International Pacific Halibut Commission

Eighty-eighth Annual Meeting

Cover artwork: Joan Forsberg

International Paci c Halibut Commission
Eighty-eighth Annual Meeting
Anchorage Hilton
Anchorage, AK
January 23-27, 2012

Schedule of Sessions

Monday - January 23			Room Location
p.m.	5:00 – 8:30	United States Delegation Meeting	Dillingham/Katmai
	6:30 – 8:30	Canadian Delegation Meeting	Aspen/Spruce
Tuesday - January 24			
a.m.	7:30 - 8:00	IPHC Executive Session I	Birch/Willow
	8:00 - 1:00	Public Session I	Denali
p.m.	2:30 - 5:00	IPHC Administrative Session I	Birch/Willow
	2:30 - 5:00	Conference Board (CB) Session I	Aleutian/Alaska
	2:30 - 5:00	Processor Advisory Group (PAG) I	Iliamna
	7 :00 - 9:30	IPHC Reception	Top of the World
Wednesday - January 25			
a.m.	8:30 - 5:00	IPHC Administrative Session II	Birch/Willow
	8:30 - 5:00	Conference Board Session II	Aleutian/Alaska
	8:30 - 5:00	Processor Advisory Group II	Iliamna
p.m.	6:30 – 8:30	HANA Reception (open to commercial industry and agency staff)	Anchorage Museum
Thursday - January 26			
a.m.	8:30 - 9:30	IPHC, CB, and PAG Joint Session	Aleutian/Alaska
	9:30 - 5:00	IPHC Administrative Session III	Birch/Willow
Friday - January 27			
a.m.	7:30 - 8:30	IPHC Executive Session II	Denali
	9:00 - 11:00	IPHC Meeting (public welcome)	Denali

- IPHC office is located in the Portage Room
- Breakout rooms available – Dillingham & Aspen (contact IPHC staff for availability)

International Pacific Halibut Commission
Eighty-eighth Annual Meeting

Hilton Anchorage
Anchorage, AK
January 24-27, 2012

Public Session
January 24, 2012
Denali Ballroom

8:00 a.m.	**Opening of meeting**
	Chairperson and Vice-chairperson opening remarks
	Introductions
8:15	**Director's remarks**
	Staff presentations
	The 2011 Fishery
	Analysis of the impacts of potential size limit changes
	Harvest policy considerations and Management Strategy Evaluation
	IPHC Stock Assessment
	Staff Regulatory Proposals: 2012
10:15	**Coffee**
10:30	**Staff presentations (continued)**
12:00	**Questions and discussion**
1:00 p.m.	**Announcements and adjournment**
7:00-9:30	**IPHC Reception (no host) – Top of the World**

Acronyms commonly used in this document:

4IC	survey stations positioned around the Pribilof Islands
4ID	survey stations positioned around St. Matthews Island
4N	Norton Sound – used when referring to NMFS survey stations in the BS
4S	Bering Sea shelf south of Norton Sound
BAWM	bycatch and wastage mortality
BS	Bering Sea
CEY	constant exploitation yield
CLR	staff catch limit recommendation
CPUE	general term for catch per unit effort
Ebio	Exploitable biomass (in weight)
FCEY	fishery constant exploitation yield
GHL	Guideline Harvest Level
GOA	Gulf of Alaska
LE	lost egg production
LSbio	lost spawning biomass
LY	lost yield
NPUE	number (of fish) per unit effort
O26	halibut with a fork length equal or greater than 26 inches
O32	halibut with a fork length equal to or greater than 32 inches
PAT	pop-up archival transmitting tag
PHI	prior hooking injury
PIT	passive integrated transponder tag
POST	Pacific ocean shelf tracking program - receiver/transmitter array project
SBR	spawning biomass per recruit
SSA	standardized stock assessment survey
SUFastD	Slow up fast down
SUFullD	Slow up full down
Tbio	Total biomass (in weight)
U26	halibut with a fork length under 26 inches
U32	halibut with a fork length of under 32 inches
WPUE	weight (lbs) per unit effort

Notes:

The Pacific halibut fishery, 2011

Heather L. Gilroy

The International Pacific Halibut Commission (IPHC or Commission) estimates all halibut removals taken off the Pacific coast and eastern Bering Sea, and uses this information in the IPHC's harvest policy and the stock assessment. When the Commission was established in 1923, the commercial fishery, which dates back to the late 1800s, was the only documented source of harvest. Since that time, the commercial catch has continued to be the largest removal coastwide. Through the years, estimates of other removals have been added progressively: bycatch mortality in the 1960s, sport catch in the late 1970s, wastage in the 1980s, and personal use (subsistence) in the 1990s. In 2011, the removals from all sources total 60.5 million pounds (Table 1). Total removals have declined from the 90-100 million range which occurred during 1998-2007, and are now at a level similar to the mid-1980s. The legal-size limit for the commercial halibut fishery is 32 inches or greater. The removals of halibut 32 inches or over in total length are known as O32, and removals of halibut under 32 inches in total length are U32. A further breakdown has been provided in Table 1 for U32 halibut for bycatch mortality and wastage.

This report reviews the catch by commercial and sport fisheries, bycatch mortality estimates, and the allocation programs within each country. In addition, catch versus catch limits or harvest limits are also reported.

Personal use removals include the Washington State treaty tribal ceremonial and subsistence (C&S) fishery, the British Columbia Food, Social, and Ceremonial (FSC) fishery, and the Alaska subsistence fishery (Williams 2012a). The C&S fishery is part of a catch sharing plan and is estimated at 25,300 pounds for 2011 by the treaty tribes. The Canadian Department of Fisheries and Oceans (DFO) provided the estimate of the FSC fishery catch. For 2011, FSC catch was estimated at 405,000 pounds, which has been unchanged since 2007. The Commission has not seen documentation on the estimation methodology; it is reported simply as the sum of all allocations within the FSC communal licenses including recent treaty settlements (T. Karim, DFO, pers. comm.). The Alaska subsistence harvest was estimated by Alaska Department of Fish and Game (ADF&G) to be approximately 0.8 million pounds for 2010, the latest year for which information is available. The 2010 harvest is slightly lower than in 2009, and below the 2004-2005 high of 1.2 million pounds harvested. The Alaska program was implemented in 2003.

Wastage accounts for the loss of halibut from the commercial fishery. It includes O32 halibut killed by lost and abandoned longline gear (0.99 million pounds) and U32 halibut that are discarded due to regulation and die (2.2 million pounds) (Gilroy and Hare 2012).

In addition to data compiled by the IPHC, other sources of halibut data include federal and state agencies. All 2011 data are net weight and considered preliminary at this time. These data were updated in December 2011 after the completion of the IPHC Report of Assessment and Research Activities (RARA) 2011 and the stock assessment tables, so numbers provided here may differ slightly from those reports. Catch limit, as referred to here, is the IPHC catch limit set by the Commissioners at the Annual Meeting. The adjusted catch limit represents the IPHC catch limit with adjustments. Adjustments come from the Commission approved underage and overage programs from the previous year's quota share program and other quota leasing programs determined by DFO in British Columbia. The IPHC regulatory areas are provided in Figure 1.

Allocation programs, updates, and totals

The authority for domestic allocation among the user groups rests with the national governments. Currently, both the United States and Canadian governments have allocation plans within a single regulatory area or within smaller local areas.

Washington, Oregon, and California – Area 2A

Comprehensive user group allocation occurs in Area 2A. The Commission determines the Area 2A total catch limit for all user groups, and the Pacific Fishery Management Council (PFMC) allocates halibut catch limits among user groups through a Catch Sharing Plan (CSP). In this plan, 44.4% is allocated to the sport fishery, 35% to the treaty tribes, and 20.6% to the non-treaty commercial fishery.

The PFMC CSP specifies that a primary limited-entry longline sablefish (*Anoplopoma mbria*) fishery north of Point Chehalis, WA (46°53'18"N) would be allocated part of the Washington sport allocation only if the Area 2A catch limit was over 900,000 pounds and the amount available to the incidental fishery was over 10,000 pounds. Because the amount available for the incidental fishery did not exceed the 10,000-pound threshold, there was no incidental halibut fishery during the limited entry sablefish fishery in 2011. Therefore, in 2011 the Area 2A catch limit was divided among a sport fishery, a treaty Indian commercial fishery and a ceremonial and subsistence fishery, a non-treaty commercial directed fishery, and an incidental halibut fishery during the salmon troll season (Table 2). The total 2011 catch of 934,000 pounds was over the catch limit by 3%.

British Columbia – Area 2B

Since 2005, DFO has had an allocation framework for the commercial and recreational sectors, in which the recreational sector is allocated a 12 percent "ceiling" of a combined commercial/recreational catch limit. When managed to the allocation ceilings, both sectors' catch will fluctuate with stock abundance.

For 2011, the Commission adopted a catch limit for Area 2B of 7.65 million pounds for the combined recreational and commercial fisheries. An additional 248,000 pounds was added to include the projected commercial wastage from O26 halibut, resulting in a total catch limit of 7.898 million pounds. The commercial fishery allocation of 88% of the total catch limit (6,950,240 pounds) was reduced by 248,000 pounds to account for wastage, resulting in 6,702,240 pounds being allocated to the Individual Vessel Quota (IVQ) holders. In 2011, additional adjustments were made by DFO which included pounds available from the underage/overage plan and quota held by DFO for First Nations through a relinquishment process. The remaining 0.948 million pounds of the combined catch limit was allocated to the recreational sector. The total Area 2B catch of 7.87 million pounds was 3% over the combined total catch limit (7.65 million pounds) (Table 3).

During 2011, the Minster of Fisheries and Oceans Canada initiated a review of the Pacific halibut allocation. DFO officials were tasked to develop long-term options for allocation with objectives of conservation, economic prosperity, and flexibility. The review process included meetings with policy makers, stakeholders, and sector representatives. The expectation is that the Minister will have a decision on any changes to the current allocation plan in advance of the 2012 fishing season.

Alaska

The Commission adopts a single commercial fishery catch limit for Area 4CDE, as the area is considered to be one biological unit. A CSP developed by the North Pacific Fishery Management Council (NPFMC) in 1996 specifies individual catch limit allocations for Areas 4C, 4D, and 4E. This CSP also allows Area 4D Community Development Quota (CDQ) to be harvested in Area 4E, and Area 4C quota shares to be fished in Areas 4C or 4D. The total commercial catch of 3.438 million pounds was under the combined Area 4CDE catch limit (3.720 million pounds) by 8%.

In 2003, the NPFMC adopted a Guideline Harvest Level (GHL) program to manage the sport guided (charter) fisheries in Areas 2C and 3A. The GHL program included a provision that the GHL adjusts by specified increments to changes in halibut abundance, but the GHL will not increase above a maximum level, nor decrease below a minimum level. In 2011, the Areas 2C and 3A sport charter harvests were under the GHLs by 51% and 22%, respectively (Table 4). Currently, the GHL program is in place until the National Marine Fisheries Service (NMFS) implements the commercial-sport charter CSP that was adopted by the NPFMC. The initial intent was for this CSP to be implemented in 2012. However, NMFS has asked the NPFMC for technical clarification of some aspects of the program. Beginning in February 1, 2011, a halibut charter moratorium was implemented restricting the charter participants to those that met the specific qualifications of fishing in qualifying years of 2004-2005 and 2009.

Detailed catch data

The commercial shery

A detailed summary of fishing seasons, catch limits, and catch by IPHC regulatory area is provided in Table 5. Commercial catch occurs in: an open-access fishery, one incidental catch fishery, and a treaty Indian fishery in Area 2A; the quota share (QS) fisheries in British Columbia and Alaska; and the Metlakatla fishery within the Annette Island Reserve in southeast Alaska (Area 2C).

Area 2A

The IPHC licensed sport charter and commercial vessels in Area 2A. In 2011, the IPHC issued 604 vessel licenses: 316 licenses for the incidental commercial catch of halibut during the salmon troll fishery: 147 for the directed commercial fishery, and 141 for the sport charter fishery. The number of licenses issued for the sport charter fishery was similar to last year, the number of licenses issued for the incidental catch during the salmon troll fishery increased by 83, and the number issued for the directed commercial fishery decreased by 45 from 2010. The increased number of licenses for the incidental halibut in the salmon troll fishery is due to the PFMC's decision to allow commercial chinook salmon (*Oncorhynchus tshawytscha*) fishing in all areas of California and Oregon for the first time in three years. Contributing factors to the decrease in the number of directed commercial licenses were the opening of a coastwide salmon troll fishery, the lower catch limit, and the closure of the incidental halibut fishery during the sablefish fishery.

In the incidental commercial halibut fishery during the salmon troll fishery, the allowable incidental catch ratio was one halibut per three chinook, plus an "extra" halibut per landing. However, the total number of incidental halibut per vessel per landing could not exceed 35. The 1:3 ratio of halibut to chinook was the same as the one used in 2010 and is more conservative than the 2008 and 2009 ratio of 1:2. The more conservative ratio was intended to ensure a longer opportunity to land incidentally caught halibut because of the lower halibut catch limit and the Area 2A coastwide chinook salmon troll fishing opportunity. The incidental commercial halibut fishery during the salmon troll season opened on May 1 and was initially closed on May 28, when it was estimated that the catch limit of 28,126 pounds was taken. Upon further evaluation of landing data, it was determined that 2,598 pounds remained in the catch limit; therefore, the fishery was reopened on July 29 with additional restrictions. Landings were limited to one halibut per seven consecutive days (Friday through Thursday). Additionally, the Oregon Department of Fish and Wildlife (ODFW) implemented a call-in requirement to enable monitoring of the landings in a timely manner. When the salmon troll fisheries closed on October 31, the incidental halibut catch (25,900 pounds) during the salmon troll season was 8% under the catch limit.

The directed commercial fishery consisted of two 10-hour fishing periods with fishing period limits (Table 6). The fishing period limits were assigned by vessel class; the H-class vessels received 10,000 pounds for the June 29 opening and 5,000 pounds for the July 13 opening. The total directed commercial catch (168,000 pounds) was 5.4%, or 8,620 pounds over the catch limit.

In Area 2A-1 the treaty Indian tribes managed their commercial allocation by assigning 75% to an open access fishery, and 25% to a restricted fishery with daily and vessel limits. Both the unrestricted and restricted fisheries consisted of two fishing periods each, and the restricted fishery included daily vessel limits of 500 pounds. The total treaty Indian commercial catch was 328,900 pounds, or 12% over the catch limit (293,200 pounds).

Area 2C Metlakatla shery

The Metlakatla Indian Community was authorized by the United States government to conduct a commercial halibut fishery within the Annette Islands Reserve. There were thirteen 2-day openings between April 15 and October 2 for a total catch of almost 62,000 pounds. This was 17,000 pounds higher than the 2010 catch, and within the historical catch range that has varied over time from a low of 12,000 pounds in 1998 to a high of 126,000 pounds in 1996.

The Quota Share sheries – British Columbia and Alaska

In Area 2B, the halibut IVQ program was implemented in 1991, and 435 vessels received IVQs. Each initial IVQ was split into two shares called blocks. Numerous changes have been made since then, including allowing temporary block transfers (1993) and then permanent block and IVQ transfers (1999). In 2006, the Groundfish Integrated Fisheries Management Plan (IFMP) went into effect. The IFMP, initially a three-year pilot program, was implemented to meet conservation needs, including addressing rockfish conservation concerns and improving catch monitoring. The IFMP was reviewed and approved by DFO in January 2010 as a permanent plan. The IFMP includes quota shares for all hook and line groundfish fisheries, transferability with limits between license holders, 100% at-sea and dockside monitoring, and vessel accountability for all catch, both landed and discarded. There is 100% monitoring through logbook recordings, video camera coverage, and dockside coverage.

In 2011, the number of vessels landing Area 2B halibut was 217, with 148 vessels with halibut licenses (L licenses and First Nations communal commercial licenses or FL licenses) and 69 vessels licensed for other fisheries but landing halibut as bycatch as part of the IFMP. The commercial catch of 6.65 million pounds for Area 2B was less than 1% under the catch limit.

In Alaska, the Individual Fishing Quota/Community Development Quota (IFQ/CDQ) halibut and sablefish fishery program has been in effect since 1995. NMFS Restricted Access Management

(RAM) allocates halibut QS to recipients by IPHC regulatory area. Quota share transfers were permitted with restrictions on the amount of QS a person could hold and the amount that could be fished per vessel. As of August 26, 2011, RAM reported that 2,740 persons held quota shares, down from the initial 4,831 persons at the start of the program (Table 7). The number of vessels catching halibut has decreased by 42 % since the implementation of the QS program.

The total catch in 2011 from the IFQ/CDQ halibut fishery for the waters off Alaska was 31.6 million pounds, which was 2.6% under the catch limit. For comparison, the 2010 commercial catch was 1% under the catch limit. For Areas 2C, 3A, and 3B, the commercial QS catch was within the catch limits by 3%. For Areas 4A, 4B, and 4CDE, the catches were within 5%, 7%, and 8% of the catch limits, respectively. One notable change was that the Area 4B 2011 catch was closer to the catch limit than in 2010, when the catch was 17% under the catch limit. As mentioned previously, the NPFMC CSP allowed Area 4D CDQ to be harvested in Area 4E and Area 4C IFQ and CDQ to be fished in Areas 4C or 4D. These two regulations were the reason the catches in Areas 4D and 4E exceeded the catch limits.

Landing patterns

The 2011 QS fishery landings were spread over nine months of the year (Table 8). On a month-to-month comparison, May was again the busiest month for total poundage (18%) from Alaska. March, August, and October were the busiest months for poundage delivered in British Columbia, with approximately 15-16% of the catch during each month. Average landing dates in British Columbia occurred later this year as 49% of the Area 2B catch was landed by the end of May in 2010, and only 37% was landed by the end of May in 2011.

Homer and Kodiak each received approximately 17-18% of the commercial catch in Alaska. This was a change from the last few years as Homer has usually received substantially more pounds than Kodiak. For example, in 2010 Homer and Kodiak received 25% and 14%, respectively. Seward (11%) received the third largest landing volumes of the Alaskan commercial catch. In SE Alaska, Sitka received 1.3 million pounds (4%), Juneau 1.07 million pounds (3%), and Petersburg 0.9 million pounds (3%). The Alaskan QS catch that was landed outside of Alaska was 1.9%.

Commercial trips from Area 2B were delivered into 10 different ports in 2011. The ports of Port Hardy (including Coal Harbour and Port McNeill), Prince Rupert/Port Edward, and Vancouver were the major landing locations, receiving 91% of the Area 2B commercial catch. Port Hardy received over 3.0 million pounds of halibut or 46% of the Area 2B commercial catch. Prince Rupert/Port Edward (38%) and Vancouver (7%) received the second and third largest landing volumes of the Area 2B commercial catch. All of the Canadian commercial catch was landed in Area 2B ports.

The sport shery

The 2011 sport harvest was estimated at 7.5 million pounds, a slight decrease of 4.1% over last year, and below the 10-11 million pound amounts from 2004-2008 (Table 9). The largest decline in harvest was seen in Area 2C, due to the guided fishery restrictions, with all other areas having slight increases over last year.

Washington, Oregon, and California

The Area 2A sport harvest of 0.386 million pounds (Williams 2012b) was below the allocation by 4.6% (Table 10). To manage the sport fishery to the CSP allocation, the area is subdivided into six subareas with their own quotas, with four core areas having in-season catch monitoring. A subarea is closed when the subarea quota is achieved. The in-season management includes fishery openings in the spring and fall, changes in the number of fishing days allowed within a week, and closing fishing seasons from weekly to every other week (Table 11). Tracking and validation of the landing is done by dockside by state creel samplers. The two subareas without in-season monitoring (Inside Washington waters and southern Oregon/California) have daily bag limits and a fixed season length typically based on fishing success in the preceding year. For the southern Oregon/California subarea, in 2011 the fishers in the southern Oregon portion had exceptional fishing success uncharacteristic to the area. Therefore, without the CSP allowing for an in-season closure, the catch exceeded the subarea's quota. The agency staffs have agreed to work in 2012 to review the catch estimation and monitoring procedures in this area and will also be examining methods for stock estimation and fishery closures for the 2013 sport season.

British Columbia

DFO provided a preliminary 2011 sport catch estimate of 1.220 million pounds, which exceeded the sport fishery allocation by 272,000 pounds (29%). The DFO estimates are from mixed sources including overflights, on-water vessels counts, lodge logbooks, and creel sampling by DFO and the Haida Fisheries Program. Piece counts are available from lodge logbooks and creel samples, but size composition data are limited, and lodge data are mostly (56%) self-reported and unverified.

DFO instituted several management restrictions on the sport fishery to constrain the harvest to stay within the sport allocation and extend the season as long as possible. The management restrictions were similar to those implemented in 2010, and included a reduction of the daily bag limit from two to one halibut, a reduction in the possession limit from three-fish to two, and a prohibition on halibut retention in Area 121 seaward of 12 nmi (SW off Vancouver Island). The season was the shortest on record, opening on March 1 and closing on September 5. In August, DFO projected that the sport allocation would be reached before the usual December 31 season closing date, so an early closure was not unexpected.

