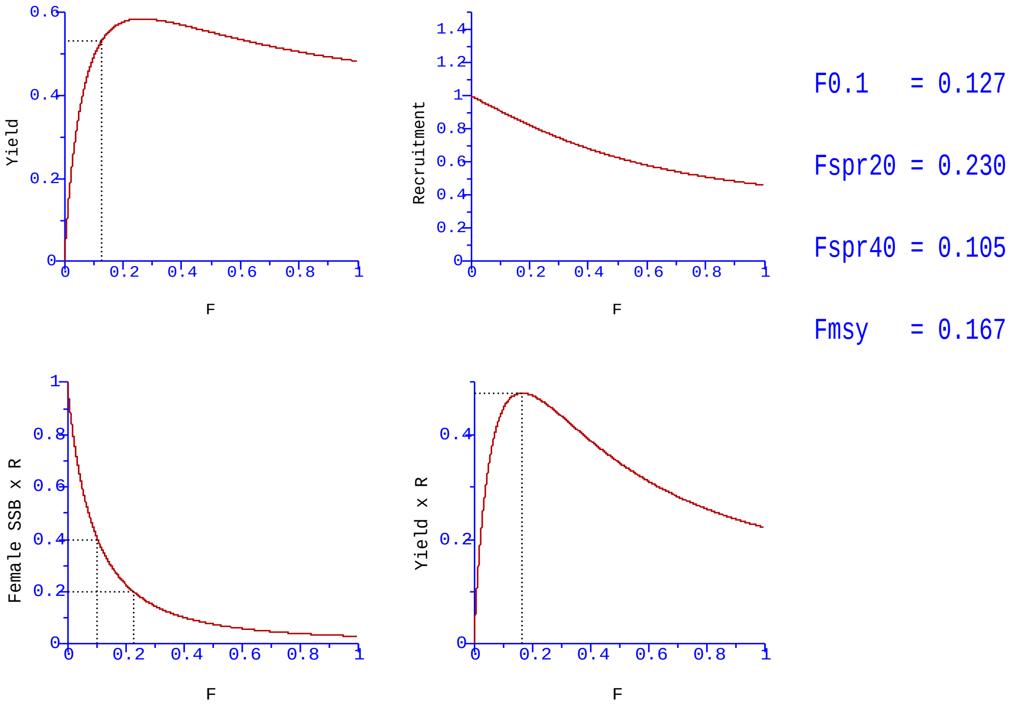


Figure 17.4. Morwong yield per recruit reference point calculations

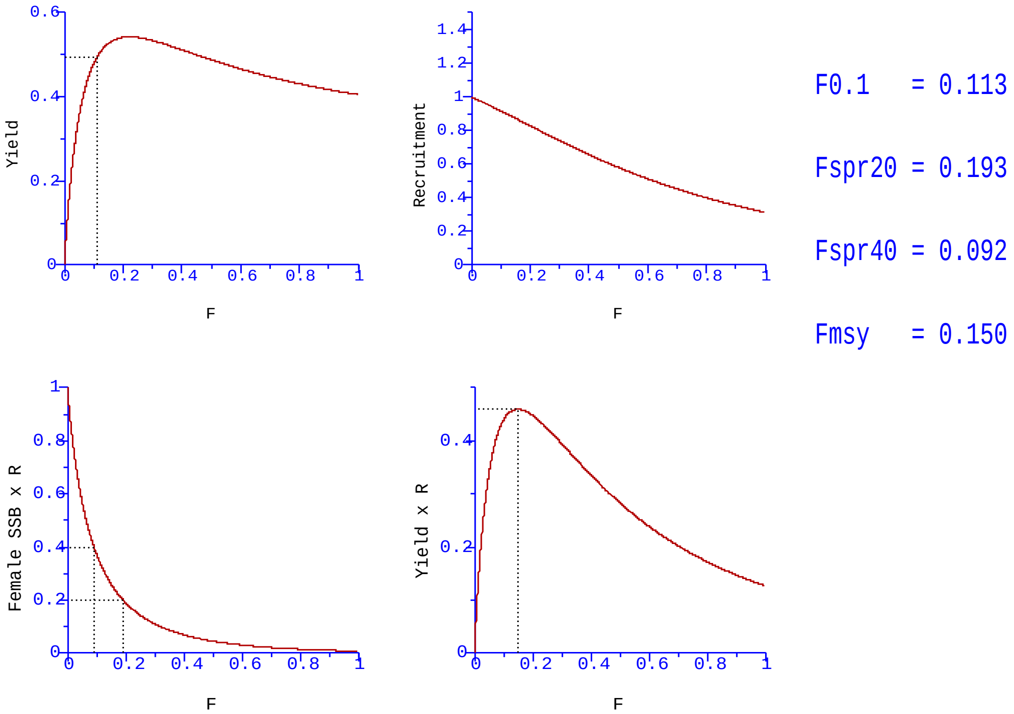


Figure 17.5. Silver trevally yield per recruit reference point calculations

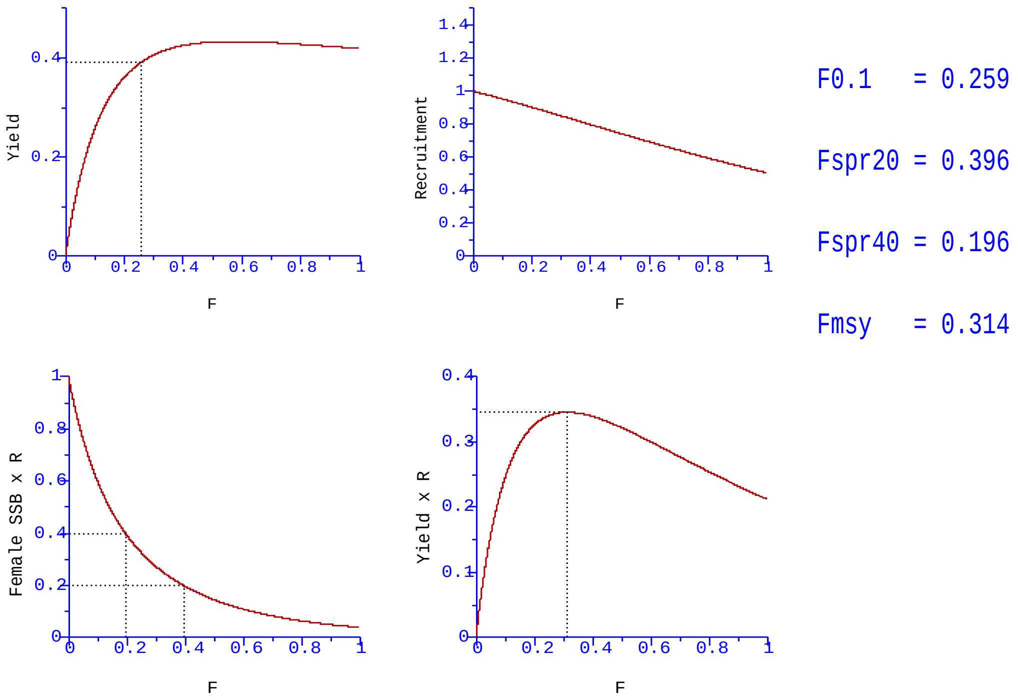


Figure 17.6. Spotted warehou yield per recruit reference point calculations

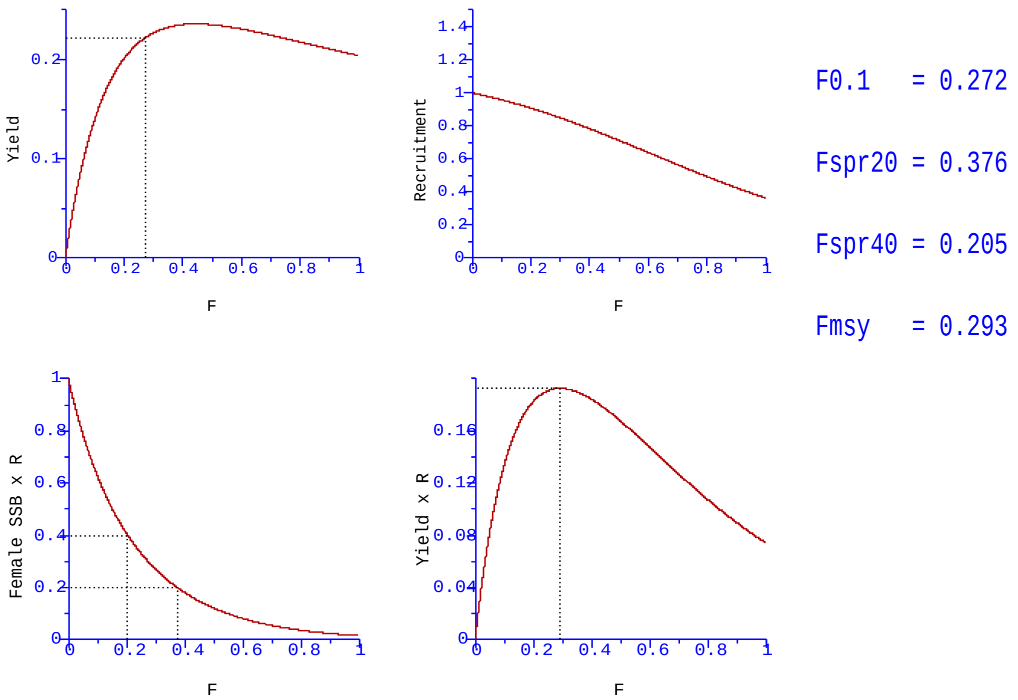


Figure 17.7. Blue warehou yield per recruit reference point calculations

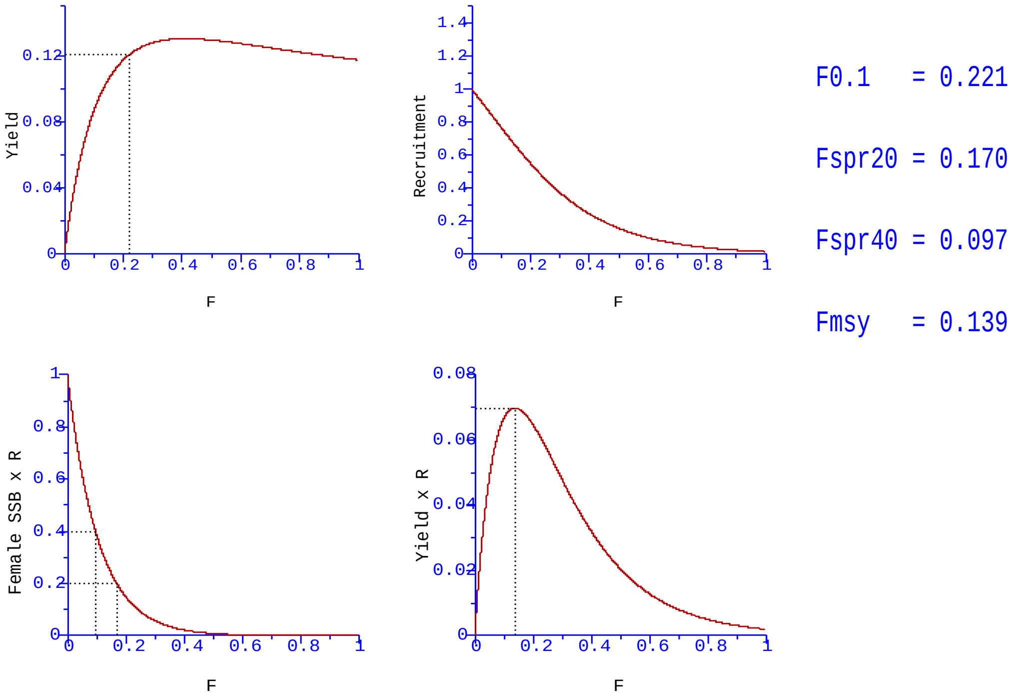


Figure 17.8. John dory yield per recruit reference point calculations

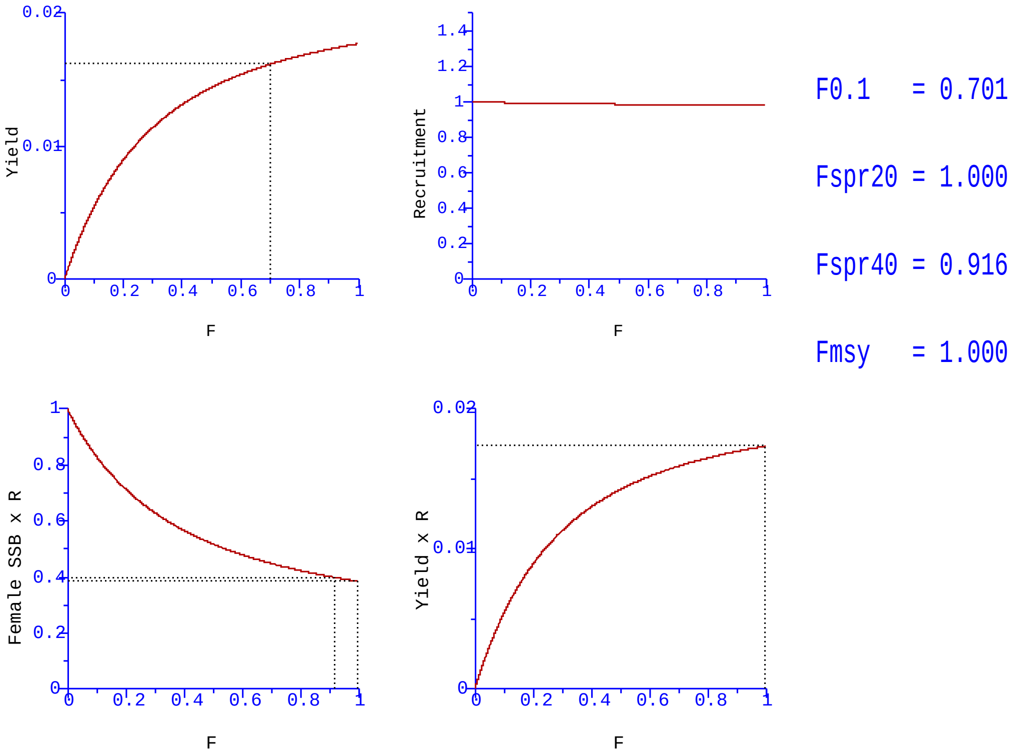


Figure 17.9. School whiting yield per recruit reference point calculations

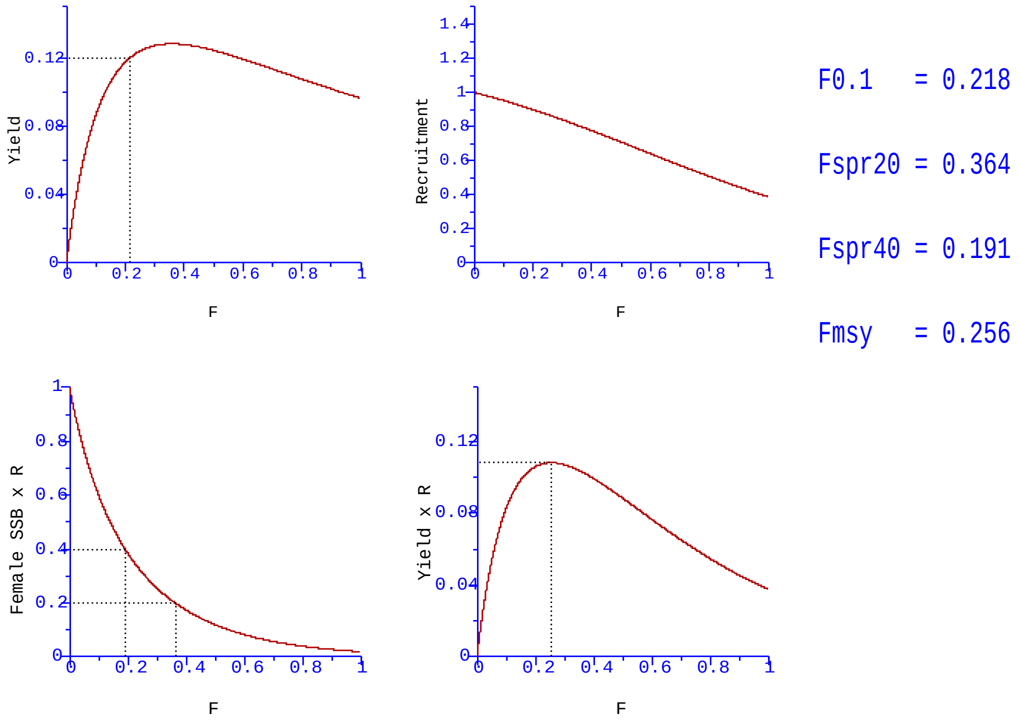


Figure 17.10. Mirror dory yield per recruit reference point calculations

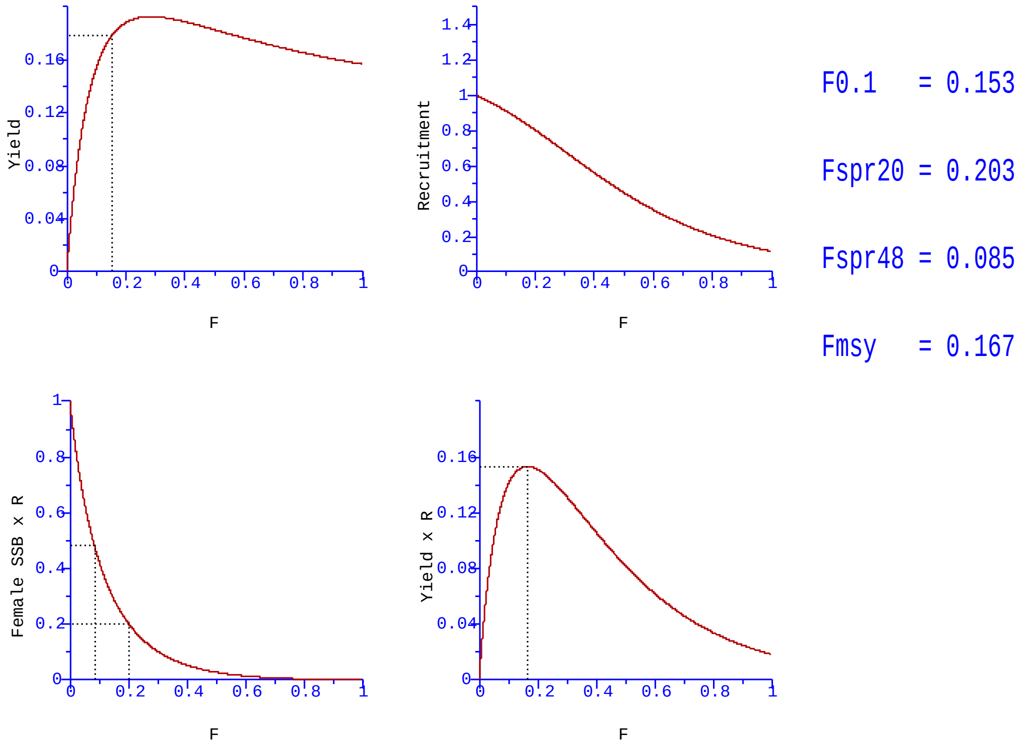


Figure 17.11. Pink ling yield per recruit reference point calculations

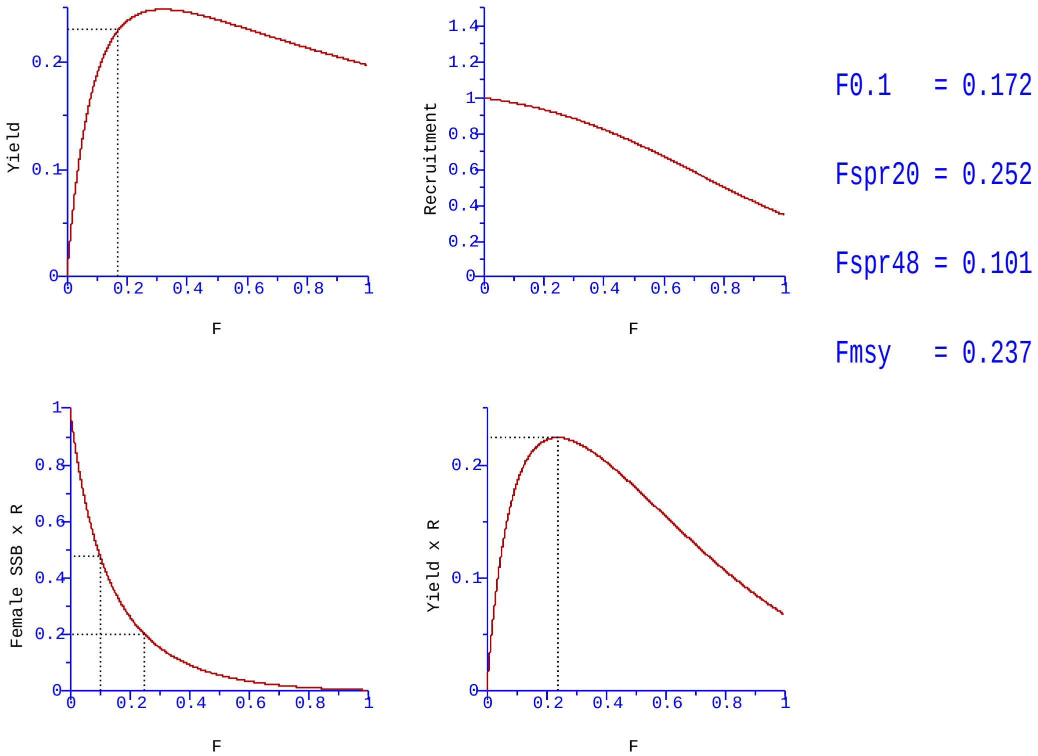


Figure 17.12. Blue grenadier yield per recruit reference point calculations

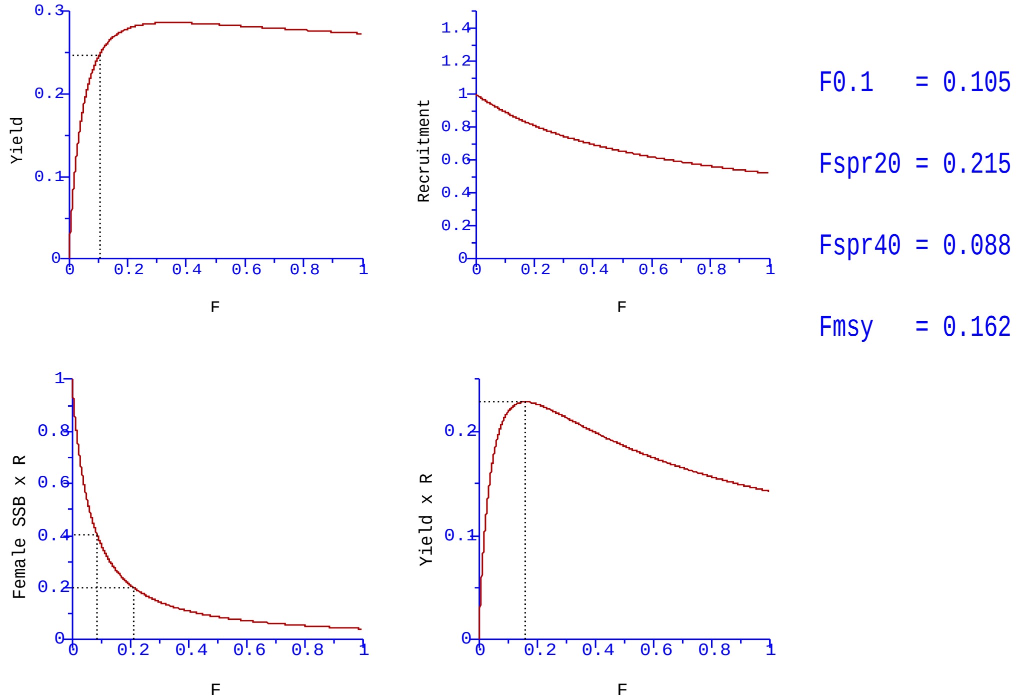


Figure 17.13. Ribaldo yield per recruit reference point calculations

17.3.2 Catch curves

The resulting estimates of Z are shown in Figure 17.14 to Figure 17.24. Raw annual catch curve fits are shown, as well as plots of Z values versus year per population and fleet. Any positive slopes in the annual fits (which therefore give negative Z values) have been excluded, as well as a relatively small number of estimates where the automated fitting procedure appeared to perform badly.

The results of catch curve analysis are shown together with the total mortality figures (Z) that resulted in spawning biomasses of 20% and 40% of pristine (solid horizontal lines).

A summary of Z estimates from catch curve analysis (given the assumption that Z has been unchanged over the lifetime of each cohort, clearly untrue for many species) is given in Table 17.2, and the Z values resulting in 20% and 40% depletion from the previous yield analysis are also shown. Recent Z estimates are taken from the values in Figure 17.14 to Figure 17.24 by summing the values from estimates from the most recent 5 years, and from age-based estimates rather than length-based where possible. The coefficients of variation (CV) of the recent 5-year averages are also shown. Silver trevally has dome shaped selectivity invalidating this method, so results are not shown for that species. Results for blue grenadier are also not shown because the age structure is dominated by very strong cohorts, also invalidating this method – see Figure 17.23. Details of which values were averaged are given in the Appendix, Section 17.7. Values that were averaged are shown in bold type.

Table 17.2. Yield and most recent 5-year average Z value summary

	Flathead	Redfish	Morwong	Silver trevally	Spotted warehou	Blue warehou	John dory	School whiting	Mirror dory	Ling	Blue grenadier	Ribaldo
$Z_{20\%}$												
$Z_{40\%}$												
Z_{F1}	0.40		0.20		0.42	0.85	0.44	1.23	0.42	0.41		0.10
CV	0.34		0.29		0.06	0.50	0.24	0.11	0.29	0.87		NA
Z_{F2}	0.39		0.24							0.42		
CV	0.39		0.36							0.47		
Z_{P1}		0.13										
CV		0.27										
Z_{P2}		0.12										
CV		0.49										

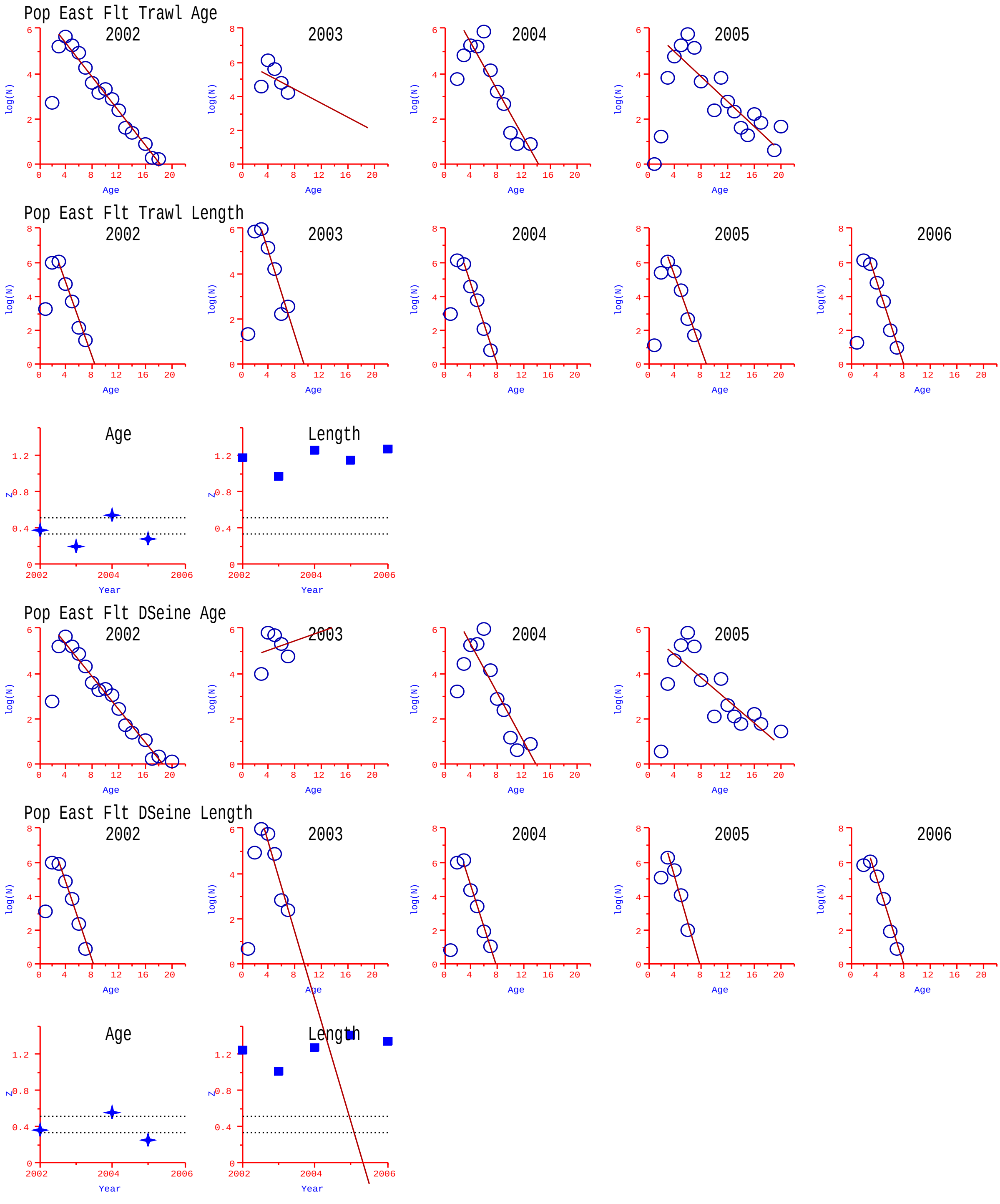


Figure 17.14. Flathead catch curve results

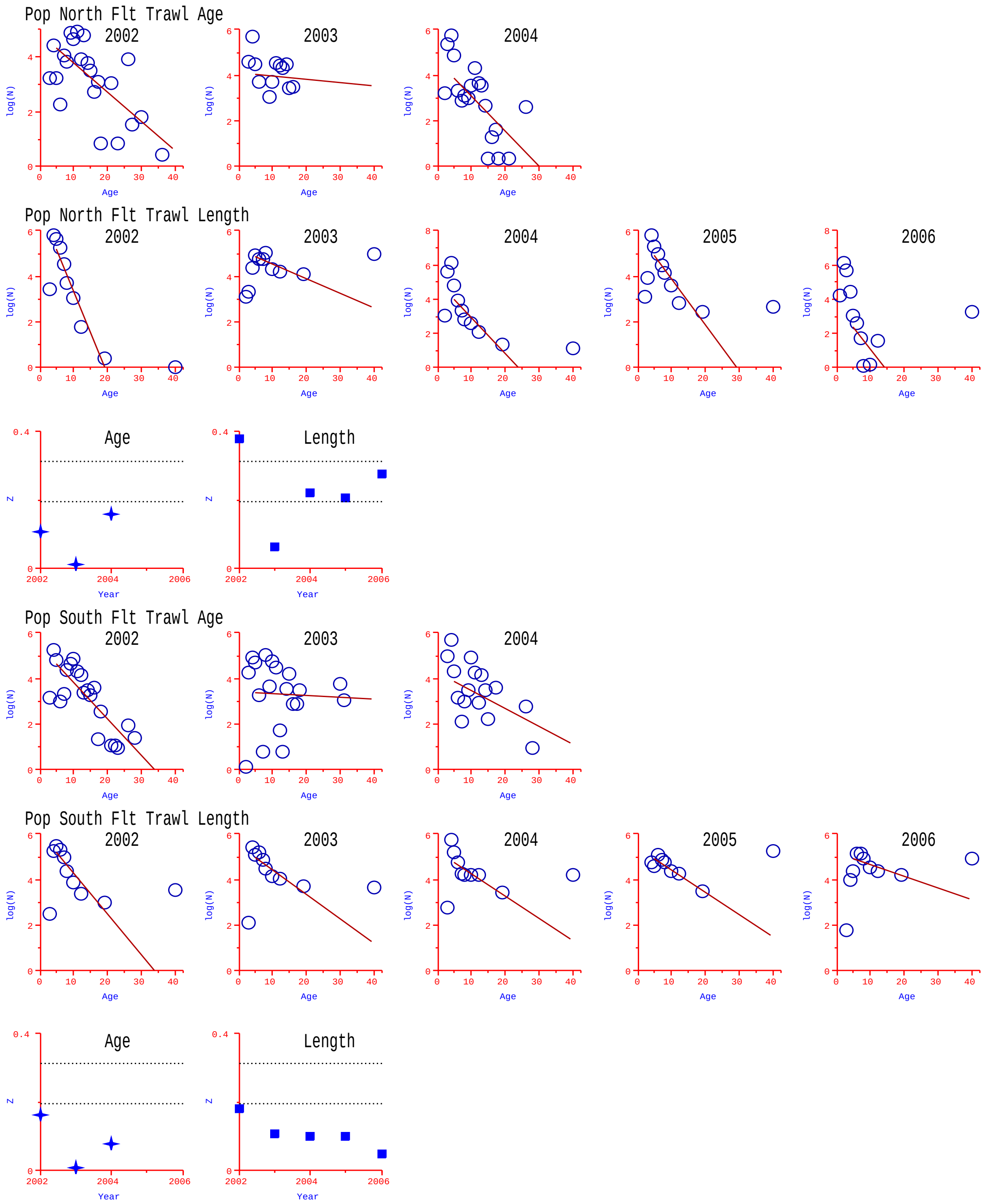


Figure 17.14. Redfish catch curve results

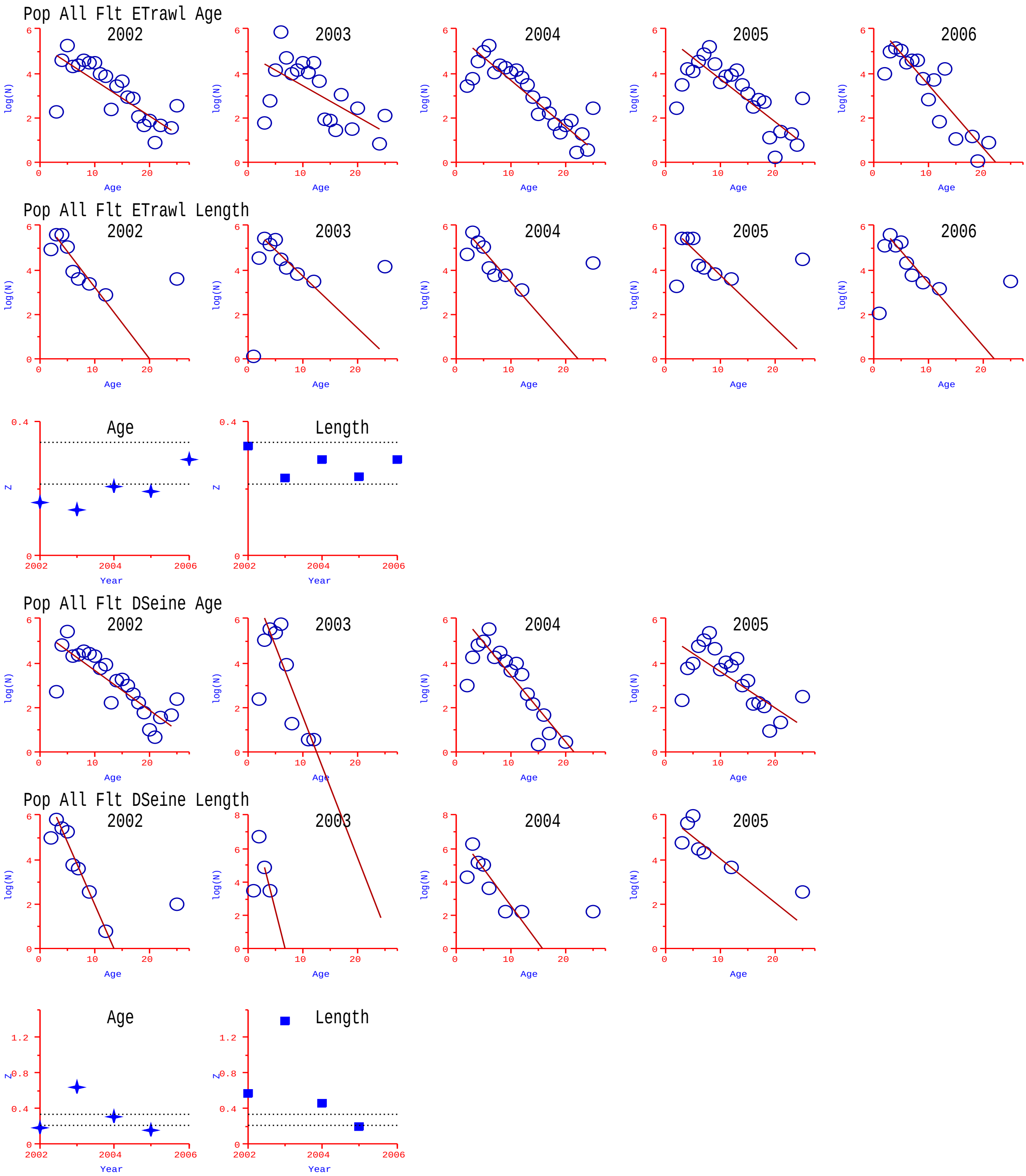


Figure 17.15. Morwong catch curve results

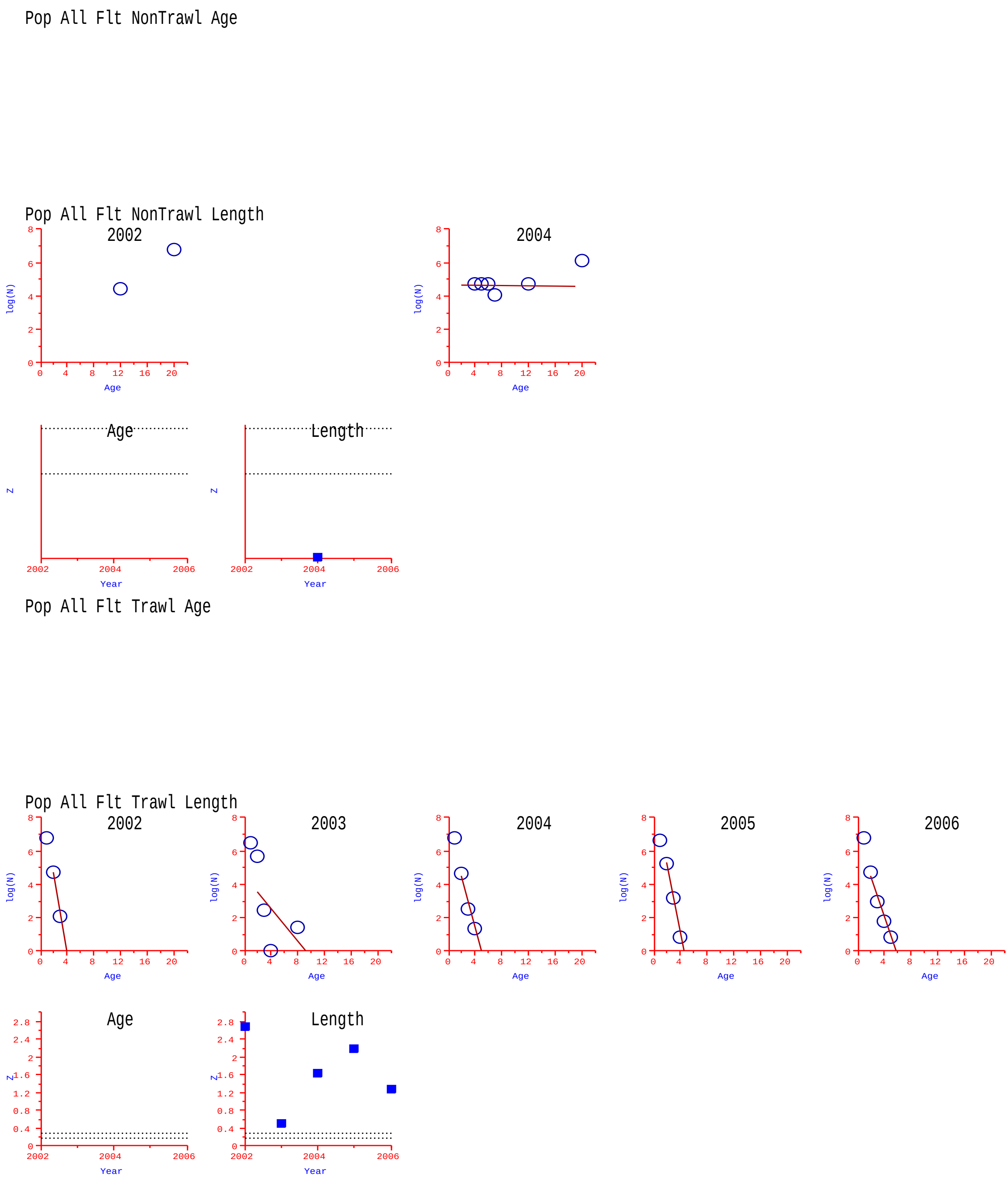


Figure 17.16. Silver trevally catch curve results

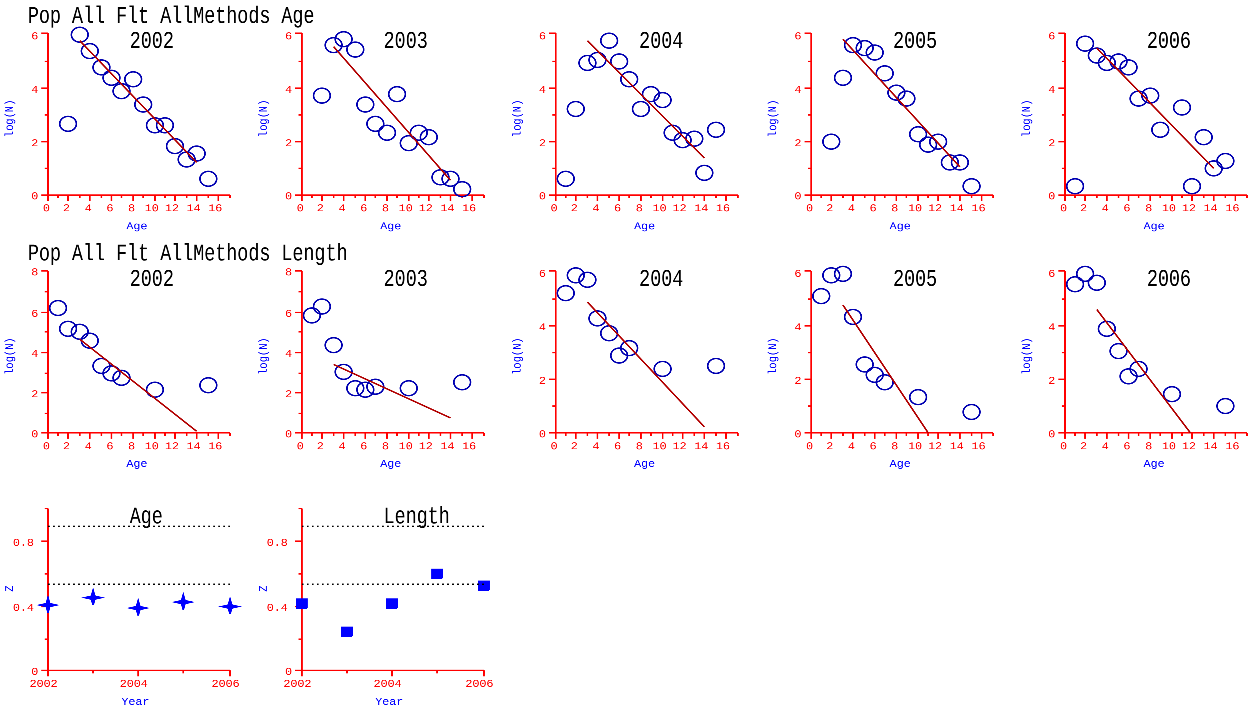


Figure 17.17. Spotted warehou catch curve results

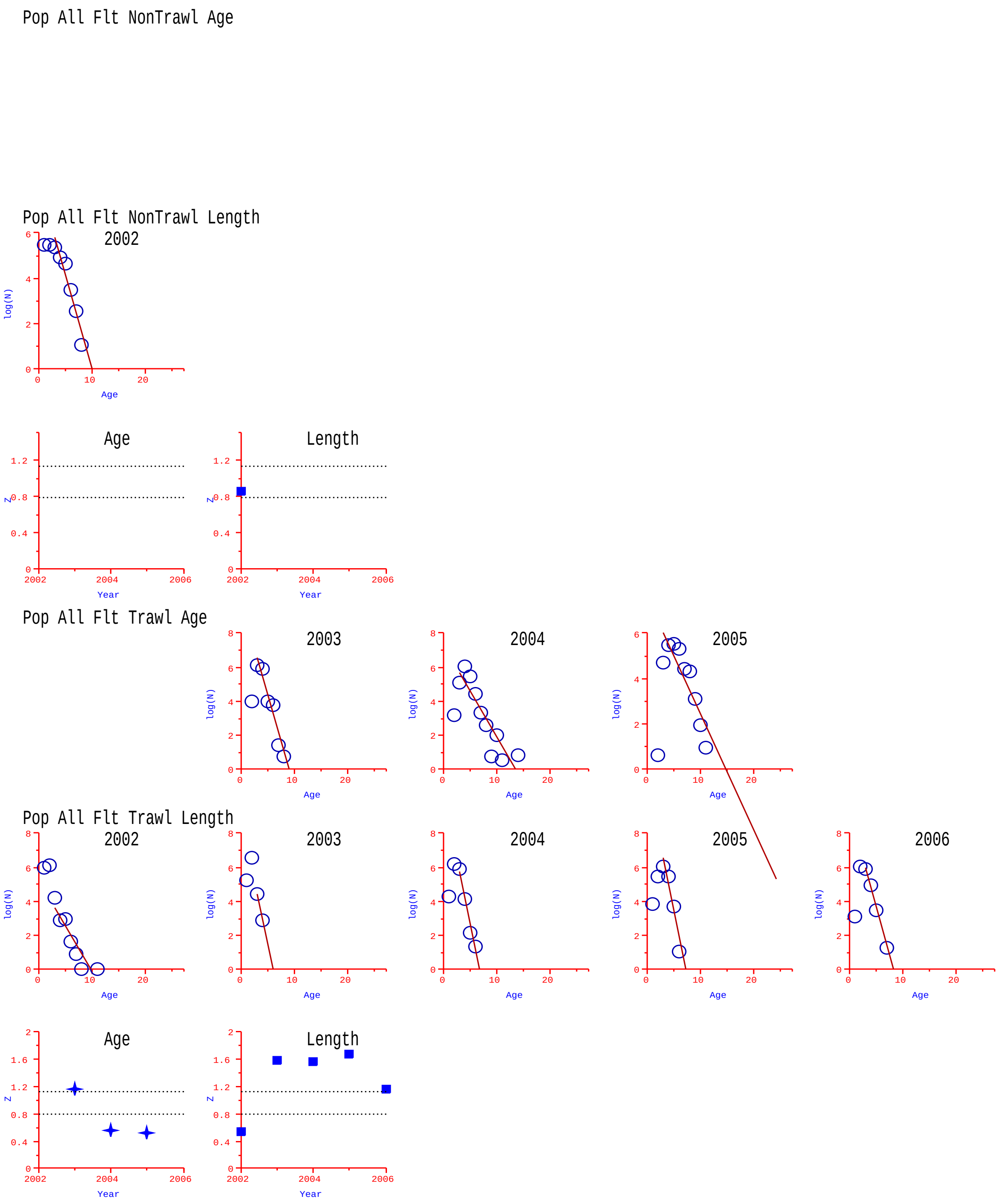


Figure 17.18. Blue warehou catch curve results

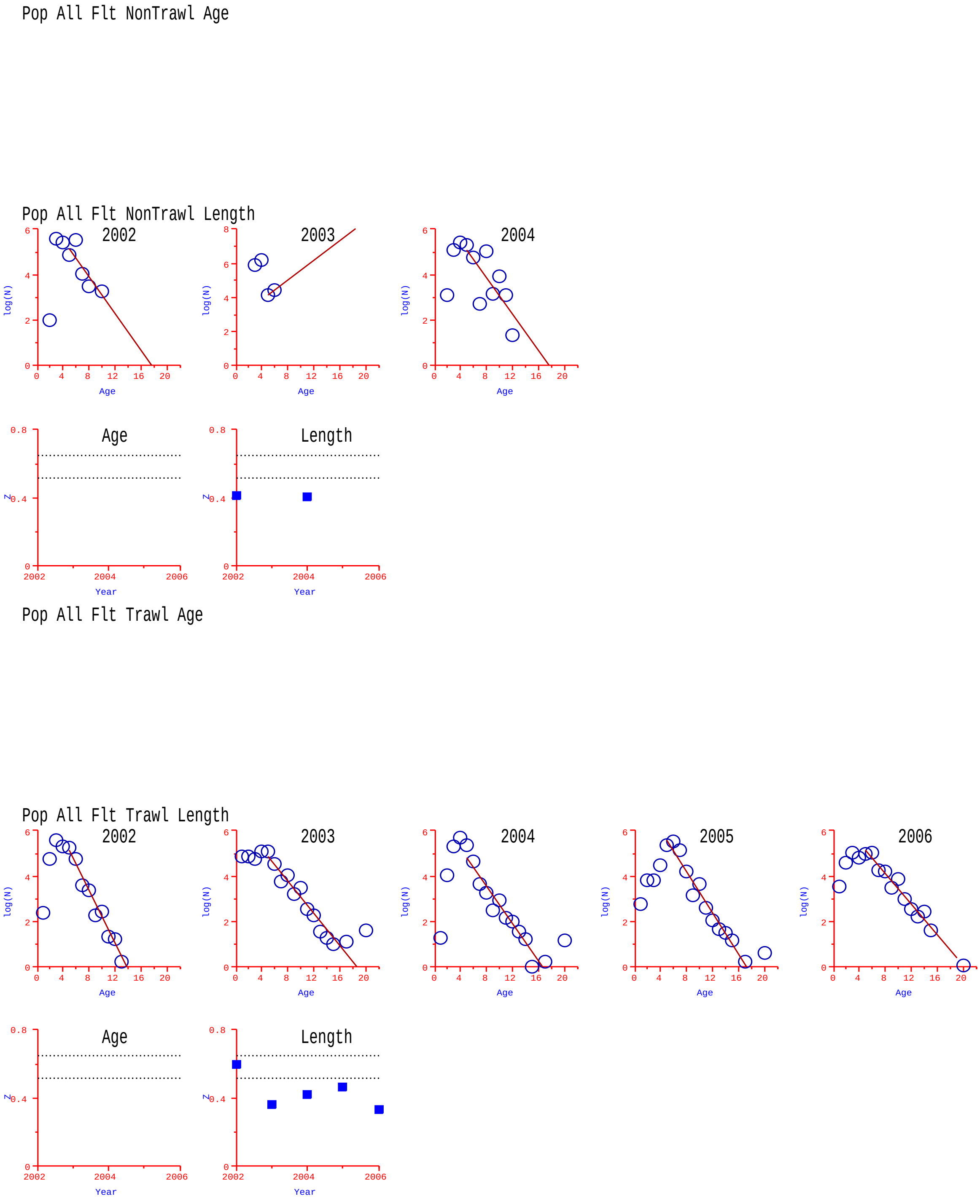


Figure 17.19. John dory catch curve results

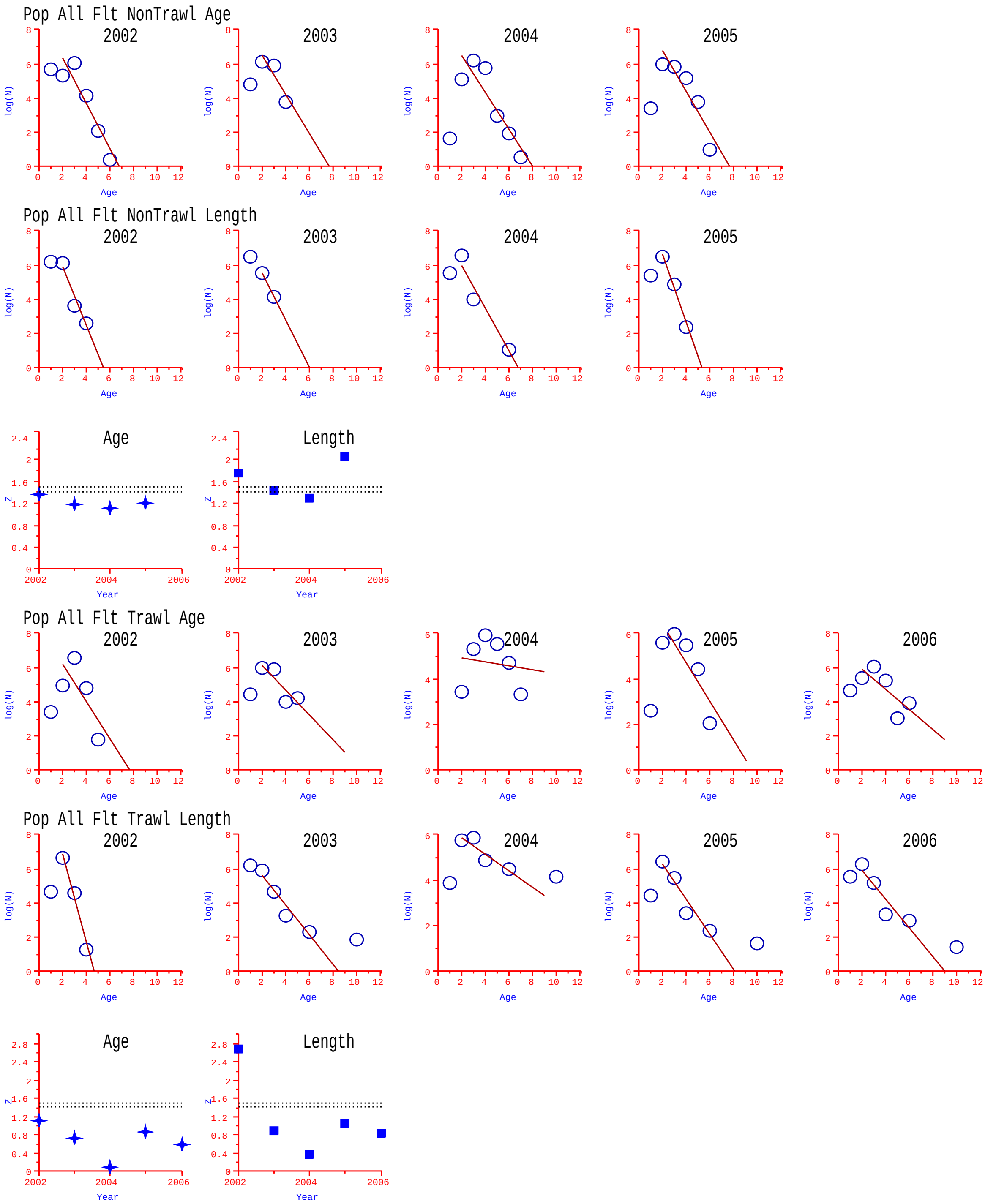
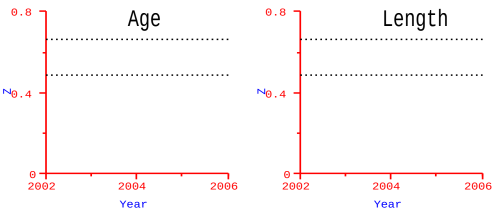


Figure 17.20. School whiting catch curve results

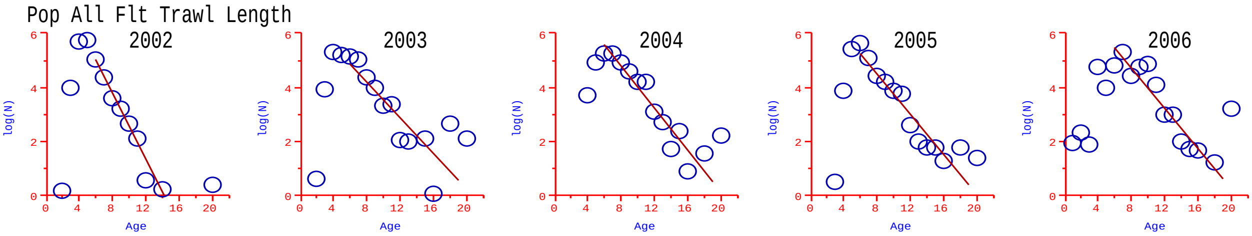
Pop All Flt NonTrawl Age

Pop All Flt NonTrawl Length



Pop All Flt Trawl Age

Pop All Flt Trawl Length



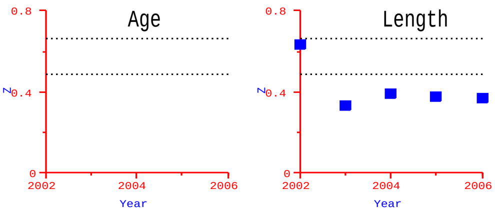


Figure 17.21. Mirror dory catch curve results

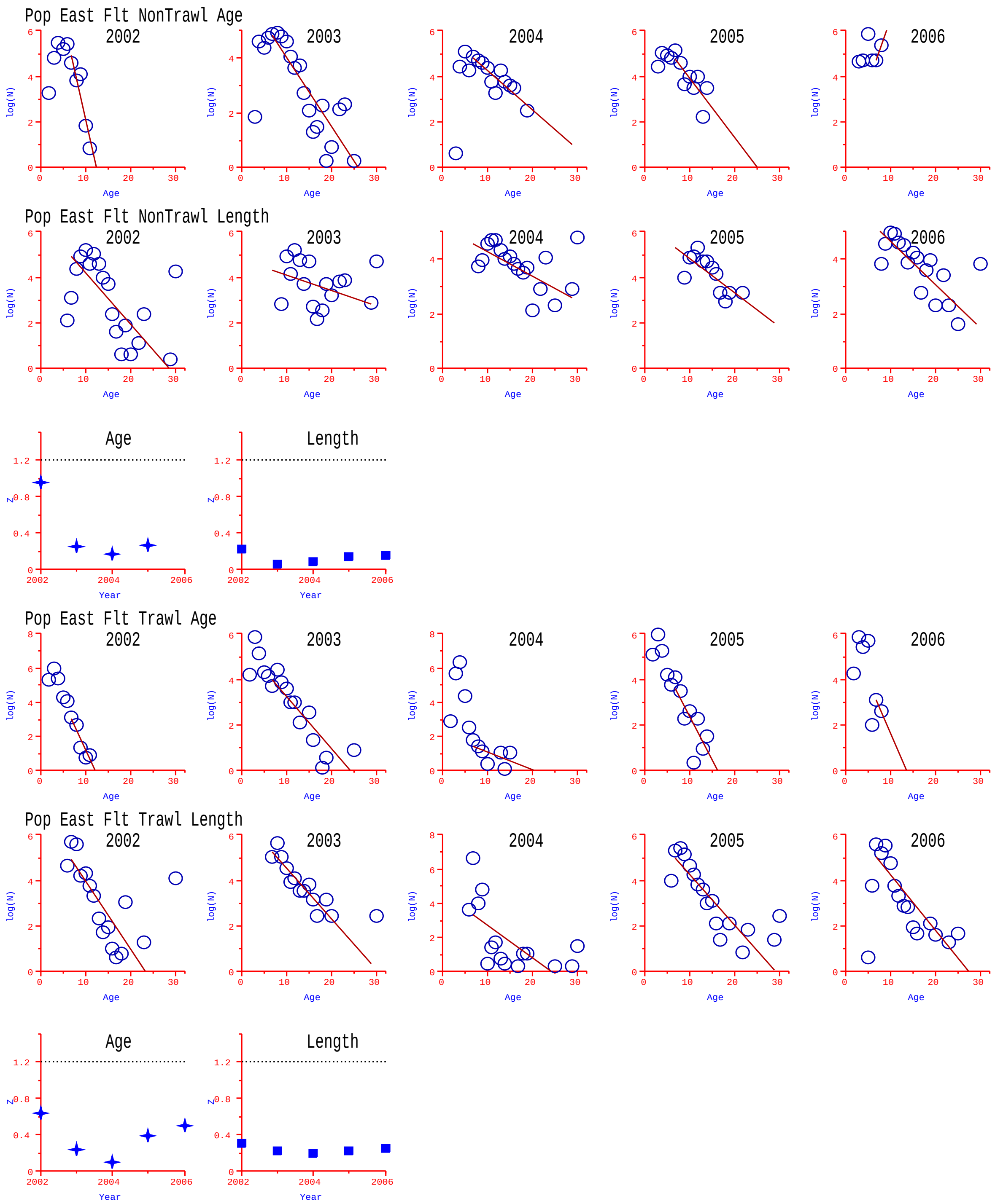


Figure 17.22. Pink ling catch curve results

Note: ignore Z targets and limits in this figure, they haven't been calculated

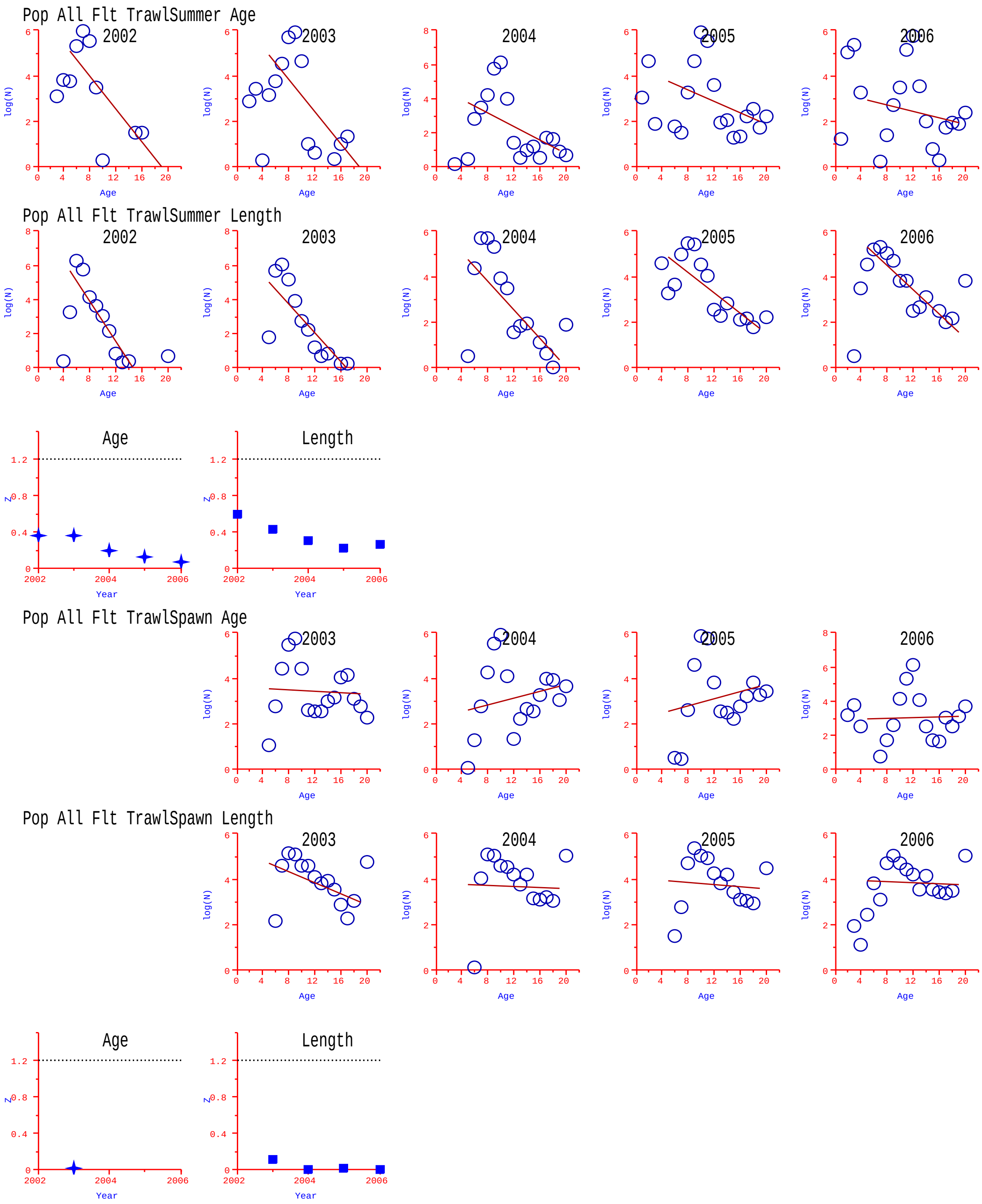


Figure 17.23. Blue grenadier catch curve results

Note: ignore Z targets and limits in this figure, they haven't been calculated

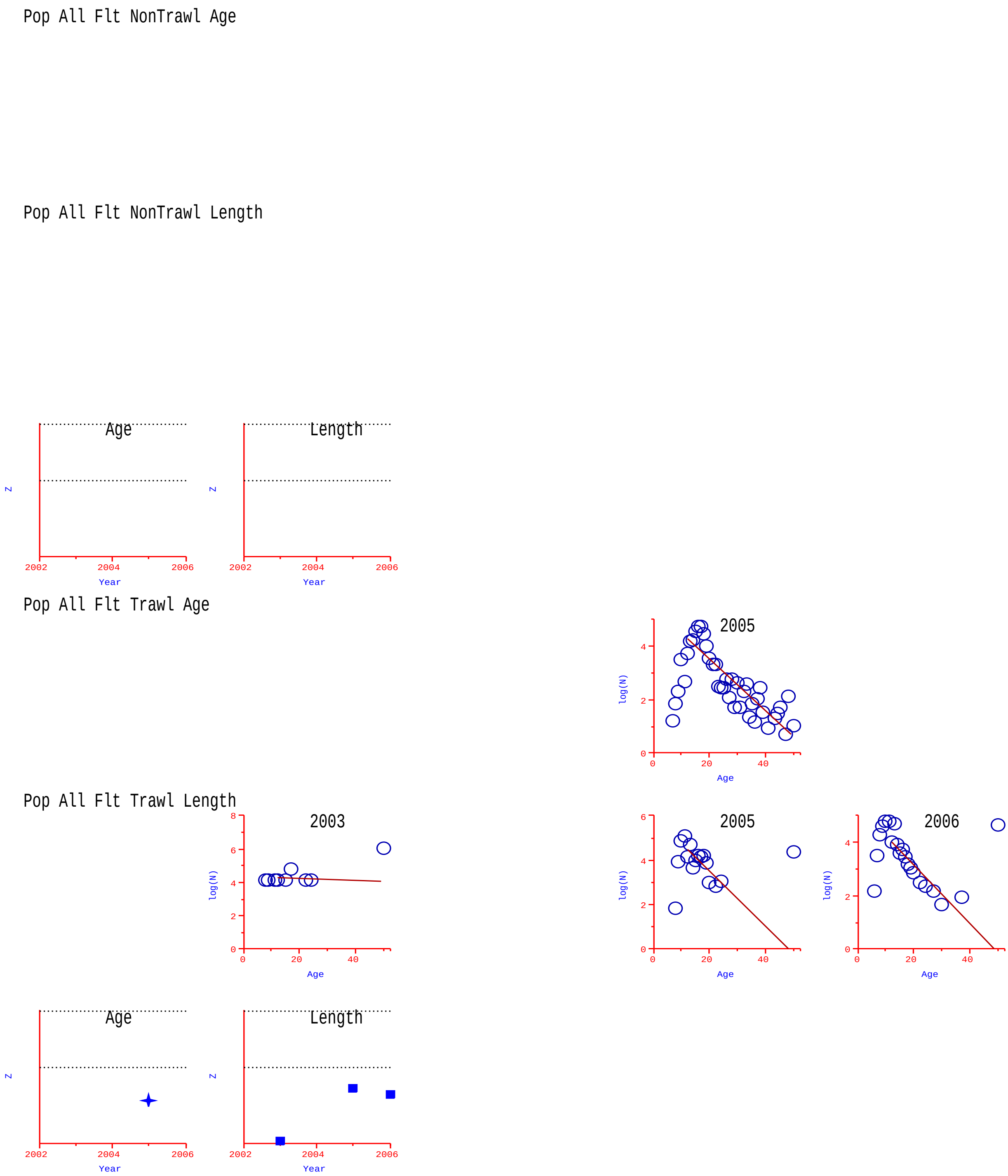


Figure 17.24. Ribaldo catch curve results

17.3.3 Tier 3 calculations

The means for calculating recommended biological catch using the Tier 3 harvest control rule (HCR3) is given in Smith (2005).

HCR3 will apply to species and/or stocks where there are robust estimates of natural mortality rate M and current fishing mortality rate F_{cur}, but no direct estimates of current biomass B_{cur}. Since there is no quantitative assessment, the RBC can not be calculated by applying a target fishing mortality rate to an estimate of current biomass. Instead, the RBC is calculated by varying the current catch level up or down depending on whether F_{cur} is above or below the target fishing mortality rate, which for Tier 3 is set at $F_{targ} = M$. The current catch level C_{cur} is calculated as the average catch over the past 4 years (where catch = landings + estimated discards). The discard rate applied to the average catch is weighted using a multiple of 8 for the most recent year (y), 4 for y-1, 2 for y-2 and 1 for y-3. The formula for calculating the RBC is:

RBC = 1.2 * C_{cur}	$F_{cur} < 0.5M$
RBC = 1.1 * C_{cur}	$0.75M > F_{cur} > 0.5M$
RBC = C_{cur}	$M > F_{cur} > 0.75M$
RBC = 0.9 * C_{cur}	$1.25M > F_{cur} > M$
RBC = 0.8 * C_{cur}	$1.5M > F_{cur} > 1.25M$
RBC = 0.5 * C_{cur}	$2M > F_{cur} > 1.5M$
RBC = 0	$F_{cur} > 2M$

Single current Z values (Z_{cur}) are created for those stocks with multiple fleets or sub-stocks simply by averaging across fleets or sub-stocks using equal weighting.

The functional form of the Tier 3 multiplier (p) calculated using the Tier 3 control rule is currently a step function in relation to the current F/M value. This means that if the F/M value for a species is near the edge of a step, a small change can cause a large change in the p value used to calculate the RBC. To remove this behavior it has been suggested that a smooth function be fitted to the current F/M vs p relationship. A simple functional relationship could not be found that fitted well through the step function, so a polynomial or spline function was used. The parameters for the fitted smooth function are as follows:

$$p = 1.2 + (-0.0295 * r) + (0.2313 * r^2) + (-1.209 * r^3) + (1.0413 * r^4) + (-0.283 * r^5)$$

where $r = F_{cur}/M$

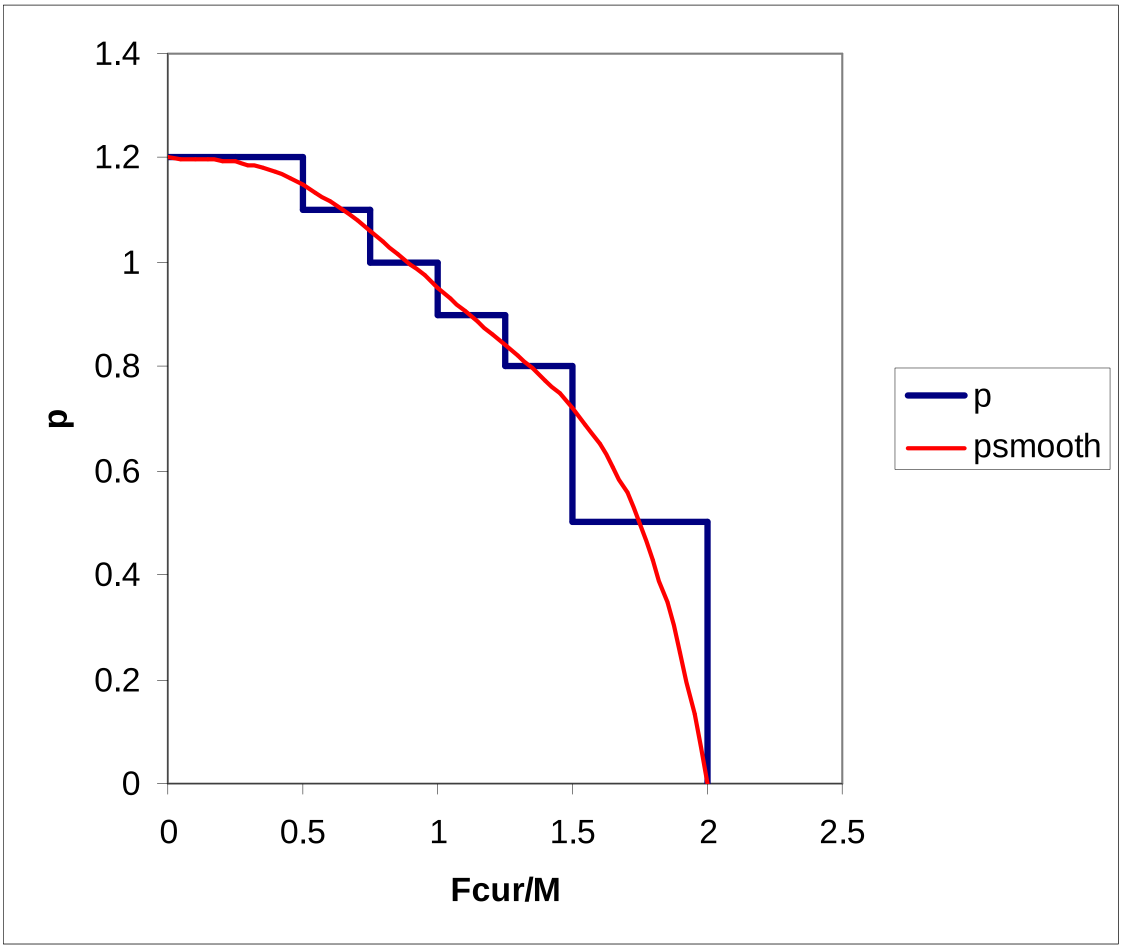


Figure 17.25. Fitted smooth relationship and step function.

Table 17.3. Tier 3 results.

	Flathead	Redfish	Morwong	Silver trevally	Spotted warehou	Blue warehou	John dory	School whiting	Mirror dory	Ling	Blue grenadier	Ribaldo
Z_{cur}	0.39	0.13	0.22	NA	0.42	0.85	0.44	1.23	0.42	0.42	NA	0.10
F_{cur}	0.19	0.03	0.11	NA	0.17	0.40	0.08	0.73	0.12	0.22	NA	0.02
M	0.20	0.10	0.11	NA	0.25	0.45	0.36	0.50	0.30	0.20	NA	0.08
p	1.00	1.20	1.00	NA	1.10	1.00	1.20	0.80	1.20	0.90	NA	1.20
p smooth	**0.96**	**1.19**	**0.95**	**NA**	**1.09**	**1.00**	**1.19**	**0.74**	**1.17**	**0.91**	**NA**	**1.19**
2006 values	(0.77)	(0.84)	(0.79)		(1.11)	(0.83)	(1.20)	(0.94)	(1.16)	(0.81)	(0.00)	(1.19)

* Note: Z values given here for school whiting is the one from simple catch curves. Last year this was calculated separately using a different method, as was blueeye trevalla. These may again be calculated independently this year.

17.4 Discussion

Yield per recruit and catch curve analysis this year was carried out using a different processing system to that used in the past. The current CSIRO stock assessment data processing system is built using Microsoft C++ and Microsoft Foundation Classes to handle the Windows Graphics User Interface. The earlier system was written in FORTRAN and exported data files for additional processing using R. The current system is fully integrated, more easily allows changes to how the data are processed, and produces data files in a suitable format for direct use with Stock Synthesis 2.

The methods used for yield analysis are similar to that used in the past and show similar results, although the program code has been rewritten. This is also true for the fitting of catch curves. The fitting procedure is different to that used in the past because the input parameters set the upper and lower age classes assumed to be fully selected. The lower bound is now the age class above the age where 95% selection occurs. The upper bound is the age below the last that is used as a plus group.

Results this year a broadly comparable to those produced last year. The greatest source of difference is that catch curves often show great variability from year to year, probably due to differing levels and distributions of age and length sampling. As the results are an average over valid values from the past 5 years, the average may change considerably due to the inclusion or dropping of an outlier. Secondary differences are probably due to the method for selecting age classes to be included in the regression.

There have been many discussions and a workshop this year that will lead to changes in the way that Tier 3 analyses are carried out. The current system can be improved in various ways including (a) improved use of available data, (b) improved methods for calculating catch curves, (c) alignment of Tier 3 rules with Tier 1 and 2 by the inclusion of Z target and limit points within the management rule and (d) removal of catch curves from Tier 3 with replacement by another method of determining current F/Z levels.

There are many options within each of the categories above, but I will only choose three of them here. For option (a) it would probably be best to only use length data alone as a very last resort. Before that, it would be possible to apply an average age length key from all years to the length data. The disadvantage of that would be that estimates of Z would no longer be independent as they are now. However, that probably outweighs the use of length data alone. For option (c) the Z_{20} “limit” and Z_{40} “target” reference levels are already calculated for Tier 3, but are not used in the rule for determining the RBC. Those, as well as perhaps Z_{48} (or other appropriate target) should be used within the Tier 3 rule in a comparable way to Tiers 1 and 2. For option (d), it has become clear that the “ratcheting” behaviour of the current Tier 3 rule is very undesirable. Catch curves for long-lived species will not change over long time periods, and when they do, will be adversely affected by recruitment events. A solution to this problem is required.

17.5 Acknowledgements

Central Age Facility data was provided by Kyne Krusic-Golub (PIRVIC), ISMP and AFMA logbook data was processed and provided by Matthew Koopman and Anne Gason (PIRVIC).

17.6 References

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17.7 Appendix – Details of values that were averaged to calculate total Z

Details of values that were averaged to calculate total Z (shown in bold type). Iage is the regression intercept when ALK and length was used, Ilen is the regression intercept when length data was split using VB parameters. Zage is from the regression slope when age data was used, Zlen when only length data was used. SSage is the number of otolith samples used from that year, SSlength is the number of length samples used from that year.