For the 2011 season only, DFO implemented an experimental leasing program, where interested recreational fishers could receive experimental licenses that would allow them to lease halibut quota from commercial quota holders and allow continued sport fishing after the general sport fish closure. The program allowed for a market-based transfer system and provided the recreational sector access to fish outside their management allocation. The program had limited success with 4,000 pounds transferred with few pounds caught.

Alaska

Estimates of the sport fishery harvest off Alaska are supplied by ADF&G and different methods were used to project guided (charter) and unguided (private) catch estimates. The number of fish harvested by the guided fishery is estimated from data reported by the ADF&G mandatory charter logbook program. The unguided fishery harvest in number of fish is estimated from the Statewide Harvest Survey (SWHS). Average weight data from creel sampling in the current year is then used to estimate the pounds caught in both sectors.

The Area 2C sport harvest is projected to have decreased substantially in 2011, to 1.31 million pounds from 1.97 million pounds in 2010 (Table 4). For the guided fishery, the average weight decreased from 26.4 to 9.4 pounds and the number of fish (41,200) remained about the same.

The substantial decline in average weight was a result of the 37-inch (fork length) maximum size limit, implemented to keep the sector harvest under the GHL. Since 2009, the guided fishery had the same GHL (0.788 million pounds), and the same daily bag limit of one-fish, but 2011 saw the addition of the size restriction. The guided fishery harvest has been above the GHL since 2004 (often substantially so) and was above the GHL in 2009 and 2010, by 58 and 38 percent, respectively, but was substantially below the GHL by 51 percent in 2011. In contrast to the guided fishery, the number of fish increased in the Area 2C private sector by 6.5% and the average weight remained unchanged.

In Areas 3A, 3B, and 4, the daily bag limit of two halibut for the guided and unguided fishery remained unchanged. Area 3A had a slight increase of 6% in harvest from the previous year, resulting from an increase in number of fish caught. The guided sector's harvest was under the GHL. Areas 3B and 4 had harvests higher than in 2010

The 2011 projected sport harvest for Alaska is 5.9 million pounds and the final 2010 estimate is 6.3 million pounds, showing a decrease of 6% in 2011.

Bycatch mortality and upcoming programs

IPHC receives bycatch estimates, size, and release condition data from the observer programs which operate off Canada and the U.S. Not all fisheries are observed, therefore bycatch rates and discard mortality rates from similar fisheries are used to calculate bycatch mortality in unobserved fisheries.

In 2011, bycatch mortality was estimated at 10 million pounds (Table 12), a 6% decrease from 2010, and the lowest since 1986 (Williams 2012c). Historically, bycatch mortality peaked at 20 million pounds in 1992 due to the growth and expansion of the Alaska groundfish fisheries, and declined to between 12-14 million pounds in the late 1990s, and has been below 11 million for the last two years.

In 2010, the PFMC took actions that lowered the halibut bycatch mortality in Area 2A in 2011. The program is similar to the B.C. trawl program, where there is individual vessel accountability for bycatch mortality. The PFMC adopted a management program for the Area 2A groundfish trawl fishery which provided for an individual bycatch quota (IBQ) system for the shoreside groundfish trawl fishery, 100% observer coverage, and real-time reporting. With the IBQ incentives the Area 2A halibut bycatch mortality in the trawl fishery was lowered by more than half, from 0.300 to 0.090 million pounds.

For Alaska, the NPFMC and NMFS continued work to restructure the Alaska observer program. The expectation is that all groundfish fisheries, including the halibut fishery, will fall into two observer coverage categories (greater than or equal to 100% coverage, or less than 100% coverage). Vessels that have had coverage requirements of greater than 100% coverage will continue with the current program by contracting directly with observer providers. The remaining groundfish vessels will be managed under an ex-vessel fee-based structure, with coverage determined through a sampling and deployment plan that is developed by NMFS. The expectation is that this will provide less biased halibut bycatch estimation in fisheries that currently have low or no coverage and where the deployment coverage was scheduled by the vessels. In addition, halibut fisheries, which have had no observer coverage, will be monitored. Electronic monitoring is being developed for some portions of the groundfish fleet. The implementation of the restructured observer program is not likely to occur before 2013. For more information on both programs, see the Council webpages: http://www.pcouncil.org/ and http://www.fakr.noaa.gov/npfmc/.

References

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Williams, G. H. 2012b. 2010 sport fishery review. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2011:45-52.

Williams, G. H. 2012c. Incidental catch and mortality of Pacific halibut, 1962-2011. Int. Pac. Halibut Comm. Report of Assessemnt and Research Activities 2011:381-398.

Table 1. The 2011 preliminary estimates of total removals (thousands of pounds, net weight), 2011 catch limits and catch of Paci c halibut by regulatory area, and 2011 sport guideline harvest level and sport guided harvest for Areas 2C and 3A (Preliminary, December 2011).

Area	2A	2B	2C	3A	3B	4	Total
Commercial	523	6,654	2,293	14,266	7,336	7,754	38,826
Sport	386	1,220	1,313	4,541	25	18	7,503
Bycatch Mortality:							
O32 fish	106	152	214	1,035	430	2,107	4,044
U32 fish	34	145	127	1,863	755	3,028	5,952
Breakdown of U32							
U32/O26	*31*	*122*	*88*	*846*	*402*	*1,037*	*2,526*
U26 sh	*3*	*23*	*39*	*1,017*	*353*	*1,991*	*3,426*
Personal Use[2]	25[3]	405	425	313	23	54[4]	1,245
Wastage Mortality:							
O32 fish	4	20	5	29	7	34	99
U32 fish	6	177	65	881	752	332	2,213
Breakdown of U32							
U32/O26	*6*	*173*	*61*	*840*	*678*	*293*	*2,051*
U26 sh	*0*	*4*	*4*	*41*	*74*	*39*	*162*
IPHC Research	18	80	91	291	102	83	665
Total Removals	1,102	8,853	4,533	23,219	9,430	13,410	60,547
2011 Catch Limits[5]	910[6]	7,650[7]	2,330	14,360	7,510	8,310	41,070
2011 Catch	933[6]	7,874[7]	2,293	14,266	7,236	7,764	40,366
2011 Sport GHL			788	3,650			NA
2011 guided harvest			388	2,837			NA

[1] Area 2A bycatch is the 2010 estimate as the 2011 estimate will not be available until 2012.
[2] Includes 2010 Alaskan subsistence harvest estimates.
[3] Treaty Indian ceremonial and subsistence fish authorized in the 2011 catch sharing plan.
[4] Includes 17,000 pounds of sublegal halibut retained in the 2011 Area 4DE Community Development Quota.
[5] Does not include poundage from the underage/overage programs in Area 2B or Alaska
[6] Includes commercial, sport, and treaty subsistence catch
[7] Includes commercial and sport catch

Table 2. The Area 2A 2011 catch limits allocated by the Paci c Fishery Management Council Catch Sharing Plan and preliminary catch estimates (pounds, net weight).

Area	Catch Limit	Catch[1] Estimate
Non-treaty directed commercial	159,380	168,000
Non-treaty incidental commercial during salmon troll fishery	28,126	25,900
Treaty Indian commercial	293,200	328,916
Treaty Indian ceremonial and subsistence	25,300	25,300
Sport – Washington	216,489	202,354
Sport – Oregon/California	187,506	183,226
Total allocation	910,000	933,696
IPHC research catch		17,500
Total	910,000	951,196

[1] Preliminary as of December 2011.

Table 3. The 2011 Area 2B catch limits as allocated by the Canadian Department of Fisheries and Oceans and estimated catches (thousands of pounds, net weight).

Fishery	Allocation	Catch Estimate[1]
Commercial fishery	6,702.2[3]	6,654.0
Sport fishery[2]	947.8	1,220.0
Total allocation/catch	7,650.0	7,874.0
IPHC research catch		80.0
Total	7,650.0	7,954.0

[1] Preliminary as of December 2011.

[2] An experimental permit program was implemented in 2011 which allowed sport operators to lease quota from commercial operators. Details on the amount leased were not available at time of writing.

[3] Adjustments totaling -32,000 pounds were made to the commercial fishery catch limit which included carryover from the previous year's underage/overage plan and quota held by DFO for First Nations through relinquishment processes.

Table 4. The Area 2C and 3A sport charter halibut harvest and Guideline Harvest Level (GHL) (millions of pounds, net weight), 2000-2011.

	Area 2C				Area 3A			
Year	Private	Guided	Total	GHL	Private	Guided	Total	GHL
2000	1.121	1.130	2.251	-	2.165	3.140	5.305	-
2001	0.721	1.202	1.923	-	1.543	3.132	4.675	-
2002	0.814	1.275	2.090	-	1.478	2.724	4.202	-
2003	0.846	1.412	2.258	1.432	2.046	3.382	5.427	3.650
2004	1.187	1.750	2.937	1.432	1.937	3.668	5.606	3.650
2005	0.845	1.952	2.798	1.432	1.984	3.689	5.672	3.650
2006	0.723	1.804	2.526	1.432	1.674	3.664	5.337	3.650
2007	1.131	1.918	3.049	1.432	2.281	4.002	6.283	3.650
2008	1.265	1.999	3.264	0.931	1.942	3.378	5.320	3.650
2009	1.133	1.249	2.383	0.788	2.023	2.734	4.758	3.650
2010	0.885	1.086	1.971	0.788	1.587	2.698	4.285	3.650
2011	0.925	0.388	1.313	0.788	1.704	2.837	4.541	3.650

Table 5. Commercial shing periods, number of shing days, catch limit, commercial, research and total catch (thousands of pounds, net weight) by regulatory area for the 2011 Paci c halibut commercial shery (preliminary, December 2011).

Area 2A	Fishing Period	Catch Limit	No. of Days	Commercial Catch	Research Catch	Total Catch
Treaty Indian	Unrestricted:					
	3/20 –22		48-hours	148.6		
	5/1 – 2		19-hours	116.9		265.5
	Restricted:					
	3/12-19, 3/24-28		13 days	63.4		63.4
Total		293.2		328.9		328.9
Commercial Incidental in Salmon Fishery	5/1 – 5/28	28.1	28 days	25.5		
	7/29 – 10/31		95 days	0.4		
Total				25.9		25.9
Directed[1]	6/29		10-hours	99.0		
	7/13		10-hours	69.0		
Directed Total		159.4		168.0		168.0
2A Total		480.7		522.8	17.5	540.3
Area	**Fishing Period**	**Catch Limit**	**Adjusted Catch Limit[2]**	**Commercial Catch**	**Research Catch**	**Total Catch**
2B	3/12 – 11/18	6,702.2	6,670.0	6,654.0[3]	80.0	6,734.0
2C	3/12 – 11/18	2,330.0	2,407.0	2,293.0[4]	91.0	2,384.0
3A	3/12 – 11/18	14,360.0	14,505.0	14,266.0	291.0	14,557.0
3B	3/12 – 11/18	7,510.0	7,615.0	7,336.0	102.0	7,438.0
4A	3/12 – 11/18	2,410.0	2,450.0	2,286.0	36.0	2,322.0
4B	3/12 – 11/18	2,180.0	2,268.0	2,030.0	32.0	2,062.0
4C	3/12 – 11/18	1,690.0	1,723.0	788.0[5]	5.0	793.0
4D	3/12 – 11/18	1,690.0	1,715.0	2,192.0[5, 6]	10.0	2,202.0
4E	3/12 – 11/18	340.0	340.0	458.0[6]	0.0	458.0
Alaska Total		32,510.0	33,023.0	31,649.0	567.0	32,216.0
Grand Total		39,692.9	40,173.7[7]	38,825.8	664.5	39,490.3

[1] Fishing period limits by vessel class.
[2] Includes adjustments from the underage/overage programs. Additionally, in 2B, quota held by DFO for First Nations through relinquishment processes are included.
[3] Includes the pounds that were landed by Native communal commercial licenses (FL licenses).
[4] Includes the pounds taken in the Metlakatla fishery within the Annette Island Reserve.
[5] Area 4C IFQ and CDQ could be fished in Area 4D by NMFS and IPHC regulations.
[6] Area 4D CDQ could be fished in Area 4E by NMFS and IPHC regulations.
[7] Includes Area 2A catch limit.

Table 6. The shing period limit (pounds, net weight) by vessel class used in the 2011 directed commercial shery in Area 2A.

Vessel Class		Fishing Period & Limits	
Letter	**Feet**	**June 29**	**July 13**
A	0-25	840	420
B	26-30	1,050	525
C	31-35	1,680	840
D	36-40	4,630	2,315
E	42-45	4,980	2,490
F	46-50	5,960	2,980
G	51-55	6,650	3,325
H	56+	10,000	5,000

Table 7. The number of vessels catching halibut since the implementation of the Area 2B IVQ shery and number of vessels and permit holders catching halibut since the implementation of the Alaska IFQ.

Year	Number of vessels shing in Area 2B	Number of vessels shing in Alaska	Number of quota share holders in Alaska
1991	435	no IFQ fishery	no IFQ fishery
1992	433	no IFQ fishery	no IFQ fishery
1993	355	no IFQ fishery	no IFQ fishery
1994	318	no IFQ fishery	no IFQ fishery
1995	295	2,206	4,831
1996	278	2,130	NA
1997	284	2,163	NA
1998	287	1,802	NA
1999	268	1,847	NA
2000	238	1,841	3,541
2001	239	1,728	3,507
2002	216	1,643	3,500
2003	225	1,592	3,435
2004	219	1,513	3,315
2005	222	1,495	3,239
2006	214	1,476	3,210
2007	210	1,499	3,076
2008	200	1,417	2,907
2009	187	1,326	2,851
2010	236	1,316	2,780
2011	217	1,286	2,740

Table 8. The total pounds (thousands, net weight, preliminary) of 2011 commercial landings (not including research catch) of Paci c halibut for Alaska and British Columbia by regulatory area and month.

Regulatory Area	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
2B[1]	1,046	771	622	480	713	1,020	453	993	556	6,654
2C[2]	329	349	468	313	164	276	242	152[3]		2,293
3A[2]	1,656	2,008	2,930	2,054	1,358	1,547	1,531	991	191	14,266
3B[2]	134	382	1,367	1,379	956	1,524	860	586	148	7,336
4A[2]		58[4]	395	257	306	737	268	265[3]		2,286
4B[2]		74[4]	348	333	425	332	307	211[3]		2,030
4CDE[2]			319	757	823	582	405	453	99	3,438
Alaska Total	2,119	2,871	5,827	5,093	4,032	4,998	3,613	2,658	438	31,649
Total	3,165	3,642	6,449	5,573	4,745	6,018	4,066	3,651	994	38,303

[1] Based on landing ratios from DFO website.
[2] Based on landings from NMFS RAM Division
[3] Weight combined with the previous month for confidentiality purposes.
[4] Weight combined with the previous month for confidentiality purposes.

Table 9. Harvest of halibut by sport shers (millions of pounds, net weight) by regulatory area, 1977-2011. (Estimates for 2011 are preliminary).

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1977	0.013	0.008	0.072	0.196	-	-	0.289
1978	0.010	0.004	0.082	0.282	-	-	0.378
1979	0.015	0.009	0.174	0.365	-	-	0.563
1980	0.019	0.006	0.332	0.488	-	-	0.845
1981	0.019	0.012	0.318	0.751	-	0.012	1.112
1982	0.050	0.033	0.489	0.716	-	0.011	1.299
1983	0.063	0.052	0.553	0.945	-	0.003	1.616
1984	0.118	0.062	0.621	1.026	-	0.013	1.840
1985	0.193	0.262	0.682	1.210	-	0.008	2.355
1986	0.333	0.186	0.730	1.908	-	0.020	3.177
1987	0.446	0.264	0.780	1.989	-	0.030	3.509
1988	0.249	0.252	1.076	3.264	-	0.036	4.877
1989	0.327	0.318	1.559	3.005	-	0.024	5.233
1990	0.197	0.381	1.330	3.638	-	0.040	5.586
1991	0.158	0.292	1.654	4.264	0.014	0.127	6.509
1992	0.250	0.290	1.668	3.899	0.029	0.043	6.179
1993	0.246	0.328	1.811	5.265	0.018	0.057	7.725
1994	0.186	0.328	2.001	4.487	0.021	0.042	7.065
1995	0.236	0.887	1.751	4.511	0.022	0.055	7.462
1996	0.229	0.887	2.129	4.740	0.021	0.077	8.083
1997	0.355	0.887	2.172	5.514	0.028	0.069	9.025
1998	0.383	0.887	2.501	4.702	0.017	0.096	8.586
1999	0.338	0.859	1.843	4.228	0.017	0.094	7.379
2000	0.344	1.021	2.251	5.305	0.015	0.073	9.009
2001	0.446	1.015	1.923	4.675	0.016	0.029	8.104
2002	0.399	1.260	2.090	4.202	0.013	0.048	8.012
2003	0.404	1.218	2.258	5.427	0.009	0.031	9.347
2004	0.487	1.613	2.937	5.606	0.007	0.053	10.703
2005	0.484	1.841	2.798	5.672	0.014	0.050	10.859
2006	0.516	1.752	2.526	5.337	0.014	0.046	10.191
2007	0.504	1.556	3.049	6.283	0.025	0.044	11.461
2008	0.481	1.536	3.264	5.320	0.026	0.040	10.667
2009	0.458	1.098	2.383	4.758	0.030	0.024	8.751
2010	0.373	1.156	1.971	4.285	0.024	0.016	7.825
2011	0.386	1.220	1.313	4.541	0.025	0.018	7.503
2010-2011 change							
Pounds	0.013	0.064	(0.658)	0.256	0.001	0.002	(0.322)
Percent	3.5%	5.5%	(33.4%)	6.0%	4.2%	12.5%	(4.1%)

Table 10. Area 2A 2011 sport harvest allocations and preliminary catch estimates (pounds, net weight) by subarea.

			Under/Over	
Subarea	**Allocation**	**Estimate**	**Pounds**	**Percent**
WA Inside Waters	58,155	45,856	(12,299)	(21)
WA North Coast	108,792	103,741	(5,051)	(4.6)
WA South Coast	43,500	45,100	1,600	3.7
Columbia River	15,418	11,279	(4,139)	(26.7)
OR Central Coast	172,505	169,956	(2,549)	(1.5)
South OR/California	5,625	9,648	4,023	71.5
Total	403,995	385,580	(18,415)	(4.6)

Table 11. Summary of the 2011 Paci c halibut sport shery seasons. No size limits were in effect unless otherwise noted.

Regulatory Area & Region	Fishing Dates	Fishing Days per week	No. of Fishing Days	Daily Bag Limit
Area 2A - Washington, Oregon & California				
WA Inside Waters				
East of Low Point	May 5 – 21	3 (Thurs - Sat)	9	1
	May 26 - 29	4 (Thurs - Sun)	4	1
Low Point to Sekiu River	May 26 – 29	4 (Thurs - Sun)	4	1
	Jun 2 – 18	3 (Thurs - Sat)	9	1
WA North Coast (Sekiu River to Queets River)	May 12 - 21	2 (Thurs, Sat)	4	1
	Jun 2, 4, 16, 30	2 (Thurs, Sat)	4	1
WA South Coast (Queets River to Leadbetter Pt.)				
All depths	May 1 - 22	2 (Sun, Tues)	7	1
Northern nearshore	May 2 – May 21	5 (Mn, Wd-Sa)	15	1
	May 23 – Jul 24	7 (Mon – Sun)	33	1
Columbia River (Leadbetter Pt. to Cape Falcon)	May 5 – Jun 4	3 (Thurs - Sat)	15	1
	Aug 5 - Sep 30	3 (Fri - Sun)	57	1
OR Central Coast (Cape Falcon - Humbug Mtn.)				
All Depths	May 13 - Jun 25	3 (Thurs - Sat)[a]	14	1
	Aug 5 – 6	2 (Fri - Sat)	2	1
Less than 40 fathoms	May 1 – Jul 6	7 (Sun - Sat)	37	1
	Aug 13 – Oct 31	7 (Sun – Sat)	80	1
OR/CA (South of Humbug Mtn.)	May 1 - Oct 31	7 (Sun - Sat)	184	1
Area 2B - British Columbia	Mar 1 - Sep 5	7 (Sun - Sat)	188	1
Area 2C - Alaska				
Guided anglers	Feb 1 - Dec 31	7 (Sun - Sat)	334	1[b]
Unguided anglers	Feb 1 - Dec 31	7 (Sun - Sat)	334	2
Areas 3 and 4 - Alaska	Feb 1 - Dec 31	7 (Sun - Sat)	334	2

[a]Fishing was prohibited during May 19-21.

[b]A maximum size limit of 37 inches (fork length) was in effect in 2011.