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
FLT	1	1	2002	6.87	9.50	**0.38**	1.17	1,153	6,208
FLT	1	1	2003	6.08	8.88	0.21	0.97	102	4,686
FLT	1	1	2004	7.56	9.76	**0.54**	1.27	326	10,247
FLT	1	1	2005	6.11	9.84	**0.28**	1.15	872	12,658
FLT	1	1	2006	0.00	9.85	0.00	1.27	0	13,317
FLT	1	2	2002	6.84	9.82	**0.37**	1.24	1,153	3,569
FLT	1	2	2003	4.59	9.39	-0.11	1.01	102	1,896
FLT	1	2	2004	7.51	9.72	**0.55**	1.27	326	3,991
FLT	1	2	2005	5.87	10.83	**0.25**	1.41	872	1,834
FLT	1	2	2006	0.00	10.32	0.00	1.34	0	1,375
FLT	2	1	2002	6.21	9.38	0.29	1.19	149	5,201
FLT	2	1	2003	0.00	9.17	0.00	0.94	0	574
FLT	2	1	2004	0.00	8.53	0.00	0.85	0	1,520
FLT	2	1	2005	6.65	9.58	0.19	1.19	19	889
FLT	2	1	2006	0.00	6.59	0.00	0.30	0	810
FLT	2	2	2002	0.00	0.00	0.00	0.00	0	0
FLT	2	2	2003	0.00	0.00	0.00	0.00	0	0
FLT	2	2	2004	0.00	0.00	0.00	0.00	0	0
FLT	2	2	2005	1.57	9.68	-0.39	1.08	19	2,085
FLT	2	2	2006	0.00	0.00	0.00	0.00	0	0

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
RED	1	1	2002	4.85	7.13	**0.11**	0.38	414	767
RED	1	1	2003	4.13	5.20	0.01	0.06	185	398
RED	1	1	2004	4.65	5.12	**0.16**	0.22	458	3,239
RED	1	1	2005	0.00	5.97	0.00	0.21	0	1,505
RED	1	1	2006	0.00	3.76	0.00	0.28	0	2,673
RED	2	1	2002	5.45	6.10	**0.16**	0.18	258	1,725
RED	2	1	2003	3.45	5.56	0.01	0.11	473	1,835
RED	2	1	2004	4.27	5.28	**0.08**	0.10	227	1,719
RED	2	1	2005	0.00	5.44	0.00	0.10	0	2,169
RED	2	1	2006	0.00	5.17	0.00	0.05	0	3,037

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
MOW	1	1	2002	5.32	6.45	**0.16**	0.33	379	5,757
MOW	1	1	2003	4.83	6.09	**0.14**	0.23	250	4,066
MOW	1	1	2004	5.79	6.27	**0.21**	0.29	557	3,544

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
MOW	1	1	2005	5.66	6.12	**0.19**	0.24	471	5,747
MOW	1	1	2006	6.32	6.27	**0.29**	0.29	123	13,604
MOW	1	2	2002	5.48	7.65	**0.18**	0.57	379	487
MOW	1	2	2003	8.03	9.04	0.65	1.39	250	61
MOW	1	2	2004	6.47	7.07	**0.30**	0.46	557	108
MOW	1	2	2005	5.27	6.02	0.16	0.20	471	78
MOW	1	2	2006	0.00	0.00	0.00	0.00	0	0
MOW	1	3	2002	5.20	6.42	0.15	0.31	379	2,116
MOW	1	3	2003	4.89	6.51	0.16	0.30	250	424
MOW	1	3	2004	4.96	5.58	0.11	0.19	557	1,248
MOW	1	3	2005	5.65	6.20	0.19	0.25	471	1,391
MOW	1	3	2006	5.36	5.37	0.16	0.09	123	520
MOW	1	4	2002	4.79	3.04	0.11	-0.19	379	1,918
MOW	1	4	2003	3.39	3.03	0.00	-0.18	250	1,680
MOW	1	4	2004	4.56	3.36	0.08	-0.16	557	873
MOW	1	4	2005	4.79	4.71	0.11	0.01	471	1,426
MOW	1	4	2006	5.04	4.92	0.12	0.04	123	690

Catch Curves

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
TRE	1	1	2002	0.00	-1.#IND	0.00	1.#QNAN	0	47
TRE	1	1	2003	0.00	0.00	0.00	0.00	0	0
TRE	1	1	2004	0.00	4.65	0.00	0.00	0	17
TRE	1	1	2005	0.00	0.00	0.00	0.00	0	0
TRE	1	1	2006	0.00	0.00	0.00	0.00	0	0
TRE	1	2	2002	0.00	10.10	0.00	2.67	0	1,392
TRE	1	2	2003	0.00	4.57	0.00	0.50	0	571
TRE	1	2	2004	0.00	7.78	0.00	1.64	0	2,540
TRE	1	2	2005	0.00	9.69	0.00	2.19	0	2,250
TRE	1	2	2006	0.00	7.10	0.00	1.29	0	15,415

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
TRS	1	1	2002	6.99	5.88	**0.41**	0.41	722	22,043
TRS	1	1	2003	6.92	4.13	**0.45**	0.24	444	8,685
TRS	1	1	2004	6.91	6.13	**0.39**	0.42	601	7,506
TRS	1	1	2005	7.06	6.54	**0.43**	0.60	625	12,697
TRS	1	1	2006	6.68	6.18	**0.40**	0.53	334	7,852

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
TRT	1	1	2002	0.00	8.38	0.00	0.86	0	339
TRT	1	1	2003	0.00	0.00	0.00	0.00	0	0
TRT	1	1	2004	0.00	0.00	0.00	0.00	0	0
TRT	1	1	2005	0.00	0.00	0.00	0.00	0	0
TRT	1	1	2006	0.00	0.00	0.00	0.00	0	0
TRT	1	2	2002	0.00	5.27	0.00	0.55	0	6,270
TRT	1	2	2003	10.04	9.20	**1.16**	1.58	432	4,005
TRT	1	2	2004	7.37	10.42	**0.55**	1.57	909	2,392
TRT	1	2	2005	7.63	11.61	0.52	1.67	743	2,269
TRT	1	2	2006	0.00	9.45	0.00	1.17	0	2,250

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
DOJ	1	1	2002	0.00	7.25	0.00	0.42	0	70
DOJ	1	1	2003	0.00	2.74	0.00	-0.29	0	46
DOJ	1	1	2004	0.00	7.16	0.00	0.41	0	158
DOJ	1	1	2005	0.00	0.00	0.00	0.00	0	0
DOJ	1	1	2006	0.00	0.00	0.00	0.00	0	0
DOJ	1	2	2002	0.00	8.13	0.00	**0.60**	0	6,934
DOJ	1	2	2003	0.00	6.68	0.00	**0.36**	0	4,351
DOJ	1	2	2004	0.00	6.90	0.00	**0.42**	0	6,460
DOJ	1	2	2005	0.00	7.92	0.00	**0.46**	0	3,494
DOJ	1	2	2006	0.00	6.81	0.00	**0.34**	0	3,180

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
WHS	1	1	2002	9.12	9.38	**1.38**	1.75	560	396
WHS	1	1	2003	8.81	8.43	1.17	1.44	471	189
WHS	1	1	2004	8.71	8.58	**1.10**	1.29	649	591
WHS	1	1	2005	9.20	10.73	**1.21**	2.05	393	558
WHS	1	1	2006	0.00	0.00	0.00	0.00	0	0
WHS	1	2	2002	8.44	12.25	1.12	2.69	560	1,017
WHS	1	2	2003	7.58	7.36	**0.72**	0.89	471	967
WHS	1	2	2004	5.09	6.61	**0.08**	0.37	649	6,176
WHS	1	2	2005	8.14	8.38	0.86	1.05	393	4,160
WHS	1	2	2006	7.08	7.58	**0.59**	0.84	314	9,524

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
DOM	1	1	2002	0.00	0.00	0.00	0.00	0	0
DOM	1	1	2003	0.00	0.00	0.00	0.00	0	0
DOM	1	1	2004	0.00	0.00	0.00	0.00	0	0
DOM	1	1	2005	0.00	0.00	0.00	0.00	0	0
DOM	1	1	2006	0.00	0.00	0.00	0.00	0	0
DOM	1	2	2002	0.00	8.81	0.00	**0.63**	0	6,460
DOM	1	2	2003	0.00	6.87	0.00	**0.33**	0	2,896
DOM	1	2	2004	0.00	7.92	0.00	**0.39**	0	2,186
DOM	1	2	2005	0.00	7.53	0.00	**0.37**	0	2,993
DOM	1	2	2006	0.00	7.74	0.00	**0.37**	0	1,582

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
LIG	1	1	2002	11.60	6.56	**0.95**	0.23	434	769
LIG	1	1	2003	6.67	4.80	**0.26**	0.07	388	104
LIG	1	1	2004	6.03	5.23	**0.17**	0.09	162	253
LIG	1	1	2005	6.68	6.38	**0.27**	0.15	277	108
LIG	1	1	2006	0.06	6.23	-0.66	0.16	27	622
LIG	1	2	2002	7.48	7.07	**0.64**	0.31	434	2,813
LIG	1	2	2003	5.65	6.80	**0.24**	0.22	388	174
LIG	1	2	2004	2.20	4.71	0.11	0.20	162	201
LIG	1	2	2005	6.37	6.56	**0.40**	0.22	277	1,447
LIG	1	2	2006	6.60	6.75	0.50	0.25	27	873

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
GRE	1	1	2002	6.93	8.65	0.37	0.60	1,687	9,416
GRE	1	1	2003	6.72	7.19	0.36	0.43	1,514	5,023

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
GRE	1	1	2004	4.75	6.31	0.20	0.31	1,369	4,392
GRE	1	1	2005	4.38	6.02	0.13	0.23	2,173	6,195
GRE	1	1	2006	3.34	6.63	0.07	0.26	1,681	2,937
GRE	1	2	2002	0.00	0.00	0.00	0.00	0	0
GRE	1	2	2003	3.64	5.30	0.02	0.12	1,514	946
GRE	1	2	2004	2.20	3.85	-0.08	0.01	1,369	3,201
GRE	1	2	2005	2.15	4.09	-0.08	0.03	2,173	2,434
GRE	1	2	2006	2.89	3.97	-0.01	0.01	1,681	6,376

Species	Population	Fleet	Year	Iage	Ilen	Zage	Zlen	SSage	SSlength
RIB	1	1	2002	0.00	0.00	0.00	0.00	0	0
RIB	1	1	2003	0.00	0.00	0.00	0.00	0	0
RIB	1	1	2004	0.00	0.00	0.00	0.00	0	0
RIB	1	1	2005	0.00	0.00	0.00	0.00	0	0
RIB	1	1	2006	0.00	0.00	0.00	0.00	0	0
RIB	1	2	2002	0.00	0.00	0.00	0.00	0	0
RIB	1	2	2003	0.00	4.40	0.00	0.01	0	16
RIB	1	2	2004	0.00	0.00	0.00	0.00	0	0
RIB	1	2	2005	5.43	5.98	**0.10**	0.13	671	189
RIB	1	2	2006	0.00	5.36	0.00	0.11	0	566

18. Data Appraisal and Progress on Harvest Strategy Evaluation for Blue Eye Trevalla: update for July 2007 SlopeRAG meeting.[13]

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18.1 Data Appraisal for Possible 2007 TIER 3 Analysis

There were no blue eye trevalla otoliths aged by the CAF in 2006, thus prohibiting both catch curve analysis for this year based solely on age data, and construction of an age-length key (ALK) for 2006 in order to convert length data for this year to an age composition. It should be possible to apply an old ALK (say for example, that obtained using data for 2005), to the length data available for 2006, in order to obtain a (possibly incorrect) age composition for this most recent year. The length data for 2006 (for all gear types and zones) were collected from 11 trips for port lengths, and from 7 shots for the observer data.

Updated CPUE standardizations for blue eye caught by trawl are provided by Haddon (2007). Separate analyses are conducted for blue eye caught in eastern and western zones, and suggest slightly increasing trend in the east, and a declining trend in the west. Analyses of the blue eye length data by Fay (Section 18.4, Appendix) suggest that there are indeed differences in the length composition data among eastern and western zones, and that although the length composition of trawl catches are distinct from those captured by hook and line methods, there does not exist much evidence suggesting differences between length compositions from dropline and longline catches. These analyses can help to identify fleet structure for blue eye when conducting stock assessment, although additional examination of CPUE trends for gear types other than trawl are also required.

18.2 Harvest Strategy Evaluation

18.2.1 Introduction

In the SESSF, blue eye trevalla are caught by a number of gear types on the continental slope, and on offshore sea mounts. Assessment of the fishery is complicated by spatial and seasonal variability in size-structure and availability of the fish, multiple gear types, gear selectivity, and jurisdictional factors (Smith and Wayte 2002). The SESSF has recently adopted a harvest strategy framework as a basis for setting TACs. This framework is based on a set of harvest control rules, with the decision as to which rule to apply for a particular stock being dependent on the type of information available on

[13] Paper presented to the Slope Resource Assessment Group in July, 2007

stock status, with the intent that as information quality declines, the appropriate control rule is more precautionary in approach (i.e. recommends lower catches and maintains the stock at higher spawning biomass). The Tier 3 harvest control rule applies to stocks where there is no estimate of current biomass, but where robust estimates of the rate of natural mortality M, and the current fishing mortality rate, F_{CUR}. Estimates of total mortality, Z are typically derived from catch curve analyses. Tier 1 is for the most information-rich case, RBCs are calculated based on the results obtained from fitting an age-structured population dynamics model (*e.g.* Stock Synthesis 2, Methot 2005) to the available data.

This work will use a simulation modelling approach to address the following:

1. *How does the tier 3 control rule for a blue eye trevalla-like population perform in the absence of fleet/spatial structure?*

2. *What considerations are necessary for application of the tier 3 HCR when considering multiple fleets / areas / movement? How well does the tier 3 HCR perform given this additional uncertainty?*

3. *How does the performance of the tier 3 HCR compare to other control rules? What is the cost of adjusting the control rule to obtain a given outcome?*

The approach consists of tuning a (potentially) spatial length- and age-structured operating model to represent a set of hypotheses for the dynamics of the blue eye population and fishery. This model is then projected over a historical period, given a known catch history, and data akin to that available from the SESSF is generated given the known 'true' population. The harvest strategy framework is then used to determine an RBC given an estimation method and the appropriate tier control rule, this catch is then allocated by fleet and region within the operating model and the population updated given this new catch, and additional data generated. The assessment / population update cycle is repeated for the pre-specified projection period, given specifications as to the frequency of assessment / update of the RBC. Following projection for a number of simulations, each representing different random realizations of the operating model given the input specifications, the necessary performance metrics are calculated. Performance of the various control rules will be assessed by calculating the following: probability of being close to (+/- 1%) the target biomass (B_{TARG}) at the end of the projection period; probability of going below B_{LIM} during the projection period; spawning biomass relative to B_0 following projection period; probability of true F being close to F_{TARG}; probability of going above F_{LIM}; and total/average/variability in catch over the projection period.

18.2.2 Section Outlines

18.2.2.1 Performance of tier 3 rule in absence of multiple fleets and spatial structure.

This section consists of testing the tier 3 catch control rule under a set of simple scenarios that allow for the investigation of the sensitivity of performance to key uncertainties, without the additional complexities associated with handling multiple fleets and spatial dynamics. The simulations essentially involve a repetition of the material complete last year, except that these analyses make use of output from a dynamic operating model, enabling the assessment of population impacts of the control rules, as opposed to identifying whether or not the rule results in making the correct decision (adjust catch up or down).

The tier 3 evaluation analyses will look at 2 estimation methods, the Chapman and Robson (1960) catch curve estimator, and the multiyear catch curve approach (Mark Bravington, CSIRO, pers commn.). For both of these estimators, simulations will be conducted that examine change in performance associated with uncertainty in:

- choice of M for application of HCR (0.05, 0.08, 0.12),
- the frequency at which the catch curve estimation is applied (every year, every 2 years, every 5 years),
- spawning depletion relative to B_0 at beginning of projection period,
- selectivity (asymptotic vs dome-shaped), time varying selectivity (random variation but no trend over time),
- true values for M and steepness (h), and
- age composition sample size.

The other specifications for the operating model will be set at fixed values plausible for blue eye trevalla, with the model structure defined as a single stock inhabiting a single region, and being exploited by a single fleet. It will be assumed that there is no ageing error, and that the multiyear catch curve method ‘knows’ the correct parameters for the growth curve.

Initial analyses suggest that, for a long-lived species such as the blue eye trevalla, applying the 2006 tier 3 control rule every year results in the systematic reduction of catch, with a consequent increase in spawning biomass (Figure 18.1). However, as applied, the control rule does not appear to be self-correcting, suggesting that the inertia in the age structure is such that the estimation method is not able to detect reductions in F resulting from the declining RBC.

18.2.2.2 Considerations for application, and performance of tier 3 rule when there are multiple fleets / regions / movement.

When age data are available from multiple fleets, operating in 1 or more areas, with uncertainty regarding the degree of spatial structure in the population among areas, the problem arises as to how best to determine the mortality rate Z to use for the RBC calculations. That is, when considering multiple fleets and areas, what estimates of mortality should be used?

This section will expand the operating model structure to 2 fleets (with different selectivities, e.g. 'trawl' and 'hook-and-line'), 2 areas (e.g. slope/seamount) and movement among areas (pre- or post-recruit dispersal), with the intent being to examine the impact in performance of the harvest strategy given this additional structure. Focus will be given to evaluating performance of the rule given several options for the Z to use when calculating F_{CUR}. Methods examined will include:

i. a single catch curve using all the data (both fleets and areas),

ii. just data from the dominant fleet (largest proportion of catch), then a single catch curve over both areas,

iii. dominant fleet, but obtain separate mortality estimates by area, then weight estimates by:

  a. variance of estimates,

  b. proportion of annual catch in each area.

iv. conduct separate analyses by fleet and area, weight estimates as in (iii).

v. conduct separate analyses by fleet and area, choose highest estimate of Z.

18.2.2.3 Comparing performance among harvest strategies

This section will compare the results of the previous section with the performance obtained when using other harvest strategies. That is, how does the tier 3 rule compare to say tier 1, and can the tier 3 rule be modified to obtain the desired performance?

The tier 1 analyses will involve generating additional data from the operating model (including CPUE indices, and length compositions), and then fitting Stock Synthesis to this data, and using the tier 1 HCR to calculate the RBC used to update the population dynamics. Performance of tier 1 will be compared to that of tier 3, so as to examine whether the less data-rich analysis is indeed more precautionary, in that it results in a larger stock biomass, and gives lower catches. These analyses will enable the cost of moving to tier 3 to be assessed.

The second part of this section will involve examining the change in performance obtained when the tier 3 control rule is adjusted. That is, is it possible to adjust the control rule in order to obtain the desired performance / target, and what is the cost associated with doing this? In addition, what needs to be done to a tier 3 type analysis in order to achieve the same targets as those of the tier 1 rule, and what risks are involved in doing this? These analyses will involve changing the tier 3 control rule by modifying:

i. the value of F_{LIM}, the fishing mortality rate at which catch is set at zero,

ii. the maximum allowed multiplier of the current catch,

iii. the value for F_{TARG}, the target fishing mortality rate, this is currently set at M.

18.2.3 Current Status and Timeline

The operating model is coded as per specifications developed by Mr Fay and Dr's Andre Punt, Tony Smith, and Sally Wayte. The full mathematical details are omitted here for ease of presentation and because they encompass a wider range of scenarios for the population and fishery dynamics than are considered in the analyses discussed here. The initial tier 3 analyses with a single area and fleet are currently being conducted. The operating model and HCR application are currently being tested using Stock Synthesis 2 (SS2), by generating deterministic data using the operating model, fitting SS2 to these data and seeing whether the assessment method returns the 'correct' answer. This is an important step in terms of identifying errors within the coding of the model, and to provide a baseline for interpreting the results when evaluating the various tier rules. The analyses in Sections 18.2.2.1 and 18.2.2.2, and the comparison with the tier 1 rule will be completed by mid-September 2007. The analyses in Section 18.2.2.3 concerned with adjusting the tier 3 rule will be undertaken following this, with completion planned for December 2007.

18.3 References

Chapman, D.G. and D.S. Robson. 1960. The analysis of a catch curve. Biometrics 16:354-368.

Haddon, M. 2007. Standardized Commercial Catch-Effort data for selected Shelf and Slope Assessment Group Species for 1986 - 2006. SESSF Document 2007/10.

Smith, A.D.M. and Wayte (eds). 2002. The South East Fishery 2001. Fishery Assessment Report compiled by the South East Fishery Assessment Group. Australian Fisheries Management Authority, Canberra.

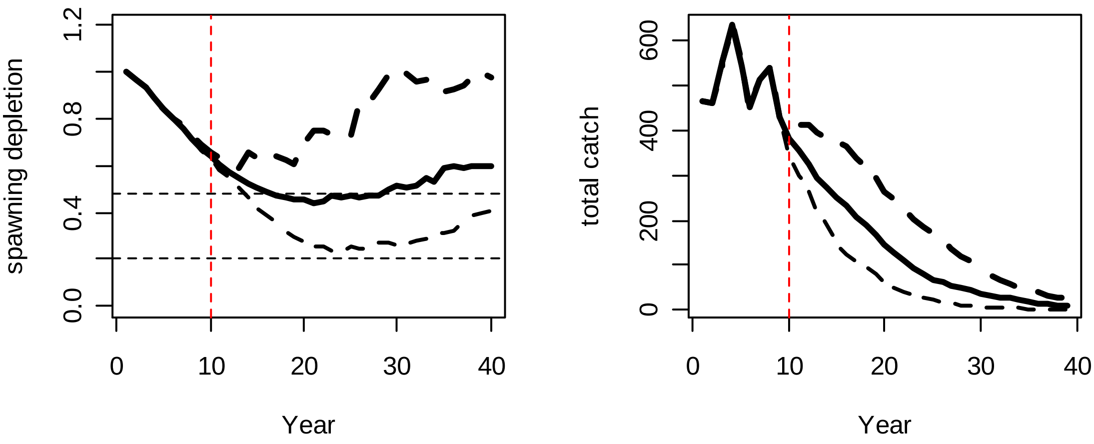

Figure 18.1. Median and 90% interval of the trajectories of spawning biomass and total catch for initial analyses when the 2006 tier 3 harvest control rule is applied on an annual basis. The dashed vertical red lines indicate the beginning of the RBC-based projection period, and the upper and lower dashed black lines in the left panel correspond to 48% and 20% of B_0.

18.4 Appendix: Assessing fleet structure in the Australian fishery for blue eye trevalla (Hyperoglyphe antarctica)

18.4.1 Introduction

Identifying fleet structure in fisheries is often a necessary step prior to analysis for stock assessment. It may be desirable to separate components of the fishery that have showed tendencies to exhibit differences over time in either abundance trends or age/length composition, because such differences may represent spatial structure in the exploited population (or differential spatial response to fishing mortality), or result from differences in the availability of fish to particular gear types (e.g. Walters and Martell 2004).

Decisions regarding fleet structure frequently result from visual inspection of available data, and *apriori* knowledge about the fishery, perhaps making use of information provided by resource users. Fishing fleets are often separated based on some measurable physical quantity of the vessels employed in the fishery, such as gear type, vessel size, or horsepower. Fleets may also be identified based on some general aspects of fisher behavior (Hilborn 1985, Marchal *et al*., 2006), or through the ecological characteristics of the species complex targeted/captured (e.g. Murawski *et al*., 1983; Pelletier and Ferraris, 2000). Recently, the use of multivariate statistical methods has become increasingly common when undertaking analyses in order to better define fishing fleets. For example, Jimenez *et al*. (2004) used cluster analysis and linear discriminant analysis to define fleets and fishing trip types based on technical vessel characteristics and species composition of landings. Pelletier and Ferraris (2000) identified fisher groups exhibiting different 'fishing tactics' from catch and effort data using ordination and classification techniques. Central to these studies are fisheries that exhibit diverse characteristics in terms of gears employed, species targeted, areas fished, and individual behaviour.

Blue eye trevalla (*Hyperoglyphe antarctica*) is a high-valued species in Australia's South East Scalefish and Southern Shark Fishery (SESSF). The fishery for blue eye is characterised by a large number of gear types operating in multiple areas, with uncertainty in stock structure among these areas, and apparent spatial variability in key biological parameters, such as those determining growth rates. Stock assessment for the fishery is complicated by spatial and seasonal variability in size-structure and availability of the fish, multiple gear types, gear selectivity, and jurisdictional factors (Smith and Wayte 2002). Blue eye are caught primarily by hook and line methods on the continental slope and on offshore sea mounts, although they are also caught as bycatch (often retained) in the trawl sector of the fishery, as young fish (40-50 cm in length) recruit from continental shelf waters to slope areas. Selectivity issues arise for both the hook and line sector of the blue eye trevalla fishery as well as the trawl sector due to both variable age at recruitment from ages 2-5 yrs, and avoidance behaviour by fishers of non-marketable larger mature adults (ie. selectivity-at-length is likely dome-shaped). Given the uncertainty in the apparent spatial variability in availability, defining fishing fleet units in the fishery is important, current scientific advice for management of blue eye is based on a fishery control rules that uses catch curves to assess the rate of fishing mortality relative to a pre-specified target. Performance of this control rule has been shown to degrade when fisheries exhibiting different (and uncertain) selectivities operate in multiple areas, with uncertain spatial structure among areas in the exploited population (Fay 2006).

In this paper, length composition data from the blue eye trevalla fishery were analysed using clustering, ordination, and discrimination techniques, in order to summarise the observed variability among gear types and zones fished. Any similarities in length compositions among zones and gear types might suggest identifiable units that could represent distinct fleets for stock assessment, either representing differences in fish availability, or perhaps spatially explicit population responses to fishing, indicating some degree of stock structuring. The cluster methods used focused on defining groups within the data. An ordination technique (Principal components analysis) was employed to describe what components of the length composition contributed to the observed variability among the data. Linear discriminant analysis was also employed to investigate how groups such as gear type and zone fished were able to account for separation of the data.

18.4.2 Material and Methods

18.4.2.1 Data

Annual length composition data for blueeye trevalla from both state and federal port samples were available by year for four gear types and seven zones (areas), ranging from 1980 to 2005. Figure 18.1 shows the geographic locations of the zones, while Table 18.1 lists the zones and gear types, and the abbreviations for them used throughout the paper. Compositions based on fewer than 100 sampled fish were removed from the analysis to mitigate the impact of small sample size on the variability of the data. The proportions at length were summarized into thirteen 5cm length bins, with the first length bins including all fish smaller than 45 cm, and the last length bin comprising all fish greater than or equal to 100 cm in caudal fork length. The resulting data matrix was then of dimensions 143 rows and 13 columns, with each row, or object in the analyses described below, being an individual length composition from known gear type and area, and the descriptor variables being the proportions of fish in each length bin. As most of the analyses described below perform best when all descriptors have similar variance, the proportions in each column were standardized to have mean zero and unit variance.

18.4.2.2 Dissimilarity matrix

The cluster and ordination methods described below all require a dissimilarity or distance matrix between the individual length compositions. Many measures of dissimilarity have been developed, and the use of a particular metric depends largely on the characteristics of the data set and the properties of which the analyst wishes to emphasize. Euclidean distance (ED), corresponding to usual geometric distance, was chosen as the dissimilarity measure for the analyses here because all the descriptor variables (columns in the data matrix) are continous, measured on the same scale (normalized proportions), and non-membership (zero) for a given descriptor is an indication of similarity. The ED between objects (rows) *i* and *j* in the data matrix is then

$$ED_{ij} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk} \right)^2} \tag{0.1}$$

where *p* is the number of descriptor variables.

Cluster Analysis

The goal of cluster analysis is to identify distinct groups within multivariate data sets (McGarigal *et al*., 2000). Two methods of hierarchical agglomerative clustering were employed to the standardized length composition data in an attempt to define groups of similar objects. Hierarchical agglomerative clustering algorithms begin by assigning objects to their own groups and then proceed by fusing objects until all objects are part of one group. Non-hierarchical methods such as *k-means* were not used because these methods rely on dividing the objects into a fixed pre-specified number of groups, and there was no *apriori* reason to assume a particular number of groups within the data, particularly as the goal of the analyses is to see if separation of objects into multiple distinct fleets is indeed necessary.

The clustering algorithms used were the unweighted paired-group mean average (UPGMA), and complete linkage. These methods both use the computed distance matrix to cluster objects, but differ in the way in which objects are compared to clusters when joining objects together to form groups. In UPGMA, an object's dissimilarity to a cluster is defined by the mean of the distances between that object and each point in the cluster, whereas complete linkage considers the dissimilarity between entities/clusters to be that between the farthest members in the group, ie the largest dissimilarity. UPGMA maximizes the correlation between the input and output dissimilarities, and is space-conserving. Complete linkage is useful for identifying distinct clusters as it is a space dilating technique where clusters agglomerate slowly.

UPGMA and complete linkage methods were applied to the calculated distance matrix, and the resulting clustering solutions examined for distinct group structure. The resulting dendrograms of relationships among clusters / objects were delineated at several points to examine the resulting cluster structure for a given number of groups.

18.4.2.3 Ordination

While clustering methods are used to define groups in the data, they do not give any indication as to the ecological relationships that produce the clustering solution. Ordination techniques organize objects along gradients defined by combinations of the descriptor variables, and aim to allow interpretation of multivariate data by reducing the dimensionality of the data set to a small number of major gradients in variability. The placing of objects in ordination space can then be correlated to descriptor variables through the correlation of descriptor variables with the axes used in the ordination.

Principal Components Analysis (PCA) is a commonly used ordination technique that uses the Euclidean distance matrix to derive *p* principal components (where *p* is the number of descriptor variables) which are linear combinations of the descriptors that maximize the variance explained in the distance matrix. The desired outcome is that a large proportion of the variability within the data set can be summarized by a few principal components. Once the principal components have been derived, PC scores for the objects in the analysis can be calculated to arrange the data along these new axes (Everitt 2004).

PCA was applied to the standardized data matrix, and the resultant eigenvalues of the principal components were examined to determine which components should be retained for summarizing the ordination. As the data were standardized prior to the analysis, the method deals with the correlation matrix, and the sum of the eigenvalues from the PCA is equal to the number of variables in the analysis. The value of the individual eigenvalues relative to this sum indicates the amount of variance explained by that principal component. In general, eigenvalues greater than 1 are considered significant. In addition, the PCA eigenvalues were also compared to the values expected if the proportions of variance explained were generated at random and sorted in descending order, the so-called broken stick distribution (e.g. Everitt 2004). Eigenvalues greater than that expected under the broken stick are considered significant in terms of retention in the ordination procedure. Correlation of descriptor variables with the retained principal components were compared to the retained PC scores for the length composition objects in order to explain the distribution of these objects in the ordination space. Initial analyses suggested that length compositions from the Cascade Plateau (CASC) and New South Wales seamounts (NSM), along with those from the NSW slope area were distinct outliers, and their presence was perhaps preventing identification of structure among the remaining objects. The PCA was therefore also run on a data set in which the length compositions from these areas were removed prior to standardization.

18.4.2.4 Linear Discriminant Analysis

While PCA summarises variability in the data in terms of the descriptor variables, it does not formally describe how distinct groups of objects differ. Discriminant analysis is an eigenanalysis technique similar to PCA that is used to identify combinations of the descriptor variables that maximize the variation between two or more groups of objects (McGarigal *et al*., 2000). The linear combinations of discriminating variables are known as *canonical functions*, and as well as providing optimal separation among groups, provide details as to what variables contribute most to the separation among groups. Once the canonical functions are derived, they can be used to predict group membership for unknown (or known) objects based on the values of the discriminating variables.

The length compositions in the data matrix are well-placed in a number of distinct grouping structures. Data can be grouped by gear type, zone, and year. In terms of identifying fleets, understanding how zone and gear contribute to separation of objects is of particular interest. If either of these grouping variables result in discriminating canonical functions that enable reliable estimation of group membership, then it can perhaps be assumed that these groupings correspond to distinct structures within the length composition data. Similarly, if separation of objects is possible by year, then this would be an indication of little ‘fleet’ structure, with say inter-annual cohort variability dominating the variability within the data (ie. noise rather than a signal). Linear discriminant analyses were performed on both the complete standardized dataset and the subset of the data with seamount and NSW data removed, as with PCA. In addition to gear, zone, and year, several further groupings of objects were developed that related to higher levels of the gear and zone groupings. Grouping structures considered included: zone; gear; year; zone & gear; east/west of Bass Strait; trawl/non-trawl; gear & east/west; and east/west & trawl/non-trawl.

The performance of each of the discriminant analyses at creating separation among groups was assessed by the ability of the canonical functions to correctly assign group membership. This was done using leave-one out cross-validation (Venables and Ripley, 2002) whereby the discriminant analysis was performed *n* times (where *n* is the number of objects), each time removing 1 of the length compositions from the data set, deriving the canonical functions without that data, and then predicting the group membership of the data left out of the analysis. In the absence of very large datasets where it is possible to separate data into 'training' and 'testing' sets, this method prevents optimistic predictions of correct classification rate exhibited when the canonical functions are used to predict group membership for the same data they were derived from. The classification rate of a particular discriminant analysis (group structure) is then the percentage of group-membership predictions that are correct using this method.

18.4.3 Results

18.4.3.1 Cluster analysis

The results of the cluster analyses varied slightly with the clustering algorithm (UPGMA vs complete linkage). In general however, the data from the seamount areas (CASC and NSM) were the slowest objects to fuse with other clusters during the agglomeration, forming their own distinct clusters. However, the CASC objects tended to remain separated in single-member clusters rather than forming their own distinct group, suggesting that although these data are different from the remainder, there is a large amount of variation within this group. A small number of samples from EVIC also formed a slow-fusing cluster. The data from the NSW slope area also fell out fairly cleanly. Visually, there appeared to be little structure among the remaining data, although the clustering methods tended to place these data into two large groups. However, it was not clear from the grouping variables (e.g. gear type, zone) how these groups differed. Figure 18.2 plots the UPGMA results in ordination space (along PC I and PC II, see below), for grouping structures determined by intersecting the cluster dendrograms at heights resulting in 4, 5, 6, and 7 clusters. The cluster structure for complete linkage at these groupings was the same.

18.4.3.2 Ordination

Table 18.2 shows the eigenvalues corresponding to the principal components derived from the PCAs on the full data set, and the subset following removal of data from seamounts and NSW. Values greater than 1 are shaded, which implies retention of the first three principal components for both analyses. For the complete data set, the eigenvalues for the first two principal components are greater than those expected under a broken-stick distribution (Table 18.2) and together, these two components account for

69% of the variation in the data (increases to 81% with PC III). Figure 18.3 plots the length composition objects in ordination space along these first two principal components (PC I and PC II), and also shows the correlation of the thirteen length bins with these components. The presence of large fish (>75 cm) was negatively correlated with PC I, whereas the presence of small fish was positively correlated with this same axis. This led to the separation of CASC, NSW, and NSM data (which contained higher proportions of larger fish than continental slope areas) along this axis. Separation of objects in ordination space along PC II was largely due to a positive correlation with the presence of juvenile post-recruit fish of length 55 –65 cm in the length compositions (Figure 18.3). Figure 18.4 plots the data along principal components I and II when the seamount and NSW data were removed from the analysis. Table 18.2 demonstrates that these components only account for 60% of the variance in the data (73% with PC III), and indeed that only the loadings on PC I are significant under the broken stick. Figure 18.4 shows a somewhat similar pattern to the previous PCA (Figure 18.3), however it is much easier to observe the structure among objects in ordination space with the outliers removed. PC II appears almost completely dominated by a positive correlation with the 55cm length bin, whereas presence of mid-size to large fish (>65 cm) are more correlated with PC I. There appears to be some separation of east and west zones along PC I, with western Tasmania (WTAS) data being dominated by small recruits (fish <55 cm). Figure 18.4 also plots the data in terms of the gear type, and there seems to be little pattern, except for perhaps some separation of bottom trawl (BT) data from other gear types along PC I.

18.4.3.3 Discriminant analysis

Table 18.3 shows the performance of the different levels of grouping variables used in the dsicriminant analyses, by means of the correct-classification rate resulting from the leave-one out cross-validation. High classification rate indicates that the canonical functions derived from the discriminant analysis do well at separating objects among groups, that is the variability in the grouping variables correlates well with that in the descriptor variables. Performance of the different groupings was very similar for both the complete data set and the ‘slope’ subset. Unsurprisingly given the results of the cluster analyses and PCA, the analysis on the full data set with zone defining the group structure was excellent at correctly classifying data from the Cascade Plateau and New South Wales. The classification rates for year as the grouping were very low (<20%), although with 22 years in the data this is greater than would be expected by chance, perhaps indicating that there is indeed some consistency among length data from the same year.

Zone appeared to account for some degree of separation among objects when it was used as the grouping variable, with a classification rate of 54% on the subset of the data, even when the atypical seamount data had been removed (Table 18.3). Figure 18.5 shows the results of this analysis by plotting the canonical scores for the objects given the first two canonical functions. Canonical axis 1 appears to separate objects as to their locations east and west of Bass Strait, whereas canonical axis 2 provides separation between objects from Tasmania and Victoria (Figure 18.4). Gear type had a similar correct-classification rate to zone (Table 18.3), and Figure 18.6 shows the positions of the length composition objects along the first two canonical axes, for the slope data subset. Axis 1 provides separation of meshnet data from the other gear types, and axis 2 is able to distinguish largely the bottom trawl length compositions from the dropline and longline data, although there is some degree of overlap.

Gear type and zone, along with year, are typically the most frequently reported grouping structures in the length composition data. However, other group labels can be assigned to objects based on either combinations of these, or some higher level property of the data. Table 18.3 lists the correct-classification rates for these additional groups, with the highest classification rates occurring when the dimensionality of the group structure is reduced to two, either east/west of Bass Strait, or whether the gear type is trawl or not. These seem consistent with the results of the PCAs presented in Figure 18.4. Figure 18.7 plots the canonical scores for the ‘east/west & trawl/non-trawl’ grouping for the slope dataset (4 groups). This grouping gave a similar correct-classification rate to grouping by zone (Table 18.3), however although there appears to be a good east/west separation along Axis 1, the E.T (BT from EVIC and ETAS) does not seem to be distinct (Figure 18.7). It is to be noted that Figure 18.5, Figure 18.6, and Figure 18.7 only plot the data along the first two canonical functions, whereas the classification rates in Table 18.3 are based on all the canonical functions obtained in the discriminant analysis. Therefore, there may be additional structure in the separation among groups that is not visually apparent in two dimensions.

18.4.4 Discussion

The results of the analyses described above indicate that there is indeed some pattern in the variability of blue eye trevalla length compositions, both in space and by gear type. Compared to spatial and gear effects, time was relatively unimportant in accounting for variability in the data. This suggests that the structure observed in the fishery is somewhat consistent, despite cohort variability. Availability to fishing of larger blue eye on seamounts has been well-documented, and the methods employed here clearly identified that the length composition of these landings are very different from those on the continental slopes. However, these analyses do not address the question whether the larger fish on seamounts represent faster growth in these areas, or simply differential availability of these larger individuals, perhaps due to a lack of non-target species at the depths fished from seamounts (which is one reason for the avoidance behaviour displayed by fishers for larger fish the slope habitats). The separation of data from NSW is unsurprising, as the fishery in this area is very different from that in the SESSF, and is subject to different data reporting requirements due to different jurisdictional authority. As such, the source of these data (in addition to the similarity of slope topography that far north to other zones in the SESSF) are highly uncertain.

Differences between western and eastern zones within the SESSF slope areas (WVIC and WTAS vs. EVIC and ETAS) appears to be due to differences in the relative proportions of both new-recruits, and mid-size juveniles/pre-adults, with compositions from eastern zones having lower proportions of the latter. This might reflect the sequential nature of the fishery, which was historically focused in eastern areas and has only recently begun to exploit the blue eye resource off western Victoria. The length composition of blue eye landings from bottom-trawls were typified by higher proportions of small fish relative to large fish (Figure 18.4), which is perhaps not unexpected given that the trawl fishery intercepts these new recruits as they migrate off the continental shelf from the pelagic juvenile phase to pre-adulthood on the slope. There was a great deal of overlap among the gear types however, with many dropline compositions also containing high numbers of new recruits. The difference between gear types may have been more distinct had the analyses been based on the length composition of the total catch, estimates of which are available from onboard observer data, as there is likely differential discarding rates by gear (fish smaller than 40-45 cm are generally not considered marketable). There was no real evidence to suggest any further structuring of the data by gear type, which perhaps means that droplining and longlining operations can be considered together. This is of interest, as the trend in the fishery lately has been away from dropline and towards automatic demersal longlining. It is likely that the latter method is capable of higher levels of fishing mortality however, and the small number of length samples from this gear type in the analysis suggests caution in assuming that these gears exhibit the same selectivity.

In general, the cluster analyses were less useful at identifying trends in data variability than the PCAs and discriminant analyses. This is in part because cluster analysis provides no meaning as to what ecological relationships are driving differences among groups, and also because *aprioi* knowledge of potential grouping variables (*e.g.* gear type, zone) are not incorporated. However, the lack of discernible structure among groups in the cluster analyses following identification of the seamount and NSW data might indicate that the patterns observed in the ordination and discriminant analyses are not that cohesive. Indeed, the low correct-classification rates of objects to groups following discrimination (Table 18.3) suggests that this may be the case. Alternatively, between-group variance for the slope data may simply just not be as high as that for slope vs. seamount data, which is probably to be expected.

Care should be exercised when interpreting performance of the discriminant analyses by classification rate, as the degree to which the analysis does better than chance depends on the number of groups in the data. Inspection of classification matrices which show exactly where misclassification of objects is occurring may be useful in identifying fleet structure. Additional caveats with the linear discriminant analyses are that the procedure requires equal within-group variance, and sufficient sample size by group for best performance (McGarigal *et al*., 2000). When grouping by gear, the longline and meshnet types have much lower membership than the dropline and trawl, and this may have influenced the results, perhaps explaining why the trawl/non-trawl classification (which placed these small groups with the more numerous dropline data) did better. Seamount areas also exhibited low sample size compared to the slope areas, however the impact of these on the analyses was assessed by removing them from the dataset.

The interpretation of the results from the PCAs is also not without caution. PCA depends heavily on assumptions of multivariate normality, and that Euclidean distance is an appropriate metric of dissimilarity among objects. While univariate normality does not necessarily imply multivariate normality (Everitt *et al*., 2004), qq plots of the input descriptor variables and PC scores definitely demonstrate non-normal properties. However, typical transformations of the data (*e.g.* square root, arcsine) prior to analysis did not produce noticeable differences in the results of the PCA, suggesting that the results obtained are at least somewhat robust.

Overall then, the results seem to indicate that the vulnerable populations on seamounts and NSW are distinct from those in SESSF slope zones, that there are differences east and west of Bass Strait, and that bottom trawl landings are distinct from those of other gear types. These findings suggest a definite structure when delineating fleet types. However, similarities (or differences) among annual length compositions for various zonal / gear combinations might not necessarily reflect a similar structuring in the population, or indeed that the selective impacts of fishing are the same. The seasonal availability of different lengths of Blue eye trevalla to the fishery is thought to vary spatially, and observed structuring of the annual length data might reflect variability in the intensity of sampling relative to fishing effort among seasons. Breaking apart the data by season is possible, but would result in dilution of information among objects, resulting in noisier data, and perhaps provide less opportunity for discerning any general pattern. Blue eye also exhibit high variability in length at age, with new recruits to the fishery being of similar size but ranging in age from 2 to 5 years. Any spatial variability in the vulnerability of individual cohorts would also complicate the structure observed in the length data. This could be addressed by conducting these analyses on age composition data rather than lengths, however the data requirements for this (sufficient numbers of fished aged each year for each zone and gear type) are beyond that available. Not included in this study was any attempt to quantify the impact of sampling variability on the results. Objects with low sample size were removed to address this, but the cut-off of 100 fish was arbitrary. Inclusion of some of the smaller samples produced more outliers in the PCAs, the locations of which in ordination space did not follow the patterns discussed above. A simulation approach which addressed the robustness of the applied methods to sample size impacts and other sources of uncertainty could be envisaged. Finally, complementary analyses of abundance trends could also provide information as to the validity of the fleet structuring implied by the results presented here. This would require dealing with the very ‘noisy’ catch and effort data for the fishery, however, agreement between the analyses in terms of fishery components that behave similarly would clearly further support the results obtained from length data.

Despite the limitations discussed above, the methods employed here provide concise means of summarizing the multivariate nature of composition information so that structuring within the fishery can be assessed. At the very least, they do provide direction for delineation of fleets/spatial areas for further analyses of the fishery, including stock assessment.