Table 12. Estimates (thousands of pounds, net weight) of bycatch mortality of halibut by year and area, 2001 - 2011.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011[1]
Area 2A	837	575	541	351	504	548	322	383	509	346	140
Area 2B	177	244	244	251	346	294	320	143	213	181	297
Area 2C	341	340	341	362	340	341	342	346	344	343	341
Area 3A	3,009	2,194	3,180	3,671	3,220	2,975	2,843	3,066	2,722	2,532	2,898
Area 3B	1,675	1,924	1,734	1,274	1,126	1,400	1,115	1,353	1,294	1,147	1,185
Area 4	7,120	7,273	6,822	6,735	7,692	7,491	7,262	6,555	6,297	6,082	5,134
TOTAL	13,159	12,550	12,862	12,644	13,228	13,049	12,204	11,846	11,378	10,631	9,995

[1] Preliminary

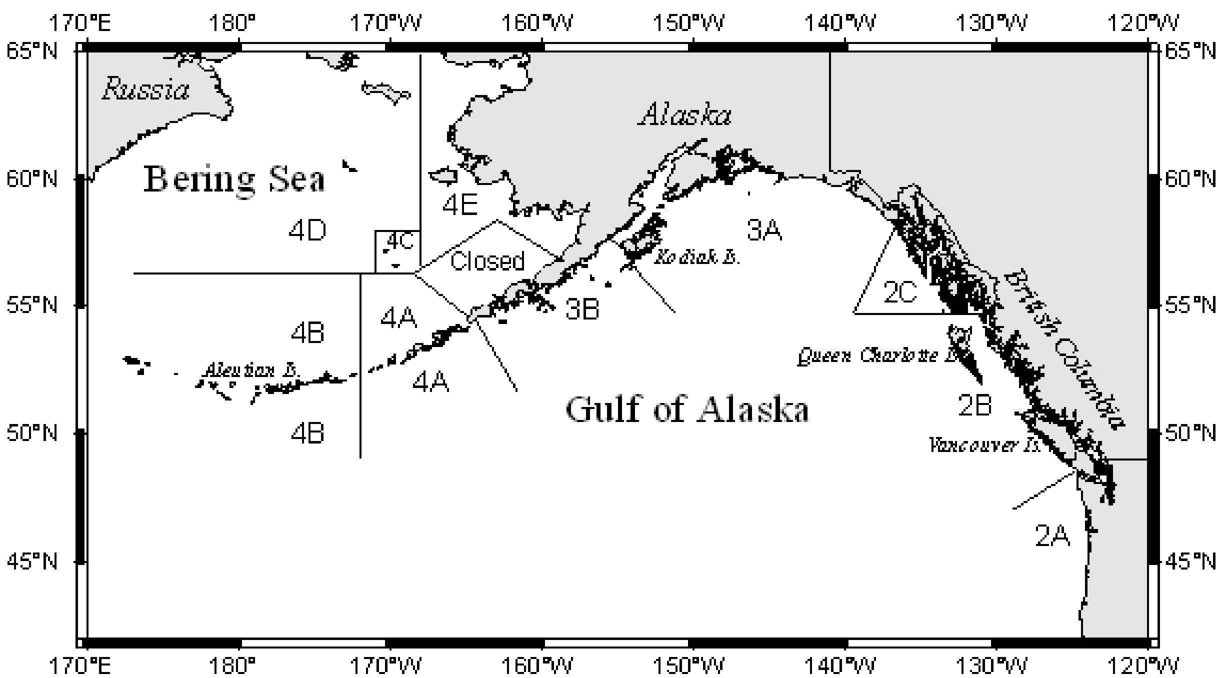

Figure 1. IPHC regulatory areas for the 2011 shery.

Harvest policy considerations for re-evaluating the minimum size limit in the Pacific halibut commercial fishery

Juan L. Valero and Steven R. Hare

Abstract

The Pacific halibut harvest strategy uses a minimum size limit of 32 inches (81.3 cm) in its commercial fishery. The current stock assessment estimates increasing trends in total halibut numbers and total biomass in spite of a decade long declining trend in exploitable biomass. The difference in estimated trends has been interpreted as resulting from decreasing availability of larger halibut to the commercial gear due to a decade's long decline in size-at-age, and increased estimates of recent recruitment. The estimated coastwide accumulation of halibut below the size limit has prompted requests to consider lowering or eliminating the current minimum size limit (MSL). This report evaluates the potential effects of modifying the MSL along with the effect of different assumptions and methods on results. Four main methods were used. First was a comparison between female maturity at age with both potential future, and observed historical changes in selectivity and age distribution of commercial landings under different MSLs. Second was a coastwide yield per recruit and spawning biomass per recruit analysis. Third was a spatially structured migratory yield per recruit and spawning biomass per recruit analysis. A fourth analysis was conducted by gradually decreasing the MSL, using simulated changes in selectivity curves under the assumption of gradual changes in weights at age of the resulting catch. Reducing or eliminating the MSL is expected to increase the capture of immature females, as supported by comparing expected changes in selectivity at age and cumulative distributions of observed catch at age for historical periods with different MSLs. A reduction or elimination of MSL does increase the proportion of females at older ages relative to status quo, with as much as 80% improvement, however the actual proportions in the population are still quite low (12% to 22% at age 25). Eliminating the MSL and assuming that retention will be similar to that of the survey, results in decreased coastwide yield per recruit and decreased spawning biomass per recruit when accounting for smaller weights-at-age expected from changes in commercial selectivity. When assuming that elimination of the MSL results in commercial landings similar to the IPHC survey, the proportion of females in the catch and in the population only marginally changes from status quo conditions. A larger decrease in the proportion of females in the catch and increase in the proportion in the population could be achieved by a major change in commercial selectivity towards smaller sizes and younger ages. However, this would result in the capture of immature females as much as four years before they mature, would require precise control of removals required by a low harvest rate (around 0.1), and would achieve lower yield per recruit than the status quo. The migratory analysis produced similar results to the coastwide yield per recruit and spawning biomass per recruit and it had low sensitivity to different assumptions on migration. Minor reductions in the MSL along with harvest rate reductions are expected to produce at most 3% increases in yield per recruit, but greater reductions in the MSL including its elimination are expected to reduce both yield per recruit and spawning biomass per recruit. The proportion of females in the population between the extremes of current MSL and a MSL of 65 cm would change from 44% to 45% for ages 6 and older, and from 12% to 22% at age 25. Overall, decreasing the MSL is expected to reduce yield per

recruit and spawning per recruit under most conditions evaluated in this work. At the extreme of MSL of 65 cm, the sex composition in the catch would still be predominantly female and although the proportion of females at older ages would increase, the actual proportions in the population would still be quite low.

Introduction

Size limits are one of the available tactics to implement a harvest strategy (Hilborn and Walters 1992). Pacific halibut has been commercially exploited since 1888. A variety of fishing gear types were used until 1944 when nets were prohibited and longlines became the main fishing gear in the directed commercial fishery (Bell 1981). The commercial fishery operated without a minimum size limit (MSL) from 1888 until 1940, when a 5 lb minimum weight was established. In 1944 a 26 inch (66 cm: equivalent to the 5 lb set in 1940) MSL was introduced and remained in place until 1973 when it was changed to an MSL of 32 inches (81.3 cm) (Myhre 1974), which is still in place today. Reasons behind past changes in MSL included protection of juveniles and expected increased yield per recruit. The stock assessment has estimated increasing trends in total halibut numbers and total biomass during the last decade in spite of a declining trend in estimated exploitable biomass. The differing estimated trends have been interpreted as resulting from decreasing availability of larger halibut to the commercial gear due to a decade's long decline in size-at-age, and increased estimates of recent recruitment. The stock assessments' estimated coastwide accumulation of halibut below the size limit has prompted requests to consider lowering or eliminating the current MSL.

Female halibut have a faster growth rate than males. The current size limit of 81.3 cm, combined with the sexual dimorphism in growth of halibut, results in a commercial fishery that is predominantly comprised of females. The sex ratio in the commercial catch is not known as the fish are eviscerated at sea, therefore survey data are used to estimate sex ratio at length in the commercial catch (Clark 2004). The IPHC setline survey does provide direct estimates of the variability in sex ratio at length (Fig. 1). The potential higher ratio of males in the commercial catch, as evidenced by their increased preponderance in the survey catch below the current MSL, has also been part of the rationale for considering lowering the MSL.

Selectivity is one of the main components of models of populations under exploitation and relates to the fishing process. Changes in selectivity, along with the assumptions regarding how to model selectivity, are expected to have profound effects on the performance of stock assessments and harvest policies. Since the beginning of the commercial fishery for Pacific halibut in 1888, selectivity has been determined by the operational characteristics of the longline gear (hook size and spacing), behavior of the fishers (e.g. historical expansion of the fishery towards deeper and northern waters and fishing grounds selection) and varying MSL. Changes in MSL are expected to result in changes in fishery selectivity. The selectivity of fish to the commercial fishing gear is affected by availability and vulnerability. Typically, selectivity describes the vulnerability of fish of a particular characteristic (say its age, size, sex) to the fishing gear as well as the availability of fish to the gear. The availability may be related to spatial differences in size or age of fish, for example different areas may have different age structures as fish migrate from nursery to adult areas. Selectivity can be a function of length, age, or both. Selectivity may also differ between sexes, or change over time and/or space. Different assumptions on the processes that selectivity describes can have a large influence on the stock assessment results and management advice (Parma 2002). In the case of Pacific halibut, the modeling of selectivity has changed over time. In the past it was modeled as a sole function of the age of the fish, however changes in size at age over time created issues that were partially resolved by including size in the modeling of selectivity. This attempted to capture the changes in size at age, but also described part of the mechanics of the fishing gear. Halibut of different sizes had different probabilities of being caught by the gear used, fish too small to be taken by the gear (e.g., mouth size too small for a typical hook size) were less likely to be caught than halibut large enough to be taken by the fishing gear. However, halibut size did not seem to be the only characteristic affecting its selectivity and age seemed to have an effect, probably affecting the availability of fish of different ages as they migrated through different areas. From early 1990s to 2006, different selectivities were used for different areas in the closed-area models. The recent renewed understanding that halibut continue migrating after the age/size at which they enter the fishery (Webster and Clark 2007, Valero and Webster 2012, Webster et al. in prep.) resulted in the adoption of a coastwide model with a single common coastwide selectivity schedule modeled as a function of halibut size.

The objective of this report is to illustrate the effect of alternative assumptions, methods, and criteria on the evaluation of potential pros and cons of changing the current MSL in the Pacific halibut commercial fishery.

Materials and methods

1. Selectivity and maturity at age

Changes in fishery selectivity following management changes to the MSL are difficult to predict (Clark and Parma 1995, Allen and Pine 2000). For this part of the analysis, we assumed that a reduction in the MSL would result in either:

1) The commercial fishery selectivity changes to the selectivity currently estimated for the IPHC survey (Fig. 2).
2) Although hook size and spacing are standardized in the IPHC survey, there are no regulations regarding hook size and spacing in the commercial gear, so reductions or elimination of the MSL could result in departures beyond those expected when assuming the commercial fishery selectivity would only change to that of the IPHC survey. In this scenario, the commercial fishery selectivity shape is unaltered but it is centered 20 cm towards smaller sizes as currently estimated (Fig. 2). A similar approach, with a larger selectivity shift towards smaller sizes was used by Parma (1998) in order to illustrate tradeoffs between yield gains and spawning biomass reductions assuming that a reduction or elimination in MSL would result in a shift of commercial selectivity toward smaller sizes than those of the IPHC survey. This scenario could be expected if potential reductions or elimination of the MSL results in major changes in commercial fishing gear, for example smaller hooks and shorter spacing. Intermediate commercial selectivity values are calculated in a subsequent section of this report. The goal of this part of the analysis was to capture the overall impact rather than try to predict gradual changes.

For each potential change in selectivity at size, resultant selectivity at age and sex was computed using coastwide lengths-at-age averaged (only average lengths and the mean predicted age at length are presented for the conversion) between 2008 and 2010 (Fig. 2, bottom). Potential reductions in MSL are expected to change not only the fishery selectivity but also the weight-at-age of the catch. Under the current MSL, the commercial fishery cannot legally retain halibut smaller than 81.3, therefore the minimum weight of legally landed halibut is (on average) somewhat larger than the weight of fish in the population associated with the MSL. Modeling work for Pacific halibut at the IPHC typically assumes that the weight-at-age of halibut caught in the survey is a good approximation of the weight-at-age of the population, at least for halibut older than age 6. We assumed that an elimination of the MSL would result in the weight-at-age of the commercial catch to be that of the survey. The rationale for this assumption is straightforward for the assumed selectivity changes (commercial selectivity changes to that of the survey): if the selectivity is assumed to be that of the survey, the weights-at-age should be expected to be the ones of the survey. In the second case of the shifted commercial selectivity towards smaller sizes, departures from the weight-at-age of the survey could be expected if average weight-at-age of younger ages (but now selected at smaller sizes) were smaller under the lower MSL. However, that does not appear to be the case as average weights associated with MSLs of 65 cm and 60 cm are lower than those of the younger ages in both the survey and commercial catches (Fig. 3).

The benefits of delaying the capture of fish after maturity have being pointed out early and frequently in the history of fisheries science (Holt 1895, Hilborn and Walters 1992, Smith 1994, Myers and Mertz 1998). Selectivities in the commercial fishery for Pacific halibut and the IPHC survey are currently modeled as a sole function of fish size, although the potential joint effect of fish age was noted when this formulation was adopted. Female halibut grow faster than males and this results in sex specific selectivities. Female maturity is determined by age (Hare 2010). Although coastwide fishery and survey selectivities at size are currently used in halibut stock assessment work, different sizes-at-age among IPHC regulatory areas results in different selectivities at age among areas. Sex and area specific selectivities at age were computed based on average 2008-2010 sizes-at-age. Female maturity was compared with selectivities at age for the commercial fishery, the IPHC survey, and a commercial fishery selectivity shifted 20 cm towards smaller sizes (Fig. 2). Area-specific cumulative distributions of female halibut captured by the commercial fishery and IPHC survey during 2009 were also plotted against female maturity. Changes in the relationship between commercially landed halibut and female maturity for historical periods with different MSL were also compared by plotting female maturity at age and cumulative catch at age. The sex composition of the commercial catch for years after 1996 is estimated based on the sex ratio of survey catches at length (Clark and Hare 2006). For earlier years, the sex composition of the commercial catches is not available so cumulative distributions of age for sexes combined was used instead for the following periods: 1935-1939 (No MSL), 1945-1973 (MSL: 65 cm) and 1974-1990 (MSL: 81.3 cm).

2. Yield per recruit and biomass per recruit

A standard age-based (ages 6 to 55) two-sex model was used to calculate yield per recruit and female spawning biomass per recruit. Size and weight-at-age were averaged for the 2008-2010 years. Model equations are described in Valero and Hare (2012).

Yield per recruit and female spawning biomass per recruit were calculated for the following scenarios:

(1) Status quo: MSL: 81.3, commercial selectivity as estimated for 2008-2010 and harvest rate of 0.215. Weight-at-age of the commercial catch is set at the 2008-2010 average commercial weight-at-age.

(2) Commercial selectivity set to the 2008-2010 IPHC survey selectivity, harvest rate of 0.215, weight-at-age of the commercial catch from the 2008-2010 average weight-at-age in the IPHC survey.

(3) The commercial fishery selectivity shape is unaltered but it is centered 20 cm towards smaller sizes as currently estimated (Fig. 2), harvest rate of 0.215. Weight-at-age of the commercial catch is set at the 2008-2010 average weight-at-age in the IPHC survey. This approach will tend to overestimate population weight at age; it is presented here to allow for comparisons with recent per-recruit analysis (e.g., Hare 2011)

(4) Same as scenario 2 but with HR at a level that reduces spawning biomass per recruit at a level equivalent to that of the status quo.

(5) Same as scenario 3 but with HR at a level that reduces spawning biomass per recruit at a level equivalent to that of the status quo.

(6 to 9) Same as scenarios 2 to 5 but with weight-at-age of the commercial catch set at the 2008-2010 average commercial weight-at-age. This approach will tend to overestimate population weight at age; it is presented here to allow for comparisons with recent per-recruit analysis (e. g., Hare 2011)

In addition to calculating yield per recruit and spawning biomass per recruit, female proportion at age in the population and in the commercial catch was calculated for scenarios 1 to 3.

3. Migratory yield per recruit and biomass per recruit

In addition to the coastwide per recruit modeling described in the previous section, area-specific yield per recruit and biomass per recruit were calculated for a spatially structured model with migration similar to the one used in Valero and Hare (2010a, 2011). The model includes ages 1 to 50, which is an accumulating age. Sex-specific size at age, maturity at age, and selectivity (survey and commercial) at size are the same as described in the previous section. The model used here includes six areas: Area 4 (a combination of IPHC Regulatory Areas 4A, 4B, and 4CDE) and Regulatory Areas 3B, 3A, 2C, 2B, and 2A (Fig. 4). Model equations are described in Valero and Hare (2012). Migration is assumed to occur instantaneously at the beginning of the year, before any source of mortality occurs. Analysis of traditional (Hoag et al. 1983, Quinn et al. 1985) and PIT tag (Webster and Clark 2007, Webster et al. in prep.) recoveries suggest that the fraction of fish migrating is a function of fish size/age, with smaller/younger fish more likely to migrate than larger/older fish. Two migration scenarios were used. In the first scenario (“1M”) fish of all sizes migrate following a single migration matrix based on results of the PIT tag model (Webster 2009). In the second scenario (“2M”), migration of halibut smaller than 65 cm was based on tagging results of juveniles (Hilborn et al. 1995, Valero and Webster 2012) whereas migration of halibut larger than 65 cm was based on PIT tag model results (Webster 2009, Webster et al. in prep.). Other equations are area specific versions of equations iii to vii listed in the previous section (For more details see Valero and Hare 2010a). The distribution of age 1 halibut was based on the relative distribution of age-1 halibut from IPHC juvenile trawl surveys (Best 1977, see Fig. 2 in Valero and Hare 2010b). Yield per recruit and spawning biomass per recruit were calculated for each area under different migration scenarios for scenarios 1 to 5 described in the previous section. Per recruit calculations were based on age six halibut.

4. Gradual changes in MSL and gradual changes in selectivity

To analyze the potential effects of gradual changes in the size limit upon fishery yield and female spawning biomass, we used a deterministic per-recruit model very similar to that used by Hare (2011) to quantify the effect of differentially accounting for the catch of U32 halibut. Model equations are described in Valero and Hare (2012).

The length-based selectivities used in this part of the analysis are illustrated in Figure 13. Two different sets of selectivities, termed Pattern A and Pattern B are derived, both on the basis of modifying the current commercial selectivity curve estimated from the halibut stock assessment. For Pattern A, we assume that relative selectivity for halibut over 90 cm would not be affected by a reduced size limit, but that selectivities below 90 cm would increase. Such a pattern might arise if less "shaking" of fish visually judged to be near the size limit occurs as the size limit decreases. Selectivity at length in the current halibut assessment is estimated as a piecewise linear function at every 10 cm interval, with intermediate values interpolated. Selectivity is assumed to be 1.0 at a length of 120 cm and other sizes are computed relative to that size. Selectivities are 0.27, 0.06, and 0.004 at 90, 80, and 70 cm, respectively, (note that despite the size limit of 81.3 cm, halibut below that size are still landed thus resulting in selectivities greater than 0 down to 70 cm). To model how selectivity would change with a reduced size limit, we incrementally shifted the relative selectivities at 80 and 70 cm. Thus, for a size limit reduced by 2 cm, the 0.06 selectivity at 80 cm was shifted to 78 cm and the 0.004 selectivity at 70 cm was shifted to 68 cm, with intermediate values linearly interpolated. Pattern B was derived by modeling selectivity as a logistic function. A logistic function was first fitted to the 10 cm interval values of the commercial selectivity estimated by the assessment. This fit, which is very similar to the piecewise linear model, provides two parameters: k (slope) and L50 (length at 50% selectivity). The estimated values for the logistic fit were: 0.1677 (k) and 97.132 (L50). We then shifted the logistic curve to the left to mimic a commercial fishery response to a decreasing size limit. This was accomplished by keeping the same value of the k parameter and decreasing L50 by 1 cm for each cm the size limit was reduced. This type of pattern might result if more fishers shift to smaller gear, or lower their discard rates on smaller fish. The effective selectivities of sequentially shifting both selectivity patterns are illustrated as dashed red lines in Figure 13.