18.4.5 References

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18.4.6 Tables

Table 18.1. Abbreviations used for areas and gear types

Area		Gear	
NSW	New South Wales	BT	bottom trawl
EVIC	Eastern Victoria & Bass Strait	DL	dropline
ETAS	Eastern Tasmania	LL	demersal longline
WTAS	Western Tasmania	MN	meshnet
WVIC	Western Victoria & Bass Strait		
CASC	Cascade Plateau		
NSM	New South Wales seamounts		

Table 18.2. Eigenvalues and variance explained for the principal components analyses. Values in bold represent those higher than expected under a broken stick distribution assumption, shaded values are greater than 1.

	Principal Components												
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**XIII**
Broken Stick	3.18	2.18	1.68	1.35	1.10	0.90	0.73	0.59	0.46	0.35	0.25	0.16	0.08
All data													
eigenvalues	**5.65**	**3.32**	1.52	0.88	0.67	0.45	0.20	0.18	0.07	0.03	0.01	0.01	0.00
% variance explained	0.44	0.26	0.12	0.07	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
cumulative % variance	0.44	0.69	0.81	0.88	0.93	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
No CASC, NSW, NSM													
eigenvalues	**5.93**	1.91	1.59	0.99	0.83	0.58	0.41	0.29	0.25	0.09	0.08	0.04	0.00
% variance explained	0.46	0.15	0.12	0.08	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.00
cumulative % variance	0.46	0.60	0.73	0.80	0.87	0.91	0.94	0.96	0.98	0.99	1.00	1.00	1.00

Table 18.3. Correct-classification rates (%) for the discriminant analyses using leave-one out cross validation.

Grouping variable	Classification rate
all data	
zone	0.51
gear	0.6
gear & zone	0.38
year	0.16
'slope' data (no CASC/NSW/NSM)	
zone	0.54
gear	0.58
year	0.17
east/west	0.76
trawl/non-trawl	0.75
gear & zone	0.36
gear & east/west	0.40
east/west & trawl/non-trawl	0.52

18.4.7 Figures

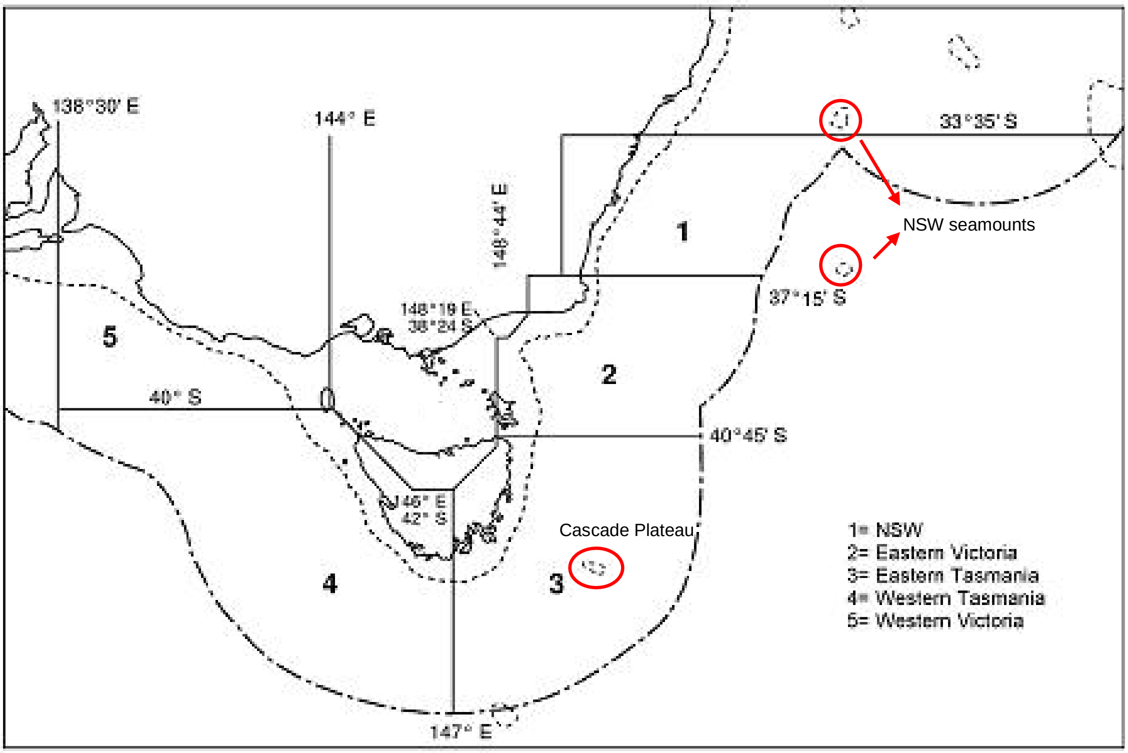


Figure 18.2. Geographic location of zones within the SESSF.

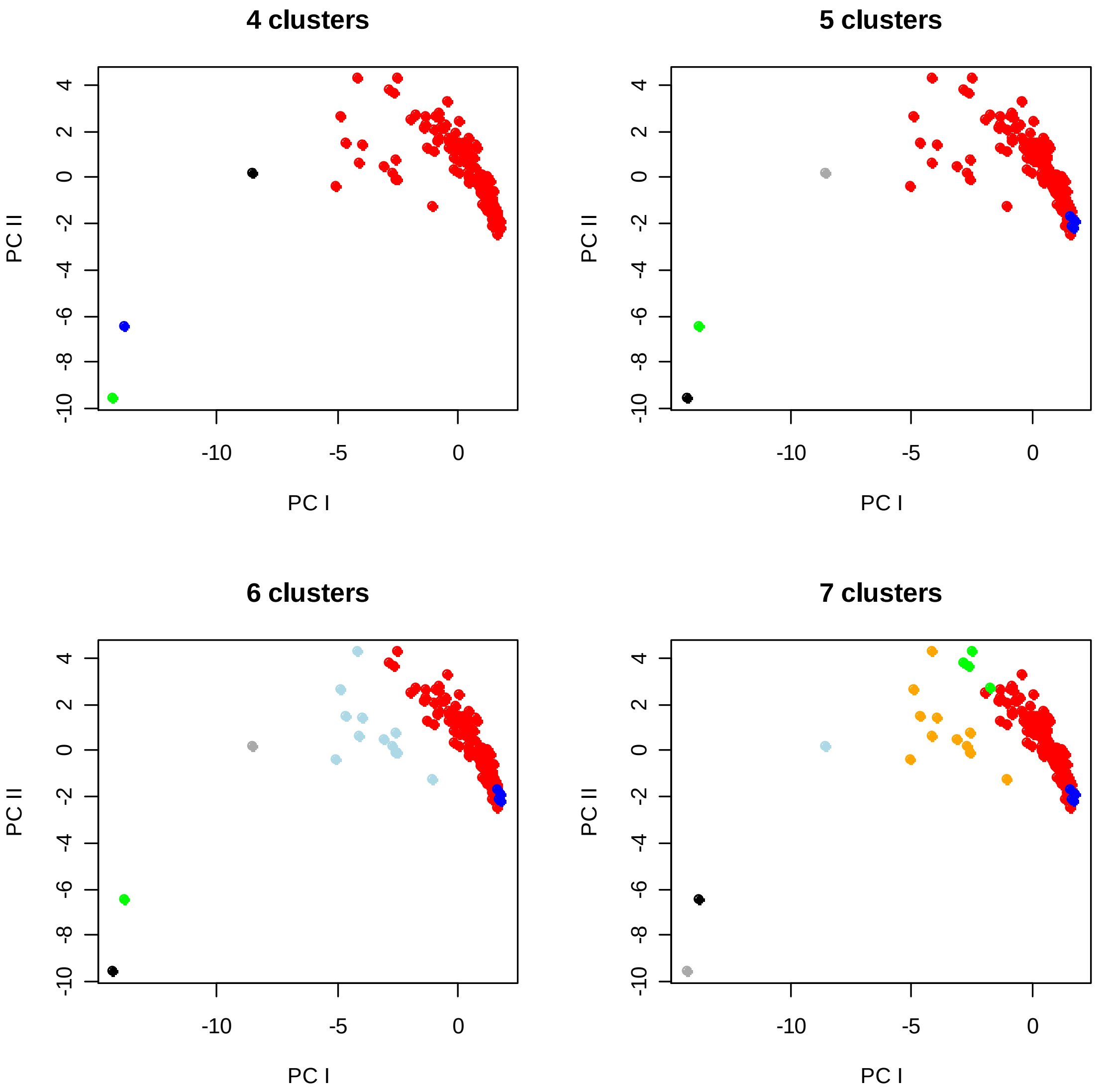


Figure 18.3. Cluster structure along PC I and PC II resulting from UPGMA clustering when there are four, five, six, and seven clusters. Each color represents a different cluster.

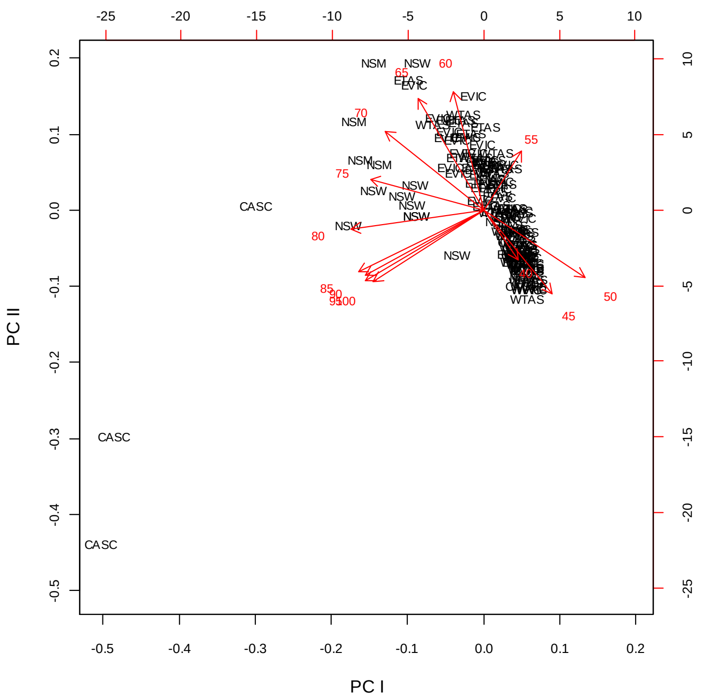
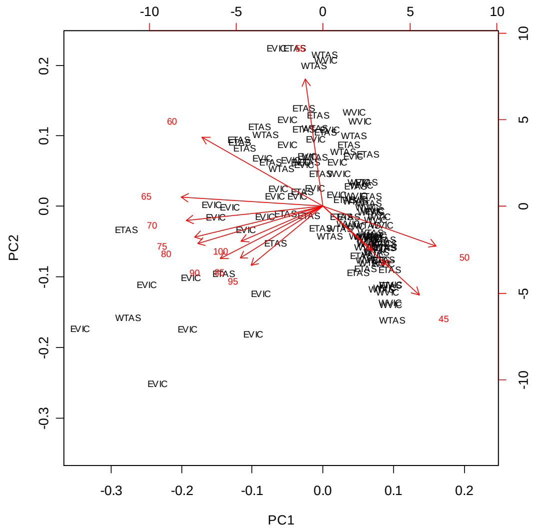


Figure 18.4. Ordination plot of length compositions along principal components I & II, derived from the PCA on the full standardized dataset. Arrows indicate correlations of length bins with the principal components. Individual length compositions are plotted by zones.



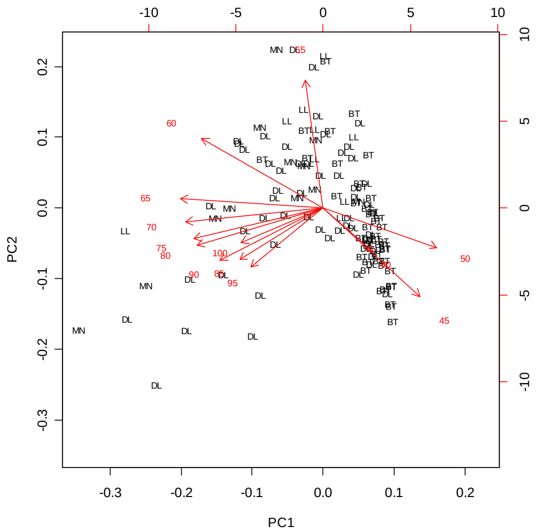


Figure 18.5. Ordination plot of length compositions along principal components I & II, derived from the PCA with CASC/NSM/NSW data removed. Arrows indicate correlations of length bins with the principal components. PC II was not considered significant under a broken-stick distribution for this analysis. Plotting characters for each length composition correspond to zones (left panel) and gear type (right panel).

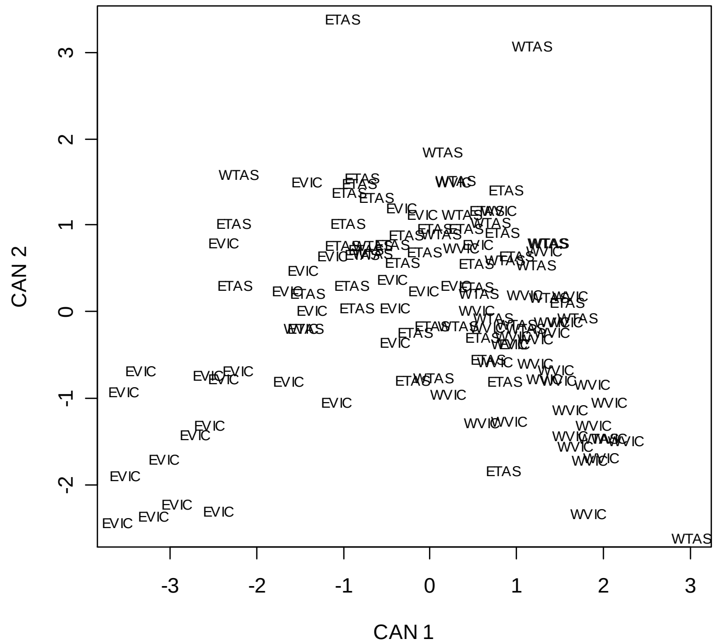


Figure 18.6. Canonical scores for Discriminant analysis of 'slope' length compositions grouped by zone.

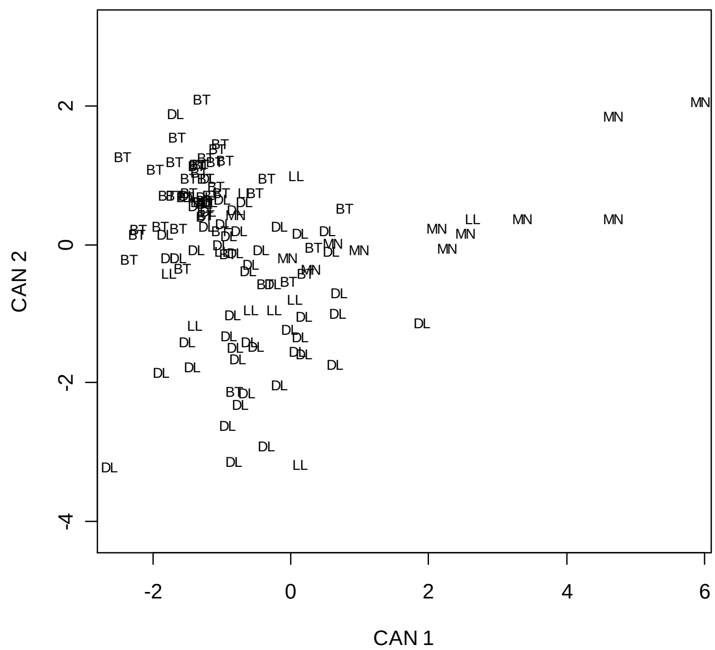


Figure 18.7. Canonical scores for the Discriminant analysis of 'slope' length compositions grouped by gear type.

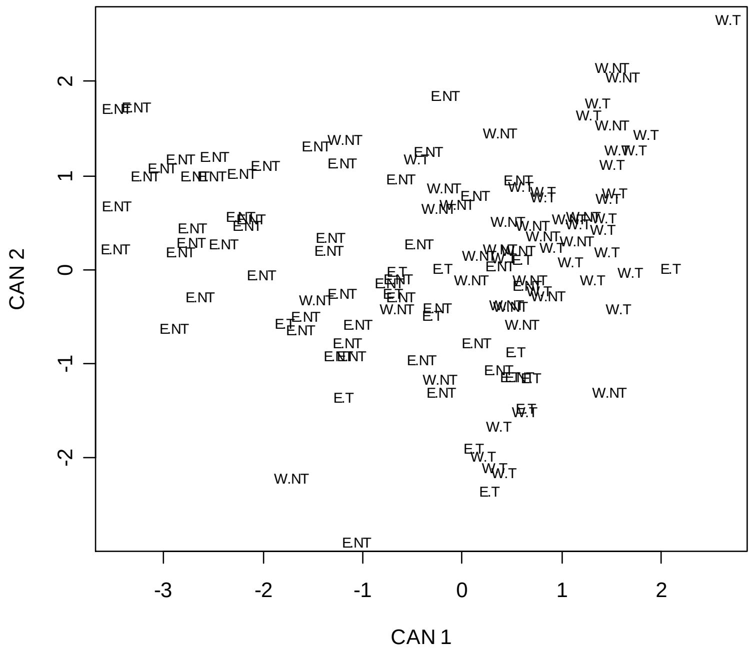


Figure 18.8. Canonical scores for the Discriminant analysis of ‘slope’ length compositions grouped by East/West and Trawl/Non-Trawl.

19. TIER 4 Analyses 1994 - 2006

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19.1 Introduction

The TIER 4 harvest control rules are the fall back procedure applied to species with the least amount of information. Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher TIER analyses. In essence TIER 4 analyses require knowledge of the time series of total catches and of catch rates, either standardized or simple geometric mean catch rates.

19.2 Methods

19.2.1 Calculation of the Recommended Biological Catch

A simple regression of catch rates against year over a four year time frame is used to provide a gradient which acts as a multiplier for the average catch over the same four year period. If the gradient is positive the Recommended Biological Catch (RBC) may increase and if the gradient is negative the RBC may decrease. The RBC is used to decide what future Total Allowable Catch (TAC) will apply. The analysis includes a regression of catch rates against years to generate the gradient used to modify the average catch:

$$CE_i = \text{Intercept} + \text{Gradient} \cdot \text{Year}_i$$

where CE_i is the catch rate (relative to the catch rate in 1994) for a sequence of *i* years, *i* is 1 to 4, the Intercept and Gradient are the parameters of the linear regression, and Year_i is simply the sequence of the four most recent years (though the gradient may be calculated for any sequence of four years).

The use of catch rates standardized relative to 1994 puts all analyses onto the same scale and leads to more consistent results and removes the need to use arbitrary alpha values for each species. The scaling of the relationships brought about by using different absolute levels of catch rate confuse the analyses and highlight the advantages of scaling the catch rate data relative to 1994 (Haddon, 2006). The analyses have been conducted on total catches across the entire SESSF. For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (Haddon, 2007; relative to rates in 1994). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of catch rates to use in the analyses is not always straightforward. In those cases, the standardized time series accounting for the majority of catch was used (relative to 1994) in the regressions. For some species, (i.e. John Dory, Mirror Dory, and Ribaldo, new standardizations were conducted as described in each of those sections).

The fact that the catch rates are relative to catch rates in 1994 was the subject of much discussion this year. It was decided that the analyses would be more correct if the regression estimates could be made independent of whichever year was chosen as the standard year. The simplest solution is to regress the natural logarithm of catch rates:

$$Ln(CE_i) = Intercept + Gradient \, . \, Year_i$$

In the following tables, the first set of RBC analyses reflects the analysis as conducted last year, below the diagrams for each species is a further table of RBC values that derive from the log-transformed data. It is recommended that these values be used to make management decisions.

The RBC is defined as:

$$RBC = (1 + \alpha \, . \, Gradient) * C_{CUR}$$

where α is a constant, which determines the sensitivity of the of the analysis to changes in the catch rate, the Gradient is derived from the regression between catch rates and year, (for the previous 4 years) and C_{CUR} is the total removals that includes total SEF catch by trawl and non-trawl, State catches, and discards, averaged over the previous four years.

By regressing against the proportional changes in catch rates rather than absolute catch rates, difficulties in setting the alpha value (the multiplier on the gradient in the equation above) to values that suite all species are alleviated. The alpha value determines the sensitivity of the analysis to changes in the gradient of any trend in the catch rates. Values of alpha greater than one obviously will magnify the impact of changes in the gradient. It is recommended that values of alpha greater than one not be used.

All data relating to catches and discards from State waters and SEF2 data sets were provided by Matt Koopman of PirVIC with assistance from Anne Gason.

All catch rate data were derived from the standard GenLog database provided by Mike Fuller of CSIRO Hobart.

Standard analyses were setup in Excel, which provided the tables and graphs required for the TIER4 analyses. Instead of simply giving the statistics for the last four year the trends that have occurred from 1994 to 2006 are presented so as to make trends through time apparent. This provides an appreciation of the stability of the TIER 4 analysis for each species considered.

19.2.2 Estimation of Weighted Average of Discards for TAC calculation

The RBC for the 2008 depends on being able to predict the discards in 2007. Rather than simply taking the average discards from 2003-2006 it was decided and approved by the RAG to take a weighted average of the discards from the previous four years. The schedule of weights is 1:0 for 2006, 0.5 for 2005, 0.25 for 2004 and 0.125 for 2003. This obviously places more weight on the most recent year. The calculation of discards (D) in year *i* is taken as:

$D_i = (1.0D_{i\text{-}1} + 0.5D_{i\text{-}2} + 0.25D_{i\text{-}3} + 0.125D_{i\text{-}4})/1.875$

The TAC for 2008 is taken to be the RBC for 2008 minus the weighted average of discards from 2003-2006. The estimate D_i is presented in the report for each species.

19.3 Results

For the SLOPE assessment group TIER 4 analyses were required for eastern Blue Warehou, Western Gemfish, and both inshore Ocean Perch and Offshore Ocean Perch.

19.4 Discussion

The use of averaged catches over the previous four years certainly smoothes the catch history. However, its use could lead to a change in catches between years even when the analysis recommends no change (i.e. exhibits a zero slope). All that would be required is for catches in previous years to be higher than in the most recent year and a zero change will still lead to a reduction from the previous year’s catch.

More analyses, comparisons, and discussion concerning the implications of the TIER 4 analyses are required.

19.5 Blue Eye (TBE – 37445001 – Hyperoglyphe antarctica)

Table 19.1. Blue Eye Trevalla. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 20 and 30 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	413.202		1.0000	0.000	324.037	0.000	89.210
1995	634.436		0.6973	0.000	567.053	0.000	67.388
1996	893.081		0.5610	0.000	811.820	0.000	81.300
1997	732.786	668.376	0.5162	0.000	620.157	0.000	112.644
1998	599.413	714.929	0.5877	0.000	123.012	380.439	95.962
1999	706.643	732.981	0.5963	0.000	132.608	464.658	109.377
2000	780.525	704.842	0.3930	37.000	89.462	565.410	88.653
2001	698.345	696.231	0.3809	33.000	77.613	478.397	109.335
2002	615.479	700.248	0.3913	0.100	102.362	427.969	85.048
2003	651.112	686.365	0.3763	0.160	51.623	556.565	42.764
2004	716.534	670.367	0.3784	1.400	64.457	566.917	83.760
2005	549.170	633.074	0.3823	0.000	55.587	450.678	42.905
2006	603.553	630.092	0.4238	0.060	42.776	493.851	66.866

Table 19.2. Blue Eye Trevalla. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.15878), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **0.229** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	413.202					
1995	0.6973	634.436					
1996	0.5610	893.081					
1997	0.5162	732.786	668.376	-0.15878	562.249	456.121	243.866
1998	0.5877	599.413	714.929	-0.03737	688.213	661.498	608.066
1999	0.5963	706.643	732.981	0.01774	745.987	758.993	785.005
2000	0.3930	780.525	704.842	-0.03609	679.407	653.972	603.103
2001	0.3809	698.345	696.231	-0.08236	638.889	581.546	466.862
2002	0.3913	615.479	700.248	-0.06272	656.329	612.409	524.571
2003	0.3763	651.112	686.365	-0.00397	683.640	680.915	675.464
2004	0.3784	716.534	670.367	-0.00223	668.872	667.376	664.384
2005	0.3823	549.170	633.074	-0.00248	631.506	629.937	626.801
2006	0.4238	603.553	630.092	0.01462	**639.302**	**648.512**	**666.932**

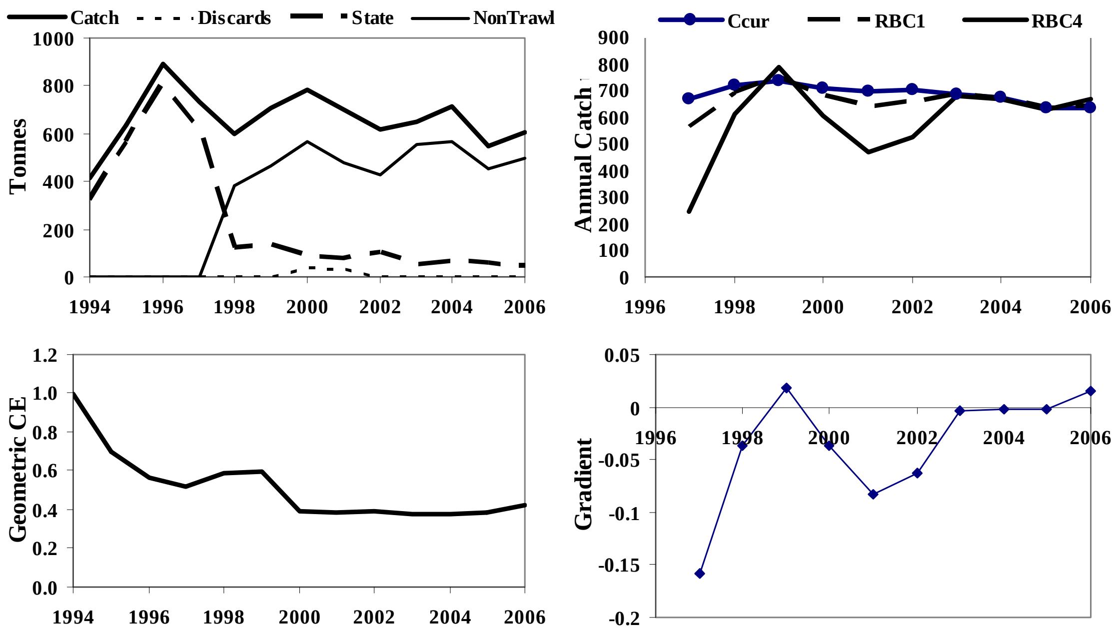

Figure 19.1. Plots of the various analyses for Blue Eye Trevalla using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Blue Eye.

Year	RBC1	RBC2	RBC4	LnGrad
1997	521.230	374.083	79.790	-0.22016
1998	672.292	629.656	544.383	-0.05964
1999	755.914	778.848	824.715	0.03129
2000	648.226	591.611	478.379	-0.08032
2001	576.629	457.026	217.821	-0.17179
2002	609.538	518.829	337.410	-0.12954
2003	679.272	672.180	657.994	-0.01033
2004	666.456	662.544	654.721	-0.00584
2005	629.027	624.981	616.889	-0.00639
2006	**653.173**	**676.254**	**722.416**	0.03663

19.6 Blue Grenadier (GRE – 37227001 – Macruronus novaezelandiae)

Table 19.3. Blue Grenadier. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for the spawning fishery (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	3282.175		1.0000	0.000	126.682	0.000	3155.493
1995	2812.359		0.5342	0.000	51.541	0.000	2760.818
1996	3078.789		0.7941	0.000	40.338	0.000	3038.451
1997	4550.755	3431.020	0.6172	0.000	17.700	0.000	4533.055
1998	8704.683	4786.647	0.6543	2959.000	12.824	0.000	5733.742
1999	9473.962	6452.047	0.5765	140.000	8.359	0.000	9325.603
2000	8784.402	7878.450	0.6058	129.000	0.599	0.000	8654.803
2001	9129.199	9023.061	0.9822	1.000	0.469	3.684	9124.046
2002	9169.997	9139.390	0.6586	5.270	0.011	3.808	9160.908
2003	8492.643	8894.060	0.5467	9.810	0.057	8.925	8473.851
2004	6428.639	8305.120	0.4496	27.190	0.042	9.878	6391.529
2005	4819.716	7227.749	0.8216	526.640	0.071	10.222	4282.783
2006	3968.832	5927.458	1.5418	246.830	0.077	11.442	3710.484

Table 19.4. Blue Grenadier. The trawl CPUE is the standardized mean catch rate data from the spawning fishery relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.08885), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **276.359** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	3282.175					
1995	0.5342	2812.359					
1996	0.7941	3078.789					
1997	0.6172	4550.755	3431.020	-0.08885	3126.157	2821.294	2211.569
1998	0.6543	8704.683	4786.647	0.01835	4874.502	4962.357	5138.067
1999	0.5765	9473.962	6452.047	-0.06156	6054.884	5657.721	4863.395
2000	0.6058	8784.402	7878.450	-0.01119	7790.321	7702.192	7525.934
2001	0.9822	9129.199	9023.061	0.10130	9937.117	10851.174	12679.286
2002	0.6586	9169.997	9139.390	0.06228	9708.562	10277.734	11416.077
2003	0.5467	8492.643	8894.060	-0.05009	8448.547	8003.033	7112.006
2004	0.4496	6428.639	8305.120	-0.17097	6885.189	5465.259	2625.398
2005	0.8216	4819.716	7227.749	0.03918	7510.961	7794.174	8360.598
2006	1.5418	3968.832	5927.458	0.33571	**7917.362**	**9907.267**	**13887.076**

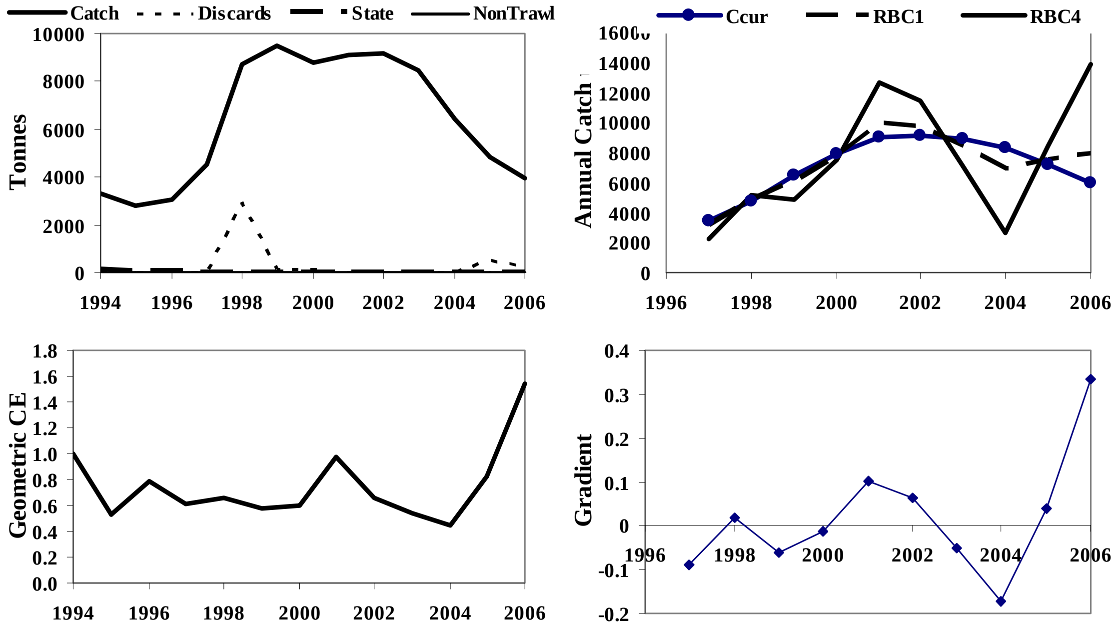

Figure 19.2. Plots of the various analyses for Blue Grenadier using Standardized CPUE from the spawning fishery relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Blue Grenadier

Year	RBC1	RBC2	RBC4	LnGrad
1997	3070.311	2709.601	1988.183	-0.10513
1998	4957.340	5128.033	5469.419	0.03566
1999	5870.000	5287.954	4123.860	-0.09021
2000	7734.836	7591.222	7303.995	-0.01823
2001	10167.404	11311.747	13600.433	0.12682
2002	9946.158	10752.926	12366.462	0.08827
2003	8264.702	7635.344	6376.627	-0.07076
2004	6203.597	4102.075	0.000	-0.25304
2005	7565.851	7903.953	8580.157	0.04678
2006	**8128.346**	**10329.235**	**14731.013**	0.37130

19.7 Blue Warehou East (TRT – 37445005 – Seriolella brama)

Table 19.5. Blue Warehou East. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 10, 20, and 30 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	901.519		1.0000	0.000	453.110	0.000	448.409
1995	777.404		0.9867	0.000	326.364	0.000	451.040
1996	1008.168		0.8970	0.000	373.121	0.000	635.046
1997	690.588	844.420	0.8943	0.000	190.547	0.000	500.041
1998	887.072	840.808	0.8812	15.202	266.850	79.291	525.729
1999	730.865	829.173	0.7559	2.515	283.003	287.743	157.604
2000	408.862	679.347	0.4382	6.185	113.480	81.015	208.182
2001	153.004	544.951	0.3962	25.661	25.980	29.412	71.951
2002	148.094	360.206	0.2284	1.116	71.886	3.720	71.372
2003	100.911	202.718	0.1772	7.646	42.301	1.191	49.773
2004	155.645	139.414	0.2175	61.624	31.148	0.932	61.941
2005	61.400	116.513	0.1538	18.307	17.198	0.808	25.087
2006	61.896	94.963	0.1695	4.147	26.390	0.551	30.809

Table 19.6. Blue Warehou East. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.04067), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **15.820** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	901.519					
1995	0.9867	777.404					
1996	0.8970	1008.168					
1997	0.8943	690.588	844.420	-0.04067	810.077	775.733	707.047
1998	0.8812	887.072	840.808	-0.03190	813.983	787.159	733.510
1999	0.7559	730.865	829.173	-0.04363	792.996	756.819	684.464
2000	0.4382	408.862	679.347	-0.14938	577.865	476.383	273.419
2001	0.3962	153.004	544.951	-0.17728	448.344	351.737	158.524
2002	0.2284	148.094	360.206	-0.16246	301.688	243.170	126.133
2003	0.1772	100.911	202.718	-0.09507	183.445	164.172	125.626
2004	0.2175	155.645	139.414	-0.05873	131.226	123.038	106.663
2005	0.1538	61.400	116.513	-0.01834	114.376	112.239	107.965
2006	0.1695	61.896	94.963	-0.00867	**94.139**	**93.316**	**91.668**

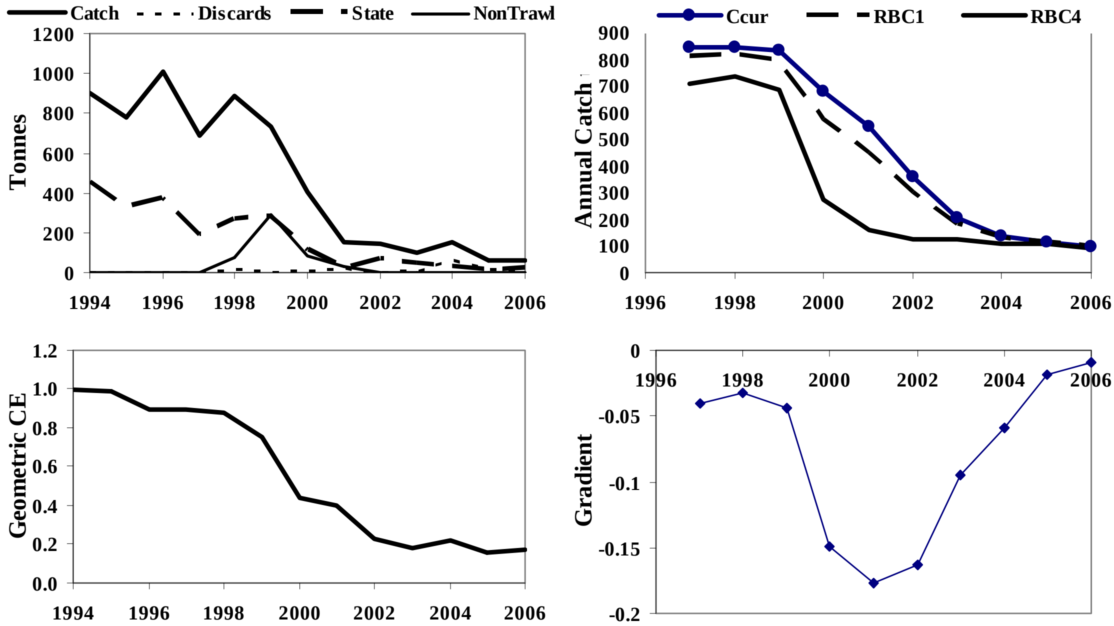

Figure 19.3. Plots of the various analyses for Blue Warehou using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Blue Warehou East.

Year	RBC1	RBC2	RBC4	LnGrad
1997	808.080	771.741	699.062	-0.04303
1998	812.046	783.285	725.761	-0.03421
1999	785.385	741.597	654.022	-0.05281
2000	523.519	367.691	56.035	-0.22938
2001	384.552	224.154	0.000	-0.29434
2002	227.233	94.259	0.000	-0.36916
2003	136.495	70.273	0.000	-0.32667
2004	110.794	82.174	24.935	-0.20529
2005	105.083	93.653	70.793	-0.09810
2006	**90.410**	**85.857**	**76.752**	-0.04794

19.8 Blue Warehou West (TRT – 37445005 – Seriolella brama)

Table 19.7. Blue Warehou East. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 40 and 50 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	406.562		1.0000	0.000	0.000	0.000	406.562
1995	308.911		0.8825	0.000	0.000	0.000	308.911
1996	215.284		0.6662	0.000	0.000	0.000	215.284
1997	290.925	305.420	0.4040	0.000	0.000	0.000	290.925
1998	470.809	321.482	0.6590	70.798	0.000	1.157	398.854
1999	211.027	297.011	0.7543	13.485	0.000	0.048	197.494
2000	236.056	302.204	0.3818	9.815	0.000	1.106	225.135
2001	240.861	289.688	0.3732	13.339	0.000	1.330	226.193
2002	248.604	234.137	0.3739	6.254	0.000	0.000	242.350
2003	214.648	235.042	0.4169	11.844	0.000	0.886	201.918
2004	518.986	305.775	0.4112	319.816	0.000	0.787	198.383
2005	542.403	381.160	0.6633	255.613	0.000	0.510	286.281
2006	663.518	484.889	0.7629	269.173	0.000	0.285	394.060

Table 19.8. Blue Warehou West. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.20043), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **255.154** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	406.562					
1995	0.8825	308.911					
1996	0.6662	215.284					
1997	0.4040	290.925	305.420	-0.20043	244.205	182.990	60.559
1998	0.6590	470.809	321.482	-0.09327	291.499	261.515	201.548
1999	0.7543	211.027	297.011	0.05193	312.436	327.861	358.711
2000	0.3818	236.056	302.204	0.00287	303.070	303.936	305.668
2001	0.3732	240.861	289.688	-0.12299	254.058	218.428	147.168
2002	0.3739	248.604	234.137	-0.11497	207.218	180.299	126.461
2003	0.4169	214.648	235.042	0.01060	237.534	240.026	245.010
2004	0.4112	518.986	305.775	0.01569	310.572	315.369	324.962
2005	0.6633	542.403	381.160	0.08625	414.034	446.908	512.655
2006	0.7629	663.518	484.889	0.12901	**547.445**	**610.001**	**735.114**

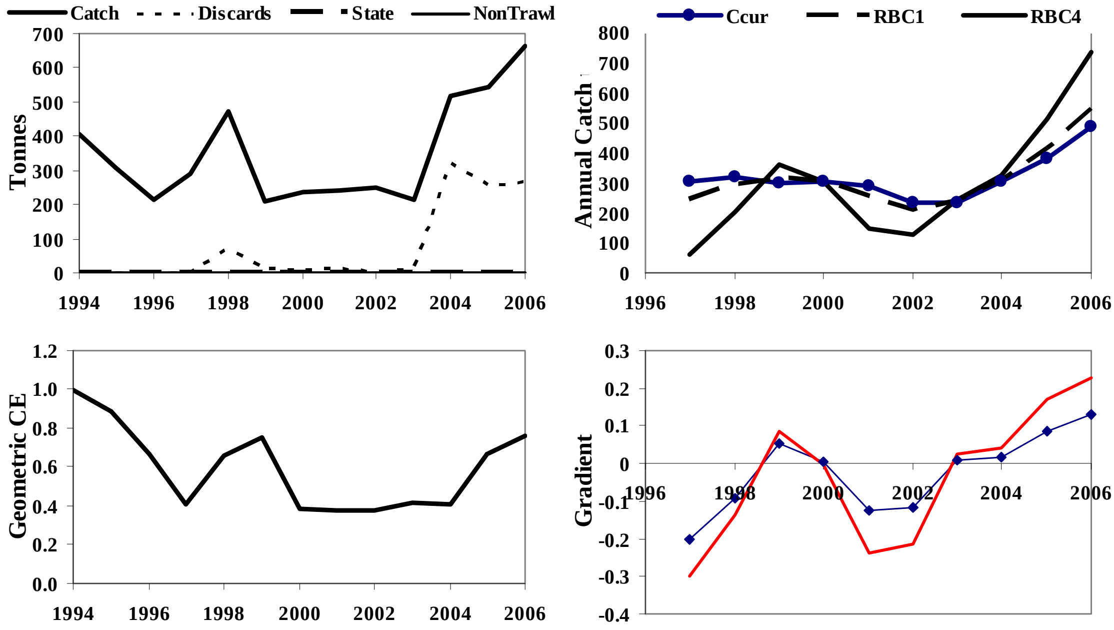

Figure 19.4. Plots of the various analyses for western Blue Warehou using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Blue Warehou West.