The capture, release, and subsequent mortality of halibut is termed discard (or release) mortality. On the basis of previous work, discard mortality is estimated to be 16% of discarded catch if careful release procedures are followed. The precise level of discard catch and mortality, absent cameras or onboard observers, cannot be precisely known. For the halibut assessment, commercial discard is estimated from the relative numbers of commercially legal (over 32 inches, or O32) to commercially sublegal (under 32 inches, or U32) halibut in the top 33% of the IPHC survey stations and applied to the total commercial catch. For the purposes of this analysis, however, we need an estimate of discard selectivity at length. In theory, a reduction in the size limit should result in a reduction in discard mortality and an increase in yield. To estimate discard mortality, we proceeded as follows. We assumed that the actual capture selectivities by the commercial fishery are described by the selectivity estimated for the IPHC setline survey (blue line in Fig. 13). Discard probability (or selectivity) was set equal to the difference between survey selectivity at length and the appropriate (for the reduced size limit) commercial size limit. As the size limit is increasingly lowered, the commercial selectivity curve begins to reach, or exceed, the survey selectivity curve. For lengths where the commercial curve exceeds the survey curve, discard selectivities were set to zero. Discard mortality was then computed as 16% of the discard selectivity. The parameters of the female maturity curve were taken from Hare and Clark (2005). Survey weights at age were taken from the halibut stock assessment dataset and averaged across the years 2008 through 2010.

Commercial weight-at-age, which is a key factor in estimating yield per recruit (YPR), was linearly interpolated between the survey weight-at-age and the 2008-2010 mean commercial weight-at-age as the MSL was changed in the simulations. The form of the interpolation was as follows: Survey weights-at-age were used for a MSL of 65 cm and commercial weights at age for MSLs of 81-85 cm. A linear interpolation was used to set weights-at-age for each cm change in the MSL, thus adding 1/16 of the difference in mean weight-at-age between the survey and commercial weights-at-age to the survey weight-at-age, for each cm the MSL was greater than 65 cm (up to 81 cm). The effect of this interpolation can be visualized from Figure 3, which illustrates the smaller survey and larger commercial observed weights-at-age. While more sophisticated approaches are possible, involving growth modeling and integration across variability in size-at-age, this method provides an approximation of the effect of capturing smaller halibut in the commercial catch as a result of a decreased size limit, and is more realistic than using a static commercial weight-at-age for all MSLs. The reduced commercial weights-at-age were interpolated similarly for both selectivity patterns, even though Selectivity Pattern A assumed no change in selectivity above 90 cm.

Summary statistics were computed as described in Valero and Hare (2012) and include:

YPR: yield per recruit,

SPR_{ratio}: ratio of female spawning biomass (FSBio) per recruit to unfished FSBio per recruit,

AAFS: average age of female spawners in the population,

AWC: average weight in the catch,

NIC: numbers in the catch,

RNIC: NIC relative to NIC at status quo (i.e., MSL of 81.3 cm, HR of 0.215),

DPR: discard weight per recruit.

These summary statistics were used to characterize changes in both the at-sea population as well as in the commercial catch as the size limit was varied. Computations were conducted across two control variables: MSL and harvest rate (HR). The HR was defined as the fraction of the EBio taken as commercial catch. Because the EBio was defined on the basis of the commercial selectivity curve, EBio increased with decreasing size limit. Thus, for example, at a given HR of 0.2, more yield would be taken at a size limit of 75 cm than at a size limit of 81 cm. However, the increased yield would also result in a greater reduction in SPR_{ratio}. In order to maintain the same level of SPR_{ratio}, the HR needs to be decreased in concert with the lowered size limit. This is a fundamental and necessary aspect of the precautionary IPHC harvest policy and critical to an understanding of how selectivities and HRs are tied to the definitions of EBio and Constant Exploitation Yield (CEY). The combinations of MSL and HR that maintain the same reduction in SPR_{ratio} as the status quo values of 81.3 cm and 0.215 HR are hereafter termed “status quo equivalents”. The per-recruit calculations were made for a MSL ranging from a high of 85 cm down to a low of 65 cm, in 1-cm intervals. Harvest rate was varied across the range of 0 (i.e., no fishing) to 0.30. This structure allowed for two dimensional plotting of the summary statistics. All summary plots illustrate both the performance of the status quo (MSL of 81.3 cm, HR of 0.215) as a black dot and the status quo equivalents as blue “x’s”.

The interpretation, and utility, of the six summary statistics are as follows:

SPR_{ratio} – Spawning biomass per recruit ratio. Recruitment is defined as halibut entering the fishable population at age six. Thus, the calculations are based on initiating the population with a proportion of 0.5 males and 0.5 females. The population is then fished until the age six recruits reach age 50. Summing the mature females across ages gives the equilibrium FSBio. The ratio of FSBio to the unfished FSBio is the SPR_{ratio}. Note that there is no feedback loop between spawning biomass and recruitment, thus the ratio of FSBio is the same as the ratio of SPR.

YPR – Yield per recruit. This is the cumulative commercial catch per age-six recruit. For halibut, YPR tends to monotonically increase with increased HR and lowered MSL.

AAFS – Average age of female spawners. This provides a measure of how the age of female spawners in the population varies with HR and MSL.

AWC – Average weight in the catch. This is total weight of the catch divided by the total number of halibut in the catch.

RNIC – Relative numbers in the catch, expressed as percentage. This is how many fish comprise the catch and is displayed relative to the numbers in the catch given the status quo values of the control parameters (i.e., MSL of 81.3 cm and a HR of 0.215).

DPR – Discard mortality per recruit. This is the cumulative loss of halibut due to capture and release. This decreases with MSL but increases with HR.

An additional set of summary statistics are provided next to better characterize the relative sex contributions to YPR, numbers in the catch, and numbers in the ocean across the range of MSLs and HRs. These output statistics are restricted to the "status quo equivalent" values and are reported in Table 6. These additional statistics are the percent female and male contribution to YPR, numbers in the catch (NIC) and numbers in the ocean (NIO).

Results

1. Selectivity and maturity at age

Coastwide, status quo conditions result in female maturity to be to the left of female commercial selectivity by around one year (Fig. 2, Bottom). That is, the rate at which females mature by age outpaces the rate at which they are captured by around a year. If the commercial selectivity of females were to match that of the IPHC survey, the maturity and selectivity would be very close until about the age of 50% maturity; afterwards the maturity outpaces the selectivity (Fig. 2, Bottom). A shift in the commercial selectivity towards smaller sizes (20 cm smaller) would result in the female commercial selectivity outpacing female maturity by about four years (Fig. 2, Bottom). Results by IPHC regulatory area are similar to the coastwide results, with selectivities of Areas 2A, 2B, 2C, and 4 having greater proportions of immature females than the other areas (Fig. 5). Cumulative distributions of females at age in the commercial catch observed in 2009 show a greater proportion of immature females in the commercial catch of Areas 2B, 2A, 3B (and to a lesser degree 4A) than in other areas (Fig. 6, Top). The proportion of immature females in the catch is larger for the IPHC survey selectivity and shifted towards younger females (2 to 3 years younger than 50% maturity) than in the commercial catch (less than 2 years younger than the 50% maturity) depending on the area (Fig. 6, Bottom). The proportion of immature females in survey catches is smallest for areas 3A and 4B (Fig. 6, Bottom). Several caveats for the comparisons of maturity at age and observed cumulative age distributions of the commercial catch during historical periods with different MSL should be noted. Since the sex composition of the commercial catch is unknown before 1996, the distributions include both sexes. In addition, the female maturity at age used corresponds to recent estimates in the absence of historically cotemporaneous estimates of maturity at age. Observed cumulative combined-sex age distributions of the available historical years with no MSL (1935-

1939) show female maturity at age being to the right of the cumulative catch for all available areas (Area 4 was not fished at the time). That is, the capture of fish outpaced the maturity at age by up to 3 to 4 years depending on the area. Areas 2A, 2B and 2C showed the greatest proportion of immature fish in the catch (Fig. 7, Top). In a similar way, observed cumulative combined-sex age distributions of historical years with MSL: 65 cm (1945-1973) show female maturity at age being to the right of the cumulative catch for all available areas (Area 4 was not fished at the time), although the age of fish captured was larger than was the case with no MSL (Fig. 7, Center). The period 1974 to 1990 (MSL: 81.3) shows an increase in the age of capture, although except for Area 4, maturity at age still is to the right of the cumulative age distribution on the catch (Fig. 7, Bottom).

2. Yield per recruit and biomass per recruit

Coastwide yield per recruit and spawning biomass per recruit decrease when maintaining a harvest rate of 0.215 for the scenario with commercial selectivity changing to that of the IPHC survey (Table 1). A further shift of commercial selectivity towards smaller sizes results in an increase in YPR but a drop in SBR of 0.17 of the unfished level, compared to the status quo of 0.37. Using harvest rates that result in reductions in spawning biomass per recruit equivalent to the status quo reduces available yield per recruit and harvest rates of 0.165 with survey selectivity and 0.101 with shifted commercial selectivity (Table 2). Results are sensitive to the assumed weight at age of the commercial catch under changing selectivities. If weight at age of the commercial catch is assumed fixed (even if changing selectivity) then estimates of yield per recruit increase (Tables 3 and 4) under comparable spawning biomass per recruit reductions as the previous cases with changing weight at age of the commercial catch (Tables 1 and 2).

A reduction or elimination of MSL does increase the proportion of females at older ages relative to status quo, with as much as 80% improvement, however the actual proportions in the population are still quite low (12% to 22% at age 25) (Fig. 8). A larger decrease in the proportion of females in the catch and increase in the proportion in the population would be expected in the scenario with a shift in commercial selectivity towards smaller sizes and younger ages (Fig. 8), although that will require a reduction of target HR to 0.101 (Fig. 8).

3. Migratory yield per recruit and biomass per recruit

Coastwide estimates of yield per recruit and spawning biomass per recruit reductions from the migratory model were similar (Figs. 9 to 12) to that of the single area coastwide analysis presented in the previous section. The distribution of yield per coastwide recruit varies depending on the migration scenario (Figs. 9 and 10, Top panels) but the total is similar. Under both scenarios considered here, spawning biomass per recruit reductions are greater in Areas 2 than in Areas 3 and 4 (Figs. 9 and 10, Bottom panels). Yield per recruit is lower than that of the status quo when using harvest rates that result in equivalent spawning biomass per recruit reductions as the status quo (Figs. 11 to 12, Top panels). The difference among areas in the reduction of spawning biomass per recruit is smaller when using equivalent harvest rates (Figs. 11 and 12, Bottom panels).

4. Gradual changes in MSL and gradual changes in selectivity

The purpose of this exercise was to estimate impacts on commercial yield and FSBio as the size limit is incrementally reduced, as requested by the Commission. Given the lack of a feedback loop between FSBio and recruitment, the effect of increasing selectivities at smaller sizes will be to increase the definition of EBio and generate higher yields per recruit. However, increased yield comes at the expense of reduced FSBio. To maintain the current level of FSBio conservation, decreases in the commercial MSL must be accompanied by a decrease in the HR. Given the parameter values and model structure described in the Methods section, the present MSL of 81.3 cm, together with the present commercial and discard selectivity schedules, the SPR_{ratio} is approximately 37.0%. While we will present results across the full spectrum of MSLs (65 to 85 cm) and HRs (0 to 0.30), we will focus attention on the combinations that result in the same equilibrium SPR_{ratio} as the status quo, i.e., the status quo equivalents.

There are two sets of results, corresponding to selectivity Patterns A and B, and they are illustrated in Figures 14 and 15, respectively, and discussed below. In general, the results of lowering the size limit are qualitatively similar between the two selectivity patterns. However, while qualitatively similar, there are some important differences, thus we now compare and contrast the six sets of summary statistics for the two selectivity patterns. Table 5 contains summary statistics of interest for the status quo equivalents and provides the most compact depiction of expected equilibrium impacts of reducing the size limit while maintaining the current level of FSBio conservation.

A second set of summary statistics, focusing on the sex composition of YPR, numbers in the catch (NIC) and numbers in the ocean (NIO) are listed in Table 6. This table similarly is restricted to the status quo equivalents of MSL and HR.

4.1 Impact on SPR_{ratio} (Panel a)

SPR_{ratio} is a monotonically decreasing function of fishing mortality. The rate at which it declines varies, for a given HR, between the two selectivity patterns, with a steeper decline for Pattern B. The status quo value of 37.5% is indicated by the large black dot on the plots. The HR that maintains SPR_{ratio} at (or slightly above) 37.5%, for any given MSL, can be found by drawing a horizontal line from the blue “x’s” to the HR axis. These are the HR values listed in Table 5. For Pattern A, the HR that maintains SPR_{ratio} at status quo declines by approximately 0.01 for every 5 cm the size limit is lowered; for Pattern B, the HR declines by just under 0.01 for every 1 cm drop in the size limit.

4.2 Impact on YPR (Panel b)

Across the range of HRs and MSLs considered in this analysis, YPR tends to increase with increasing harvest rate for any given MSL, but shows a more complex response, yet relatively flat, to MSL for a given harvest rate. Restricting acceptable outcomes to the MSL/HR status quo equivalents (indicated by blue x’s in Figures 14 and 15 and listed in Table 5), YPR remains equal to, or just slightly greater (3% higher at most) than, current YPR (MSL=81.3 cm, HR = 0.215) for a decreased MSL of up to 3 cm (Selectivity Pattern A) or 12 cm (Selectivity Pattern B), after which YPR decreases below the status quo. The projected increased YPR is at most 3% larger than the status quo. Beyond a MSL of about 77 cm (Selectivity Pattern A) or about 68 cm (Selectivity Pattern B), there is a steady decrease in YPR. The harvest rate required to maintain SBR at status quo also drops steadily under both patterns, though at a much greater rate for Selectivity Pattern B.

4.3 Impact on AAFS (Panel c)

Similar to SBR_{ratio}, AAFS decreases monotonically across the range of MSLs and HRs, although the effect of lowering MSL for a given harvest rate is minimal with selectivity pattern A. In the absence of fishing, the average age of female spawners in the ocean is 17; the average

age would decline by at least five years at the highest HRs and would decline more rapidly under Selectivity Pattern B. The status quo AAFS is just over 13 years of age, and this would actually increase slightly (around 1% to 4%) under any of the status quo equivalent MSL (less than 81.3 cm)/HR combinations. This occurs because a larger fraction of the yield is expected to be composed of males, thereby reducing harvest on larger, older females. The increase in AAFS is between 0.01 (Selectivity Pattern A) and 0.03 (Selectivity Pattern B) years per cm decrease in the MSL

4.4 Impact on AWC (Panel d)

One of the biggest changes that would occur with a lowered MSL would be the average weight of halibut comprising the commercial catch. The increased selectivity at smaller sizes steadily decreases the overall average weight of fish in the catch. Under status quo, average weight is around 25 pounds; this average would be around 16 to 17 pounds at the MSL/HR extreme combination. For the status quo equivalent combinations, AWC declines between 0.2 and 0.3 pounds per cm decrease in MSL.

4.5 Impact on RNIC (Panel e)

This summary statistic provides a more straightforward indicator of how much more fish would be handled with a reduced size limit than can be easily ascertained from AWC. If we once again restrict ourselves to the status quo equivalent MSL/HR combinations, there is potential for an increase of as much as a 30% (Selectivity Pattern A) to 50% (Selectivity Pattern B) increase in RNIC at the extreme MSL of 65 cm. As the MSL is decreased from 81 cm, the RNIC increases at a rate of between 2 and 3% per cm.

4.6 Impact on DPR (Panel f)

Under status quo, DPR is approximately 0.25 pounds, or about 6.5% of YPR. For any given MSL, DPR increases with harvest rate. For any given HR, DPR decreases with MSL. Across the status quo MSL/HR combinations, DPR decreases steadily and, in the case of Selectivity Pattern B, is reduced to zero at the smallest MSLs. The decrease in DPR is around 0.015 (Selectivity Pattern A) and 0.030 (Selectivity Pattern B) per cm decrease in the MSL.

4.7 Impact on sex composition of YPR, NIC and NIO (Table 6)

The forgoing summaries aggregated sex-specific information regarding YPR and RNIC. It is of interest to more closely examine how the sex composition of certain variables, specifically YPR, numbers in the catch (NIC) and numbers in the ocean respond to a change in MSL. Under status quo, females comprise approximately 82% of the YPR, 73% of the catch (in numbers) and 44% of the age-eight and older fish remaining in the ocean (in numbers). Each of these variables changes smoothly with decreasing MSL, with rates of change slightly greater under Selectivity Pattern B. As the MSL decreases, the share of YPR derived from females declines by about 0.5% per cm decrease. The percentage female NIC drops approximately 0.8% per cm decrease while the female NIO slowly increases, though by less than 0.1% per cm decrease. At the extreme MSL of 65 cm, values for female YPR, NIC, and NIO would be between 72-74%, 61-63%, and 45.4-45.5%, respectively under the two selectivity patterns.

Discussion

An effective harvest strategy should provide a framework and tools to achieve the objectives of the fishery for which it was developed. A harvest strategy often involves a number of tradeoffs (such as between conservation and exploitation) and major decisions such as the treatment of uncertainty in biological processes, observation/estimation capabilities, and implementation of management actions. Tools to implement a harvest strategy are often called harvest tactics or control rules, with size limits being one of the most widely used. Different size limits have been used throughout the history of the Pacific halibut fishery with a progression towards increasingly larger MSL and subsequently an older age composition, and greater proportion of females, in the commercial catch. On a coastwide scale, fewer immature female halibut are currently caught in the commercial fishery than could be inferred from past distributions of commercial catch at age with no MSL or lower MSL than at present. However, regulatory areas such as Areas 2A, 2B, 2C, and Area 3B are characterized by a larger proportion of immature females in the commercial catch. Decreasing the MSL to 65 cm, the overall percentage of females in the catch is expected to decrease relative to status quo from 73% to 63% (or 74% to 61% depending on assumed selectivity), intermediate MSL results in smaller decreases. Decreasing the MSL is expected to have smaller effects on the percentage of females in the ocean with a maximum expected change from 44% to 45% if the MSL is substantially reduced or eliminated. As noted, the largest change would be expected for age 25 and up where the percentage female would change from 12% (status quo) to 22% (MSL = 65 cm). However, potential reductions of the current MSL are expected to increase the proportion of immature females in the catch in those areas and widen the gap between the rate at which females are caught and the rate at which they mature. The benefits of delaying the capture of fish after maturity have been pointed out early and frequently in the history of fisheries science (Holt 1895, Hilborn and Walters 1992, Smith 1994, Myers and Mertz 1998, Parma 1998). One of the benefits of delaying capture until after fish mature is an additional level of protection for the spawning stock to uncertainty, and potential stock assessment errors. Myers and Mertz (1998) showed that a spawn-at-least-once policy could prevent a collapse of a stock even in cases when fishing mortality targets are exceeded. A spawn-at-least-once policy requires that fish become vulnerable to the commercial gear only after having spawned once. Myers and Metz (1998) analysis was based on simulated stocks with spawning stock/recruitment relationships. Although similar spawning stock/recruitment relationships are not used for halibut, management still relies on reference points that are based on relative levels in female spawning biomass relative to unfished. A precautionary approach to fisheries management would not support potential policies that are expected to increase the risks to the stock. In the context of basic life history theory, lowering or eliminating the MSL is expected to increase the capture of immature female halibut at the area specific and coastwide levels and therefore goes against a precautionary approach. In theory, the increased capture of immature females could be offset by applying lower target harvest rates to achieve similar reductions of female spawning biomass to the status quo. In practice, the historical control of realized harvest rates has been affected by retrospective bias in the stock assessment and subject to misspecifications such as in the closed-area assessments conducted prior to the 2006 change to a coastwide assessment. The retrospective bias in assessment estimates has resulted in departures between realized and target harvest rates, by as much as 63% higher than target at the coastwide level (Valero 2012b). Misspecification in the closed-area stock assessments resulted in realized harvest rates, estimated by recent coastwide stock assessments with survey-partitioned biomass, by as much as three times higher than the target in Areas 2B and 2C and as low as half the target harvest rate for Area 4 during the last decade (Valero 2012b).

A potential concern of the current MSL is the higher proportion of females relative to males in the commercial catch and resultant lower proportion of females in the population. However, only major changes in the commercial selectivity towards smaller sizes would result in a more balanced sex ratio of the commercial catch, with a resultant much lower target harvest rate and the risk associated with harvesting a larger proportion of immature females as much as four years before they mature. Since a harvest strategy has to make tradeoffs between conservation and exploitation, the risks associated with reducing or dropping the size limit would need to be evaluated with the potential yield gains (cost/benefit analysis). A single-area coastwide YPR and SBR per recruit analysis was conducted along with a multi-area migratory analysis. If the yield per recruit analysis (conducted assuming that fishing mortalities can be perfectly controlled) had indicated substantial potential gains in yield then consideration of further trade-offs with principles of life history theory mentioned before would have merit. However, both single area and migratory analyses indicated substantial reductions in spawning biomass per recruit associated with reductions/elimination of the MSL and no substantial increase in yield per recruit. When constraining harvest rates to produce equivalent reductions of spawning biomass per recruit to the status quo, yield per recruit is lower when accounting for reduced weight at age of the commercial catch under changing selectivities.