Year	RBC1	RBC2	RBC4	LnGrad
1997	213.790	122.159	0.000	-0.30001
1998	277.240	232.998	144.514	-0.13762
1999	322.612	348.214	399.416	0.08620
2000	301.159	300.115	298.025	-0.00346
2001	220.547	151.406	13.123	-0.23867
2002	184.313	134.490	34.843	-0.21280
2003	241.289	247.535	260.029	0.02658
2004	317.989	330.203	354.630	0.03994
2005	446.178	511.195	641.230	0.17058
2006	**595.978**	**707.067**	**929.246**	0.22910

19.9 Flathead (FLT – 37296001 – Neoplatycephalus richardsoni)

Table 19.9. Flathead. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate by trawler for all Zones (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	2786.959		1.0000	0.000	836.206	0.000	1950.753
1995	2735.929		1.0365	0.000	697.065	0.000	2038.864
1996	2725.609		0.9294	0.000	610.327	0.000	2115.283
1997	3093.299	2835.449	0.9330	0.000	419.555	0.000	2673.744
1998	3224.991	2944.957	0.9887	291.000	229.097	0.000	2704.894
1999	3996.333	3260.058	1.1546	267.000	218.125	0.000	3511.208
2000	3938.408	3563.258	1.2583	511.000	191.666	0.000	3235.742
2001	3152.436	3578.042	1.2192	160.000	130.592	0.281	2861.564
2002	3466.542	3638.430	1.3716	193.970	116.084	0.337	3156.151
2003	3848.200	3601.397	1.3667	178.030	174.049	0.809	3495.313
2004	3825.251	3573.107	1.2910	228.380	207.723	0.858	3388.290
2005	3422.205	3640.550	1.1136	195.140	222.843	1.145	3003.077
2006	3238.644	3583.575	1.2864	201.730	282.438	0.949	2753.527

Table 19.10. Tiger Flathead. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 =-0.03082), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **201.946** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	2786.959					
1995	1.0365	2735.929					
1996	0.9294	2725.609					
1997	0.9330	3093.299	2835.449	-0.03082	2748.061	2660.672	2485.896
1998	0.9887	3224.991	2944.957	-0.01398	2903.779	2862.602	2780.246
1999	1.1546	3996.333	3260.058	0.07312	3498.443	3736.827	4213.596
2000	1.2583	3938.408	3563.258	0.11419	3970.152	4377.046	5190.834
2001	1.2192	3152.436	3578.042	0.07952	3862.579	4147.116	4716.190
2002	1.3716	3466.542	3638.430	0.06119	3861.066	4083.702	4528.974
2003	1.3667	3848.200	3601.397	0.04774	3773.331	3945.266	4289.135
2004	1.2910	3825.251	3573.107	0.02106	3648.366	3723.625	3874.142
2005	1.1136	3422.205	3640.550	-0.08496	3331.244	3021.938	2403.326
2006	1.2864	3238.644	3583.575	-0.04181	**3433.741**	**3283.907**	**2984.239**

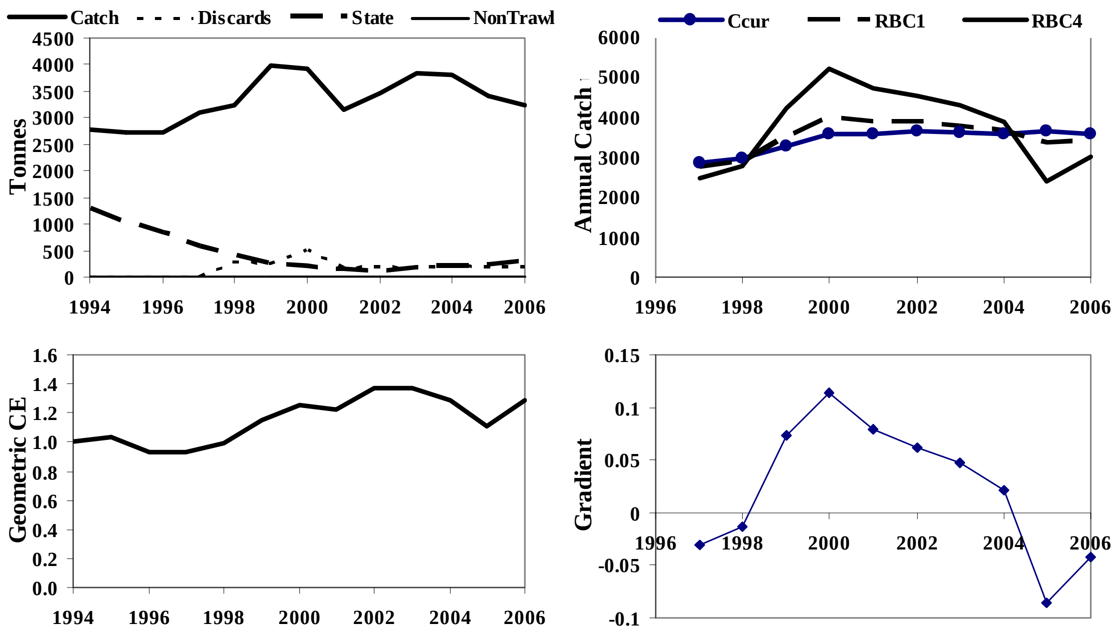

Figure 19.5. Plots of the various analyses for Tiger Flathead using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Flathead.

Year	RBC1	RBC2	RBC4	LnGrad
1997	2745.502	2655.556	2475.662	-0.03172
1998	2904.375	2863.792	2782.627	-0.01378
1999	3491.143	3722.228	4184.397	0.07088
2000	3938.317	4313.375	5063.492	0.10526
2001	3833.768	4089.494	4600.946	0.07147
2002	3814.937	3991.443	4344.457	0.04851
2003	3733.047	3864.698	4127.999	0.03656
2004	3633.202	3693.296	3813.485	0.01682
2005	3392.239	3143.928	2647.307	-0.06821
2006	**3465.555**	**3347.534**	**3111.494**	-0.03293

19.10 Eastern Gemfish (GEM – 37439002 – Rexea solandri)

Table 19.11. Eastern Gemfish. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate from the spawning run out of Zones 10 – 30 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	266.110		1.0000	0.000	131.931	0.000	134.179
1995	251.022		0.6735	0.000	157.756	0.000	93.266
1996	315.471		0.8622	0.000	204.700	0.000	110.771
1997	529.152	340.439	1.1673	0.000	136.395	0.000	392.757
1998	396.133	372.944	0.7959	23.000	127.144	0.000	245.989
1999	278.201	379.739	0.6979	31.000	88.664	0.000	158.537
2000	152.746	339.058	0.4749	29.000	30.747	0.000	92.999
2001	118.245	236.331	0.4929	8.000	23.859	2.702	83.684
2002	91.467	160.165	0.3704	13.600	16.174	3.564	58.129
2003	198.011	140.117	0.5237	115.170	7.781	2.697	72.363
2004	180.752	147.119	0.5005	83.210	17.731	2.683	77.128
2005	188.446	164.669	0.4485	77.650	14.054	8.598	88.144
2006	147.819	178.757	0.7036	46.350	15.060	0.730	85.679

Table 19.12. Eastern Gemfish. The spawning run CPUE is the standardized mean catch rate data for trawls relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = 0.06906), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **64.199** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	266.110					
1995	0.6735	251.022					
1996	0.8622	315.471					
1997	1.1673	529.152	340.439	0.06906	363.948	387.457	434.476
1998	0.7959	396.133	372.944	0.06721	398.012	423.079	473.213
1999	0.6979	278.201	379.739	-0.08642	346.924	314.108	248.477
2000	0.4749	152.746	339.058	-0.21751	265.308	191.559	44.059
2001	0.4929	118.245	236.331	-0.11320	209.578	182.826	129.320
2002	0.3704	91.467	160.165	-0.09647	144.714	129.263	98.361
2003	0.5237	198.011	140.117	0.00239	140.453	140.788	141.459
2004	0.5005	180.752	147.119	0.01764	149.713	152.308	157.497
2005	0.4485	188.446	164.669	0.02112	168.147	171.625	178.581
2006	0.7036	147.819	178.757	0.04876	**187.474**	**196.191**	**213.625**

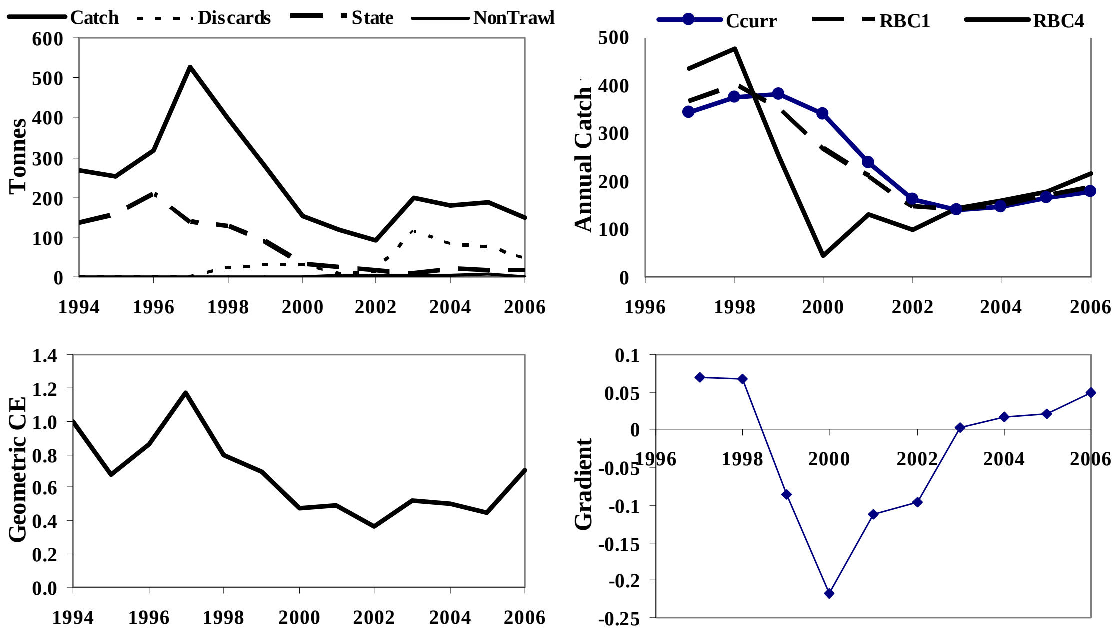

Figure 19.6. Plots of the various analyses for Eastern Gemfish using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Eastern Gemfish

Year	RBC1	RBC2	RBC4	LnGrad
1997	364.645	388.850	437.262	0.07110
1998	402.918	432.891	492.838	0.08037
1999	341.119	302.498	225.257	-0.10170
2000	243.127	147.197	0.000	-0.28293
2001	193.258	150.185	64.040	-0.18226
2002	130.315	100.466	40.767	-0.18637
2003	140.226	140.336	140.554	0.00078
2004	152.897	158.676	170.233	0.03928
2005	173.379	182.089	199.508	0.05289
2006	**192.630**	**206.502**	**234.247**	0.07761

19.11 Western Gemfish (GEM – 37439002 – Rexea solandri)

Table 19.13. Western Gemfish. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	138.266		1.0000	0.000	0.000	0.000	138.266
1995	124.409		0.9154	0.000	0.000	0.000	124.409
1996	208.329		0.9956	0.000	0.000	0.000	208.329
1997	226.983	174.497	0.8623	0.000	0.000	0.000	226.983
1998	197.371	189.273	0.9676	12.000	0.000	0.000	185.371
1999	276.813	227.374	0.9378	5.000	0.000	0.000	271.813
2000	379.236	270.101	0.9676	30.000	0.000	0.000	349.236
2001	262.393	278.953	0.7968	9.000	0.000	0.363	253.030
2002	148.055	266.624	0.6036	9.140	0.000	0.441	138.474
2003	190.104	244.947	0.7273	12.580	0.000	3.918	173.606
2004	158.760	189.828	0.7430	8.920	0.000	3.655	146.185
2005	163.957	165.219	0.7364	1.640	0.000	5.732	156.585
2006	155.250	167.018	0.6199	0.550	0.000	28.211	126.489

Table 19.14. Western Gemfish. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.03330), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **2.759** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	138.266					
1995	0.9154	124.409					
1996	0.9956	208.329					
1997	0.8623	226.983	174.497	-0.03330	168.686	162.874	151.252
1998	0.9676	197.371	189.273	0.00233	189.714	190.155	191.037
1999	0.9378	276.813	227.374	-0.00680	225.827	224.279	221.185
2000	0.9676	379.236	270.101	0.02862	277.831	285.560	301.020
2001	0.7968	262.393	278.953	-0.04826	265.490	252.027	225.100
2002	0.6036	148.055	266.624	-0.11734	235.339	204.054	141.483
2003	0.7273	190.104	244.947	-0.09140	222.559	200.170	155.394
2004	0.7430	158.760	189.828	-0.00378	189.111	188.395	186.961
2005	0.7364	163.957	165.219	0.04141	172.061	178.903	192.587
2006	0.6199	155.250	167.018	-0.03288	**161.526**	**156.034**	**145.050**

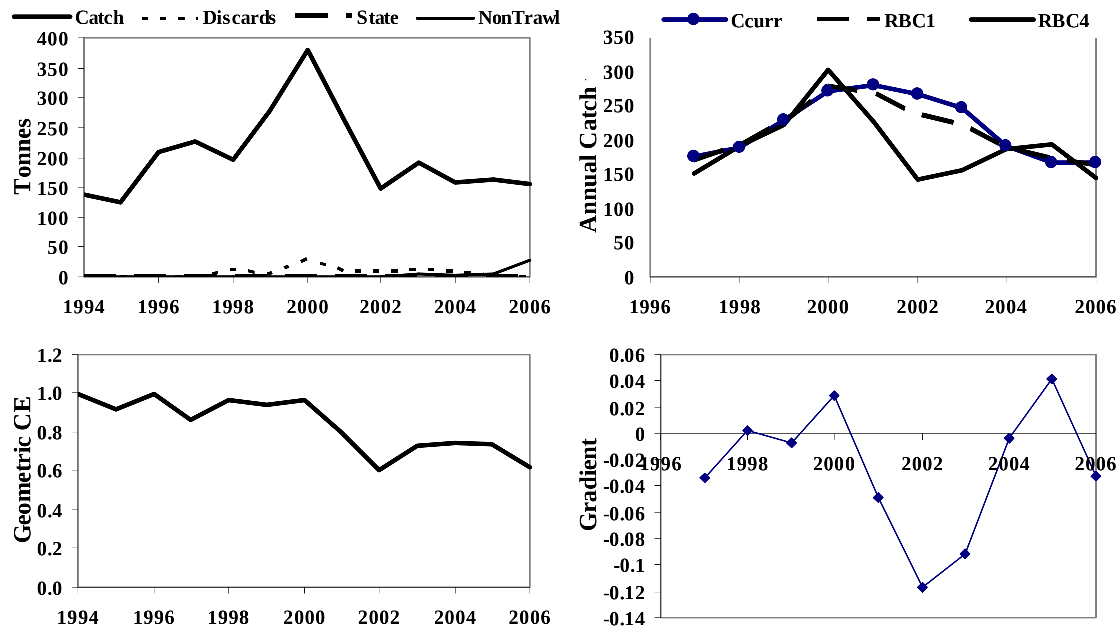

Figure 19.7. Plots of the various analyses for Western Gemfish using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Western Gemfish

Year	RBC1	RBC2	RBC4	LnGrad
1997	168.204	161.912	149.327	-0.03606
1998	189.701	190.130	190.986	0.00226
1999	225.915	224.456	221.539	-0.00642
2000	278.594	287.088	304.075	0.03145
2001	263.571	248.190	217.426	-0.05514
2002	226.201	185.779	104.933	-0.15161
2003	217.170	189.393	133.839	-0.11340
2004	189.384	188.941	188.054	-0.00234
2005	175.429	185.640	206.060	0.06180
2006	**158.862**	**150.707**	**134.396**	-0.04883

19.12 Jackass Morwong *(MOR – 37377003* Nemadactylus macropterus*)*

Table 19.15. Jackass Morwong. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for trawlers all Zones 10 to 60 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	1034.932		1.0000	0.000	225.635	0.000	809.297
1995	981.801		1.0270	0.000	160.930	0.000	820.871
1996	972.505		0.9717	0.000	89.062	0.211	883.232
1997	1213.726	1050.741	1.1085	0.000	82.173	3.192	1128.361
1998	976.082	1036.029	0.9403	34.000	56.807	4.519	880.756
1999	1037.195	1049.877	1.0150	45.000	41.159	17.667	933.370
2000	977.483	1051.122	0.8418	27.000	41.029	29.294	880.159
2001	878.752	967.378	0.5223	12.000	50.298	2.263	814.191
2002	904.674	949.526	0.5477	25.440	29.376	1.874	847.984
2003	848.261	902.292	0.4841	71.850	28.583	3.311	744.517
2004	842.687	868.593	0.4832	47.380	35.358	4.593	755.357
2005	872.176	866.950	0.5468	38.610	35.512	5.979	792.075
2006	885.302	862.107	0.6697	78.550	32.991	5.296	768.465

Table 19.16. Jackass Morwong. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = 0.02702), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **63.297** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	1034.932					
1995	1.0270	981.801					
1996	0.9717	972.505					
1997	1.1085	1213.726	1050.741	0.02702	1079.134	1107.527	1164.312
1998	0.9403	976.082	1036.029	-0.01231	1023.278	1010.528	985.028
1999	1.0150	1037.195	1049.877	-0.00382	1045.864	1041.851	1033.825
2000	0.8418	977.483	1051.122	-0.07254	974.877	898.632	746.143
2001	0.5223	878.752	967.378	-0.14273	829.303	691.228	415.079
2002	0.5477	904.674	949.526	-0.17214	786.076	622.626	295.725
2003	0.4841	848.261	902.292	-0.10477	807.757	713.222	524.151
2004	0.4832	842.687	868.593	-0.01810	852.876	837.158	805.723
2005	0.5468	872.176	866.950	-0.00035	866.643	866.337	865.724
2006	0.6697	885.302	862.107	0.06204	**915.593**	**969.079**	**1076.052**

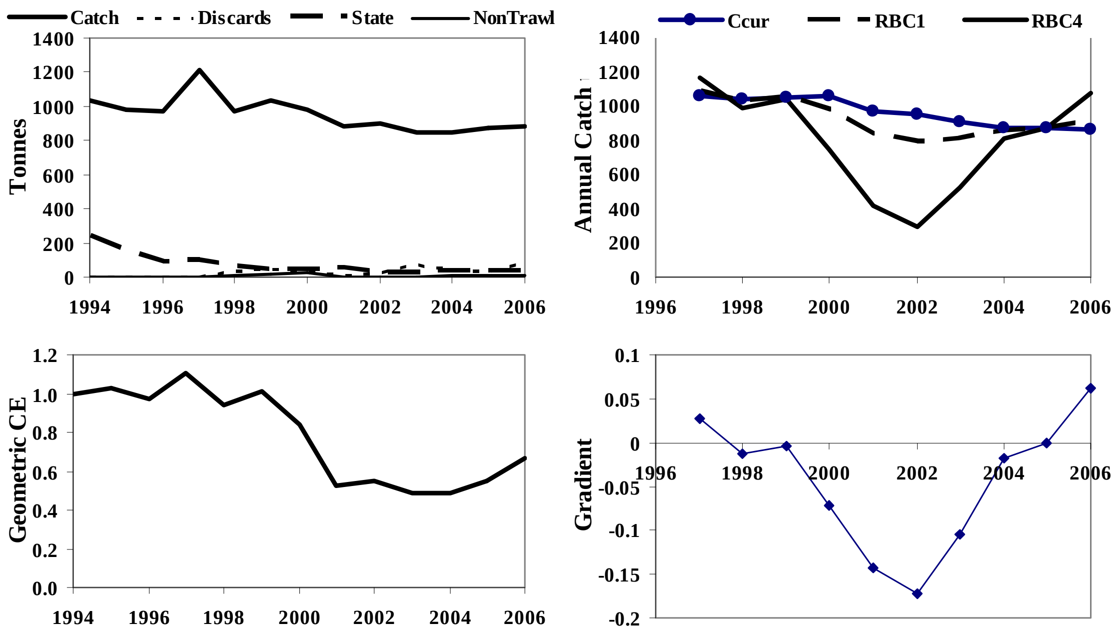

Figure 19.8. Plots of the various analyses for Jackass Morwong using trawl standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Jackass Morwong

Year	RBC1	RBC2	RBC4	LnGrad
1997	1077.398	1104.054	1157.368	0.02537
1998	1022.287	1008.545	981.061	-0.01326
1999	1046.339	1042.801	1035.725	-0.00337
2000	972.373	893.624	736.127	-0.07492
2001	778.638	589.898	212.418	-0.19510
2002	728.480	507.434	65.342	-0.23280
2003	756.814	611.337	320.381	-0.16123
2004	837.587	806.581	744.569	-0.03570
2005	866.371	865.793	864.636	-0.00067
2006	**956.707**	**1051.307**	**1240.507**	0.10973

19.13 John Dory (DOJ – 37264004 Zeus faber)

Table 19.17. John Dory. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 10 and 20 (see below) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	409.516		1.0000	0.000	292.690	0.000	116.826
1995	282.375		0.8609	0.000	167.707	0.000	114.668
1996	248.392		0.6717	0.000	112.957	0.000	135.436
1997	119.324	264.902	0.5264	0.000	29.137	0.000	90.187
1998	158.070	202.040	0.5417	3.000	39.699	0.000	115.371
1999	176.070	175.464	0.6233	3.000	35.478	0.000	137.592
2000	226.129	169.898	0.5841	17.000	39.400	0.000	169.730
2001	170.543	182.703	0.4727	6.000	29.668	0.051	134.824
2002	183.877	189.155	0.4729	1.660	19.529	0.014	162.673
2003	196.219	194.192	0.4711	3.190	28.153	0.084	164.793
2004	195.564	186.551	0.4989	1.740	27.514	0.113	166.197
2005	129.715	176.344	0.4321	3.530	23.452	0.060	102.673
2006	107.044	157.136	0.4819	0.640	22.633	0.047	83.724

Table 19.18. John Dory. The trawl CPUE is the standardized mean catch rate data relative to 1994 (see below), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.16099), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **1.727** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	409.516					
1995	0.8609	282.375					
1996	0.6717	248.392					
1997	0.5264	119.324	264.902	-0.16099	222.255	179.607	94.313
1998	0.5417	158.070	202.040	-0.11028	179.759	157.478	112.915
1999	0.6233	176.070	175.464	-0.01297	173.188	170.912	166.360
2000	0.5841	226.129	169.898	0.02547	174.226	178.554	187.210
2001	0.4727	170.543	182.703	-0.02462	178.205	173.707	164.711
2002	0.4729	183.877	189.155	-0.05628	178.508	167.862	146.569
2003	0.4711	196.219	194.192	-0.03389	187.611	181.030	167.868
2004	0.4989	195.564	186.551	0.00769	187.986	189.421	192.291
2005	0.4321	129.715	176.344	-0.00946	174.676	173.008	169.672
2006	0.4819	107.044	157.136	-0.00343	**156.596**	**156.057**	**154.979**

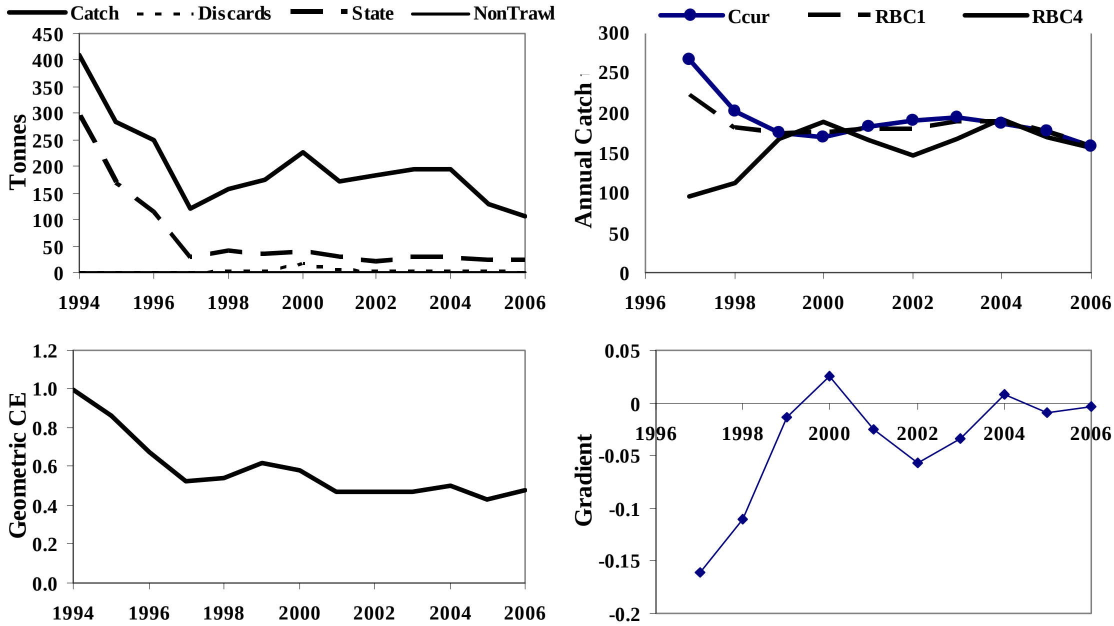

Figure 19.9. Plots of the various analyses for John Dory using Standardized CPUE relative to 1994 (see below), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

The data for John Dory were standardized in SAS 9.1 using a statistical model:

LNCE = Year Month Vessel DepCat Zone Month*DepCat

where DepCat was a series of 50 metre depth categories. A comparison of the this optimum model with the geometric mean shows little difference (Figure 19.9)

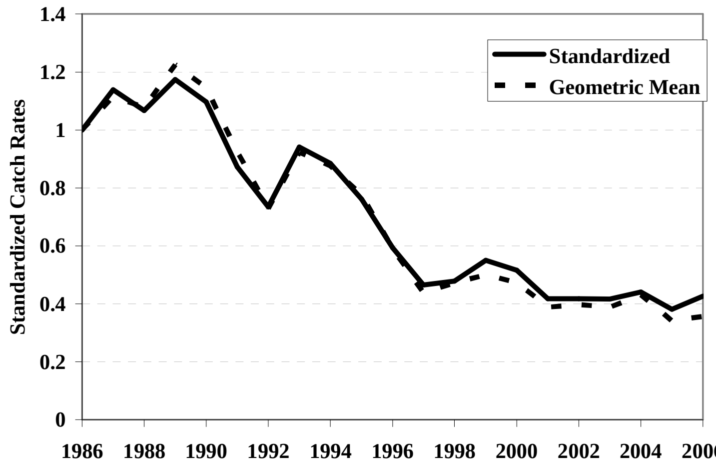

Figure 19.10. Comparison of the standardized catch rates for John Dory relative to the geometric mean catch rates from Zones 10 and 20 trawlers.

Alternative RBC calculations using natural log transformed catch rates. John Dory

Year	RBC1	RBC2	RBC4	LnGrad
1997	207.336	149.770	34.638	-0.21731
1998	169.038	136.036	70.031	-0.16335
1999	172.035	168.606	161.747	-0.01954
2000	177.584	185.270	200.643	0.04524
2001	174.049	165.394	148.085	-0.04737
2002	169.474	149.792	110.430	-0.10405
2003	181.671	169.151	144.109	-0.06448
2004	189.503	192.456	198.361	0.01583
2005	172.581	168.819	161.295	-0.02134
2006	**155.948**	**154.761**	**152.385**	-0.00756

19.14 Mirror Dory (DOM – 37264003 *Zenopsis nebulosus*)

Table 19.19. Mirror Dory. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for trawls across all Zones (see below) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	478.366		1.0000	0.000	175.518	0.000	302.848
1995	427.324		0.9216	0.000	159.691	0.000	267.633
1996	549.460		0.8906	0.000	166.450	0.000	383.010
1997	594.785	512.484	0.9442	0.000	69.042	0.000	525.743
1998	554.374	531.486	0.8812	115.000	26.988	0.000	412.386
1999	434.139	533.189	0.7750	52.000	36.911	0.000	345.228
2000	310.405	473.426	0.5217	93.000	11.121	0.000	206.284
2001	598.752	474.417	0.5787	292.000	10.343	0.096	296.313
2002	642.076	496.343	0.7745	96.920	21.650	0.029	523.477
2003	901.087	613.080	0.9677	163.710	67.351	0.505	669.521
2004	786.634	732.137	0.9623	170.310	94.815	0.008	521.501
2005	713.648	760.861	1.0630	52.720	70.433	0.058	590.437
2006	516.330	729.425	1.0890	26.880	84.586	0.074	404.791

Table 19.20. Mirror Dory. The trawl CPUE is the standardized mean catch rate data relative to 1994 (see below), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.01983), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **62.017** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	478.366					
1995	0.9216	427.324					
1996	0.8906	549.460					
1997	0.9442	594.785	512.484	-0.01983	502.321	492.158	471.831
1998	0.8812	554.374	531.486	-0.00675	527.896	524.305	517.125
1999	0.7750	434.139	533.189	-0.04098	511.339	489.488	445.787
2000	0.5217	310.405	473.426	-0.13737	408.391	343.355	213.285
2001	0.5787	598.752	474.417	-0.11607	419.352	364.287	254.157
2002	0.7745	642.076	496.343	0.00554	499.093	501.844	507.345
2003	0.9677	901.087	613.080	0.15336	707.105	801.129	989.179
2004	0.9623	786.634	732.137	0.13439	830.531	928.925	1125.713
2005	1.0630	713.648	760.861	0.08601	826.301	891.741	1022.620
2006	1.0890	516.330	729.425	0.04645	**763.310**	**797.195**	**864.965**

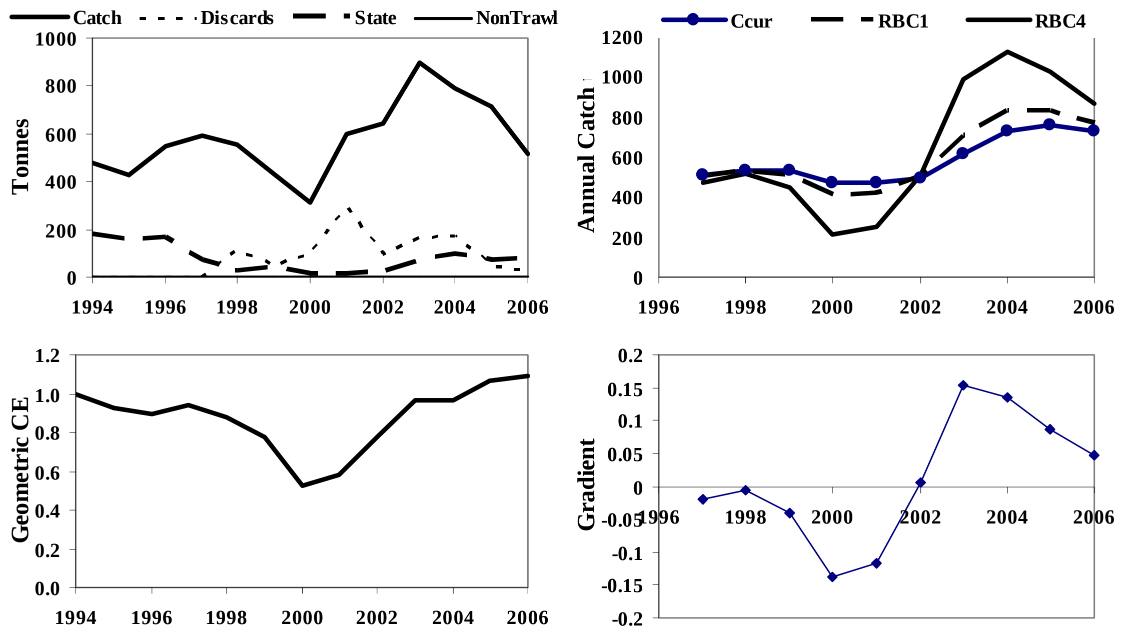

Figure 19.11. Plots of the various analyses for Mirror Dory using Standardized CPUE relative to 1994 (see below), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

The data for Mirror Dory were standardized in SAS 9.1 using a statistical model:

LNCE = Year Month Vessel DepCat Zone Month*DepCat

where DepCat was a series of 50 metre depth categories. A comparison of the this optimum model with the geometric mean shows significant differences (Figure 19.11)

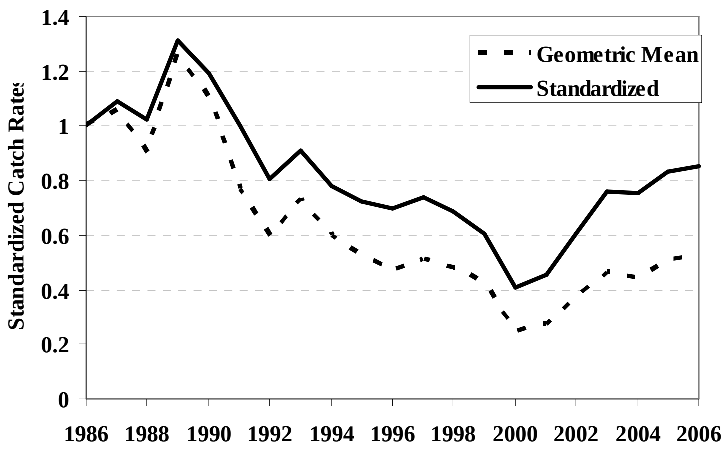

Figure 19.12. Comparison of the standardized catch rates for Mirror Dory relative to the geometric mean catch rates from trawlers in all zones.

Alternative RBC calculations using natural log transformed catch rates. Mirror Dory

Year	RBC1	RBC2	RBC4	LnGrad
1997	501.907	491.331	470.178	-0.02064
1998	527.447	523.409	515.332	-0.00760
1999	507.268	481.346	429.503	-0.04862
2000	383.091	292.757	112.089	-0.19081
2001	395.802	317.187	159.956	-0.16571
2002	501.388	506.432	516.521	0.01016
2003	744.565	876.050	1139.020	0.21447
2004	860.132	988.126	1244.114	0.17482
2005	832.710	904.559	1048.257	0.09443
2006	**762.523**	**795.621**	**861.817**	0.04538

19.15 Offshore Ocean Perch (REG – 37287001 – Helicolenus percoides)

Table 19.21. Offshore Ocean Perch. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 10 and 20 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	485.377		1.0000	0.000	226.542	0.000	258.835
1995	517.060		0.9198	0.000	232.117	0.000	284.942
1996	509.690		0.8389	0.000	182.062	0.000	327.629
1997	510.086	505.553	0.8810	0.000	106.649	5.312	398.126
1998	551.335	522.043	0.7733	174.000	41.056	6.250	330.030
1999	463.273	508.596	0.8884	64.000	43.461	7.018	348.795
2000	384.470	477.291	0.6744	34.000	42.683	9.086	298.700
2001	408.451	451.882	0.7397	46.000	35.993	8.597	317.861
2002	353.704	402.475	0.7180	22.470	45.519	18.885	266.830
2003	406.509	388.284	0.7642	27.800	34.671	30.940	313.098
2004	405.684	393.587	0.7403	42.440	20.454	66.129	276.661
2005	339.593	376.373	0.8479	17.100	15.280	34.518	272.696
2006	280.641	358.107	0.7426	20.980	19.157	56.110	184.394

Table 19.22. Offshore Ocean Perch. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.04379), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **23.261** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	485.377					
1995	0.9198	517.060					
1996	0.8389	509.690					
1997	0.8810	510.086	505.553	-0.04379	483.414	461.274	416.994
1998	0.7733	551.335	522.043	-0.03974	501.297	480.552	439.061
1999	0.8884	463.273	508.596	0.00410	510.682	512.767	516.939
2000	0.6744	384.470	477.291	-0.05047	453.204	429.117	380.943
2001	0.7397	408.451	451.882	-0.03147	437.660	423.439	394.995
2002	0.7180	353.704	402.475	-0.04460	384.523	366.571	330.667
2003	0.7642	406.509	388.284	0.02478	397.906	407.528	426.772
2004	0.7403	405.684	393.587	0.00479	395.473	397.358	401.129
2005	0.8479	339.593	376.373	0.03658	390.140	403.908	431.443
2006	0.7426	280.641	358.107	0.00428	**359.639**	**361.171**	**364.234**

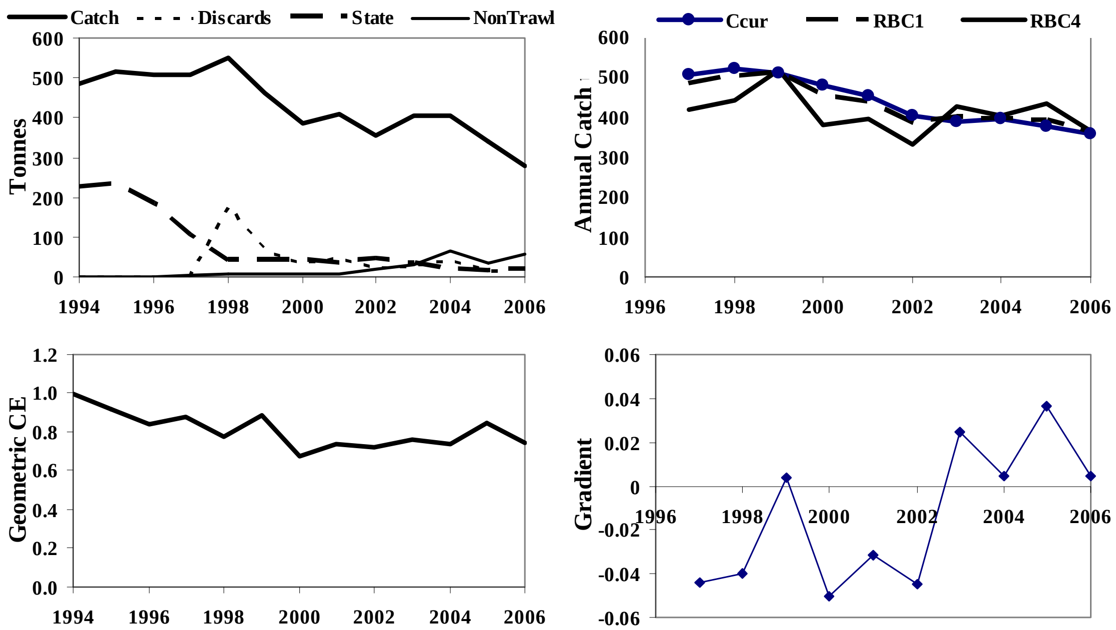

Figure 19.13. Plots of the various analyses for Offshore Ocean Perch using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Offshore Ocean Perch

Year	RBC1	RBC2	RBC4	LnGrad
1997	481.681	457.809	410.065	-0.04722
1998	497.428	472.812	423.582	-0.04715
1999	510.724	512.851	517.107	0.00418
2000	445.650	414.009	350.728	-0.06629
2001	433.411	414.939	377.997	-0.04088
2002	380.476	358.477	314.479	-0.05466
2003	401.695	415.106	441.929	0.03454
2004	396.132	398.677	403.767	0.00647
2005	393.953	411.533	446.694	0.04671
2006	**359.885**	**361.664**	**365.220**	0.00497

19.16 Pink Ling East (LIG – 37228002 – Genypterus blacodes)

Table 19.23. Pink Ling East. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 10, 20, and 30 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	1130.726		1.0000	0.000	522.744	0.000	607.982
1995	1469.152		1.1491	0.000	672.139	0.000	797.012
1996	1661.400		0.9511	0.000	810.611	0.000	850.788
1997	1421.946	1420.806	0.9579	0.000	391.286	0.000	1030.660
1998	1334.822	1471.830	0.9118	17.879	50.861	118.814	1147.268
1999	1229.159	1411.832	0.8971	3.538	50.738	166.969	1007.915
2000	1032.685	1254.653	0.7147	1.427	18.943	197.215	815.099
2001	883.025	1119.923	0.5385	4.352	9.879	220.325	648.469
2002	856.225	1000.273	0.4489	5.900	15.616	223.392	611.317
2003	909.890	920.456	0.5005	1.147	8.277	250.493	649.974
2004	1029.529	919.667	0.4743	1.203	12.195	411.573	604.557
2005	818.558	903.550	0.5147	2.095	14.814	306.076	495.573
2006	749.886	876.966	0.6125	2.603	14.132	259.792	473.360