These results are highly sensitive to assumptions on the weight at age resulting from different selectivities. If commercial weight at age is assumed not to change even with changes in commercial selectivity then harvest rates equivalent to the status quo results in higher yield per recruit. Since current commercial weight at age is strongly influenced by the current MSL, assuming no changes in weight at age when the current MSL is either reduced or eliminated seems to be problematic. Assuming that the weight at age of the commercial catch will change seems more realistic and the approach taken here was to assume it would be that of the IPHC survey. Approaches that are more realistic were followed by Clark and Parma (1995) and Parma (1998) by using numerical integration to compute the average weight at age for males and females in the commercial catch as a function of the size at age distribution in the population, the size selectivity and the legal size limit. That approach implies modeling growth, its variability at age and the effects of size-selective fishing as part of the analysis. Previous work on the potential effects of size-selective fishing mortality on Pacific halibut found that yield per recruit analyses that ignored changes in size at age by using constant selectivities and weights at age may result in biased estimates of mean spawning biomass per recruit and serious overestimation of optimal fishing levels (Deriso and Parma 1988, Parma and Deriso 1990).

Most of the analyses and discussion in this paper reflect a comparison between the current MSL of 81.3 cm and elimination of the size limit. The analysis on gradual changes in the MSL attempts to interpolate between the extremes and consider the effect of small changes, assuming a linear decrease of weights-at-age in the catch with decreasing MSL. At the extreme MSL of 65 cm, which is similar to having no size limit, the results of the gradual analysis are similar to the other analyses: there would a loss in terms of yield per recruit when controlling for spawning biomass per recruit. Maintaining the status quo SBR would necessitate managing at a lower HR. The commercial catch would be comprised of a much larger number of small fish though there would be at most a 10% decrease in the female component of the catch as well as an increase in the proportion (at most 3%) and average age (from 13.1 to 13.6) of females in the population. In one part of our analysis we estimated weight at age for ages derived from lengths, but assuming no variation in the age-length relationship. A simple linear interpolation method was used to predict how average weight at age in the commercial catch would respond to gradual changes in MSL, in the other part of our analysis. Like many aspects of this modeling work attempting to estimate the effect of a changed size limit, it is uncertain how realistic the interpolated values are, although it is reasonable to assume that a MSL between the current and an eliminated MSL would result in commercial weights at age intermediate between the IPHC survey and commercial weight-at-age. Thus, while acknowledging the uncertainty of the magnitude and shape of the interpolated commercial weight-at-age, the gradual analysis suggests the following: YPR remains near, or marginally above (at most 3% higher) the status quo for a few cm below the current MSL and that the proportion of females in the catch decreases gradually from around 73% to 63%, while the proportion of females in the ocean increases at most from 44% to 45%.

Other works suggest it can be extremely difficult to measure the efficacy of size limits given the effects of non-stationary population processes such as variable recruitment and the number of years required to see an effect (Allen and Pine 2000). Analyses presented here rely on equilibrium condition assumptions. Short or medium term population projections based on recent stock assessment population estimates could be used to illustrate the effect of changing MSL. However, there are a number of population trends (e.g. size at age) and revisions of recent estimates (e.g. recruitment) that have made those projections unreliable (Valero 2012a, 2012b). In addition, requests for eliminating the size limit should be put in the context of current regulations, which at present do not regulate the characteristics of the fishing gear such as hook size and spacing. There is no guarantee that reducing or eliminating the size limit would not result in a shift towards fishing gear that could target progressively smaller fish efficiently (e.g., smaller hooks, shorter hook spacing). It could be argued that careful monitoring of changes in commercial selectivity from potential MSL changes could be possible in areas where the commercial fishery is monitored (for example Area 2B at present). An illustration of potential problems when relying on monitoring to detect selectivity changes can be illustrated by the distribution of U32 halibut in commercial landings, along with the percentage of U32 halibut relative to the total landed by area and coastwide (Fig. 16). Even though the current MSL of 32 inches has been in place coastwide since 1974, there are substantial percentages of U32 commercially landed halibut in the catch, with one of the highest percentages (8.24% as of 2008) corresponding to the only area that is currently fully observed (Area 2B). Under these conditions, modifications of fisher's behavior and resultant changes in selectivity due to changes in MSL (potentially including differences among areas) are expected to not only be unpredictable but also difficult to monitor. Finally, part of the rationale for requests to reduce or eliminate the size limit are based on recent stock assessment estimates of large and increasing trends in total halibut numbers and total biomass in spite of decreasing trends of exploitable biomass. Recent analysis shows that ongoing retrospective bias in recent assessment estimates has resulted not only in consistent downward revisions of previous biomass estimates, but also in reversal of originally increasing trends to decreasing trends, including trends on total biomass (Valero 2012b). Given the effects of retrospective bias and the potential effects of assumed selectivity types on trends and levels of total biomass (Valero 2012c), independent validations of the numbers and biomass of small halibut estimated by recent stock assessments seems necessary. Overall, minor reductions in the MSL along with harvest rate reductions are expected to produce at most 3% increases in yield per recruit but greater reductions in the MSL including its elimination are expected to reduce both yield per recruit and spawning biomass per recruit. The proportion of females in the population between the extremes of current MSL and a MSL of 65 cm would change from 44% to 45% for ages 6 and older, and from 12% to 22% at age 25.

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Table 1. Coastwide yield per recruit and female spawning biomass per recruit under status quo (MSL: 81.3, commercial selectivity as estimated for 2008-2010 and target harvest rate of 0.215) and assuming commercial selectivity changes to either the 2008-2010 estimated IPHC survey selectivity or a modi ed 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes. Weight at age of the catch is either that of the commercial catch for 2008-2010 (08-10 Commercial) or that of the 2008-2010 IPHC survey (08-10 Survey and 08-10 Commercial shift).

		Yield per recruit		Spawning biomass per recruit	
Selectivity	**HR**	**lb**	**Relative to status quo**	**Relative to max**	**Relative to status quo**
08-10 Commercial	*0.215*	4.14	1.00	0.37	1.00
08-10 Survey	*0.215*	4.01	0.97	0.31	0.82
08-10 Commercial shift	*0.215*	4.72	1.14	0.17	0.47

Table 2. Coastwide yield per recruit and female spawning biomass per recruit under status quo (MSL: 81.3, commercial selectivity as estimated for 2008-2010 and target harvest rate of 0.215) and status quo equivalent scenarios assuming commercial selectivity changes to either the 2008-2010 estimated IPHC survey selectivity or a modi ed 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes. Status quo equivalent scenarios use HR that reduces spawning biomass per recruit to the same level as the status quo. Weight at age of the catch is either that of the commercial catch for 2008-2010 (08-10 Commercial) or that of the 2008-2010 IPHC survey (08-10 Survey and 08-10 Commercial shift).

		Yield per recruit		Spawning biomass per recruit	
Selectivity	**HR**	**lb**	**Relative to status quo**	**Relative to max**	**Relative to status quo**
08-10 Commercial	0.215	4.14	1.00	0.37	1.00
08-10 Survey	0.165	3.67	0.89	0.37	1.00
08-10 Commercial shift	0.101	3.75	0.91	0.37	1.00

Table 3. Coastwide yield per recruit and female spawning biomass per recruit under status quo (MSL: 81.3, commercial selectivity as estimated for 2008-2010 and target harvest rate of 0.215) and assuming commercial selectivity changes to either the 2008-2010 estimated IPHC survey selectivity or a modi ed 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes. Weight at age of the catch is that of the commercial catch for 2008-2010 for all scenarios.

		Yield per recruit		Spawning biomass per recruit	
Selectivity	HR	lb	Relative to status quo	Relative to max	Relative to status quo
08-10 Commercial	0.215	4.14	1.00	0.37	1.00
08-10 Survey	0.215	5.03	1.22	0.31	0.83
08-10 Commercial shift	0.215	6.82	1.65	0.18	0.47

Table 4. Coastwide yield per recruit and female spawning biomass per recruit under status quo (MSL: 81.3, commercial selectivity as estimated for 2008-2010 and target harvest rate of 0.215) and status quo equivalent scenarios assuming commercial selectivity changes to either the 2008-2010 estimated IPHC survey selectivity or a modi ed 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes. Status quo equivalent scenarios use HR that reduces spawning biomass per recruit to the same level as the status quo. Weight at age of the catch is either that of the commercial catch for 2008-2010 for all scenarios.

		Yield per recruit		Spawning biomass per recruit	
Selectivity	HR	lb	Relative to status quo	Relative to max	Relative to status quo
08-10 Commercial	0.215	4.14	1.00	0.37	1.00
08-10 Survey	0.166	4.52	1.09	0.37	1.00
08-10 Commercial shift	0.101	4.97	1.20	0.37	1.00

Table 5. Summary statistics for the two Selectivity Patterns of the analysis on gradual changes in MSL. These values correspond to the "x's" in Figures 14 and 15. Status quo is highlighted. Abbreviations are as follows: minimum size limit (MSL), harvest rate (HR), yield per recruit (YPR), average weight in the catch (AWC), relative numbers in catch (RNIC), discard-per-recruit (DPR). See text for details and interpretation.

Selectivity Pattern A							Selectivity Pattern B						
MSL	HR	YPR	AAFS	AWC	RNIC	DPR	MSL	HR	YPR	AAFS	AWC	RNIC	DPR
65	0.187	3.513	13.39	17.05	32.7	0.082	65	0.116	3.696	13.67	16.18	50.0	0.000
66	0.188	3.563	13.38	17.52	31.0	0.085	66	0.119	3.740	13.63	16.79	46.3	0.000
67	0.190	3.615	13.36	17.98	29.5	0.089	67	0.123	3.789	13.59	17.38	43.2	0.000
68	0.191	3.655	13.35	18.48	27.4	0.094	68	0.127	3.829	13.55	17.97	40.0	0.000
69	0.193	3.698	13.33	18.96	25.7	0.099	69	0.131	3.860	13.51	18.56	36.6	0.000
70	0.194	3.728	13.33	19.47	23.3	0.105	70	0.136	3.894	13.47	19.13	33.7	0.001
71	0.196	3.760	13.31	19.97	21.3	0.112	71	0.141	3.918	13.43	19.70	30.6	0.007
72	0.197	3.780	13.30	20.50	18.8	0.121	72	0.146	3.930	13.39	20.28	27.3	0.018
73	0.199	3.803	13.28	20.99	16.7	0.134	73	0.152	3.944	13.35	20.84	24.3	0.032
74	0.201	3.819	13.27	21.50	14.4	0.148	74	0.158	3.947	13.31	21.40	21.2	0.050
75	0.203	3.831	13.25	22.01	12.1	0.164	75	0.164	3.941	13.29	21.97	17.9	0.071
76	0.204	3.836	13.25	22.50	9.8	0.179	76	0.171	3.935	13.25	22.52	14.8	0.097
77	0.206	3.847	13.23	22.95	8.0	0.194	77	0.179	3.928	13.21	23.05	12.0	0.124
78	0.208	3.852	13.22	23.42	5.9	0.211	78	0.186	3.902	13.20	23.60	8.6	0.157
79	0.210	3.854	13.20	23.90	3.9	0.230	79	0.195	3.884	13.16	24.13	5.7	0.192
80	0.212	3.852	13.19	24.38	1.8	0.249	80	0.204	3.854	13.14	24.65	2.7	0.233
81	0.214	3.849	13.18	24.85	-0.2	0.269	81	0.214	3.822	13.12	25.17	-0.2	0.278
82	0.216	3.819	13.16	25.07	-1.9	0.281	82	0.225	3.754	13.09	25.46	-3.1	0.323
83	0.218	3.785	13.15	25.31	-3.6	0.294	83	0.237	3.685	13.07	25.75	-6.0	0.372
84	0.220	3.748	13.14	25.57	-5.6	0.309	84	0.249	3.607	13.05	26.04	-9.0	0.425
85	0.223	3.714	13.12	25.83	-7.4	0.326	85	0.263	3.529	13.03	26.32	-11.9	0.486

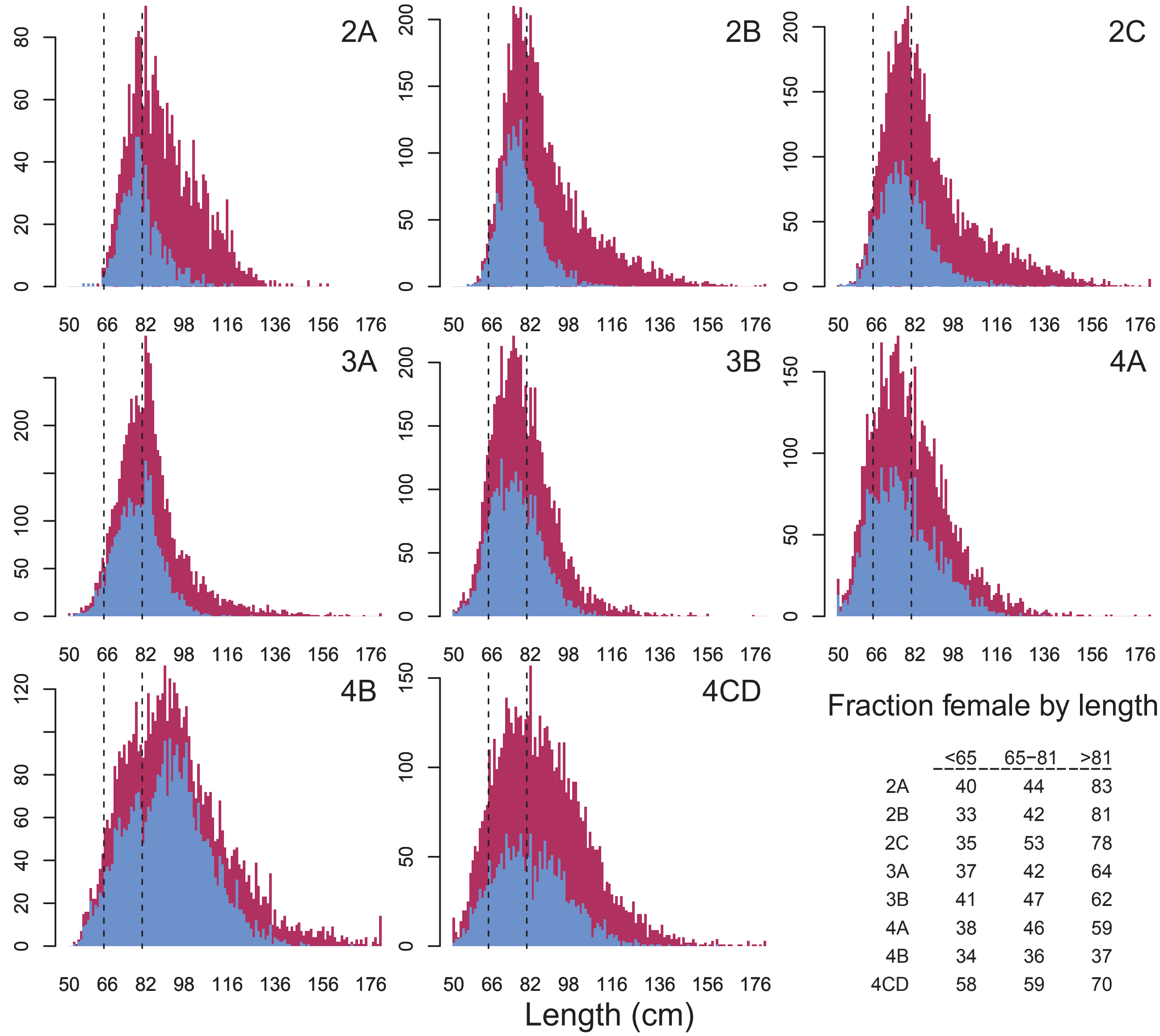
Table 6. Summary of sex-speci c compositions of yield per recruit (YPR), numbers in catch (NIC) and numbers in the ocean (NIO). Values for YPR, NIC, and NIO are percentages and values correspond to “status quo equivalents” of minimum size limit (MSL) and harvest rate (HR). See text for details and interpretation.

Selectivity Pattern A

		Females			Males		
MSL	HR	YPR	NIC	NIO	YPR.M	NIC.M	NIO.M
65	0.187	76.6	62.8	45.4	23.4	37.2	54.6
66	0.188	76.6	63.2	45.3	23.4	36.8	54.7
67	0.190	76.7	63.7	45.2	23.3	36.3	54.8
68	0.191	76.8	64.2	45.1	23.2	35.8	54.9
69	0.193	77.0	64.7	45.0	23.0	35.3	55.0
70	0.194	77.3	65.3	45.0	22.7	34.7	55.0
71	0.196	77.6	65.9	44.9	22.4	34.1	55.1
72	0.197	77.9	66.6	44.8	22.1	33.4	55.2
73	0.199	78.3	67.2	44.7	21.7	32.8	55.3
74	0.201	78.6	67.9	44.6	21.4	32.1	55.4
75	0.203	79.0	68.5	44.6	21.0	31.5	55.4
76	0.204	79.5	69.3	44.5	20.5	30.7	55.5
77	0.206	79.9	70.0	44.4	20.1	30.0	55.6
78	0.208	80.4	70.8	44.4	19.6	29.2	55.6
79	0.210	80.9	71.5	44.3	19.1	28.5	55.7
80	0.212	81.3	72.1	44.3	18.7	27.9	55.7
81	0.214	81.8	72.9	44.2	18.2	27.1	55.8
82	0.216	82.3	73.7	44.1	17.7	26.3	55.9
83	0.218	82.8	74.5	44.1	17.2	25.5	55.9
84	0.220	83.3	75.3	44.0	16.7	24.7	56.0
85	0.223	83.7	75.9	44.0	16.3	24.1	56.0

Selectivity Pattern B

		Females			Males		
MSL	HR	YPR	NIC	NIO	YPR.M	NIC.M	NIO.M
65	0.116	73.1	61.4	45.5	26.9	38.6	54.5
66	0.119	73.6	62.1	45.4	26.4	37.9	54.6
67	0.123	74.1	62.8	45.2	25.9	37.2	54.8
68	0.127	74.6	63.5	45.1	25.4	36.5	54.9
69	0.131	75.2	64.2	45.0	24.8	35.8	55.0
70	0.136	75.8	65.0	44.9	24.2	35.0	55.1
71	0.141	76.4	65.8	44.8	23.6	34.2	55.2
72	0.146	77.0	66.6	44.7	23.0	33.4	55.3
73	0.152	77.6	67.5	44.6	22.4	32.5	55.4
74	0.158	78.3	68.3	44.5	21.7	31.7	55.5
75	0.164	78.9	69.2	44.4	21.1	30.8	55.6
76	0.171	79.6	70.0	44.3	20.4	30.0	55.7
77	0.179	80.2	70.9	44.3	19.8	29.1	55.7
78	0.186	80.9	71.8	44.2	19.1	28.2	55.8
79	0.195	81.5	72.6	44.1	18.5	27.4	55.9
80	0.204	82.1	73.4	44.1	17.9	26.6	55.9
81	0.214	82.7	74.3	44.0	17.3	25.7	56.0
82	0.225	83.2	75.1	43.9	16.8	24.9	56.1
83	0.237	83.8	75.9	43.9	16.2	24.1	56.1
84	0.249	84.4	76.6	43.8	15.6	23.4	56.2
85	0.263	84.9	77.4	43.8	15.1	22.6	56.2



	<65	65–81	>81
2A	40	44	83
2B	33	42	81
2C	35	53	78
3A	37	42	64
3B	41	47	62
4A	38	46	59
4B	34	36	37
4CD	58	59	70

Figure 1. Illustration of sex ratio at length of halibut caught (and sexed) on the IPHC setline survey between 2009 and 2011. Male frequencies are in blue, females in red. Vertical lines indicate lengths of 65 and 81.3 cm.