Table 19.24. Pink Ling East. The trawl? CPUE is the standardized mean catch rate data relative to 1994 for Zones 10 - 30 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.03243), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **2.183** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	1130.726					
1995	1.1491	1469.152					
1996	0.9511	1661.400					
1997	0.9579	1421.946	1420.806	-0.03243	1374.730	1328.653	1236.500
1998	0.9118	1334.822	1471.830	-0.07051	1368.056	1264.282	1056.733
1999	0.8971	1229.159	1411.832	-0.02082	1382.439	1353.047	1294.262
2000	0.7147	1032.685	1254.653	-0.07442	1161.282	1067.912	881.171
2001	0.5385	883.025	1119.923	-0.13022	974.091	828.259	536.595
2002	0.4489	856.225	1000.273	-0.15207	848.158	696.043	391.812
2003	0.5005	909.890	920.456	-0.07324	853.046	785.636	650.815
2004	0.4743	1029.529	919.667	-0.01411	906.687	893.707	867.746
2005	0.5147	818.558	903.550	0.01711	919.014	934.477	965.404
2006	0.6125	749.886	876.966	0.03765	**909.986**	**943.006**	**1009.045**

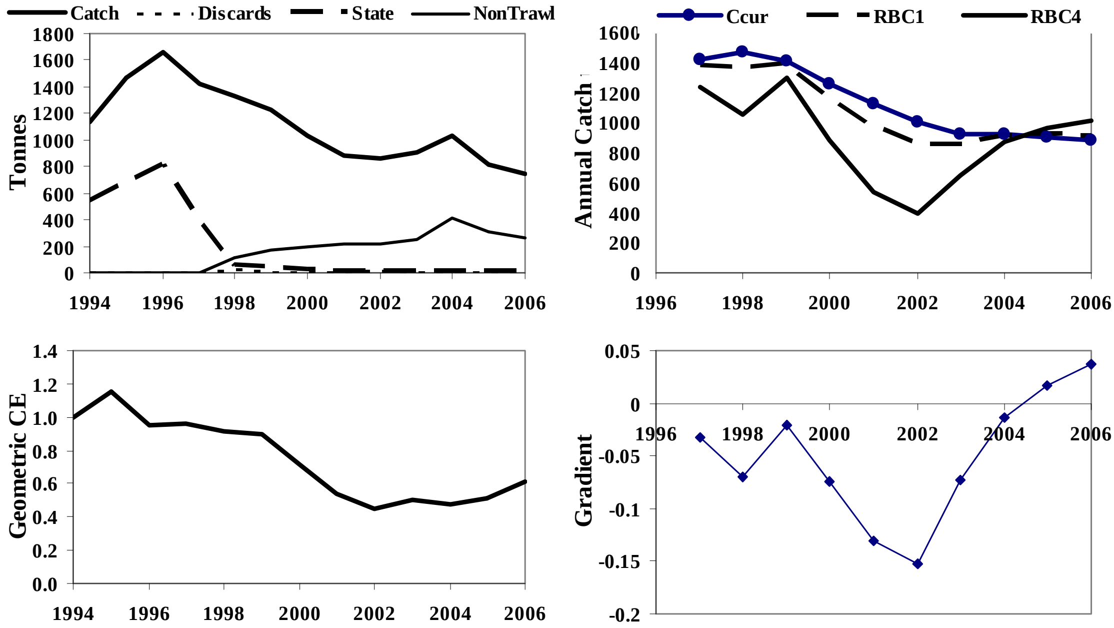

Figure 19.14. Plots of the various analyses for Pink Ling (East) using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Pink Ling East

Year	RBC1	RBC2	RBC4	LnGrad
1997	1375.603	1330.400	1239.994	-0.03181
1998	1370.746	1269.663	1067.496	-0.06868
1999	1380.098	1348.364	1284.895	-0.02248
2000	1142.393	1030.134	805.614	-0.08947
2001	917.558	715.193	310.464	-0.18070
2002	764.201	528.128	55.982	-0.23601
2003	805.308	690.159	459.862	-0.12510
2004	894.625	869.582	819.496	-0.02723
2005	935.759	967.967	1032.384	0.03565
2006	**937.281**	**997.596**	**1118.227**	0.06878

19.17 Pink Ling West (LIG – 37228002 – *Genypterus blacodes*)

Table 19.25. Pink Ling West. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 40 and 50 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	332.598		1.0000	0.000	0.000	0.000	332.598
1995	475.350		1.0603	0.000	0.000	0.000	475.350
1996	582.921		1.0842	0.000	0.000	0.000	582.921
1997	707.044	524.478	1.1570	0.000	0.000	0.000	707.044
1998	640.049	601.341	1.1245	23.121	0.000	83.571	533.356
1999	805.138	683.788	0.8904	8.462	0.000	103.535	693.141
2000	839.111	747.835	0.8104	9.573	0.000	54.776	774.762
2001	855.943	785.060	0.7248	0.648	0.000	156.258	699.037
2002	760.934	815.282	0.6389	0.740	0.000	298.817	461.378
2003	709.588	791.394	0.6497	0.693	0.000	226.982	481.912
2004	738.630	766.274	0.6013	0.777	0.000	438.875	298.978
2005	601.504	702.664	0.4979	2.355	0.000	338.417	260.732
2006	450.660	625.096	0.5227	0.277	0.000	194.785	255.597

Table 19.26. Pink Ling West. The trawl? CPUE is the standardized mean catch rate data relative to 1994 for Zones 40 - 50 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = 0.04949), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **0.926** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	332.598					
1995	1.0603	475.350					
1996	1.0842	582.921					
1997	1.1570	707.044	524.478	0.04949	550.434	576.390	628.302
1998	1.1245	640.049	601.341	0.02655	617.308	633.276	665.211
1999	0.8904	805.138	683.788	-0.06138	641.817	599.846	515.904
2000	0.8104	839.111	747.835	-0.12739	652.568	557.301	366.766
2001	0.7248	855.943	785.060	-0.12793	684.630	584.200	383.340
2002	0.6389	760.934	815.282	-0.08401	746.793	678.305	541.327
2003	0.6497	709.588	791.394	-0.05679	746.450	701.506	611.617
2004	0.6013	738.630	766.274	-0.03595	738.727	711.181	656.088
2005	0.4979	601.504	702.664	-0.04714	669.537	636.411	570.157
2006	0.5227	450.660	625.096	-0.04845	**594.809**	**564.523**	**503.950**

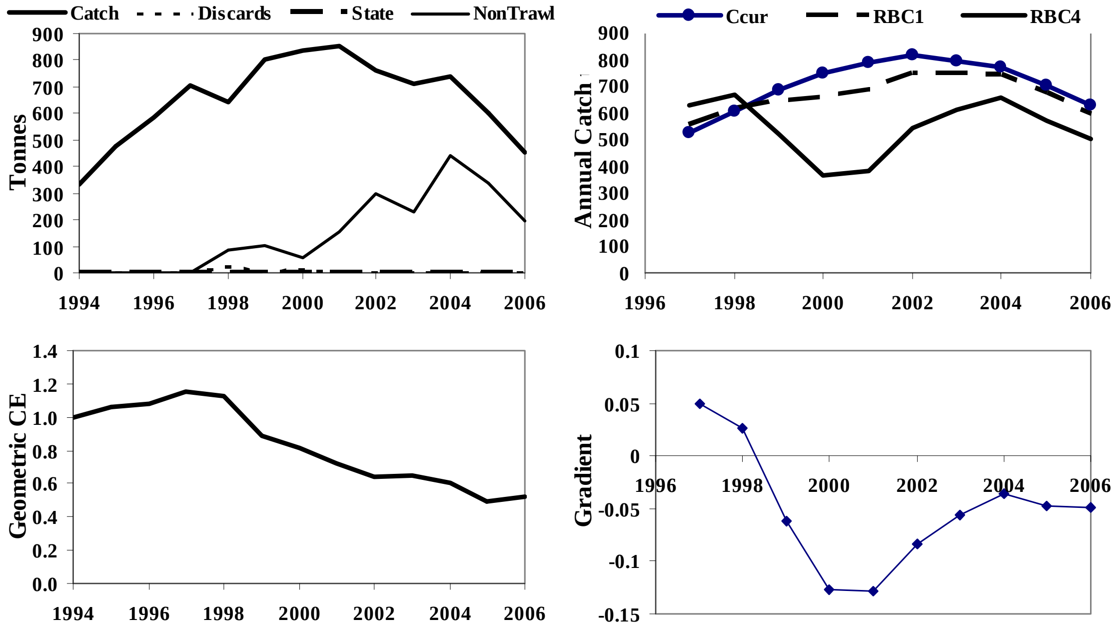

Figure 19.15. Plots of the various analyses for Pink Ling (West) using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Pink Ling West

Year	RBC1	RBC2	RBC4	LnGrad
1997	548.592	572.706	620.934	0.04598
1998	615.861	630.382	659.423	0.02415
1999	641.448	599.109	514.430	-0.06192
2000	650.498	553.161	358.486	-0.13016
2001	674.214	563.368	341.675	-0.14119
2002	725.002	634.723	454.164	-0.11073
2003	728.949	666.503	541.613	-0.07891
2004	724.640	683.006	599.738	-0.05433
2005	644.658	586.651	470.638	-0.08255
2006	**572.501**	**519.907**	**414.719**	-0.08414

19.18 RedFish (RED – 37258003 – Centroberyx affinis)

Table 19.27. RedFish. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zone 10 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	1957.210		1.0000	0.000	1343.683	0.000	613.527
1995	1999.572		0.6401	0.000	789.203	0.000	1210.369
1996	2219.833		0.5503	0.000	784.081	0.000	1435.752
1997	1840.798	2004.353	0.6383	0.000	303.982	0.000	1536.816
1998	4159.469	2554.918	0.7913	2324.000	83.346	0.000	1752.124
1999	1415.976	2409.019	0.6096	69.000	94.939	0.000	1252.037
2000	1092.909	2127.288	0.4068	233.000	27.446	0.000	832.463
2001	1584.662	2063.254	0.3972	738.000	52.093	0.545	794.025
2002	1821.778	1478.831	0.3513	894.850	46.951	0.155	879.822
2003	1074.161	1393.378	0.3410	347.500	48.604	0.828	677.230
2004	935.043	1353.911	0.2972	377.440	58.124	1.005	498.474
2005	694.027	1131.252	0.2831	126.180	35.012	0.568	532.268
2006	399.375	775.651	0.2703	13.070	64.442	0.533	321.330

Table 19.28. RedFish. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.11748), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **114.111** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	1957.210					
1995	0.6401	1999.572					
1996	0.5503	2219.833					
1997	0.6383	1840.798	2004.353	-0.11748	1768.874	1533.394	1062.436
1998	0.7913	4159.469	2554.918	0.05415	2693.266	2831.614	3108.311
1999	0.6096	1415.976	2409.019	0.03307	2488.689	2568.359	2727.698
2000	0.4068	1092.909	2127.288	-0.08761	1940.917	1754.547	1381.805
2001	0.3972	1584.662	2063.254	-0.13851	1777.477	1491.699	920.145
2002	0.3513	1821.778	1478.831	-0.07845	1362.814	1246.797	1014.762
2003	0.3410	1074.161	1393.378	-0.02434	1359.465	1325.552	1257.727
2004	0.2972	935.043	1353.911	-0.03102	1311.911	1269.911	1185.910
2005	0.2831	694.027	1131.252	-0.02484	1103.157	1075.063	1018.873
2006	0.2703	399.375	775.651	-0.02262	**758.104**	**740.557**	**705.462**

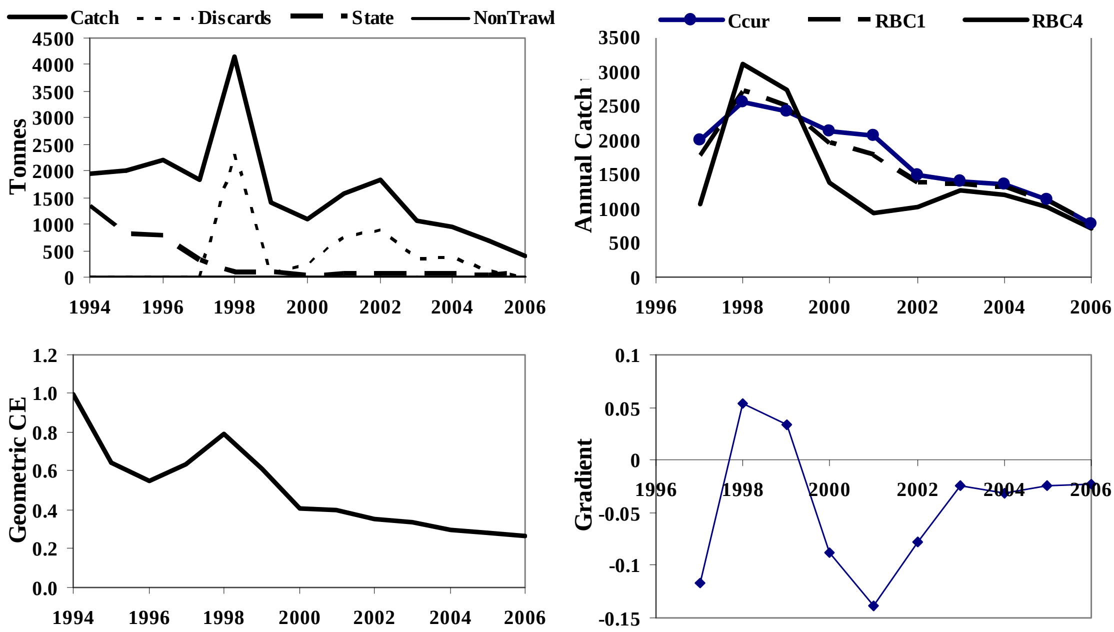

Figure 19.16. Plots of the various analyses for RedFish using Standardized CPUE relative to 1994 from Zone 10, which represents most of the catch (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Redfish

Year	RBC1	RBC2	RBC4	LnGrad
1997	1704.122	1403.891	803.429	-0.14979
1998	2755.309	2955.701	3356.483	0.07843
1999	2534.664	2660.309	2911.598	0.05216
2000	1784.358	1441.429	755.570	-0.16121
2001	1553.181	1043.108	22.962	-0.24722
2002	1230.767	982.702	486.572	-0.16774
2003	1302.486	1211.595	1029.813	-0.06523
2004	1232.111	1110.310	866.709	-0.08996
2005	1042.470	953.688	776.123	-0.07848
2006	**717.809**	**659.966**	**544.281**	-0.07457

19.19 Ribaldo (RBD – 37224002 – Mora moro)

Table 19.29. Ribaldo. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for All Zones (see below) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	28.021		1.0000	0.000	0.418	0.000	27.603
1995	95.719		1.0316	0.000	5.401	0.000	90.318
1996	85.154		0.7852	0.000	3.510	0.000	81.644
1997	103.704	78.150	0.6859	0.000	4.057	1.962	97.685
1998	119.193	100.942	0.6738	23.766	0.102	2.431	92.894
1999	70.631	94.670	0.6042	6.555	0.031	3.335	60.710
2000	71.401	91.232	0.5647	8.284	0.022	8.736	54.360
2001	80.033	85.314	0.5108	4.468	0.303	21.161	54.102
2002	179.033	100.274	0.4861	7.305	0.000	95.820	75.907
2003	232.365	140.708	0.4552	26.457	0.037	103.460	102.411
2004	215.275	176.676	0.4963	16.087	0.061	102.509	96.619
2005	127.271	188.486	0.4235	21.800	0.118	52.297	53.056
2006	120.257	173.792	0.4460	3.114	0.000	73.430	43.714

Table 19.30. Ribaldo. The trawl CPUE is the standardized mean catch rate data relative to 1994 (see below), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.11888), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **11.383** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	28.021					
1995	1.0316	95.719					
1996	0.7852	85.154					
1997	0.6859	103.704	78.150	-0.11888	68.859	59.569	40.989
1998	0.6738	119.193	100.942	-0.11728	89.104	77.266	53.590
1999	0.6042	70.631	94.670	-0.05552	89.415	84.159	73.647
2000	0.5647	71.401	91.232	-0.04331	87.281	83.329	75.426
2001	0.5108	80.033	85.314	-0.05285	80.806	76.297	67.280
2002	0.4861	179.033	100.274	-0.04082	96.182	92.089	83.903
2003	0.4552	232.365	140.708	-0.03531	135.739	130.770	120.832
2004	0.4963	215.275	176.676	-0.00743	175.363	174.050	171.423
2005	0.4235	127.271	188.486	-0.01465	185.724	182.963	177.439
2006	0.4460	120.257	173.792	-0.01004	**172.048**	**170.304**	**166.816**

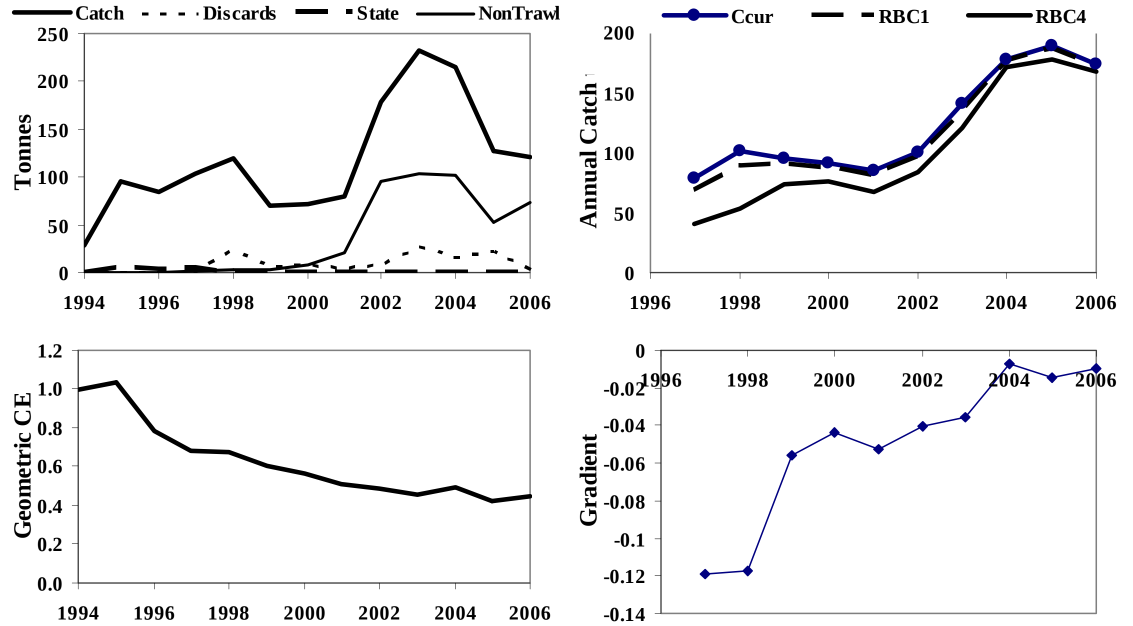

Figure 19.17. Plots of the various analyses for Ribaldo using Standardized CPUE relative to 1994 (see below), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

The data for Ribaldo were standardized in SAS 9.1 using a statistical model:

LNCE = Year Month Vessel DepCat Zone Month*DepCat

where DepCat was a series of 50 metre depth categories. A comparison of the this optimum model with the geometric mean shows significant differences (Figure 19.16)

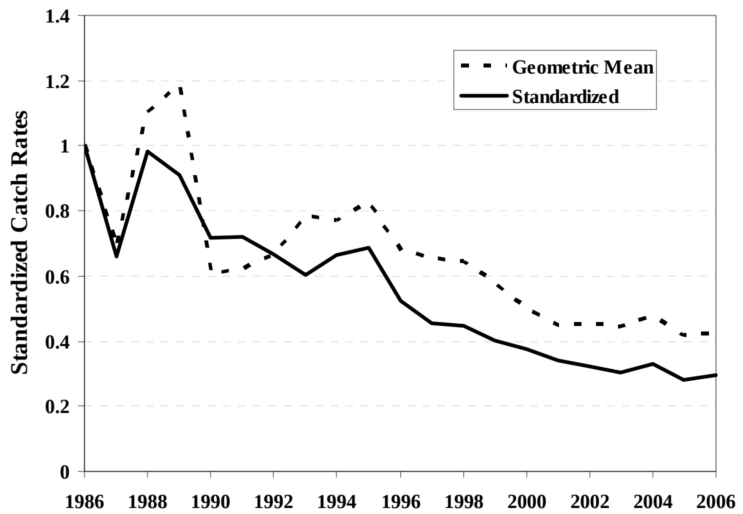

Figure 19.18. Comparison of the standardized catch rates for Ribaldo relative to the geometric mean catch rates from trawlers in all zones.

Alternative RBC calculations using natural log transformed catch rates. Ribaldo

Year	RBC1	RBC2	RBC4	LnGrad
1997	67.176	56.203	34.257	-0.14041
1998	86.678	72.413	43.884	-0.14131
1999	87.059	79.448	64.225	-0.08040
2000	84.917	78.601	65.970	-0.06923
2001	77.650	69.985	54.655	-0.08984
2002	92.726	85.178	70.082	-0.07527
2003	130.913	121.117	101.527	-0.06961
2004	173.992	171.307	165.938	-0.01520
2005	182.328	176.169	163.853	-0.03267
2006	**169.973**	**166.153**	**158.514**	-0.02198

19.20 Royal Red Prawn (PRR – 28714005 - Haliporoides sibogae)

Table 19.31. Royal Red Prawn. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zone 10 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	629.847		1.0000	0.000	482.073	0.000	147.774
1995	722.852		0.8094	0.000	529.336	0.000	193.516
1996	692.241		0.7422	0.000	424.963	0.000	267.278
1997	473.406	629.586	0.7047	0.000	285.669	0.000	187.737
1998	450.916	584.854	0.7582	12.000	228.345	0.000	210.571
1999	583.324	549.972	0.7630	2.000	205.320	0.000	376.004
2000	626.637	533.571	0.9619	3.000	206.945	0.000	416.692
2001	481.039	535.479	0.8229	11.000	227.810	0.000	242.229
2002	689.964	595.241	1.0044	15.580	240.645	0.000	433.740
2003	340.812	534.613	1.0208	17.370	135.277	0.000	188.165
2004	290.653	450.617	1.0669	43.460	74.965	0.000	172.228
2005	247.648	392.269	0.9731	40.290	40.871	0.000	166.487
2006	244.840	280.988	1.1331	26.540	25.160	0.000	193.140

Table 19.32. Royal Red Prawn. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.09530), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **31.851** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	629.847					
1995	0.8094	722.852					
1996	0.7422	692.241					
1997	0.7047	473.406	629.586	-0.09530	569.585	509.584	389.581
1998	0.7582	450.916	584.854	-0.01911	573.680	562.506	540.158
1999	0.7630	583.324	549.972	0.01158	556.343	562.713	575.455
2000	0.9619	626.637	533.571	0.07763	574.991	616.411	699.252
2001	0.8229	481.039	535.479	0.03931	556.526	577.574	619.668
2002	1.0044	689.964	595.241	0.05854	630.084	664.926	734.612
2003	1.0208	340.812	534.613	0.03580	553.754	572.895	611.176
2004	1.0669	290.653	450.617	0.07482	484.331	518.044	585.471
2005	0.9731	247.648	392.269	-0.00480	390.388	388.506	384.743
2006	1.1331	244.840	280.988	0.02432	**287.823**	**294.658**	**308.328**

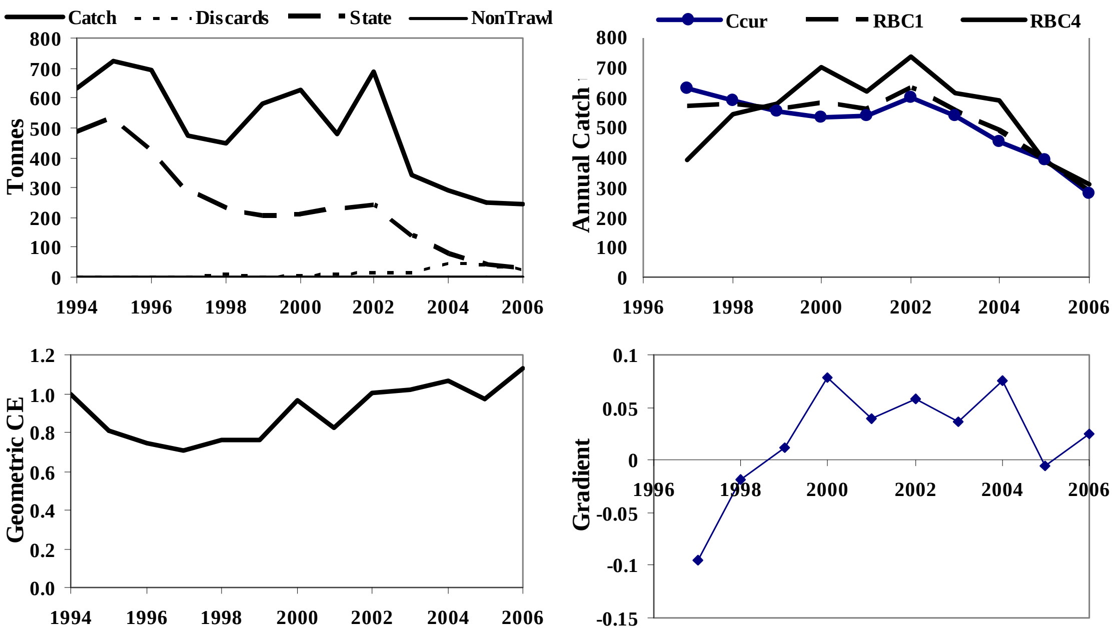

Figure 19.19. Plots of the various analyses for Royal Red Prawn using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Royal Red Prawn

Year	**RBC1**	**RBC2**	**RBC4**	**LnGrad**
1997	629.847		1	0.000
1998	722.852		0.809444	0.000
1999	692.241		0.742192	0.000
2000	473.406	629.5865	0.704741	0.000
2001	450.916	584.8537	0.758243	12.000
2002	583.324	549.9717	0.762971	2.000
2003	626.637	533.5706	0.961926	3.000
2004	481.039	535.4789	0.822944	11.000
2005	689.964	595.241	1.004417	15.580
2006	**340.812**	**534.6131**	**1.020779**	17.370

19.21 School Whiting (WHS – 37330014 – Sillago flindersi)

Table 19.33. School Whiting. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zone 60 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years. The weighted discards = **18.252** tonnes.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	1647.018		1.0000	0.000	656.797	0.000	990.221
1995	1990.790		1.2875	0.000	742.580	0.000	1248.210
1996	1695.105		0.8529	0.000	829.202	0.000	865.903
1997	1556.380	1722.323	0.6426	0.000	917.387	0.000	638.993
1998	1861.848	1776.031	0.6287	48.000	1169.056	0.000	644.792
1999	1453.810	1641.785	0.7308	5.000	824.832	0.000	623.977
2000	1298.460	1542.624	0.7389	9.000	687.243	0.000	602.217
2001	1747.332	1590.362	1.0322	28.000	1044.883	0.000	674.449
2002	1587.358	1521.740	1.0979	9.760	898.782	0.000	678.816
2003	1536.834	1542.496	1.0707	46.340	898.545	0.000	591.949
2004	1220.647	1523.043	1.0980	26.360	731.699	0.000	462.589
2005	1038.015	1345.713	1.1555	37.500	540.101	0.000	460.414
2006	1666.470	1365.491	0.9829	3.090	1185.577	0.001	477.802

Table 19.34. School Whiting. The Danish Seine CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.15068), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **18.252** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	1647.018					
1995	1.2875	1990.790					
1996	0.8529	1695.105					
1997	0.6426	1556.380	1722.323	-0.15068	1462.802	1203.280	684.237
1998	0.6287	1861.848	1776.031	-0.21866	1387.675	999.320	222.609
1999	0.7308	1453.810	1641.785	-0.03800	1579.391	1516.996	1392.207
2000	0.7389	1298.460	1542.624	0.03910	1602.935	1663.246	1783.869
2001	1.0322	1747.332	1590.362	0.12186	1784.166	1977.969	2365.576
2002	1.0979	1587.358	1521.740	0.13946	1733.963	1946.185	2370.631
2003	1.0707	1536.834	1542.496	0.10610	1706.148	1869.800	2197.105
2004	1.0980	1220.647	1523.043	0.01702	1548.964	1574.886	1626.729
2005	1.1555	1038.015	1345.713	0.02001	1372.646	1399.578	1453.443
2006	0.9829	1666.470	1365.491	-0.02059	**1337.371**	**1309.251**	**1253.011**

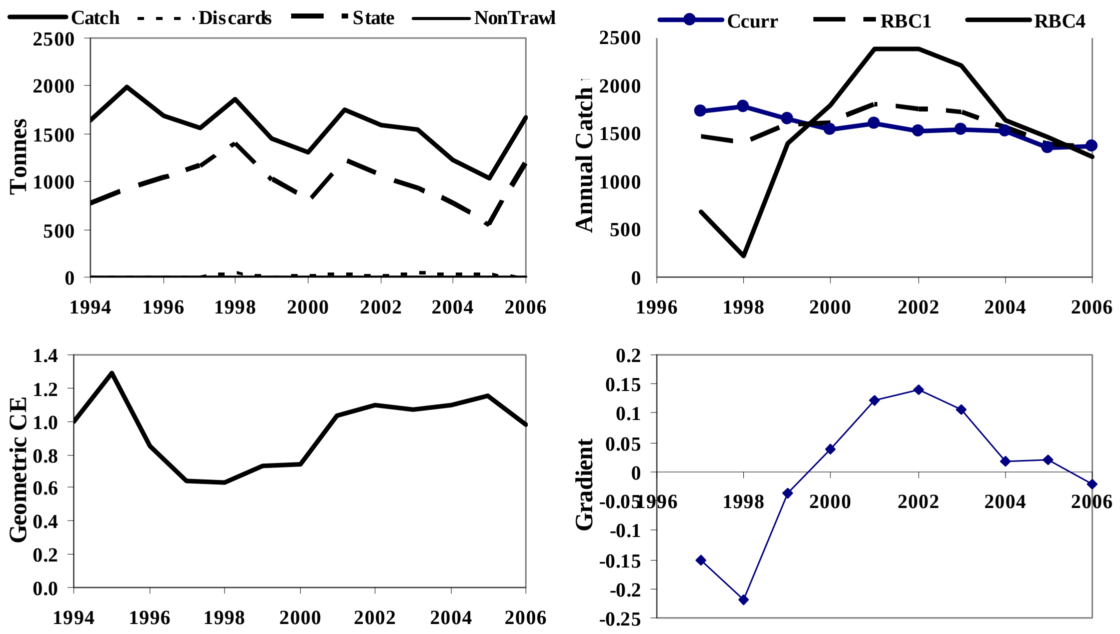

Figure 19.20. Plots of the various analyses for School Whiting using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. School Whiting				
Year	**RBC1**	**RBC2**	**RBC4**	**LnGrad**
1997	1422.898	1123.472	524.621	-0.17385
1998	1343.851	911.671	47.312	-0.24334
1999	1562.130	1482.475	1323.164	-0.04852
2000	1630.452	1718.280	1893.936	0.05693
2001	1828.656	2066.950	2543.538	0.14984
2002	1758.418	1995.096	2468.451	0.15553
2003	1723.628	1904.760	2267.024	0.11743
2004	1547.457	1571.870	1620.698	0.01603
2005	1369.749	1393.786	1441.858	0.01786
2006	**1337.407**	**1309.322**	**1253.152**	-0.02057

19.22 Silver Trevally (TRE – 37337062 – Pseudocaranx dentex)

Table 19.35. Silver Trevally. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for Zones 10 and 20 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	835.815		1.0000	0.000	697.273	0.000	138.542
1995	995.628		1.1635	0.000	793.656	0.000	201.972
1996	1018.879		1.0835	0.000	803.543	0.000	215.337
1997	785.220	908.886	1.1029	0.000	617.604	0.526	167.090
1998	628.496	857.056	0.8224	0.000	516.569	12.215	99.712
1999	488.585	730.295	0.8139	2.000	406.778	7.275	72.532
2000	493.298	598.900	0.6266	0.000	398.278	2.707	92.313
2001	649.434	564.953	0.7726	9.000	484.553	2.170	153.710
2002	517.938	537.314	0.7750	1.100	356.505	2.444	157.889
2003	525.325	546.499	0.8387	1.510	397.604	2.452	123.759
2004	655.781	587.119	0.9439	7.400	507.747	2.036	138.598
2005	402.361	525.351	0.8165	0.100	305.606	0.640	96.016
2006	367.244	487.678	0.8859	1.820	294.398	2.124	68.902

Table 19.36. Silver Trevally. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = 0.02286), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **6.566** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	835.815					
1995	1.1635	995.628					
1996	1.0835	1018.879					
1997	1.1029	785.220	908.886	0.02286	929.661	950.437	991.989
1998	0.8224	628.496	857.056	-0.10038	771.020	684.985	512.914
1999	0.8139	488.585	730.295	-0.10893	650.746	571.197	412.100
2000	0.6266	493.298	598.900	-0.14374	512.811	426.723	254.547
2001	0.7726	649.434	564.953	-0.03367	545.929	526.904	488.856
2002	0.7750	517.938	537.314	0.00295	538.897	540.481	543.649
2003	0.8387	525.325	546.499	0.06387	581.404	616.310	686.121
2004	0.9439	655.781	587.119	0.05776	621.031	654.943	722.767
2005	0.8165	402.361	525.351	0.02298	537.423	549.495	573.639
2006	0.8859	367.244	**487.678**	0.00144	**488.382**	**489.086**	**490.494**

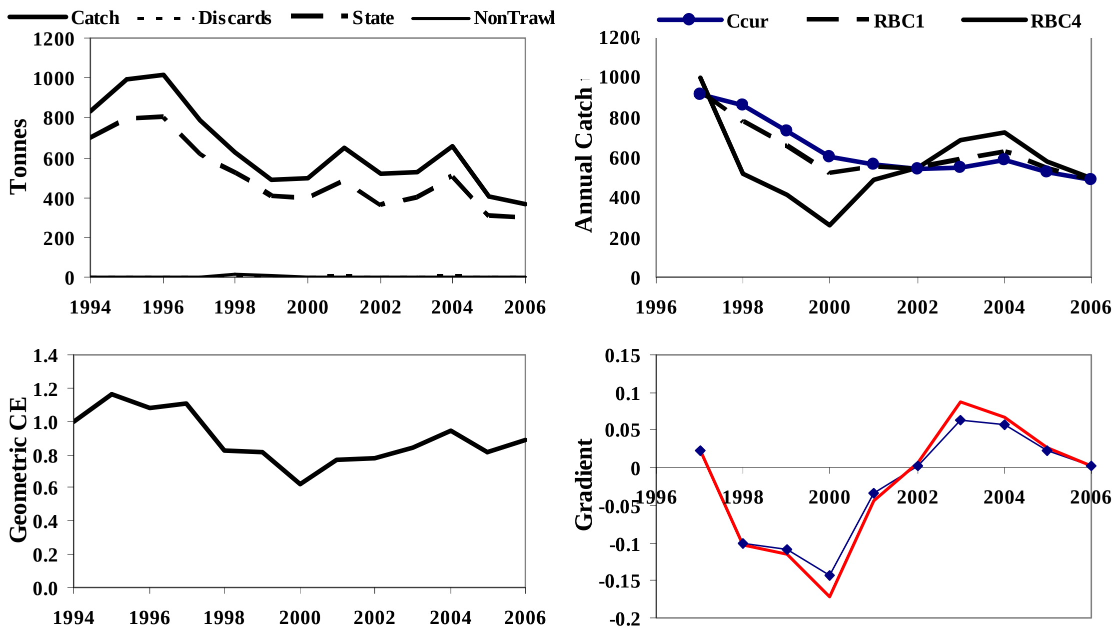

Figure 19.21. Plots of the various analyses for Silver Trevally using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Silver Trevally

Year	RBC1	RBC2	RBC4	LnGrad
1997	929.107	949.329	989.772	0.02225
1998	769.373	681.691	506.325	-0.10231
1999	646.180	562.065	393.835	-0.11518
2000	496.686	394.473	190.047	-0.17067
2001	539.587	514.222	463.491	-0.04490
2002	540.686	544.058	550.803	0.00628
2003	594.470	642.442	738.385	0.08778
2004	627.028	666.937	746.755	0.06797
2005	539.785	554.220	583.088	0.02748
2006	**488.631**	**489.583**	**491.489**	0.00195

19.23 Spotted Warehou (TRS – 37445006 – Seriolella punctata)

Table 19.37. Spotted Warehou. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for all Zones (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	2054.296		1.0000	0.000	78.956	0.000	1975.340
1995	2213.896		0.9927	0.000	117.062	0.000	2096.834
1996	2735.681		0.9813	0.000	174.562	0.000	2561.119
1997	2807.462	2452.834	0.9477	0.000	23.013	0.000	2784.449
1998	4583.954	3085.248	0.9374	2150.000	23.220	0.000	2410.734
1999	3300.217	3356.828	0.8621	45.000	1.732	0.000	3253.485
2000	3849.592	3635.306	0.7207	123.000	0.464	0.000	3726.128
2001	3990.454	3931.054	0.6938	695.000	0.324	0.923	3294.207
2002	4654.340	3948.651	0.7002	552.470	0.487	0.701	4100.682
2003	3829.763	4081.037	0.6360	769.760	1.007	12.642	3046.354
2004	4498.312	4243.217	0.7424	1183.280	3.767	0.251	3311.015
2005	3346.250	4082.166	0.7035	434.830	3.691	0.139	2907.589
2006	2459.184	3533.377	0.7180	95.630	1.810	0.086	2361.658

Table 19.38. Spotted Warehou. The trawl CPUE is the standardized mean catch rate data relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.01682), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **376.045** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	2054.296					
1995	0.9927	2213.896					
1996	0.9813	2735.681					
1997	0.9477	2807.462	2452.834	-0.01682	2411.579	2370.325	2287.817
1998	0.9374	4583.954	3085.248	-0.01994	3023.722	2962.196	2839.143
1999	0.8621	3300.217	3356.828	-0.03678	3233.377	3109.925	2863.021
2000	0.7207	3849.592	3635.306	-0.07562	3360.388	3085.469	2535.632
2001	0.6938	3990.454	3931.054	-0.08722	3588.195	3245.336	2559.617
2002	0.7002	4654.340	3948.651	-0.05128	3746.165	3543.679	3138.708
2003	0.6360	3829.763	4081.037	-0.02477	3979.944	3878.850	3676.664
2004	0.7424	4498.312	4243.217	0.00817	4277.866	4312.515	4381.813
2005	0.7035	3346.250	4082.166	0.01164	4129.679	4177.193	4272.219
2006	0.7180	2459.184	3533.377	0.02070	**3606.532**	**3679.686**	**3825.995**

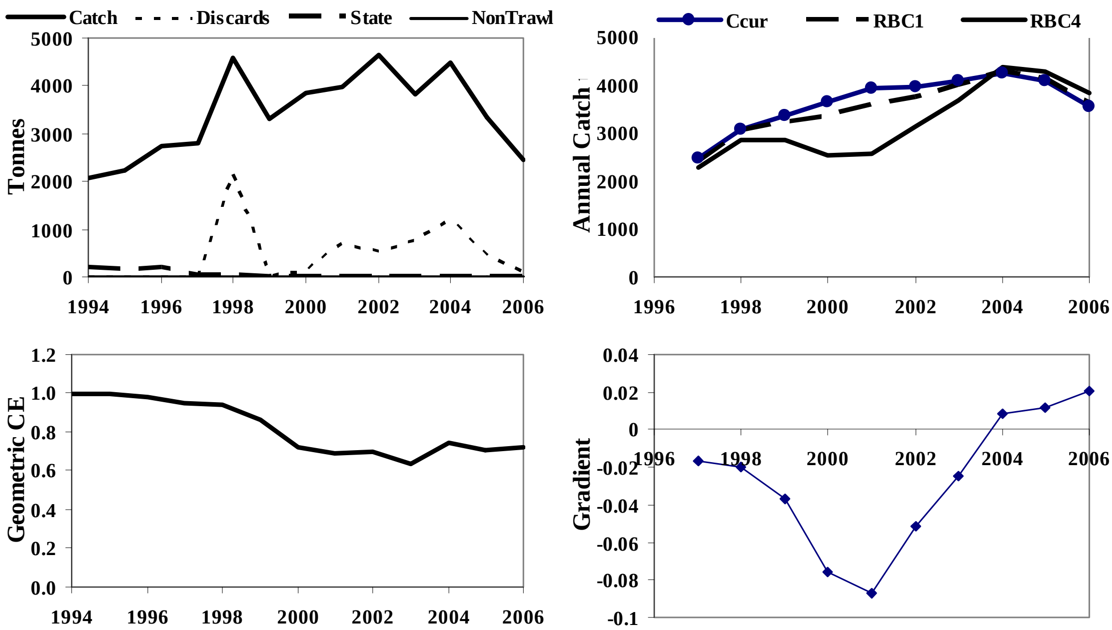

Figure 19.22. Plots of the various analyses for Spotted Warehou using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Spotted Warehou