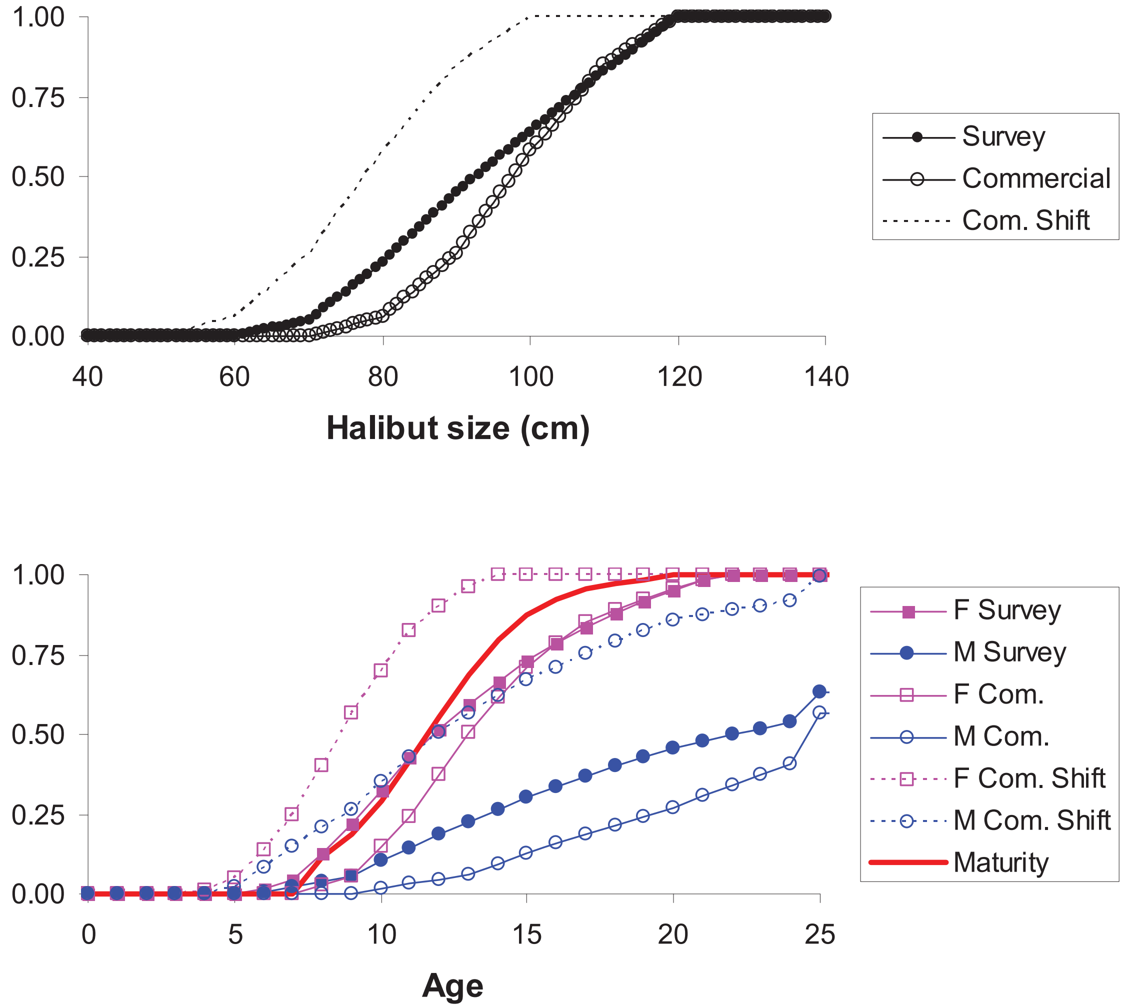


Figure 2. Coastwide selectivity at length for the commercial shery (Commercial), the IPHC survey (Survey) and that assumed under a reduction in MSL (Com. Shift).

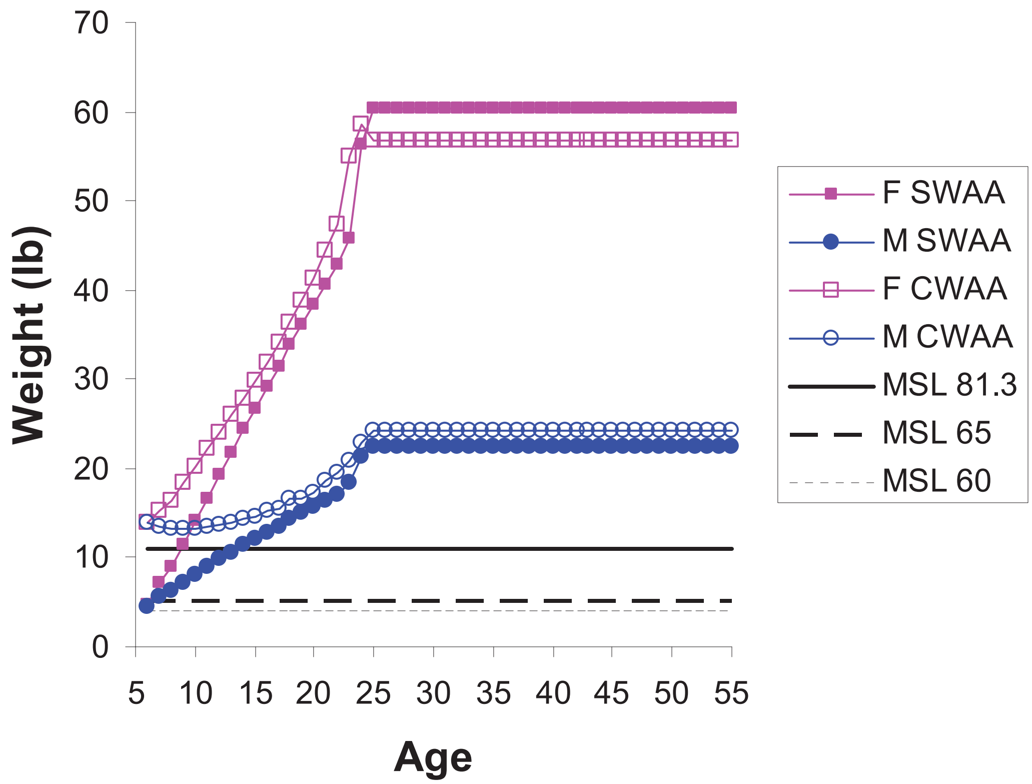


Figure 3. Observed weight-at-age in commercial (CWAA) and survey (SWAA) catches of female (F) and male (M) halibut. Horizontal lines represent average weights of halibut corresponding to MSL of 81.3 cm (solid line), 65 cm (dashed line) and 60 cm (dotted line).

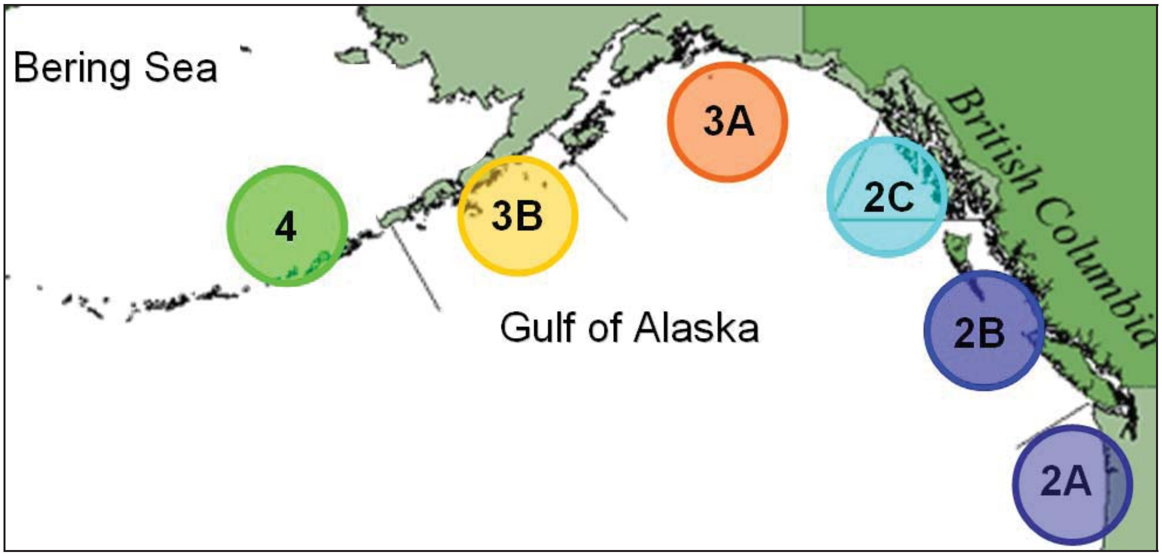


Figure 4. Map of areas included in the migratory spatially structured model. Areas 3B to 2A are IPHC regulatory areas, Area 4 is a combination of Areas 4A, 4B, and 4CDE.

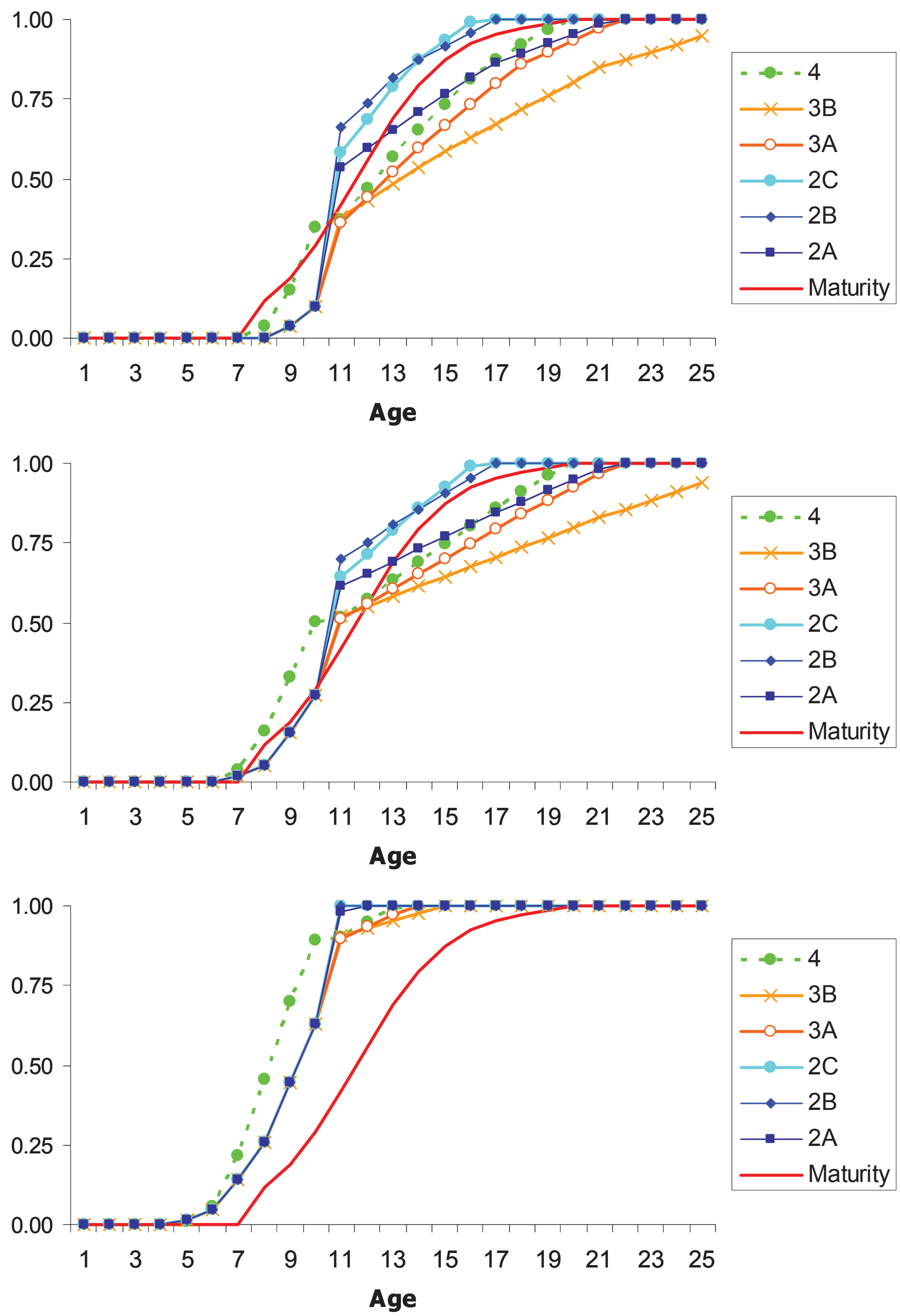


Figure 5. Female selectivities at age corresponding to selectivities at length estimated for the commercial fishery (top), the IPHC setline survey (center) and one resulting from shifting the commercial fishery 20 cm towards smaller sizes (bottom). The red line (no marker) represents female maturity.

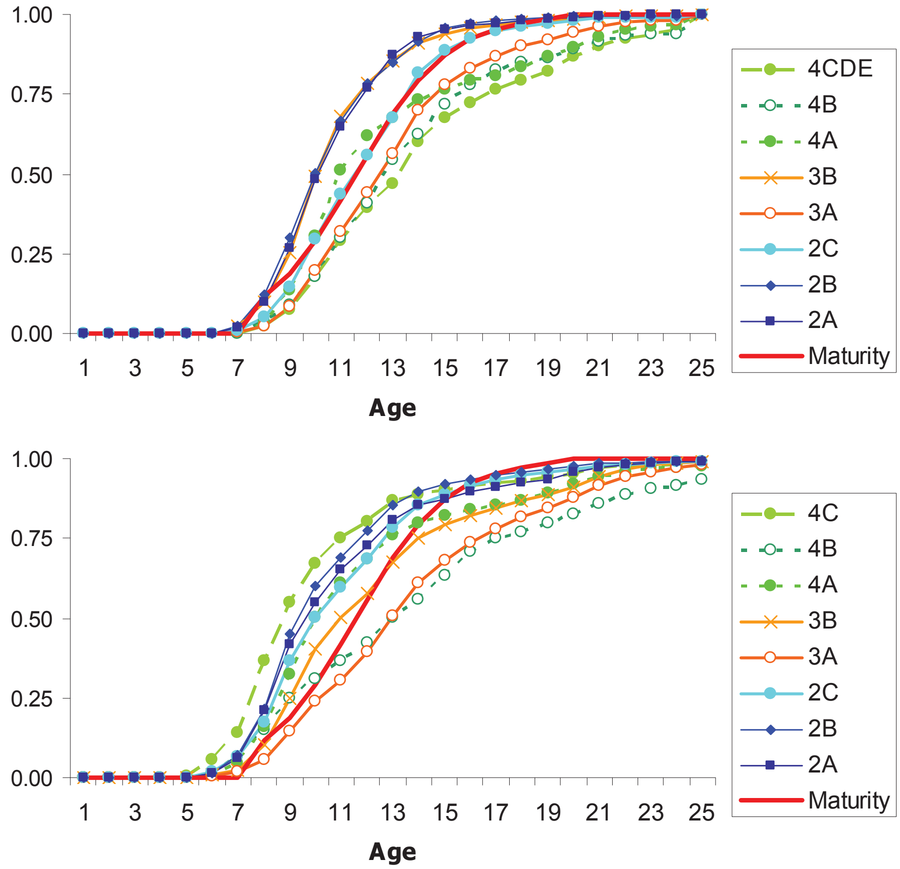


Figure 6. Female cumulative age distributions for the commercial shery (top) and the IPHC setline survey (bottom) during 2009. The red line (no marker) represents female maturity.

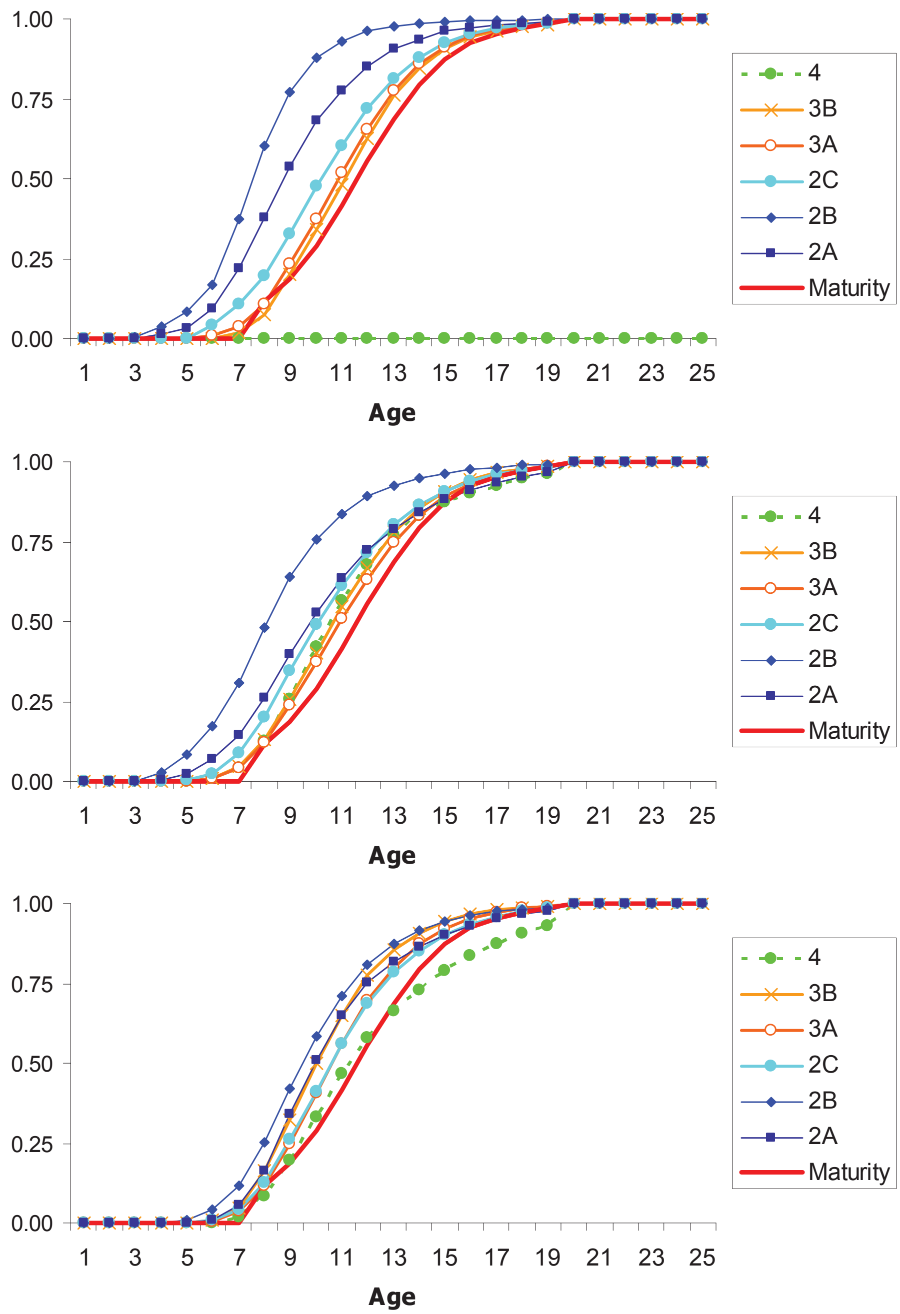


Figure 7. Cumulative age distributions for the commercial shery during time periods of different minimum size limits (MSL): No MSL during 1935-1939 (top), MSL: 65 cm during 1945-1973 (center) and MSL: 81.3 cm during 1974-1990 (bottom). The red line (no marker) represents female maturity.

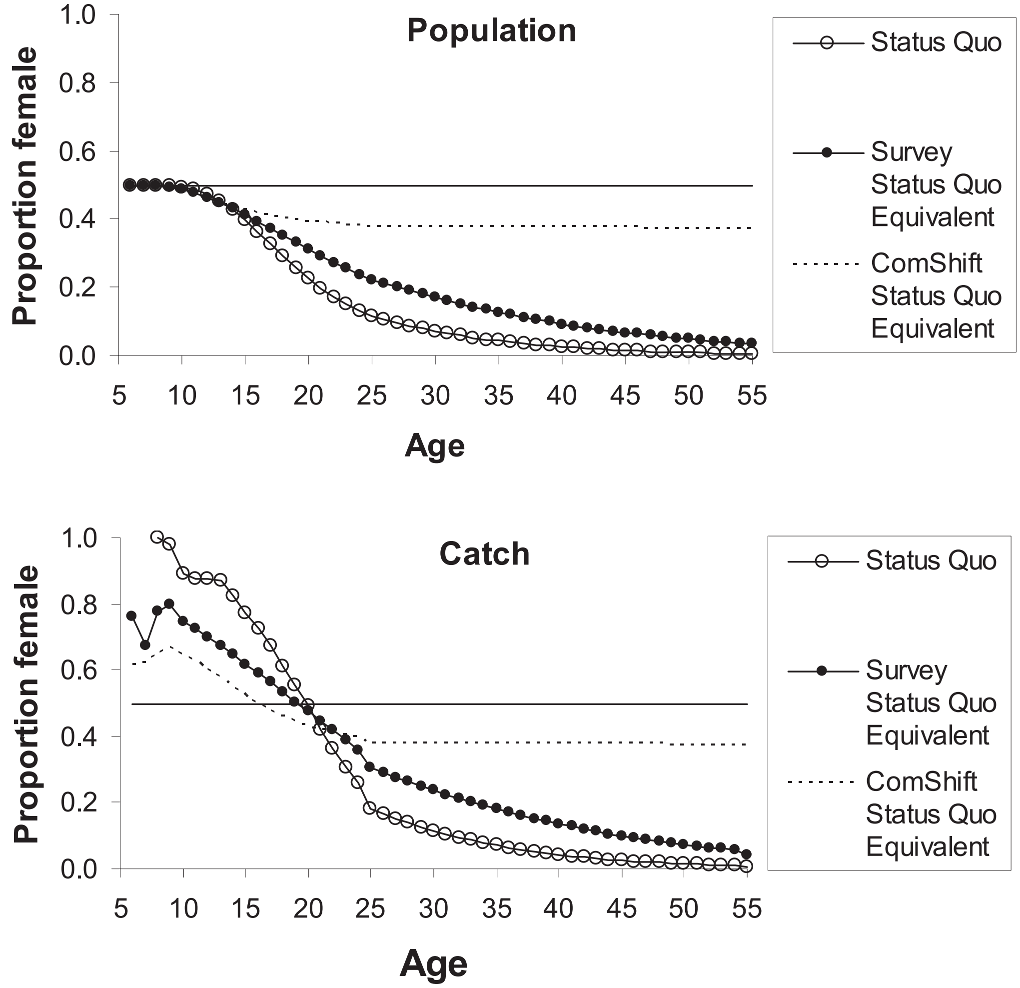
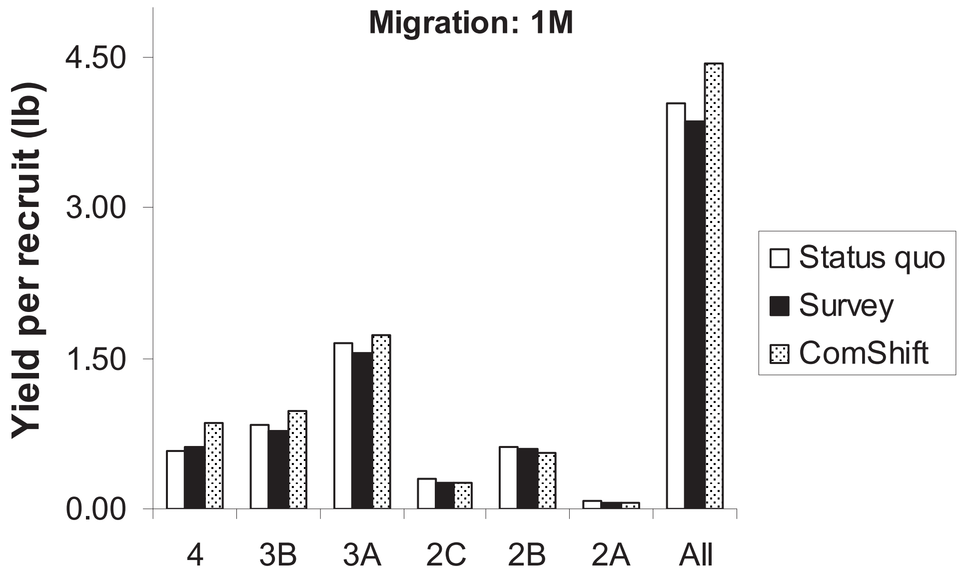


Figure 8. Proportion of female halibut in the population (Top) and in the commercial catch (Bottom) under three scenarios: 2008-2010 commercial selectivity, size limit of 81.3, HR: 0.215 (Status Quo), commercial selectivity equal to the 2008-2010 IPHC survey selectivity and HR: 0.165 (Survey Status Quo Equivalent), commercial selectivity shifted 20 cm towards smaller sizes and HR: 0.101 (ComShift Status Quo Equivalent). Status Quo equivalent HR are calculated to result in equivalent spawning biomass per recruit reductions compared to the status quo.