Year	**RBC1**	**RBC2**	**RBC4**	**LnGrad**
1997	2410.501	2368.169	2283.504	-0.01726
1998	3021.471	2957.694	2830.140	-0.02067
1999	3222.790	3088.752	2820.675	-0.03993
2000	3306.284	2977.261	2319.217	-0.09051
2001	3505.749	3080.443	2229.832	-0.10819
2002	3687.126	3425.602	2902.553	-0.06623
2003	3931.718	3782.398	3483.759	-0.03659
2004	4288.636	4334.055	4424.894	0.01070
2005	4151.123	4220.079	4357.992	0.01689
2006	**3642.870**	**3752.364**	**3971.350**	0.03099

19.24 Total Ocean Perch (REG – 37287001 – Helicolenus percoides)

Table 19.39. Ocean Perch (Offshore and Inshore combined). Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CPUE is the standardized geometric mean catch rate for the all or Total Ocean Perch for Zones 10 and 20 (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	512.191		1.0000	0.000	226.542	0.000	285.649
1995	544.522		0.9176	0.000	232.117	0.000	312.405
1996	538.466		0.8238	0.000	182.062	0.000	356.405
1997	533.172	532.088	0.8377	0.000	106.649	5.692	420.832
1998	709.339	581.375	0.7361	298.000	41.056	20.162	350.121
1999	562.500	585.869	0.8296	142.000	43.461	7.480	369.560
2000	526.002	582.753	0.6807	134.000	42.683	9.844	339.474
2001	528.998	581.710	0.7249	135.000	35.993	8.822	349.183
2002	538.319	538.955	0.6515	167.580	45.519	19.326	305.894
2003	492.988	521.577	0.6698	89.120	34.671	31.285	337.912
2004	622.117	545.606	0.6475	236.890	20.454	66.580	298.193
2005	402.705	514.032	0.7447	58.780	15.280	34.568	294.078
2006	305.331	455.785	0.6412	30.740	19.157	56.110	199.324

Table 19.40. Ocean Perch (Offshore and Inshore combined). The trawl CPUE is the standardized mean catch rate data for all or Ocean Perch only, relative to 1994 (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.04379), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **69.596** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	512.191					
1995	0.9198	544.522					
1996	0.8389	538.466					
1997	0.8810	533.172	532.088	-0.04379	508.786	485.484	438.881
1998	0.7733	709.339	581.375	-0.03974	558.272	535.168	488.962
1999	0.8884	562.500	585.869	0.00410	588.272	590.674	595.479
2000	0.6744	526.002	582.753	-0.05047	553.344	523.935	465.116
2001	0.7397	528.998	581.710	-0.03147	563.402	545.094	508.478
2002	0.7180	538.319	538.955	-0.04460	514.915	490.876	442.797
2003	0.7642	492.988	521.577	0.02478	534.502	547.427	573.277
2004	0.7403	622.117	545.606	0.00479	548.219	550.833	556.060
2005	0.8479	402.705	514.032	0.03658	532.835	551.639	589.245
2006	0.7426	305.331	**455.785**	0.00428	**457.735**	**459.685**	**463.584**

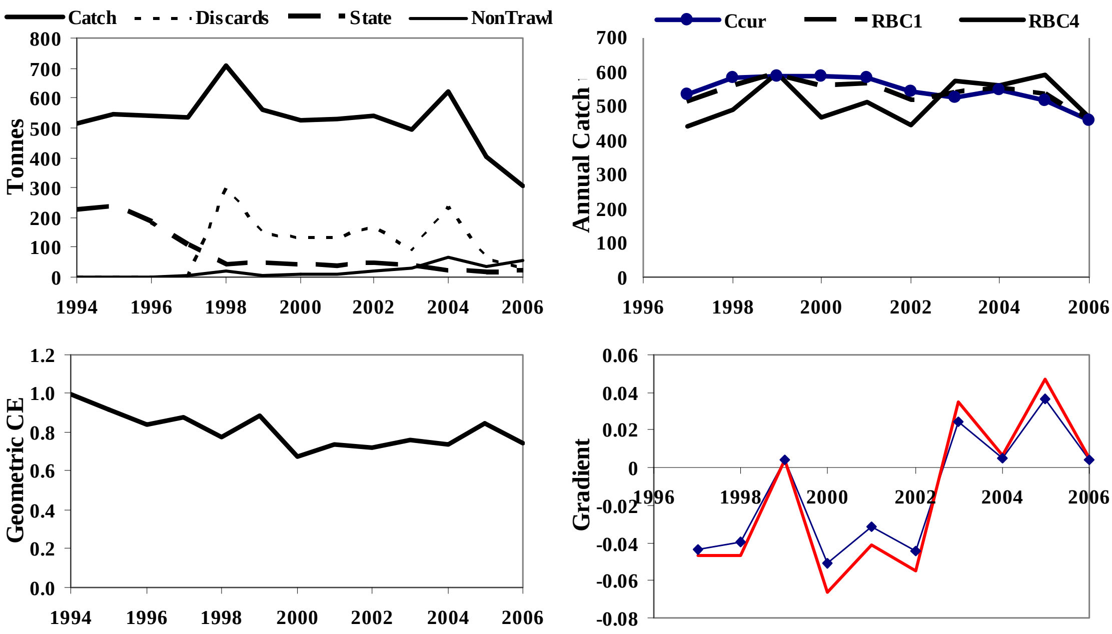

Figure 19.23. Plots of the various analyses for Total Ocean Perch using Standardized CPUE of Offshore Perch relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Total Ocean Perch

Year	RBC1	RBC2	RBC4	LnGrad
1997	506.963	481.838	431.588	-0.04722
1998	553.962	526.549	471.724	-0.04715
1999	588.320	590.771	595.673	0.00418
2000	544.121	505.489	428.224	-0.06629
2001	557.931	534.153	486.596	-0.04088
2002	509.496	480.037	421.119	-0.05466
2003	539.592	557.607	593.638	0.03454
2004	549.134	552.661	559.717	0.00647
2005	538.043	562.053	610.075	0.04671
2006	**458.049**	**460.312**	**464.839**	0.00497

19.25 Western Gemfish & GAB (GEM – 37439002 – Rexea solandri)

Table 19.41. Western Gemfish from SET and GAB. Base data for the TIER 4 calculations. Catch is the sum of Discards, State, Non Trawl and SEF2 catches (and SEF1 from GAB). All values in Tonnes. CPUE is the standardized geometric mean catch rate for the combined data (Haddon, 2007) relative to the catch rate in 1994. C_{CUR} is the average total catch (SEF2, non-trawl, discards, and State) over the previous 4 years.

Year	Catch	C_{CUR}	CPUE	Discards	State	Non Trawl	SEF2
1994	138.776		1.0000	0.000	0.000	0.000	138.266
1995	128.054		0.9161	0.000	0.000	0.000	124.409
1996	217.888		0.9845	0.000	0.000	0.000	208.329
1997	278.493	190.803	0.9061	0.000	0.000	0.000	226.983
1998	239.816	216.063	0.9580	12.000	0.000	0.000	185.371
1999	407.780	285.994	0.9439	5.000	0.000	0.000	271.813
2000	402.995	332.271	0.9751	30.000	0.000	0.000	349.236
2001	333.450	346.010	0.8113	9.000	0.000	0.363	253.030
2002	168.996	328.305	0.6299	9.140	0.000	0.441	138.474
2003	208.185	278.406	0.7334	12.580	0.000	3.918	173.606
2004	166.017	219.162	0.7638	8.920	0.000	3.655	146.185
2005	201.380	186.144	0.7672	1.640	0.000	5.732	156.585
2006	175.728	187.827	0.6885	0.550	0.000	28.211	126.489

Table 19.42. Western Gemfish. The trawl CPUE is the standardized mean catch rate data relative to 1994 for the combined data (Haddon, 2007), AnnC is the annual total catch in tonnes, C_{CUR} is the average total catch (Commonwealth trawl and non-trawl, discards, and State) over the previous 4 years, Slope is the gradient of each previous four year block of catch rates against year (e.g. 1994-1997 = -0.02134), RBC1 is the recommended biological Catch with an α of 1.0, similarly RBC4 has an α of 4.0. The weighted discards = **2.759** tonnes.

Year	CPUE	AnnC	C_{CUR}	Gradient	RBC1	RBC2	RBC4
1994	1.0000	138.776					
1995	0.9161	128.054					
1996	0.9845	217.888					
1997	0.9061	278.493	190.803	-0.02134	186.732	182.661	174.520
1998	0.9580	239.816	216.063	0.00473	217.085	218.108	220.153
1999	0.9439	407.780	285.994	-0.00699	283.995	281.996	277.999
2000	0.9751	402.995	332.271	0.01929	338.681	345.090	357.910
2001	0.8113	333.450	346.010	-0.04090	331.860	317.710	289.410
2002	0.6299	168.996	328.305	-0.11057	292.004	255.703	183.101
2003	0.7334	208.185	278.406	-0.09063	253.174	227.941	177.475
2004	0.7638	166.017	219.162	-0.00390	218.307	217.452	215.742
2005	0.7672	201.380	186.144	0.04423	194.377	202.609	219.074
2006	0.6885	175.728	**187.827**	-0.01312	185.362	182.897	177.968

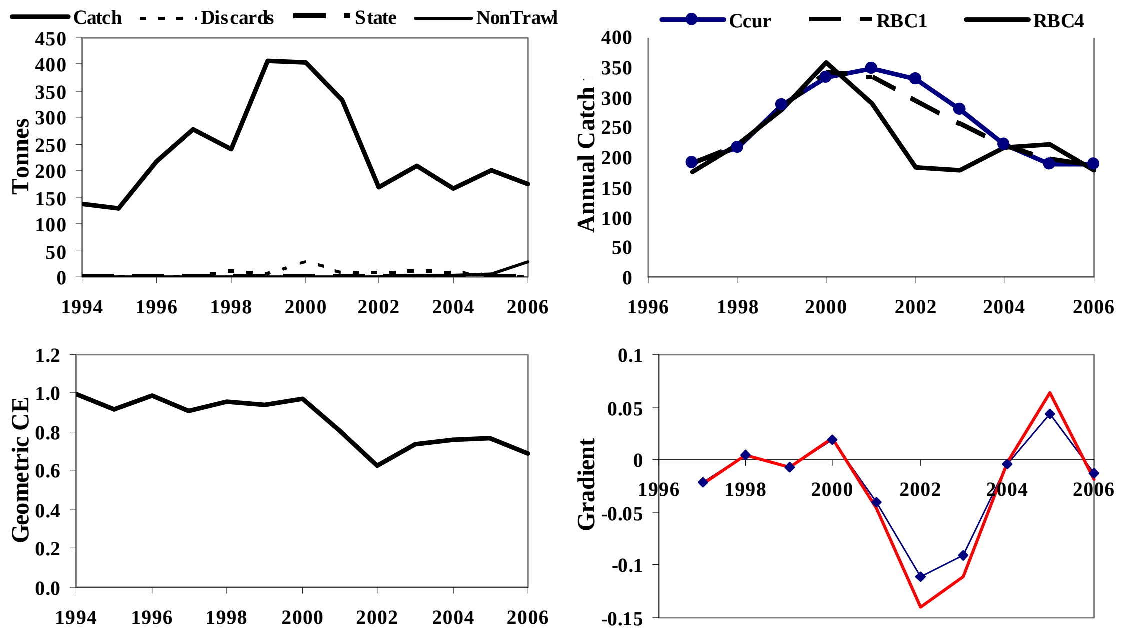

Figure 19.24. Plots of the various analyses for Western Gemfish using Standardized CPUE relative to 1994 (Haddon, 2007), along with the implied RBCs for alpha values of 1.0 and 4.0. Catch equates to total catches, State relates to all State catches, and CCUR is the average total extractions over the previous four years. The gradient refers to the gradient of catch rates over four year periods (1997 refers to 1994-1997).

Alternative RBC calculations using natural log transformed catch rates. Western Gemfish and GAB

Year	RBC1	RBC2	RBC4	LnGrad
1997	186.531	182.260	173.717	-0.02239
1998	217.169	218.276	220.489	0.00512
1999	283.974	281.954	277.914	-0.00706
2000	339.094	345.918	359.565	0.02054
2001	329.880	313.750	281.490	-0.04662
2002	282.436	236.567	144.829	-0.13971
2003	247.575	216.743	155.080	-0.11074
2004	218.529	217.896	216.629	-0.00289
2005	197.910	209.677	233.209	0.06321
2006	**184.353**	**180.878**	**173.928**	-0.01850

19.26 References

Haddon, M. (2006) Standardized commercial catch-Effort data for selected Shelf and Slope Assessment Group Species for 1986 – 2005. SESSF Document 2006/50. 55 p.

Haddon, M. (2007) Standardized Commercial Catch-Effort data for selected Shelf and Slope Assessment Group Species for 1986 - 2006. SESSF Document, 2007.

20. Tier 4 Harvest Control Rule applied to deepwater species 2007[14]

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20.1 Summary

This chapter calculates recommended biological catches (RBCs) using the Tier 4 harvest control rule for six groups of deepwater species : Cascade Plateau smooth oreo, other SEF smooth oreo, mixed basket of oreos, eastern and western deepwater sharks, and alfonsino.

20.2 Introduction

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006 and 2007 (Smith, 2007). The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis for assessing stock status or exploitation level for that stock. Tier 1 stocks have a well established and agreed quantitative stock assessment, while for Tier 2 stocks the assessment is judged to be more uncertain. Tier 3 is based on estimates of exploitation rate from catch curve analyses, while Tier 4 is based on trends in catch rates (CPUE). The original HSF is described in Smith and Smith (2005).

While the HSF was generally well received, some problems were identified during implementation in 2005, and further issues have come to light during the assessment phase in 2006. A management strategy evaluation (MSE) project has been funded to test and refine the current harvest strategies, but this will not start to deliver results until later in 2007 (Smith 2006).

The Tier 4 harvest control rule applies to species with the least amount of information about current stock status – no reliable information available on either current biomass or current exploitation rate. It is assumed that there is information available on current catch levels and on trends in catch rates.

[14] Paper presented to Deepwater Resource Assessment Group on 4 September, 2007

20.3 Methods

20.3.1 Original method

The steps in calculating the RBC for Tier 4 are as follows (Smith and Smith, 2005):

1. Calculate current catch level C_{CUR} as the average catch (landings plus discards) over the past NC years, where NC will depend on the period of "stable" effective (= binding) TACs. The default for NC is suggested to be 4 years.

2. Calculate the slope of the trend in CPUE (by regressing ln(catch rate) against year) over the past NS years. Use of the log of catch-rate ensures the regression is not sensitive to scaling. NS will depend on whether trends in CPUE tend to be relatively stable, or cyclic. For "stable" stocks, it is suggested that NS = NC (i.e. 4 years). For "cyclic" stocks, NS would need to be set at >= 2 cycle periods.

3. Calculate the RBC as $RBC = (1 + \alpha * slope) * C_{CUR}$

Issues that have arisen regarding application of the HSF for Tier 4, either during 2005 or during the assessment process in 2006, include:

a. It is not sufficiently precautionary relative to Tiers 1 to 3.

b. It fails to provide any benchmarks for stock status.

c. It would probably fail to result in recovery for an overfished stock.

d. Where the multiplier in a particular year is less than one, this will result in a decrease in catch level when applied to the TAC via the RBC. This in turn will result in a lower value for recent average catch (currently the average over the past four years). If the multiplier in the next year is one (indicating that the stock is at or close to target levels) the application of the formula will still result in a decrease in RBC because recent average catch has declined. The concern is that this could result in a "ratchet" effect with continually declining TACs even when the stock is at target levels. (Note that this should ultimately be self-correcting because the multiplier will be greater than one where the stock is above target levels, but there may be a substantial delay before the correction comes into effect). (Smith, 2007)

20.3.2 Suggested modifications

Several proposals were put forward to try to resolve issues a and b above. Although promising, there has been insufficient time to consider or properly test these suggested solutions, so they will not be implemented during 2007. Instead, it has been decided to continue to implement the current Tier 4 procedure (with some modifications outlined below), but to include further advice from the RAG on whether the resulting RBCs are appropriately precautionary given other information and considerations. The latter would include:

- Information to “scale” recent CPUE (e.g. comparison of recent average CPUE with similar data from earlier in the development of the fishery).

- Information on the biological productivity of the species (e.g. longevity)

For each Tier 4 species/stock, the RAG should provide explicit advice on

a) The Tier 4 RBC (including the necessary supplementary information on state catches and discards)

b) Additional considerations based on the dot points listed above

c) Based on these additional considerations, advice on whether the RBC should be varied and by how much

For the basic Tier 4 calculations, there is still uncertainty about the value of α to use. RBCs should be calculated for α values of 1, 2 and 4. In the absence of reasoned alternatives, the value $\alpha = 1$ should be used for the base RBC, as values greater than 1 will be over-reactive (Punt, pers. commn.).

20.3.3 Discards

The ISMP program does not provide calculated discard rates for the species considered in this document. Raw data from ISMP-observed shots on retained and discarded catch (provided by Matt Koopman, PIRVic) has been used to estimate discard rates. There are not enough observed shots to estimate discard rates for each year. The discard rates have been estimated as the ratio of discarded catch to total catch, where the catch in each case is summed over all ISMP-observed shots for that species in 2003-06. Thus the discard rates given apply to total (not landed) catch.

20.4 Results

20.4.1 Cascade smooth oreo

Scientific name: *Pseudocyttus maculatus*

CAAB species code: 37266003

Estimated discard rate: 12.3 %

Quotas were introduced for Cascade Plateau smooth oreo in 2005.

Quota 2005: 100 t
Quota 2006: 100 t
Quota 2007 (bycatch): 80 t + 13 t Jan-Apr 2008

Table 20.1. Catches from 1989-2004 are from the logbook data. Catches in 2005-06 are from the landings data. The catch rate is calculated from logbook data, and is the geometric mean of catch (kg). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln(catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	retained catch (t)	retained + discards (t)	catch rate (kg/shot)	C_{CUR}	Slope	RBC1	RBC2	RBC4
1989	128	145	5.61					
1990	92	104	5.02					
1991	1	1	4.14					
1992	11	13	6.06	66	0.048	69	72	78
1993	2	2	3.91	30	-0.140	26	22	13
1994	95	108	4.95	31	0.027	32	33	34
1995	14	16	3.91	35	-0.542	16	-3	-41
1996	142	162	4.16	72	-0.029	70	68	64
1997	282	321	4.60	152	-0.079	140	128	104
1998	103	118	4.86	154	0.331	206	257	359
1999	91	103	5.21	176	0.340	236	296	416
2000	298	340	5.26	221	0.232	272	323	425
2001	278	317	5.46	220	0.184	260	301	381
2002	285	325	4.69	271	-0.135	235	198	124
2003	105	120	4.95	275	-0.171	228	181	87
2004	101	115	5.89	219	0.154	253	287	354
2005	68	77	4.94	159	0.170	186	214	268
2006	62	70	6.13	96	0.261	**121**	**146**	**196**
				RBC minus discards:		106	128	171

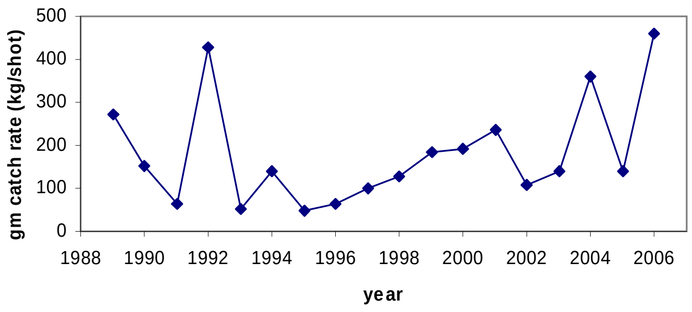

Figure 20.1. Geometric mean catch rate for Cascade smooth oreo.

20.4.2 Other SEF smooth oreo

Scientific name: *Pseudocyttus maculates*

CAAB species code: 37266003

Estimated discard rate: 12.3 %

Quotas were introduced for other SEF smooth oreo in 2005.

Quota 2005: 50 t
Quota 2006: 50 t
Quota 2007(bycatch): 40 t + 12 t Jan-Apr 2008

Table 20.2. Catches from 1987-2001 are from the logbook data. Catches in 2002-06 are from the landings data. The catch rate is calculated from logbook data, and is the geometric mean of catch (kg). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln (catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	retained catch (t)	retained + discards (t)	catch rate (kg/shot)	C_{CUR}	Slope	RBC1	RBC2	RBC4
1987	7	7	105.73					
1988	41	46	145.04					
1989	182	208	197.14					
1990	706	805	299.92	267	0.343	358	450	633
1991	979	1,116	249.84	544	0.205	655	767	990
1992	2314	2,638	374.06	1,192	0.174	1399	1606	2021
1993	611	696	137.12	1,314	-0.194	1058	803	292
1994	569	649	93.19	1,275	-0.396	770	265	-746
1995	487	555	113.67	1,135	-0.396	685	236	-662
1996	182	208	75.59	527	-0.159	443	360	192
1997	675	769	185.25	545	0.165	635	726	906
1998	603	687	162.16	555	0.196	664	773	990
1999	230	262	127.90	482	0.144	551	621	760
2000	213	243	108.05	490	-0.185	399	308	127
2001	312	355	169.64	387	-0.003	385	384	382
2002	300	342	137.68	300	0.067	321	341	381
2003	292	333	106.23	318	-0.026	310	302	285
2004	234	267	90.21	324	-0.215	254	185	45
2005	38	43	87.67	246	-0.152	209	172	97
2006	11	13	87.57	164	-0.061	154	144	124
				RBC minus discards:		135	126	109

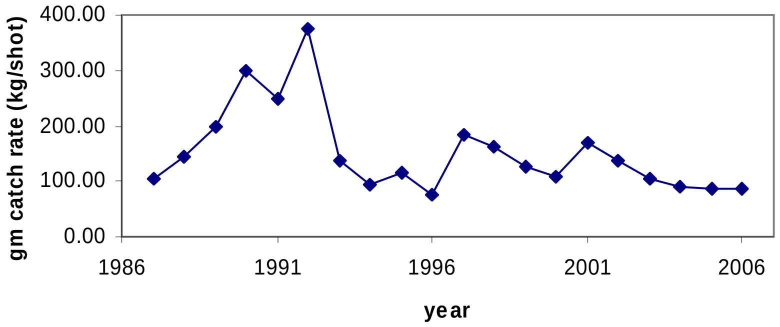

Figure 20.2. Geometric mean catch rate for other SEF smooth oreo

20.4.3 Oreo mixed basket (warty, spikey, rough and black)

Scientific name: *Allocyttus verrucosus, Neocyttus rhomboidalis, Neocyttus psilorhynchus, Allocyttus niger*

CAAB species code: 37266004, 37266001, 37266006, 37266005, 37266901 (group code)

Estimated discard rate: 16.2 %

Quotas were introduced for a mixed basket of spikey, warty, black and rough oreos in 2005.

Quota 2005: 200 t
Quota 2006: 200 t
Quota 2007: 150 t + 40 t Jan-Apr 2008 (bycatch)

Table 20.3. Catches from 1986-2004 are from the logbook data. Catches in 2005-06 are from the landings data (AFMA CatchWatch). The catch rate is calculated from logbook data, and is the geometric mean of catch (kg). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln(catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	retained catch (t)	retained + discards (t)	catch rate (kg/shot)	C_{CUR}	Slope	RBC1	RBC2	RBC4
1986	53	63	104.33					
1987	63	75	111.23					
1988	37	44	81.50					
1989	185	220	113.17	101	-0.007	100	99	98
1990	255	304	168.58	161	0.158	186	211	262
1991	109	130	87.41	175	0.061	185	196	217
1992	730	871	238.07	381	0.157	441	501	621
1993	404	482	94.52	447	-0.073	414	381	316
1994	367	438	76.46	480	-0.133	417	353	226
1995	498	594	86.59	596	-0.325	403	209	-178
1996	443	528	66.03	511	-0.095	462	413	316
1997	1,078	1,287	116.18	712	0.098	782	852	992
1998	1,307	1,560	138.14	992	0.197	1187	1382	1773
1999	546	651	103.01	1,007	0.151	1158	1310	1613
2000	488	583	97.48	1,020	-0.082	937	853	686
2001	506	604	94.58	850	-0.119	748	647	445
2002	297	355	68.42	548	-0.126	479	410	272
2003	451	538	78.05	520	-0.099	468	417	314
2004	205	244	66.54	435	-0.092	395	355	275
2005	159	190	58.26	332	-0.064	310	289	246
2006	104	124	62.64	274	-0.079	**252**	**231**	**187**
				RBC minus discards:		211	193	157

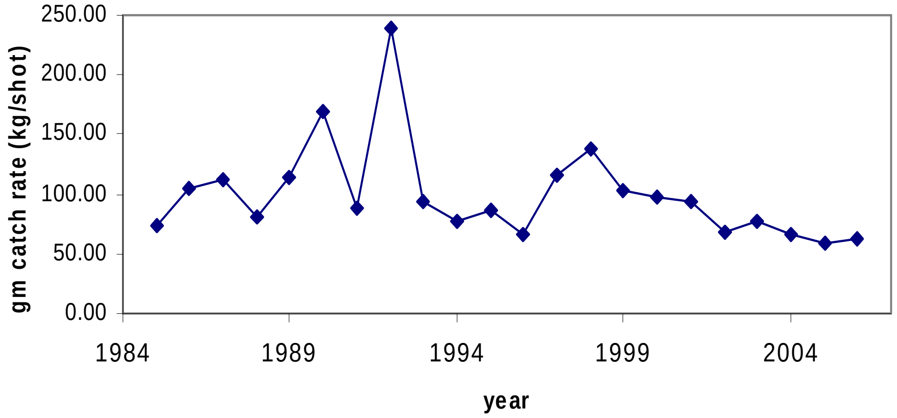

Figure 20.3. Geometric mean catch rate for oreo mixed basket.

20.4.4 Deepwater sharks

Table 20.4 The deepwater shark species included in the basket quota

Common name	Scientific name	CAAB code
brier shark	*Deania calcea*	37020003
platypus shark	*Deania quadrispinosa*	37020004
Plunket's shark	*Centroscymnus plunketi*	37020013
roughskin shark	*Centroscymnus and Deania spp.*	37020904
pearl shark	*D. calcea and D. quadrispinosa*	37020905
black shark	*Centroscymnus spp.*	37020906
lantern shark	*Etmopterus spp.*	37020907

Estimated discard rate: 2.8 %

Quotas were introduced for a mixed basket of deepwater sharks in the eastern and western SESSF in 2005. The east/west boundary is the same as that used for gemfish. The eastern area extends from NSW around the Tasmanian east coast and up the west coast to 42° S, including Bass Strait to 146° 22´. The western area is the remainder of the SESSF.

As well as the species codes in Table 20.4, the codes 37020000 (dogfish) and 37990003 (other sharks) have been used to extract catch information from the logbook database, as the codes in Table 20.4 were not in use prior to 2000. The catches (and catch rates) are from shots with depths >= 600 m.

20.4.4.1 Eastern deepwater sharks

Quota 2005: 92 t
Quota 2006: 92 t
Quota 2007: 21 t (to 30 April 2008)

Table 20.5. Catches from 1986-2004 are from the logbook data using the species codes in Table 20.4 as well as codes 37020000 (dogfish) and 37990003 (other sharks). The catches are from shots >= 600m depth. Catches in 2005-06 are from the landings data (AFMA CatchWatch). The catch rate is calculated from logbook data, and is the geometric mean of catch (kg)/effort (hrs). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln(catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	retained catch (t)	retained + discards (t)	catch rate (kg/hour)	C_{CUR}	Slope	RBC1	RBC2	RBC4
1986	56	58	14.89					
1987	16	16	12.28					
1988	7	7	8.68					
1989	54	56	54.63	34	0.355	46	58	82
1990	62	64	144.26	36	0.923	68	101	167
1991	31	32	21.53	40	0.370	54	69	98
1992	75	77	46.24	57	-0.240	43	30	2
1993	118	121	55.34	74	-0.211	58	43	11
1994	162	167	58.57	99	0.318	131	162	226
1995	184	189	70.48	138	0.132	157	175	212
1996	358	369	53.09	211	0.006	213	214	216
1997	204	210	31.83	234	-0.211	184	135	36
1998	195	200	31.75	242	-0.290	172	101	-39
1999	149	153	26.27	233	-0.211	184	135	36
2000	144	148	29.30	178	-0.044	170	162	147
2001	103	106	22.17	152	-0.097	137	122	93
2002	134	137	27.89	136	-0.010	135	133	131
2003	114	117	18.51	127	-0.115	112	98	69
2004	76	78	17.50	110	-0.112	97	85	60
2005	66	68	18.26	100	-0.133	87	74	47
2006	55	57	12.04	80	-0.125	**70**	**60**	**40**
				RBC minus discards:		68	58	39

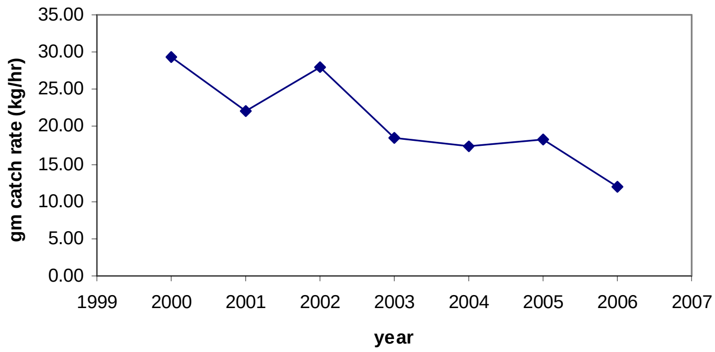

Figure 20.4 Geometric mean catch rate for eastern deepwater sharks.

20.4.4.2 Western deepwater sharks

Quota 2005: 108 t
Quota 2006: 108 t
Quota 2007: 10 t (to 30 April 2008)

Table 20.6 Catches from 1986-2004 are from the logbook data using the species codes in Table 20.4 as well as codes 37020000 (dogfish) and 37990003 (other sharks). The catches are from shots >= 600m depth.Catches in 2005-06 are from the landings data (AFMA CatchWatch). The catch rate is calculated from logbook data, and is the geometric mean of catch (kg)/effort (hrs). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln(catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	retained catch (t)	retained + discards (t)	catch rate (kg/hour)	C_{CUR}	Slope	RBC1	RBC2	RBC4
1986	1	1	17.34					
1987	1	1	8.63					
1988	1	1	27.85					
1989	2	2	50.63	1	0.439	2	2	3
1990	0	0	300.00	1	1.124	2	3	5
1991	2	2	48.46	1	0.344	2	2	3
1992	4	4	45.31	2	-0.216	2	1	0
1993	3	3	31.74	2	-0.681	1	-1	-4
1994	2	2	12.46	3	-0.443	2	0	-2
1995	101	104	20.77	28	-0.328	19	10	-9
1996	189	195	20.94	76	-0.074	70	65	54
1997	302	311	21.87	153	0.170	179	205	257
1998	255	262	17.35	218	-0.050	207	196	175
1999	201	207	17.82	244	-0.072	226	209	174
2000	358	369	22.73	287	0.014	291	295	304
2001	304	313	16.79	288	0.015	292	296	305
2002	311	320	17.38	302	-0.038	291	279	256
2003	210	216	13.41	304	-0.155	257	210	116
2004	252	260	14.11	277	-0.078	256	234	191
2005	101	104	11.59	225	-0.116	199	173	120
2006	86	88	12.58	167	-0.039	**161**	**154**	**141**
				RBC minus discards:		156	150	137

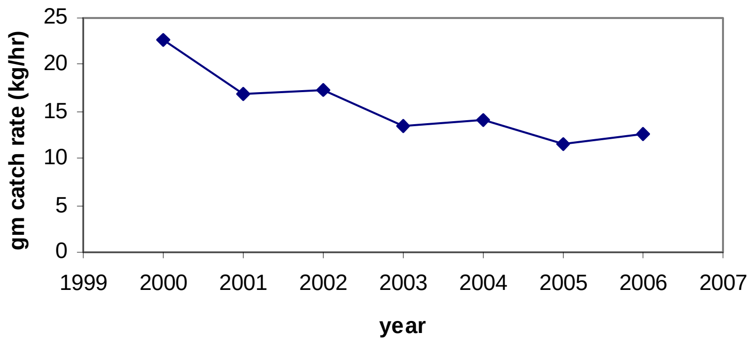

Figure 20.5 Geometric mean catch rate for western deepwater sharks.

20.4.5 Alfonsino

Scientific name: *Beryx splendens*

CAAB species code: 37258002

Estimated discard rate: low in SEF (2.4%), assume 0 in ECDWTS

Quotas were introduced for alfonsino in the East Coast Deepwater Trawl Sector (ECDWTS) in 2005. This analysis uses data from the ECDWTS only. Catches in the rest of the SESSF are very low.

Quota 2005: 500 t
Quota 2006: 500 t
Quota 2007: 500 t + 76 t Jan-Apr 2008

In 2006 the ECDWTS did not fish due to the SFRARP process for the allocation of quota.

Table 20.7 All data in this table except for the first column applies to the ECDWTS. Catches from 2000-2006 are from the logbook data. The catch rate is calculated from logbook data, and is the geometric mean of catch (kg)/effort t(hrs). C_{CUR} is the average total catch over the previous 4 years, Slope is the gradient of each previous four year block of ln (catch rates) against year, RBC1 is the Recommended Biological Catch with an α of 1.0, RBC2 with an α of 2.0, and RBC4 with an α of 4.0.

Year	catch in the SET (t)	retained catch	catch rate (kg/hour)	C_{CUR}	Slope	RBC1	RBC2	RBC4
2000	41	66	2517.15					
2001	7	312	1210.12					
2002	25	42	1012.03					
2003	6	141	927.55	140	-0.317	96	51	-38
2004	16	504	3588.18	250	0.317	329	408	567
2005	8	129	1561.49	204	0.265	258	312	421
2006	11	0	-	258*	0.260*	**325***	**392***	**527***

*Calculated using data from 2003-2005

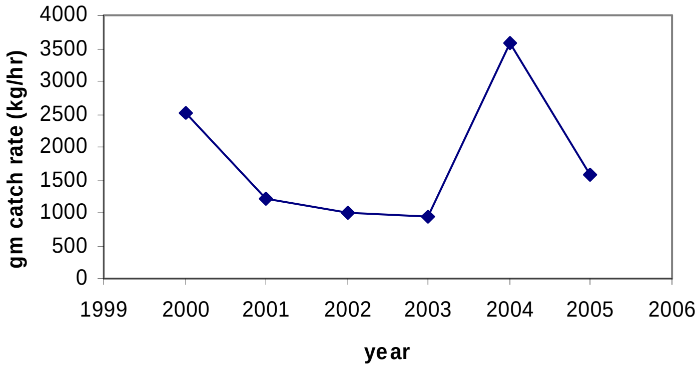

Figure 20.6 Geometric mean catch rate for alfonsino in the ECDWTS.

20.5 References

Smith, A. and D.Smith (2005) A harvest strategy framework for the SESSF. Report to AFMA, June 2005

Smith, A. (2006) Guidelines regarding implementation of the SESSF Harvest Strategy Framework for 2006. July 2006

Smith, A. (2007) Proposed revisions to the SESSF Harvest Strategy Framework for 2007 – a discussion paper

21. Tier 4 Harvest Control Rule Applied to Elephant Fish and Saw Shark 2007

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21.1 Summary

This document presents a calculation of recommended biological catches (RBCs) and implied total allowable catches TAC's using the Tier 4 harvest control rule for three species commonly caught asa minor catch component of the southern shark fishery: Elephant fish, Common Saw Shark and Southern Saw Shark. The RBC's for Common and Southern saw Shark cannot be determined individually with any accuracy due to a lack of historical differentiation of these species in industry log books and landings, instead, a combined Saw Shark RBC is presented here.

21.2 Introduction

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006 and 2007 (Smith, 2007). The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis for assessing stock status or exploitation level for that stock. Tier 1 stocks have a well established and agreed quantitative stock assessment, while for Tier 2 stocks the assessment is judged to be more uncertain. Tier 3 is based on estimates of exploitation rate from catch curve analyses, while Tier 4 is based on trends in catch rates (CPUE). The original HSF is described in Smith and Smith (2005).

The justification and basis for the HSF has received broad notional support from since introduction, however, some problems of detail and implementation have come to light during the assessment phase in 2006 and 2007 for some SEF species. A management strategy evaluation (MSE) project has been funded to test and refine the current harvest strategies, but comprehensive results are not anticipated until late in 2007 (Smith, 2006). The Tier 4 harvest control rule applies to species with the least amount of information about current stock status – no reliable information available on either current biomass or current exploitation rate. It is assumed that there is information available on current catch levels and on trends in catch rates.

Full stock assessments have been carried out for both elephant fish and saw shark in 2004 – prior to introduction of the current HSF (Punt, 2005). There remains some question as to the validity of these assessments as they are both based on somewhat unreliable catch per unit effort (CPUE) data with minimal other input data (length frequency). The Saw Shark assessment has the additional disadvantage that it bundles two species with differing (although overlapping range) and differing biological parameters.

A full independent preliminary assessment for elephant fish was developed in 2007 using a new methodology for determination of CPUE (Pribac *et al.*, 2007a) that attempts to circumvent problems associated with determing directed effort.

However additional uncertainty was identified in the elephant catch time series relating to a hitherto omitted large component of the catch arising from the recreational sector in Western Port and Port Phillip bays. Nevertheless a preliminary RBC estimate was made using this assessment and by applying a Tier 1 harvest control rule (Pribac *et al*., 2007b). The resulting base case RBC was 38mt with a spread from 6 to 85 mt. The corresponding long term “equilibrium” RBC’s were determined to be 85mt and range from 75 to 110 mt.

SharkRAG determined that there remains considerable uncertainty in the elephant fish assessment. Particularly relating to CPUE analysis, with reference to unknown levels of elephant fish targeting and between correspondence between earlier and later parts of the catch and effort series (given that logbook reporting procedures for these minor species in all likelihood underwent substantial change in the early 90’s).

With the above data and assessment uncertainties in mind, sharkRAG recommended that both the elephant fish and saw shark assessments are not yet sufficiently reliable for adoption of the Tier 1 HCR for calculation of RBC’s and instead advised that the Tier 4 HCR should be adopted for the determination of the 2008 RBC’s (SharkRAG Aug 2007).

21.3 Methods

21.3.1 Original method

The steps in calculating the RBC for Tier 4 are as follows (Smith and Smith, 2005):

1. Calculate current catch level C_{CUR} as the average catch (landings plus discards) over the past NC years, where NC will depend on the period of “stable” effective (= binding) TACs. The default for NC is suggested to be 4 years.
2. Calculate the slope of the trend in CPUE (by regressing ln (catch rate) against year) over the past NS years. Use of the log of catch-rate ensures the regression is not sensitive to scaling. NS will depend on whether trends in CPUE tend to be relatively stable, or cyclic. For “stable” stocks, it is suggested that NS = NC (i.e. 4 years). For “cyclic” stocks, NS would need to be set at >= 2 cycle periods.
3. Calculate the RBC as $RBC = (1 + \alpha * slope) * C_{CUR}$

Issues that have arisen regarding application of the HSF for Tier 4, either during 2005 or during the assessment process in 2006, include:

a) It is not sufficiently precautionary relative to Tiers 1 to 3.
b) It fails to provide any benchmarks for stock status.
c) It would probably fail to result in recovery for an overfished stock.
d) Where the multiplier in a particular year is less than one, this will result in a decrease in catch level when applied to the TAC via the RBC. This in turn will result in a lower value for recent average catch (currently the average over the past four years). If the multiplier in the next year is one (indicating that the stock is at or close to target levels) the application of the formula will still result in a decrease in RBC because recent average catch has declined. The concern is that this could result in a "ratchet" effect with continually declining TACs even when the stock is at target levels. (Note that this should ultimately be self-correcting because the multiplier will be greater than one where the stock is above target levels, but there may be a substantial delay before the correction comes into effect). (Smith, 2007)

21.3.2 Suggested modifications

Several proposals were put forward to try to resolve issues a and b above. Although promising, there has been insufficient time to consider or properly test these suggested solutions, so they will not be implemented during 2007. Instead, it has been decided to continue to implement the current Tier 4 procedure (with some modifications outlined below), but to include further advice from the RAG on whether the resulting RBCs are appropriately precautionary given other information and considerations. The latter would include:

- Information to "scale" recent CPUE (e.g. comparison of recent average CPUE with similar data from earlier in the development of the fishery).

- Information on the biological productivity of the species (e.g. longevity)

For each Tier 4 species/stock, the RAG should provide explicit advice on

- The Tier 4 RBC (including the necessary supplementary information on state catches and discards)

- Additional considerations based on the dot points listed above

- Based on these additional considerations, advice on whether the RBC should be varied and by how much

For the basic Tier 4 calculations, there is still uncertainty about the value of α to use. RBCs should be calculated for α values of 1, 2 and 4. In the absence of reasoned alternatives, the value $\alpha = 1$ should be used for the base RBC, as values greater than 1 will be over-reactive (Punt, pers. commn.).

21.3.3 Discards

The ISMP program provides limited observations on discard rates for the species considered in this document. Observations taken during survey trips using GHATF vessels also give point discard estimates for some years. These discard rates can be thought to be derived from atypical trips and so may not be representative of normal industry practise, however in the absence of any other discard estimates they were applied to the total catches as used in this report. For elephant fish these point estimates were simply applied to all years. For saw shark the discard estimates for southern and common saw sharks were catch weight averaged and applied to total reported catches.

21.4 Results

21.4.1 Elephant Fish

Scientific name: *Callorhinchus milii*

CAAB species code: 37043001

Quotas were introduced for Elephant Fish in 2002.

RBC 2004: 130 t
RBC 2005: 130 t
RBC 2006: 130 t
RBC 2007: 130 t + 21 t Jan-Apr 2008

Table 21.1. Time-series of historical catches (1973–2006) of elephant fish by the Southern Shark Fishery.

(a) GHATF Victoria Ele catch (Kg)

Year	Gear-Type				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	431	2212	0	25544	1781
1974	1648	35262	0	18668	0
1975	2923	55587	0	4150	0
1976	499	35582	0	3803	0
1977	0	64412	0	7	0
1978	0	56654	176	6	0
1979	0	91631	363	987	0
1980	2	68874	4788	1361	0
1981	0	75451	469	744	0
1982	64	53361	0	28	0
1983	20	74587	28	77	0
1984	236	61485	768	0	0
1985	414	61517	18	15	0
1986	1920	43565	117	0	0
1987	69	41081	0	0	371
1988	1911	35515	0	686	0
1989	795	33072	0	68	0
1990	1135	26082	0	0	0
1991	1049	51866	0	0	0
1992	1788	39067	79	35	0
1993	1335	23875	0	0	2969
1994	504	22270	0	0	516
1995	285	33312	322	0	0
1996	281	44690	620	181	0
1997	56	33384	70	0	0
1998	135	35853	35	0	0
1999	352	41122	24	0	0
2000	15	34278	66	0	0
2001	49	32555	5	0	0
2002	112	30870	0	0	0
2003	8	36381	242	0	0
2004	573	24598	352	0	0
2005	0	27939	5	0	0
2006	3	24770	7	0	0

(Table 21.1 Continued)

(b) GHATF Tasmania Ele catch (Kg)

Year	Gear-Type				
	Longline	**6" Mesh**	**6.5" Mesh**	**7" Mesh**	**8" Mesh**
1973	0	0	0	1348	0
1974	0	5457	0	3229	0
1975	326	6568	0	0	0
1976	883	1391	0	0	0
1977	0	1828	0	0	0
1978	0	8710	0	0	0
1979	0	7261	0	0	0
1980	0	7043	0	0	0
1981	0	5041	0	0	0
1982	0	4594	362	0	0
1983	0	5410	0	0	0
1984	0	15630	0	0	0
1985	0	46640	0	0	0
1986	677	19038	0	0	0
1987	0	21254	0	0	0
1988	5826	0	0	22097	0
1989	234	27347	0	0	448
1990	1165	14083	0	12969	0
1991	312	15899	0	0	0
1992	5114	22197	0	2302	2
1993	2411	2842	0	20871	0
1994	0	15254	0	20870	0
1995	6	6530	0	8577	0
1996	158	15065	0	14405	0
1997	0	10267	1148	9554	0
1998	1338	12786	0	0	0
1999	7	11908	0	0	0
2000	3	14727	1008	0	0
2001	0	6775	469	0	0
2002	6	6965	12	0	0
2003	9	7546	0	0	0
2004	0	7391	0	0	0
2005	0	5993	0	0	0
2006	0	4302	1895	0	0

(Table 21.1 Continued)

(c) GHATF South Australia Ele catch (Kg)

Year	Gear-Type				
	Longline	6” Mesh	6.5” Mesh	7” Mesh	8” Mesh
1973	0	0	0	0	0
1974	29	900	0	31	170
1975	0	0	0	0	0
1976	0	0	0	0	30
1977	0	2087	0	0	0
1978	0	29	0	0	0
1979	0	329	0	10	0
1980	0	205	0	10	0
1981	0	357	0	3	0
1982	0	254	0	0	0
1983	0	356	0	0	0
1984	0	73	0	3	0
1985	151	9	17	206	0
1986	0	52	0	0	0
1987	0	311	0	277	0
1988	0	623	0	442	0
1989	0	80	0	65	0
1990	8	169	181	0	0
1991	22	27	0	25	0
1992	16	18	0	453	0
1993	18	7	0	7	0
1994	0	67	21	0	0
1995	0	654	2150	0	0
1996	11	604	451	645	0
1997	18	1767	3543	50	0
1998	0	345	2340	0	0
1999	117	262	5356	50	0
2000	16	376	3398	0	0
2001	4	1948	5525	0	0
2002	4	473	2128	0	0
2003	81	1858	2708	0	0
2004	1	615	2055	0	0
2005	0	469	1896	0	0
2006	0	1096	3720	0	0

(Table 21.1 Continued)

(d) GHATF Total Ele Catch (Kg)

Year	Gear-Type				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	431	2212	0	26892	1781
1974	1677	41619	0	21928	170
1975	3249	62155	0	4150	0
1976	1382	36973	0	3803	30
1977	0	68327	0	7	0
1978	0	65393	176	6	0
1979	0	99221	363	997	0
1980	2	76122	4788	1371	0
1981	0	80849	469	747	0
1982	64	58209	362	28	0
1983	20	80353	28	77	0
1984	236	77188	768	3	0
1985	565	108166	35	221	0
1986	2597	62655	117	0	0
1987	69	62646	0	277	371
1988	7737	36138	0	23225	0
1989	1029	60499	0	133	448
1990	2308	40334	181	12969	0
1991	1383	67792	0	25	0
1992	6918	61282	79	2790	2
1993	3764	26724	0	20878	2969
1994	504	37591	21	20870	516
1995	291	40496	2472	8577	0
1996	450	60359	1071	15231	0
1997	74	45418	4761	9604	0
1998	1473	48984	2375	0	0
1999	476	53292	5380	50	0
2000	34	49381	4472	0	0
2001	53	41278	5999	0	0
2002	122	38308	2140	0	0
2003	98	45785	2950	0	0
2004	574	32604	2407	0	0
2005	0	34401	1901	0	0
2006	3	30168	5622	0	0

(Table 21.1 Continued)

(e) SETF ele catch (mt)

Year	Sub-region									
	WSA	**CSA**	**SAV-**	**SAV-**	**WBa**	**EBas**	**WTas**	**ETas**	**NSW**	**UNK**
1985	0	0	0	0	0.12	0.24	0	0.33	0.21	0
1986	0	0	0.10	0	3.55	0.85	0.04	0.46	0.15	0
1987	0	0	0	0	0.20	0.45	0.03	0.06	1.06	0
1988	0	0	0.09	0	0.19	2.02	0.14	0.17	0.49	0
1989	0	0	0	0	1.11	1.40	0.26	0.05	0.09	0
1990	0	0	0	0	0.31	0.90	0.27	0	0.37	0
1991	0	0	0	0	1.14	4.02	0.44	0.26	0.46	0
1992	0	0	0.03	0.03	2.81	2.48	0.56	0.10	0.38	0
1993	0	0	0	0	0.61	1.43	0	0.47	0.27	0
1994	0	0	0	0	1.35	2.36	0.06	0.11	0.11	0
1995	0	0	0	0	1.14	1.33	0.21	0.11	0.08	0
1996	0	0	0.02	0	2.59	2.18	0.28	0.18	0.17	0
1997	0	0	0.03	0	2.62	2.66	0.17	0.07	0.08	0
1998	0	0	0	0	4.75	3.76	0	0.17	0.02	0
1999	0	0	0.06	0	3.82	3.29	0.08	0.18	0.04	0
2000	0	0	0.08	0	3.82	4.96	0.02	0.02	0	0
2001	0	0	0.07	0.03	3.31	4.75	0.05	0.17	0.09	0
2002	0	0	0.98	0.119	4.384	7.04	1.238	0.797	0.251	0.01
2003	0	0.154	0.515	0.291	7.18	9.234	1.538	1.313	1.129	0
2004	0	1.012	1.65	0.313	6.541	12.96	1.436	0.668	0.881	0.024
2005	1.132	0.407	1.047	0.561	6.971	15.68	1.778	1.026	0.944	0.53
2006	0	0.195	0.607	0.11	4.047	10.98	1.211	0.797	0.577	0.15

(f) GABTF ele catch (mt)

Year	Sub-region									
	WSA	**CSA**	**SAV-**	**SAV-**	**WBa**	**EBas**	**WTas**	**ETas**	**NSW**	**UNK**
1988	0	0.12	0	0	0	0	0	0	0	0
1989	0.70	0.08	0	0	0	0	0	0	0	0
1990	8.35	0	0	0	0	0	0	0	0	0
1991	7.22	0	0	0	0	0	0	0	0	0
1992	8.77	0	0	0	0	0	0	0	0	0
1993	10.51	0	0	0	0	0	0	0	0	0
1994	5.32	0.04	0	0	0	0	0	0	0	0
1995	9.37	0.05	0	0	0	0	0	0	0	0
1996	9.80	0.09	0	0	0	0	0	0	0	0
1997	13.70	0.22	0	0	0	0	0	0	0	0
1998	11.82	0.16	0	0	0	0	0	0	0	0
1999	9.64	0.29	0	0	0	0	0	0	0	0
2000	9.52	0.09	0	0	0	0	0	0	0	0
2001	14.22	0.17	0	0	0	0	0	0	0	0
2002	12.01	0	0	0	0	0	0	0	0	0
2003	20.03	0.03	0	0	0	0	0	0	0	0
2004	16.03	0.119	0	0	0	0	0	0	0	0
2005	18.04	0.075	0	0	0	0	0	0	0	0
2006	22.06	0.12	0	0	0	0	0	0	0	0

Table 21.2a. Catch and discard breakdowns by region for elephant fish.

CATCH	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	1.711	29.629	45.772	0	0	0	0	0	0	0	0	39.6	0
1997	5.378	20.969	33.51	0	0	0	0	0	0	0	0	46.2	0
1998	2.685	14.124	36.023	0	0	0	0	0	0	0	0	52.8	0
1999	5.785	11.916	41.499	0	0	0	0	0	15	0	0	59.4	0
2000	3.79	15.739	34.359	0	0	0	0	0	4	0	0	66	0
2001	7.477	7.244	32.609	0	0	0	0	0	3	0	0	66	0
2002	2.605	6.983	30.982	13.111	2.035	11.424	0	9	3	0	0	66	0.261
2003	4.647	7.555	36.631	21.02	2.851	16.414	0	12	3	0	0	66	1.129
2004	2.671	7.391	25.523	19.126	2.104	19.503	0	7	2	0	0	66	0.905
2005	2.364	5.993	27.944	21.267	2.804	22.653	0	7	2	0	0	66	1.474
2006	4.816	6.197	24.78	23.118	2.008	15.029	0	7	2	0	0	66	0.592

DISCARD	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
1997	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
1998	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
1999	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2000	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2001	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2002	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2003	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2004	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2005	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0
2006	0.02	0.06	0.06	0.02	0.06	0.06	0	0	0	0	0	0	0

TOTAL	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	1.745918	31.52021	48.69362	0	0	0	0	0	0	0	0	39.6	0
1997	5.487755	22.30745	35.64894	0	0	0	0	0	0	0	0	46.2	0
1998	2.739796	15.02553	38.32234	0	0	0	0	0	0	0	0	52.8	0
1999	5.903061	12.6766	44.14787	0	0	0	0	0	15	0	0	59.4	0
2000	3.867347	16.74362	36.55213	0	0	0	0	0	4	0	0	66	0
2001	7.629592	7.706383	34.69043	0	0	0	0	0	3	0	0	66	0
2002	2.658163	7.428723	32.95957	13.37857	2.164894	12.15319	0	9	3	0	0	66	0.261
2003	4.741837	8.037234	38.96915	21.44898	3.032979	17.4617	0	12	3	0	0	66	1.129
2004	2.72551	7.862766	27.15213	19.51633	2.238298	20.74787	0	7	2	0	0	66	0.905
2005	2.412245	6.375532	29.72766	21.70102	2.982979	24.09894	0	7	2	0	0	66	1.474
2006	4.914286	6.592553	26.3617	23.5898	2.13617	15.9883	0	7	2	0	0	66	0.592

Table 21.2b. Elephant fish catch and discard summary

CATCH	REC	STATE	DISCARD
121.5597	39.6	0	4.847748
109.6441	46.2	0	3.587138
108.8877	52.8	0	3.255668
137.1275	59.4	15	3.527529
127.1631	66	4	3.275092
119.0264	66	3	2.6964
149.0041	66	12.261	3.603118
175.8209	66	16.129	4.57388
156.1479	66	9.905	3.924901
163.7724	66	10.474	4.273372
155.1748	66	9.592	3.634805

Table 21.3. Standardized Elephant Fish Catch Rate

	Rcrit		
year	0.32	0.36	0.4
1976	1.698507	1.398161	0.874107
1977	2.101416	2.625797	2.547372
1978	1.737966	1.566881	1.135537
1979	1.388924	1.625199	1.196801
1980	1.138684	1.137688	1.039904
1981	1.479584	1.218171	1.145244
1982	1.128423	1.192091	0.865472
1983	1.024225	1.173638	0.967724
1984	0.857858	0.980127	0.971097
1985	0.722404	0.661629	0.957812
1986	0.695849	0.652727	0.882182
1987	0.619622	0.576158	0.917635
1988	0.617948	0.59884	0.629655
1989	0.612578	0.689286	0.868489
1990	0.783465	0.788622	0.906544
1991	1.159516	1.126725	1.638284
1992	1.319161	1.313041	1.498008
1993	0.854979	0.804012	1.464133
1994	0.956232	0.809572	1.508113
1995	1.178897	1.173528	1.51371
1996	1.095849	0.993758	0.942819
1997	0.951589	0.930703	0.641077
1998	0.809429	0.83892	0.666544
1999	0.862407	0.836888	0.63232
2000	0.800212	0.792466	0.598358
2001	0.823433	0.837289	0.6571
2002	0.784544	0.802019	0.705655
2003	0.70607	0.735316	0.660386
2004	0.615669	0.605728	0.576117
2005	0.695085	0.701503	0.648037
2006	0.779477	0.813518	0.743767

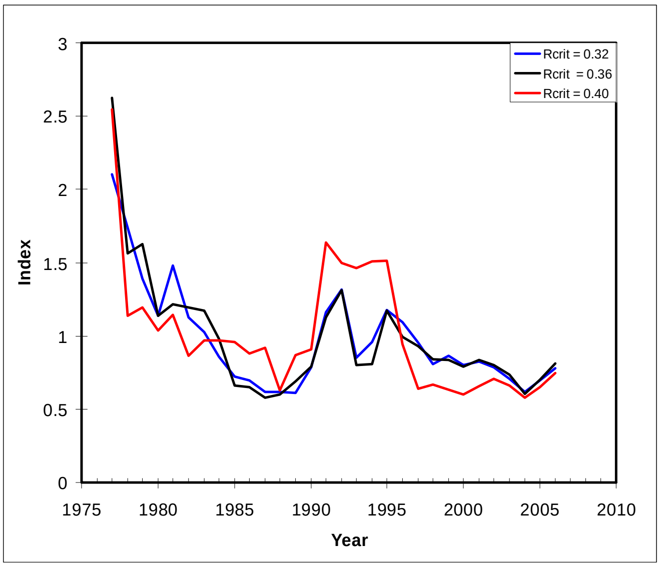

Figure 21.1. Geometric mean catch rate for Elephant fish.

Table 21.4. Base Case RBC Calculation for Elephant fish

RBC Calc						alpha		
Year	CPUE	logCPUE	AnnC	Ccurr	log grad	1	2	4
1996	1.095849	0.0915291	121.559748					
1997	0.951589	-0.0496225	109.644138					
1998	0.809429	-0.211426	108.887668					
1999	0.862407	-0.1480283	137.127529	119.30477	-0.0880476	108.8	98.3	77.3
2000	0.800212	-0.222879	127.163092	120.70561	-0.0456372	115.2	109.7	98.7
2001	0.823433	-0.1942735	119.0264	123.05117	-0.0023393	122.8	122.5	121.9
2002	0.784544	-0.2426526	149.004118	133.08028	-0.0255267	129.7	126.3	119.5
2003	0.70607	-0.3480408	175.82088	142.75362	-0.0423865	136.7	130.7	118.6
2004	0.615669	-0.4850455	156.147901	149.99982	-0.0977704	135.3	120.7	91.3
2005	0.695085	-0.3637217	163.772372	161.18632	-0.0500212	153.1	145.1	128.9
2006	0.779477	-0.2491326	155.174805	162.72899	0.0418048	169.5	176.3	189.9

RBC	169.5	176.3	189.9
REC	66	66	66
STATE	11.525	11.525	11.525
DISCARD	4.1	4.1	4.1
TAC	87.9	94.7	108.3

Table 21.5. RBC Sensitivities.

	RBC	**TAC**
Base case	170	88
No rec	101	85
2 x Rec	238	91
no states	158	87
no discard	165	88

21.4.2 Saw Shark (common and southern)

Scientific name :*Pristiophorus cirratus* & *Pristiophorus nudipinnis*

CAAB species code: 37023001 & 37023002

Quotas were introduced for Saw Shark in 2004.

Quota 2004: 434.4 t
Quota 2005: 434.4 t
Quota 2006: 434.4 t
Quota 2007: 434 t + 71 t Jan-Apr

Table 21.6. Time-series of historical catches (1973–2006) of saw shark by the Southern Shark Fishery.

(a) GHATF Victoria saw catch (Kg)

Year	Gear-Type				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	1706	30694	31	99211	2551
1974	10729	139697	0	57474	0
1975	1458	194751	0	18834	0
1976	2521	188111	0	17179	198
1977	3199	207281	0	2006	159
1978	582	248930	418	344	17
1979	184	215630	2768	8564	0
1980	94	213878	2454	5863	0
1981	104	178669	1256	7403	0
1982	114	229545	31	2325	0
1983	290	225289	287	101	0
1984	228	216069	518	491	0
1985	2344	239016	2884	62	0
1986	3390	253198	1444	0	0
1987	3844	284592	1105	0	829
1988	1728	212873	524	707	17
1989	4258	184898	0	329	38
1990	3071	157956	0	0	0
1991	5990	172623	736	0	0
1992	7928	167755	232	544	0
1993	11213	239881	0	147	4436
1994	3176	300910	0	6	1851
1995	1057	334949	2459	0	0
1996	1015	271388	870	136	0
1997	537	176992	4845	0	0
1998	262	203222	4264	0	0
1999	349	177217	109	0	0
2000	347	171789	2656	0	0
2001	276	150661	699	0	0
2002	59	138108	1339	0	0
2003	73	172657	326	28	0
2004	55	164975	1806	0	0
2005	162	134497	370	0	0
2006	61	107235	786	0	0

(Table 21.6 Continued)

(b) GHATF Tasmania saw catch (Kg)

Year	Gear-Type				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	0	0	0	586	0
1974	13261	1145	0	1045	0
1975	357	849	0	0	0
1976	0	4692	0	0	0
1977	0	3747	0	0	0
1978	0	7492	0	0	0
1979	0	4223	0	0	0
1980	0	1537	0	0	0
1981	0	1680	0	0	0
1982	0	3185	554	0	0
1983	0	2282	0	0	0
1984	0	8759	0	0	0
1985	135	11756	0	0	0
1986	1200	12561	0	0	0
1987	0	10035	0	0	0
1988	141	3981	0	6876	0
1989	394	8549	0	0	249
1990	3277	3129	0	1796	0
1991	337	7393	0	0	0
1992	11457	8058	0	1776	6
1993	7963	11521	0	3066	0
1994	1619	4644	0	4187	0
1995	19	6697	56	5322	0
1996	147	9671	504	7302	0
1997	23	4877	1755	5388	0
1998	0	7937	0	0	0
1999	13	7541	0	0	0
2000	7	5706	1630	0	0
2001	4	4444	368	0	0
2002	5	6524	499	0	0
2003	0	6626	33	0	0
2004	49	5811	0	0	0
2005	47	4713	0	0	0
2006	0	7075	3080	0	0

(Table 21.6 Continued)

(c) GHATF South Australia Saw catch (Kg)

Year	Gear-Type				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	51	0	0	12267	1290
1974	41	142	0	3642	101
1975	362	18	0	4206	4
1976	810	31836	0	2872	431
1977	675	12837	0	253	220
1978	0	10851	0	566	0
1979	52	4892	0	448	0
1980	20	3687	0	316	120
1981	0	4462	0	18	0
1982	5	8287	0	0	0
1983	58	6307	0	60	0
1984	31	4175	0	194	0
1985	179	4154	423	1960	0
1986	0	4849	0	3856	31
1987	0	14628	14	11701	617
1988	1074	15359	1416	3952	60
1989	49	8617	1312	3897	0
1990	20	6128	1279	3467	0
1991	0	20055	1720	2752	0
1992	613	6071	971	3831	0
1993	282	5114	238	5166	177
1994	117	6489	570	3838	0
1995	406	18140	13126	8705	47
1996	78	12676	1221	5800	18
1997	56	9298	29359	88	110
1998	98	16654	11479	232	0
1999	40	16830	10076	599	0
2000	18	10498	8222	137	0
2001	4042	7271	8047	0	0
2002	2	13337	6918	0	0
2003	101	18449	6198	43	0
2004	45	12590	7982	0	0
2005	0	21118	11740	0	0
2006	0	34495	6285	0	0

(Table 21.6 Continued)

(d) GHATF Total saw catch (Kg)

Year	**Gear-Type**				
	Longline	**6” Mesh**	**6.5” Mesh**	**7” Mesh**	**8” Mesh**
1973	1757	30694	31	112064	3841
1974	24031	140984	0	62161	101
1975	2177	195618	0	23040	4
1976	3331	224639	0	20051	629
1977	3874	223865	0	2259	379
1978	582	267273	418	910	17
1979	236	224745	2768	9012	0
1980	114	219102	2454	6179	120
1981	104	184811	1256	7421	0
1982	119	241017	585	2325	0
1983	348	233878	287	161	0
1984	259	229003	518	685	0
1985	2658	254926	3307	2022	0
1986	4590	270608	1444	3856	31
1987	3844	309255	1119	11701	1446
1988	2943	232213	1940	11535	77
1989	4701	202064	1312	4226	287
1990	6368	167213	1279	5263	0
1991	6327	200071	2456	2752	0
1992	19998	181884	1203	6151	6
1993	19458	256516	238	8379	4613
1994	4912	312043	570	8031	1851
1995	1482	359786	15641	14027	47
1996	1240	293735	2595	13238	18
1997	616	191167	35959	5476	110
1998	360	227813	15743	232	0
1999	402	201588	10185	599	0
2000	372	187993	12508	137	0
2001	4322	162376	9114	0	0
2002	66	157969	8756	0	0
2003	174	197732	6557	71	0
2004	149	183376	9788	0	0
2005	209	160328	12110	0	0
2006	61	148805	10151	0	0

(Table 21.6 Continued)

(e) SETF Saw catch (mt)

Year	Sub-region									
	WSA	**CSA**	**SAV-**	**SAV-**	**WBa**	**EBas**	**WTas**	**ETas**	**NSW**	**UNK**
1985	0	0	0.37	0.08	0.38	2.34	0	0.35	0.59	0
1986	0	0	1.26	0.23	0.41	7.11	0.15	0.01	10.33	0
1987	0	0	0.76	0.33	0.04	7.80	0	0.11	7.39	0
1988	0	0	0.62	0.06	1.32	10.04	0.03	0.14	18.07	0
1989	0	0	1.74	0	0.15	7.98	0	0.03	9.41	0
1990	0	0	1.77	1.76	0.60	8.38	0.12	0.11	5.00	0
1991	0	0	1.67	0.50	0.07	11.66	0.14	0.26	9.57	0
1992	0	0	2.90	1.59	0.64	11.54	0	0.15	8.74	0
1993	0	0	1.80	0.54	1.97	17.02	0	0.25	10.12	0
1994	0	0	2.18	0.77	0.55	27.37	0	0.27	12.00	0
1995	0	0	7.11	1.62	0.84	16.43	0.03	0.15	6.71	0
1996	0	0	8.60	4.61	1.44	16.84	0.03	0.22	7.23	0
1997	0	0.04	11.28	4.45	1.35	11.61	0	0.23	8.23	0
1998	0	0.10	6.70	2.96	1.02	13.98	0	0.09	5.12	0
1999	0	0.01	8.02	6.33	1.96	14.05	0	0.04	5.77	0
2000	0	0	20.31	5.02	3.16	19.46	0.91	0.36	6.81	0
2001	0	0.04	10.2	5.7	1.55	17.98	0.17	12.59	5.89	0
2002	0.01	0.055	9.298	7.297	1.638	40.63	0.306	2.441	13.71	0.02
2003	0.01	0.043	6.639	7.701	1.726	33.14	0.628	2.239	25.91	0.010
2004	0.02	0.099	8.719	9.386	2.618	33.22	0.312	1.404	28.93	0.13
2005	22.99	0.109	11.61	10.75	4.422	31.50	0.253	1.579	25.80	14.98
2006	0.01	0.221	21.72	22.38	4.588	33.15	0.777	1.783	28.25	0.072

(f) GABTF Saw catch (mt)

Year	Sub-region									
	WSA	**CSA**	**SAV-**	**SAV-**	**WBa**	**EBas**	**WTas**	**ETas**	**NSW**	**UNK**
1988	0	0.12	0	0	0	0	0	0	0	0
1989	0.70	0.08	0	0	0	0	0	0	0	0
1990	8.35	0	0	0	0	0	0	0	0	0
1991	7.22	0	0	0	0	0	0	0	0	0
1992	8.77	0	0	0	0	0	0	0	0	0
1993	10.51	0	0	0	0	0	0	0	0	0
1994	5.32	0.04	0	0	0	0	0	0	0	0
1995	9.37	0.05	0	0	0	0	0	0	0	0
1996	9.80	0.09	0	0	0	0	0	0	0	0
1997	13.70	0.22	0	0	0	0	0	0	0	0
1998	11.82	0.16	0	0	0	0	0	0	0	0
1999	9.64	0.29	0	0	0	0	0	0	0	0
2000	9.52	0.09	0	0	0	0	0	0	0	0
2001	14.22	0.17	0	0	0	0	0	0	0	0
2002	10.54	0.05	0	0	0	0	0	0	0	0
2003	25.39	0.154	0	0	0	0	0	0	0	0
2004	17.8	0.069	0	0	0	0	0	0	0	0.06
2005	21.55	0.064	0	0	0	0	0	0	0	0
2006	17.44	0.13	0.328	0	0	0	0	0	0	0

Table 21.7a. Catch and discard breakdowns by region for saw shark.

CATCH	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	19.794	17.624	273.459	0	0	0	0	0	0	0	0	0	0
1997	38.912	12.043	182.374	0	0	0	0	0	0	0	0	0	0
1998	28.463	7.937	207.747	0	0	0	0	0	0	0	0	0	0
1999	27.545	7.554	177.684	0	0	0	0	0	4	0	0	0	12
2000	18.875	7.344	174.791	0	0	0	0	0	1	0	0	0	12
2001	19.36	4.816	151.636	0	0	0	4	0	0	0	0	0	6
2002	20.257	7.028	139.506	27.253	2.747	42.276	0	4	0	0	0	0	13.732
2003	24.791	6.659	173.084	39.942	2.867	34.868	0	7	0	0	0	0	26.021
2004	20.618	5.86	166.842	36.093	1.716	35.846	0	9	0	0	0	0	29.062
2005	32.858	4.76	135.028	44.097	1.832	35.923	0	9	0	0	0	0	40.793
2006	40.78	10.155	108.081	62.248	2.56	37.744	0	9	0	0	0	0	28.325

DISCARD	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
1997	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
1998	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
1999	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2000	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2001	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2002	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2003	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2004	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2005	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0
2006	0.07	0.07	0.07	0.19	0.02	0.02	0	0	0	0	0	0	0

TOTAL	GHAT			TRAWL			STATE			REC			OTHER
Year	SA	TAS	BS	SA	TAS	BS	SA	TAS	VIC	SA	TAS	VIC	NSW
1996	21.28387	18.95054	294.0419	0	0	0	0	0	0	0	0	0	0
1997	41.84086	12.94946	196.1011	0	0	0	0	0	0	0	0	0	0
1998	30.60538	8.534409	223.3839	0	0	0	0	0	0	0	0	0	0
1999	29.61828	8.122581	191.0581	0	0	0	0	0	4	0	0	0	12
2000	20.2957	7.896774	187.9473	0	0	0	0	0	1	0	0	0	12
2001	20.8172	5.178495	163.0495	0	0	0	4	0	0	0	0	0	6
2002	21.78172	7.556989	150.0065	33.64568	2.803061	43.13878	0	4	0	0	0	0	13.732
2003	26.65699	7.160215	186.1118	49.31111	2.92551	35.57959	0	7	0	0	0	0	26.021
2004	22.16989	6.301075	179.4	44.55926	1.75102	36.57755	0	9	2	0	0	0	29.062
2005	35.33118	5.11828	145.1914	54.44074	1.869388	36.65612	0	9	0	0	0	0	40.793
2006	43.84946	10.91935	116.2161	76.84938	2.612245	38.51429	0	9	0	0	0	0	28.325

Table 21.7b. Catch and discard summary

CATCH	REC	STATE	DISCARD
334.2763	0	0	23.39934
250.8914	0	0	17.5624
262.5237	0	0	18.37666
244.7989	0	16	16.01592
229.1398	0	13	15.12978
199.0452	0	10	13.23316
276.6647	0	17.732	19.86568
340.7662	0	33.021	25.53425
330.8208	0	40.062	25.7838
328.4001	0	49.793	24.10911
326.2859	0	37.325	27.39286

Table 21.8. Standardized Saw Shark Catch Rate

year	0.8
1976	0.67725
1977	0.58264
1978	0.58362
1979	0.65895
1980	0.52543
1981	0.41337
1982	0.38344
1983	0.36787
1984	0.42797
1985	0.43471
1986	0.33993
1987	0.31311
1988	0.31135
1989	0.29478
1990	0.38329
1991	0.37164
1992	0.42208
1993	0.69465
1994	0.62177
1995	0.59332
1996	0.48387
1997	0.31144
1998	0.31921
1999	0.31649
2000	0.25442
2001	0.25619
2002	0.21388
2003	0.19226
2004	0.18533
2005	0.17093
2006	0.17427

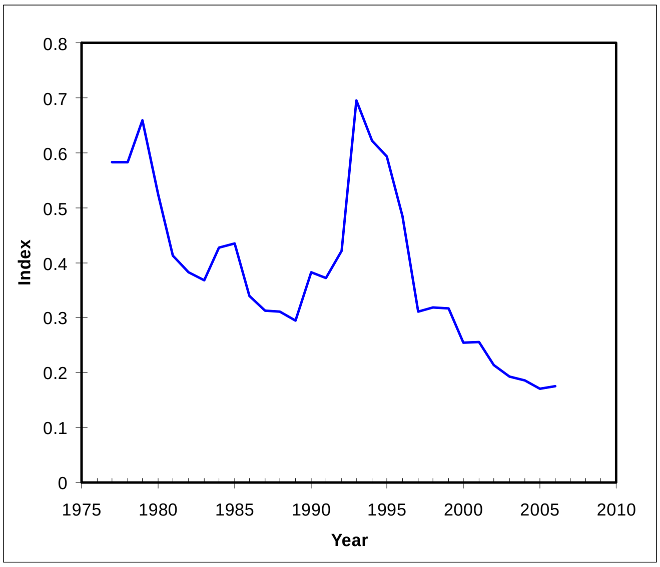

Figure 21.2. Geometric mean catch rate for Saw Shark.

Table 21.9. Base Case RBC Calculation for Saw Shark

RBC Calc						alpha		
Year	CPUE	logCPUE	AnnC	Ccurr	log grad	1	2	4
1996	0.483879	-0.72592	334.276344					
1997	0.311448	-1.1665232	250.891398					
1998	0.319219	-1.1418773	262.523656					
1999	0.316493	-1.1504545	244.798925	273.12258	-0.1248957	239.0	204.9	136.7
2000	0.254428	-1.3687386	229.139785	246.83844	-0.0615223	231.7	216.5	186.1
2001	0.256195	-1.3618156	199.045161	233.87688	-0.0878099	213.3	192.8	151.7
2002	0.213887	-1.542306	276.664677	237.41214	-0.1168632	209.7	181.9	126.4
2003	0.192269	-1.6488583	340.766245	261.40397	-0.102085	234.7	208.0	154.7
2004	0.185332	-1.6856092	330.820798	286.82422	-0.1077933	255.9	225.0	163.2
2005	0.170939	-1.7664479	328.400111	319.16296	-0.0709177	296.5	273.9	228.6
2006	0.174278	-1.7471058	326.28586	331.56825	-0.0375581	319.1	306.7	281.8

RBC	319.1	306.7	281.8
REC	0	0	0
State	40.05025	40.05025	40.05025
DISCARD	25.7	25.7	25.7
TAC	253.4	240.9	216.0

Table 21.10. RBC Sensitivities.

	RBC	TAC
Base case	319	253
+ SA 2005	326	259
no states	281	255
no discard	295	254

21.5 References

Pribac, F, A.E. Punt, G. Fay, Walker and A. S. Gason. 2007a. Standardized catch and Effort for Elephant Fish and Saw Shark up to 2005 – sharkRAG Aug 2007 powerpoint presentation

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Smith, A.D.M. and D.Smith. 2005. A harvest strategy framework for the SESSF. Report to AFMA, June 2005

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22. Benefits

The results of this project have had a direct bearing on the management of the Southern and Eastern Scalefish and Shark Fishery. Direct benefits to the commercial fishing industry in the SESSF have arisen from improvements to, or the development of, assessments under the various Tier Rules of the Commonwealth Harvest Strategy Policy for selected quota and non-quota species. Information from the stock assessments has fed directly into the TAC setting process for SESSF quota species. As specific and agreed harvest strategies are being developed for SESSF species (a process required by and agreed to under EPBC approval for the fishery), improvements in the assessments developed under this project have had direct and immediate impacts on quota levels or other fishery management measures (in the case of non-quota species).

Participation by the project's staff on SESSF Resource Assessment Groups has enabled not only the production of critical assessment reports, but also a clear communication of the reports' results to a wide audience (managers, industry). Project staff's scientific advice on quantitative and qualitative matters is also clearly valued.

The stock assessments presented in this report have provided managers and industry greater confidence when making key commercial and sustainability decisions for species in the SESSF. Some species did not have any (or recent) full quantitative assessments (e.g. silver warehou, eastern gemfish, school whiting), others required the inclusion of major new population dynamic and fishery assumptions, while others could now utilize improved or new information regarding stock size (e.g. blue grenadier). Clearly, these assessments have provided the most up-to-date information, in terms of data and methods, to facilitate the management of the Southern and Eastern Scalefish and Shark Fishery.

23. Conclusion

- Provide quantitative and qualitative species assessments in support of the four SESSFAG fishery assessment groups

The 2007 assessment of stock status of the key Southern and Eastern Scalefish and Shark fishery species is based on the methods presented in this report. Documented are the latest quantitative assessments for several of the key non-shark quota species (blue grenadier, silver warehou, pink ling, school whiting, eastern gemfish, jackass morwong, Bight redfish, deepwater flathead), catch curve and cpue standardisations for shelf and slope species. Typical assessment results provided indications of current stock status and an application of the Commonwealth harvest strategy framework. This framework is based on a set of assessments and harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available that can determine stock status (Tiers 1 to 4).

The assessment outputs from this project are a critical component of the management and TAC setting process for these fisheries. The results from these studies are being used by SESSFAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

Stock status and Recommended Biological Catch (RBC) conclusions:

For blue grenadier (*Macruronus novaezelandiae*), results of the 2007 assessment are more optimistic than previous assessments, with an increase in spawning biomass relative to the reference level primarily due to increased cpue and acoustic estimates of spawning biomass. The recruitment of 2004 is estimated to be about twice that expected from the stock-recruitment relationship and while a positive sign for the stock and fishery following several years of poor recruitment, this recruitment is not estimated to be as large as the recruitments of the mid-1990s. Results conclude that the female spawning biomass in 2006 is around 47% of the reference biomass. The Recommended Biological Catches (RBCs) for 2008 are between 3,275 t and 4,687 t (landed catch and discards), depending on the harvest control rule that is applied. The long-term RBCs are around between 5,000 and 6,000 t.

The catch of pink ling (*Genypterus blacodes*) in 2006 was 1201 tonnes, divided between the east (474 t trawl, 262 t, non-trawl) and the west (252 t trawl, 213 t, non-trawl). The assessment estimated the spawning biomass at the end of the 2007 at 28% of the virgin spawning biomass in the east and 52% in the west. The RBC for 2008 using the 20:40:48 Tier 1 rule is 688 tonnes (68 t from the east and 620 t from the west). With the 20:40:40 rule, the RBC is 858 tonnes (84 t in the east and 774 t in the west). Projections suggest a long term sustainable yield of between 1,450 and 1,600 tonnes.

For silver warehou (*Seriolella punctata*) the base-case assessment estimates that current (2006/07) spawning stock biomass is 49% of virgin stock biomass. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality. Likelihood profiles show that values for *M* larger than the base-case value of 0.25 are preferred. The RBCs for the base-case model for 2007/08 are 2,244 t and 1,709 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,987 t and 1,814 t respectively.

The base-case assessment for eastern gemfish (*Rexea solandri*) estimated that current (2007/08) spawning stock biomass was 14% of the unexploited spawning stock biomass. Fits to the length, age, and catch-rate data were reasonable. RBCs were not calculated for eastern gemfish given the low biomass estimates, the current management arrangements, and the history of the fishery. Exploration of model sensitivity showed that the model outputs are sensitive to the recent (2007) CPUE trawl survey index.

For school whiting (*Sillago flindersi*) the base-case assessment estimates that current (2008) spawning stock biomass is 35% of unfished stock biomass. Exploration of model sensitivity shows that the model outputs are sensitive to the value assumed for natural mortality, *M*, the length at 50% maturity and the projected catch used in 2007. Likelihood profiles support the use of a base case value for *M* of $0.6yr^{-}$. The RBCs for the base-case model for 2008 are 1,185 t and 904 t respectively under the 20:40:40 and 20:40:48 harvest control rules, while the long-term yields under these harvest control rules are 1,848 t and 1,685 t respectively.

An estimate of the relationship of B_{mey}=1.03xB_{msy} for tiger flathead (*Neoplatycephalus richardsoni*) has been provided by ABARE. Application of this calculation to the target B_{msy} in the RBC calculations results in a target B_{msy} of 40%x1.03=41.2%, which here has been rounded to 41%. Therefore, an additional B_{targ} level of 41% has been included in the RBC calculations. The projected RBC value using the 41% B_{msy} target was 2,743t including discards.

For jackass morwong (*Nemadactylus macropterus*) the base-case assessment for the eastern areas estimated that current spawning stock biomass is 19% of unexploited stock biomass. This assessment is largely driven by the recent catch rate indices, which indicate a 70 % decline in the stock over the last 20 years. A preliminary assessment of western zone jackass morwong using data from 1986-2006 was also performed. This assessment indicated that the stock has declined in recent years as fishing pressure has increased, but spawning stock biomass is still considerably higher than the target level. The longterm RBCs estimated for the western stock are comparable with current catch levels.

The unexploited biomass estimates for the base case models were 8,836t and 18,685t for deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) respectively. Current biomass was estimated to be at 56% of the unexploited level for deepwater flathead, and 82% for Bight redfish. Using the 20:40:48 catch control rule, the RBC was 1,154t for deepwater flathead and 3,607t for Bight redfish.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to decide the Recommended Biological Catch (RBC) for next year. Tier 3 RBC values for flathead, morwong, school whiting and ling were all less than recent average catches. Tier 3 RBC values for redfish, spotted warehou, blue warehou, John dory and mirror dory were equal to or greater than recent average catches. Due to probable dome-shaped selectivity for silver trevally caught by trawl, it has been recognized that simple catch curve methods as these should not be applied to that species.

24. Appendix A - Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

25. Appendix B – Staff

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