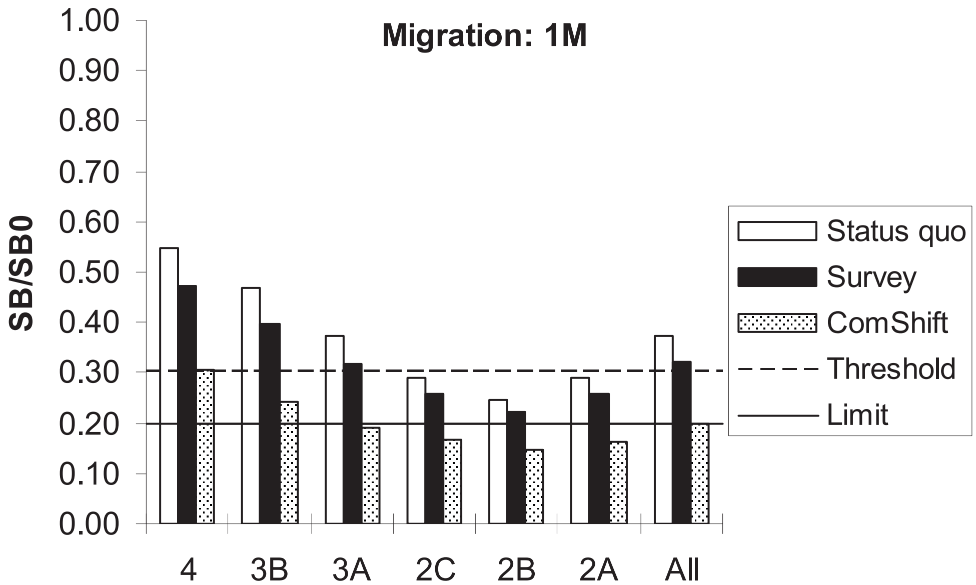
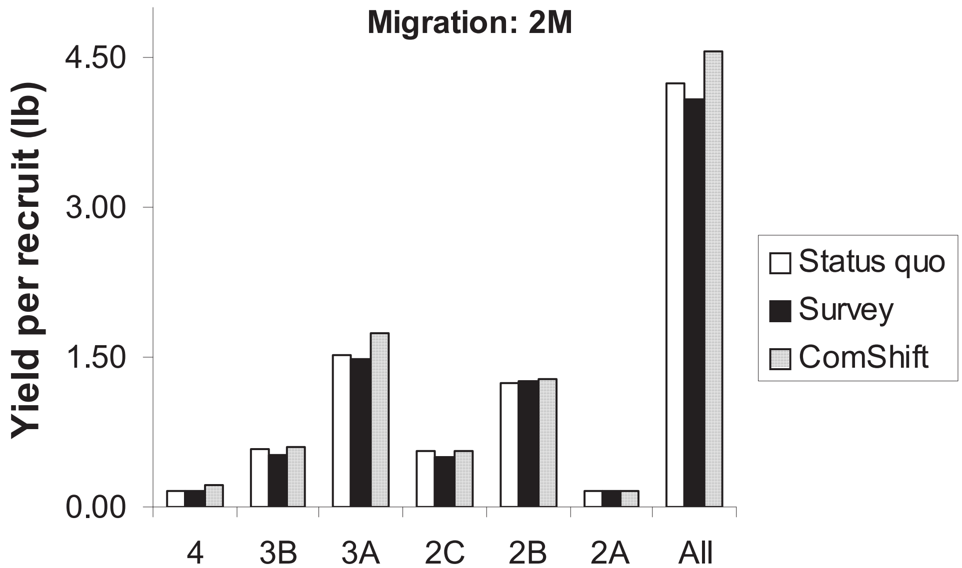


Figure 9. Yield per recruit (top) and spawning biomass per recruit relative to un shed conditions ("SB/SB0", bottom) at the coastwide ("All") and area spec c level, corresponding to the 1 migration matrix scenario ("1M") and harvest rate of 0.215. Selectivity of the commercial shery is either the average for 2008-2010 with MSL: 81.3 ("Status quo"), the 2008-2010 average IPHC survey selectivity ("Survey") or the 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes ("ComShift"). Weight at age of the commercial catch is that of the 2008-2010 IPHC survey except for the Status quo where it is that of the 2008-2010 commercial catch.



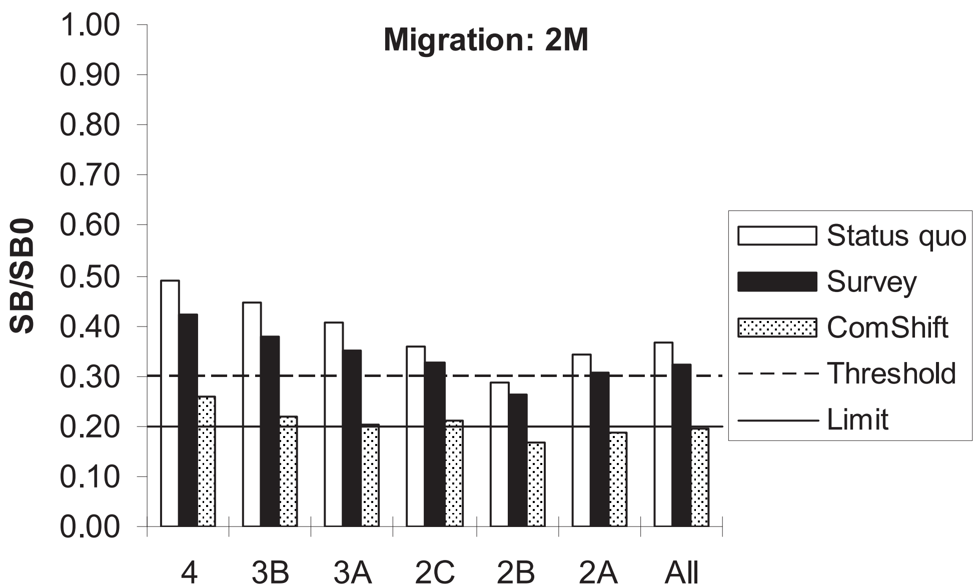
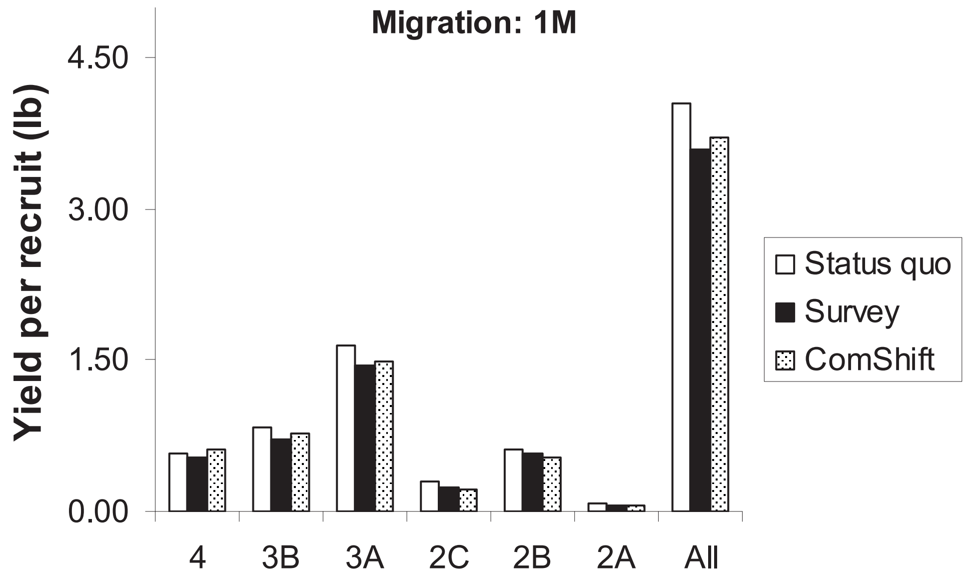


Figure 10. Yield per recruit (top) and spawning biomass per recruit relative to un shed conditions ("SB/SB0", bottom) at the coastwide ("All") and area spec c level, corresponding to the two migration matrices scenario ("2M") and harvest rate of 0.215. Selectivity of the commercial shery is either the average for 2008-2010 with MSL: 81.3 ("Status quo"), the 2008-2010 average IPHC survey selectivity ("Survey") or the 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes ("ComShift"). Weight at age of the commercial catch is that of the 2008-2010 IPHC survey except for the Status quo where it is that of the 2008-2010 commercial catch.



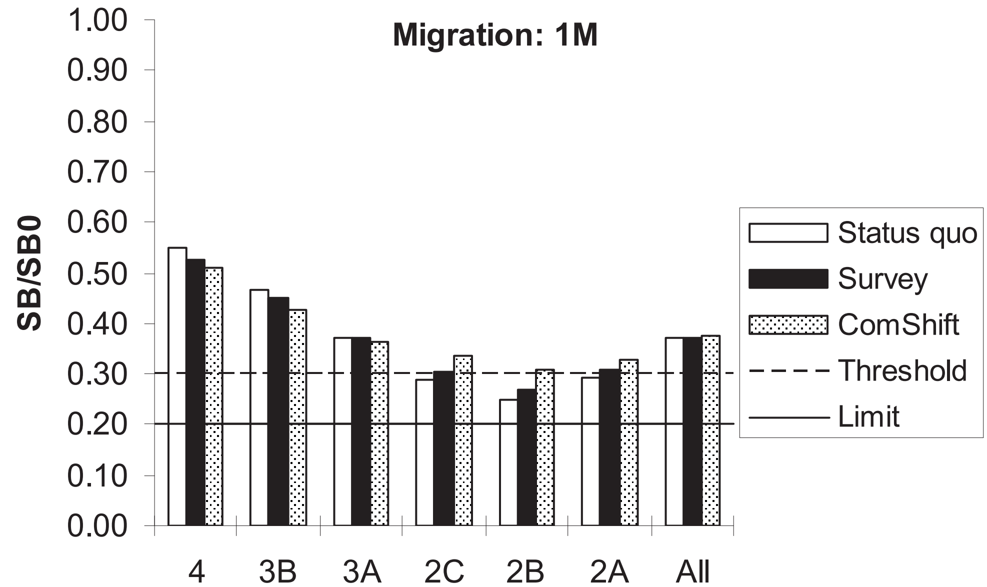
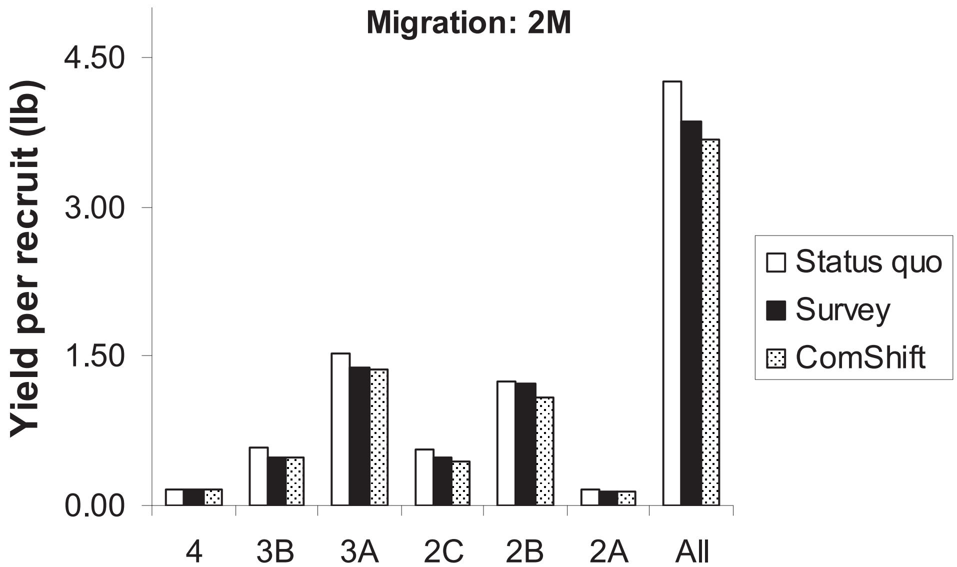


Figure 11. Yield per recruit (top) and spawning biomass per recruit relative to un shed conditions ("SB/SB0", bottom) at the coastwide ("All") and area spec c level, corresponding to the 1 migration matrix scenario ("1M"). Selectivity of the commercial shery is either the average for 2008-2010 with MSL: 81.3 ("Status quo"), the 2008-2010 average IPHC survey selectivity ("Survey") or the 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes ("ComShift"). Weight at age of the commercial catch is that of the 2008-2010 IPHC survey except for the Status quo where it is that of the 2008-2010 commercial catch. Coastwide harvest rate set at a level that results in equivalent coastwide SB/SB0 to the Status quo (HR: 0.215). Equivalent HR are 0.17 for "Survey" and 0.11 for "ComShift".



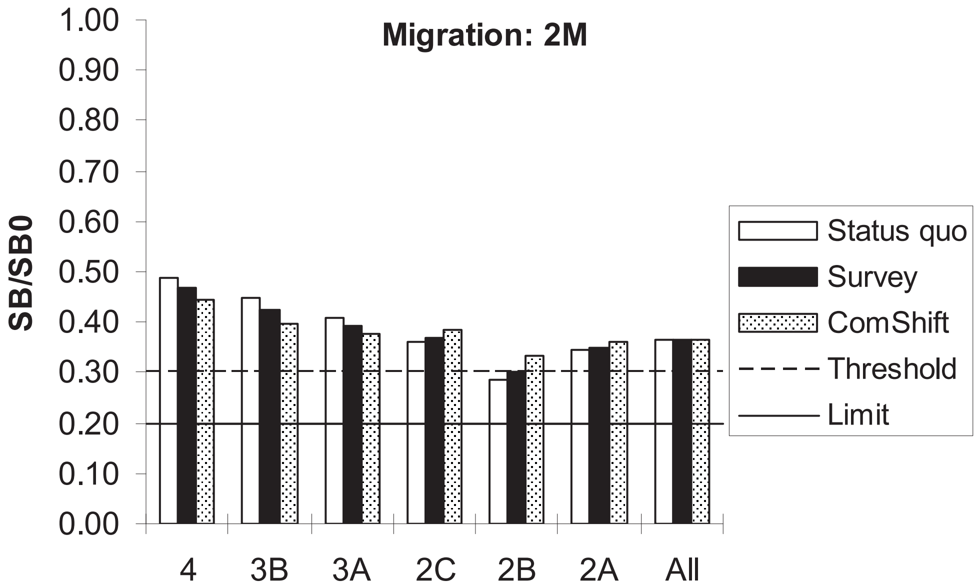


Figure 12. Yield per recruit (top) and spawning biomass per recruit relative to un shed conditions ("SB/SB0", bottom) at the coastwide ("All") and area spec c level, corresponding to the 2 migration matrices scenario ("2M"). Selectivity of the commercial shery is either the average for 2008-2010 with MSL: 81.3 ("Status quo"), the 2008-2010 average IPHC survey selectivity ("Survey") or the 2008-2010 commercial selectivity shifted 20 cm towards smaller sizes ("ComShift"). Weight at age of the commercial catch is that of the 2008-2010 IPHC survey except for the Status quo where it is that of the 2008-2010 commercial catch. Coastwide harvest rate set at a level that results in equivalent coastwide SB/SB0 to the Status quo (HR: 0.215). Equivalent HR are 0.18 for "Survey" and 0.11 for "ComShift".

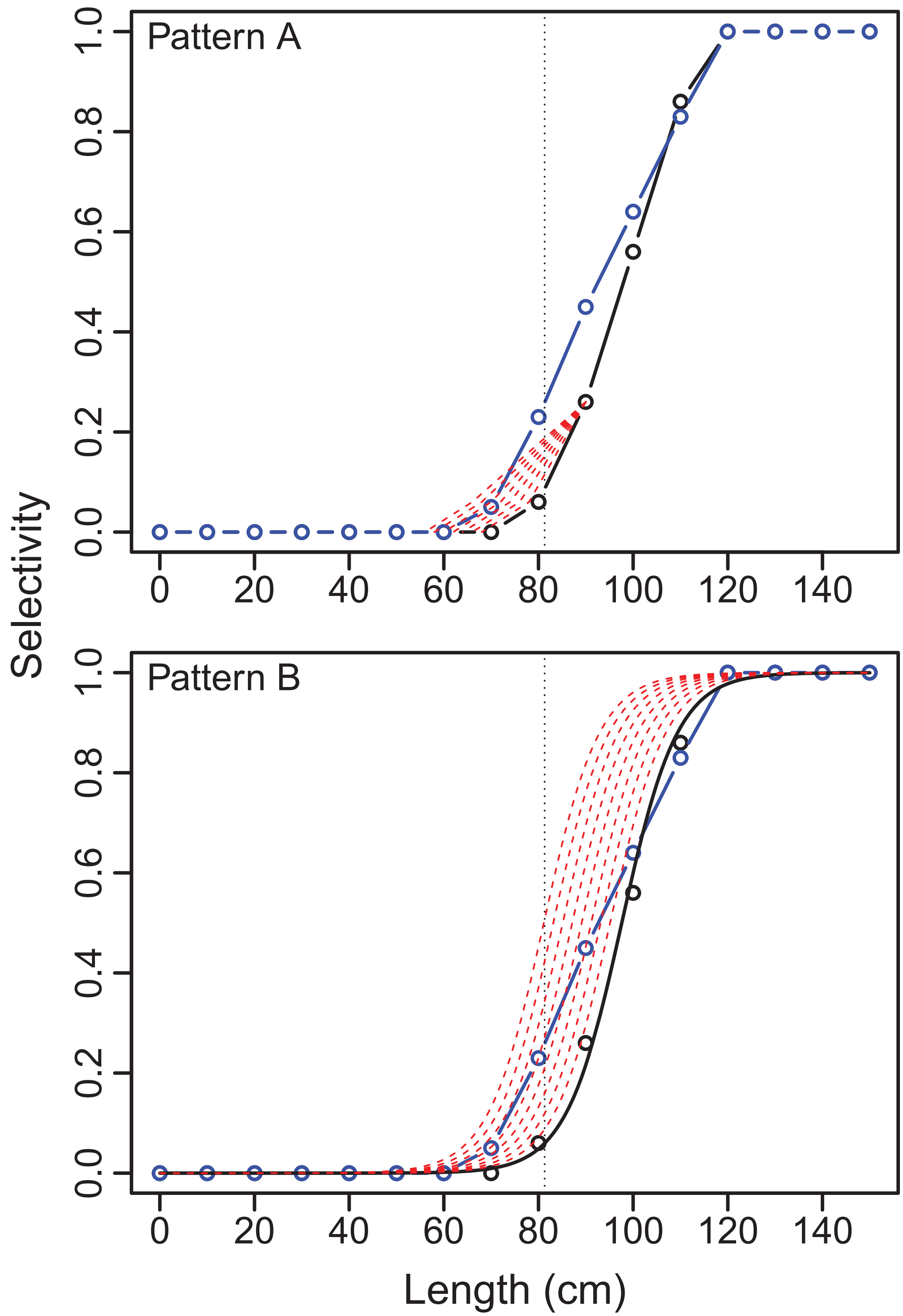


Figure 13. Illustration of selectivity patterns used in the analysis of gradual changes in selectivity. Present (or status quo) commercial and survey selectivities are indicated by black circles/lines and blue circles/lines, respectively. Dashed red lines are shown for selectivity patterns corresponding to sequential 2-cm reductions in the size limit.

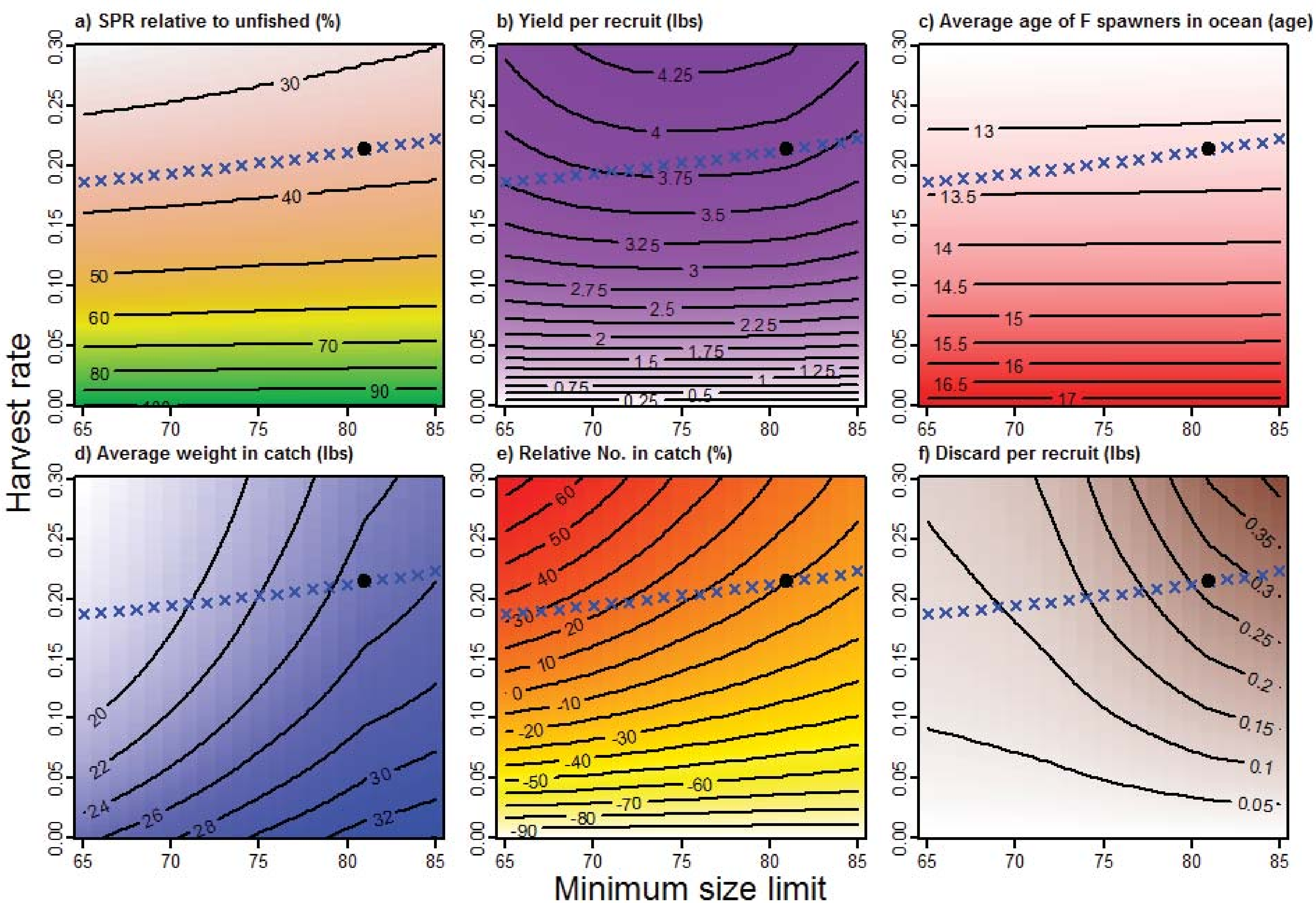


Figure 14. Summary results for gradual changes in selectivity and assumed gradual changes in commercial weight at age using Selectivity Pattern A. See text for details.

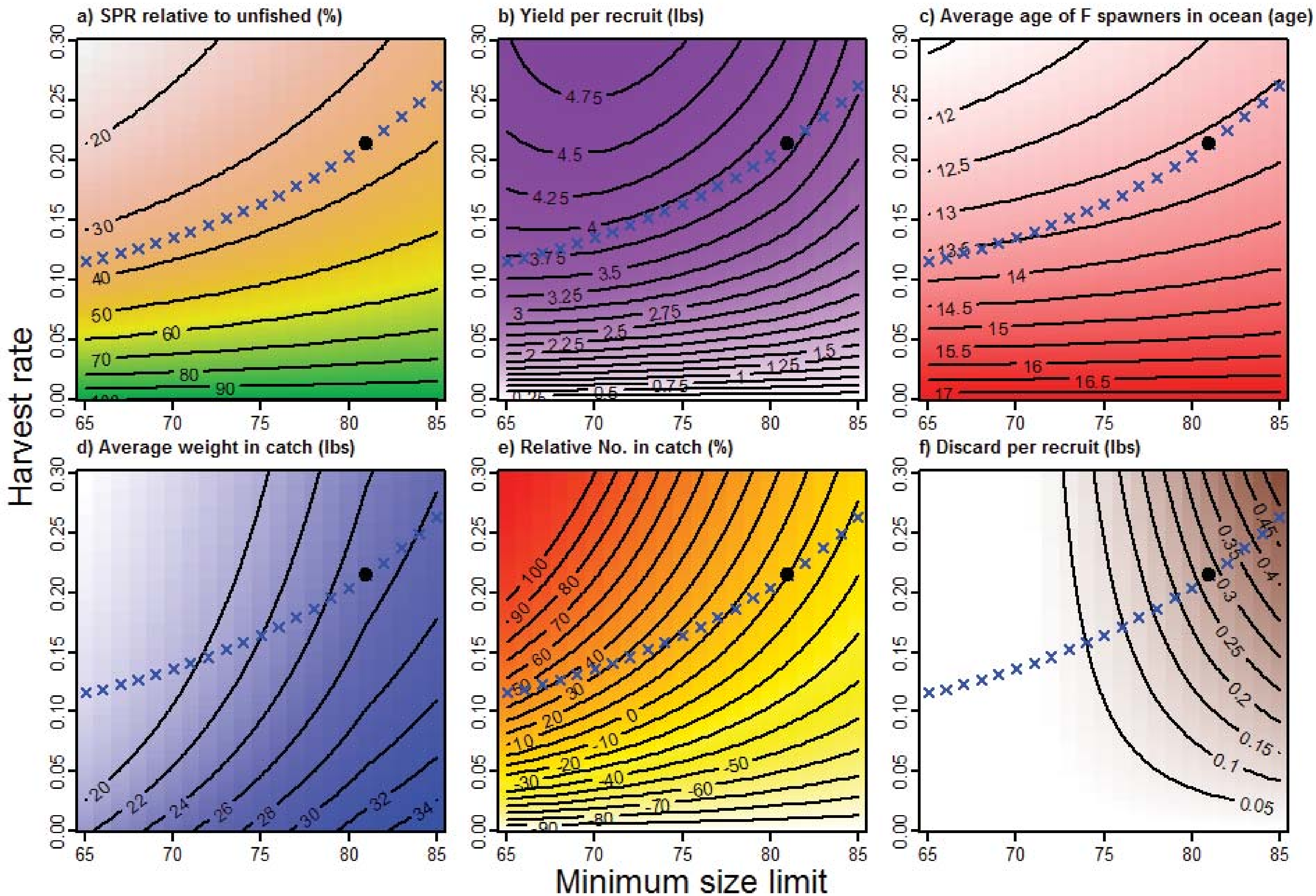


Figure 15. Summary results for gradual changes in selectivity and assumed no changes in commercial weight at age using Selectivity Pattern B. See text for details.

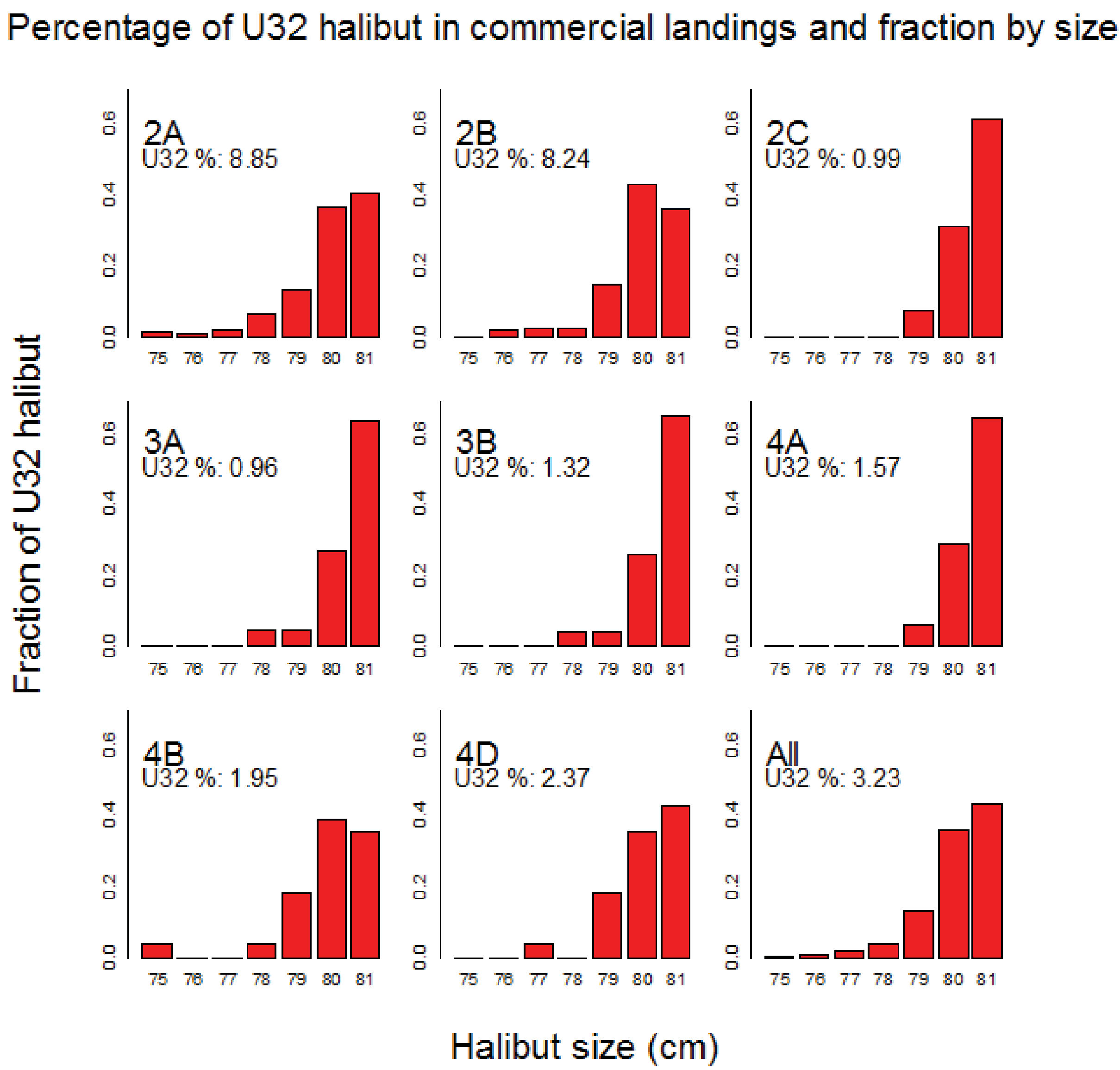


Figure 16. Size distribution of commercially landed halibut below the current 32 inch (U32) minimum size limit for each IPHC regulatory area and coastwide ("All") during 2008. U32% is the percentage of halibut under 32 inches relative to total numbers commercialy landed in 2008.

Harvest policy considerations on retrospective bias and biomass projections

Juan L. Valero

Abstract

The current IPHC harvest policy relies on a constant target harvest rate of 0.215, except for areas of specific concern where the target harvest rate is 0.161. A retrospective pattern of overestimation of biomass dating back at least to 2004 has continued to persist through 2011. This has resulted in stock assessment estimates of exploitable biomass (EBio) that show downward revisions of biomass estimates during successive years of up to 39% of the initial estimate. Due to this retrospective bias of overestimation of EBio, coastwide realized harvest rates have been up to 62% higher than target harvest rates for some recent years. The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. The revised female spawning biomass time trajectory is estimated to have dropped below the 30% (relative to unfished) reference point threshold for five consecutive years (2005 to 2009). Had the female spawning biomass been estimated below 30% at the time, a harvest rate as low as 0.14 could have been triggered by following the current harvest control rule. Alternative ways are proposed to factor the retrospective bias in the harvest strategy. One potential approach is to adjust the current target harvest rates downward by a factor equal to the cumulative observed departure between original estimates of exploitable biomass and successive retrospective revisions. Downward adjustment of current target harvest rates by 39% would result in revised target harvest rates of 0.131 (down from 0.215) for all of Area 2 and Area 3A and 0.098 (down from 0.161) for all of Area 4 and Area 3B. Another approach is to adjust target harvest rates based on departures between estimated realized harvest rates and target harvest rates. Downward adjustment of current target harvest rates would result in revised target harvest rates of 0.134 (down from 0.215) for all of Area 2 and Area 3A and 0.100 (down from 0.161) for all of Area 4 and Area 3B. Five-year biomass projections that incorporate continuing declines in size at age, downward revisions of recruitment estimates and adjusted initial conditions to take into account retrospective bias result in stable or decreasing EBio depending on harvest rate levels. Adjusting initial conditions for retrospective bias does result in SBio currently being below the 30% biomass reference point threshold. Depending on the assumed realized harvest rate levels during the projection time, SBio can be expected to either remain below or reach the 30% reference biomass threshold by 2017.

Evolution of the IPHC harvest policy

Management of Pacific halibut has relied on different methods for assessing stock trends and status as well as different harvest policy approaches. Before the 1980s the stock status was based on analyses of annual catch and catch-per-unit of effort (CPUE) (Sullivan and McCaughran 1991). During those years the notion of *normal yield* was the main tenet of management (Thompson and Bell 1934, Thompson 1950), i.e., the yield expected to maintain a stable relationship between annual catch and CPUE. In the early 1980s during a period of historically low biomass estimates, annual catch recommendations were calculated as a fraction of estimated annual surplus production in an effort to rebuild stocks (Deriso and Quinn 1985). The stocks were considered rebuilt by 1984 and a constant harvest rate policy has been in place since 1985. The target harvest rate is applied to annual estimates of exploitable biomass as defined by the estimated commercial selectivity from the stock assessment. The target harvest rate has changed over time from a high of 0.35 in 1985, to 0.30 in 1993, 0.2 in 1996, to 0.25 in 2003, 0.225 in 2004, and 0.2 since 2006 (Fig. 1). During the last decade, areas of special concern (due to trends and status of indices) had reductions of target harvest rates to 0.15 in 2006 (IPHC Regulatory Areas 4B, 4CDE), 2009 (IPHC Regulatory Area 4A), and 2010 (IPHC Regulatory Area 3B) (Fig. 1). In 2011, a change in how the IPHC accounted for bycatch mortality in the 26 to 32 inch (O26/U32) halibut size range resulted in target harvest rate increases from 0.2 to 0.215 for Areas 2A, 2B, 2C and 3A, and from 0.15 to 0.161 for Areas 3B, 4A, 4B and 4CDE. The higher harvest rates accommodate the direct deduction of O26/U32 bycatch mortality, which previously had been factored into determination of the target harvest rate (Hare 2011).

Performance of target harvest rates relative to realized harvest rates

Current target rates have been determined by simulation modeling that incorporates uncertainty in density-dependent growth responses, future levels and distribution of recruitment among areas, stock and environmental relationships, and selectivity curves (Clark and Hare 2006). Uncertainty in the annual stock assessment (other than random observation error on biomass estimates) was not incorporated in the simulations that form the basis of the current harvest strategy, nor has management uncertainty such as potential differences between recommended and established catch levels (Clark and Hare 2006). A recent review of the IPHC stock assessment and harvest policy (Francis 2008) pointed out that assuming that the realized harvest is the same as the target harvest could be a potential weakness of the current harvest policy. In response to the review, auto-correlated errors in the assessment were included in the simulations, and it was reported that the effect was relatively minor but that it was expected to result in a more frequent triggering of target harvest rate reduction (Hare and Clark 2008a). The misspecification of closed-area assessments presents an example of realized harvest rate departures from target harvest rates. In summary, area specific closed-area assessments were biased high because the main assumption, that of a closed population, was violated due to ongoing migration of halibut between areas. Misspecification in the closed-area stock assessments resulted in realized harvest rates (estimated by recent coastwide stock assessments with survey-partitioned biomass) as much as three times higher than the target in areas 2B and 2C and as low as half the target harvest rate for Area 4 during part of the last decade (Fig. 2). Estimated coastwide realized harvest rates have increased from a low of 0.14 in 1997, the earliest year estimated by the current stock assessment, to a high of 0.32 in 2007. Following the implementation of the coastwide assessment with survey-partitioned biomass, the coastwide realized harvest rate declined to 0.24 in 2011 as estimated by the assessment at the end of 2011. This rate is still above the intended coastwide harvest rate of 0.19 for 2011, resulting from the combination of area specific target harvest rates.

An important caveat should be noted regarding the most recent estimates of realized harvest rates. It is common for most (if not all) age structured stock assessment models, to produce more uncertain estimates for the most recent year in comparison to estimates for previous years. There is greater uncertainty in the most recent stock assessment year because earlier years are informed by more years of data, allowing for better tracking of cohorts as they pass through the fishery, while the most recent annual estimates are informed by much less data. Furthermore, each year the assessment estimates population quantities (biomass, numbers at age, etc.) not only for the latest year, but also for all previous years included in the model. The re-estimation of values by subsequent assessments can be random (reflecting mainly observation errors) or can show patterns of consistent, systemic downwards or upwards revisions of previous estimates. Such systematic revisions are termed retrospective patterns and the assessment model is said to have a retrospective problem (Legault 2009). The retrospective problem has been described as a systematic inconsistency among a series of estimates of population size, or related assessment variables, based on increasing periods of data (Mohn 1999). Retrospective patterns can arise for many reasons (NRC 1998, Legault 2009) including bias in the data (e.g., catch misreporting, unaccounted for mortality) or different types of model misspecification. Some types of model misspecification could be due to parameters that are assumed to be constant/variable in the analysis but are variable/constant, as well misspecification of commercial and/or survey catchability and/or selectivity (Parma 1993, Parma and Sullivan 1996). As reviewed by the National Research Council (NRC) (1998) and Legault (2009), early abundance estimates can be consistently biased (either upward or downward) with respect to corresponding estimates obtained in later assessments (e.g., some Northwest and Northeast groundfish stocks, Pacific halibut, North Sea sole). In some cases, such as with Pacific halibut, the retrospective pattern can change in direction, from underestimation to overestimation of biomass (Parma 1993). Risk associated with management actions when facing underestimation or overestimation of biomass are different depending on the emphasis of management goals. Consistent underestimation of biomass can lead to sub-optimal use of fishery resources (NRC 1998, Legault 2009). Cases of consistent overestimation of stock abundance can have severe management consequences as illustrated by the collapse of the Newfoundland northern cod and management issues on the Georges Bank yellowtail flounder (Walters and Maguire 1996, Walters and Pearse 1996, Walters and Martel 2004, NRC 1998, Legault 2009).

The coastwide stock assessment of Pacific halibut has been showing a consistent retrospective pattern since at least 2004, by which previous estimates of exploitable biomass (Fig. 3) are estimated to be smaller in subsequent assessments (see Clark and Hare 2006, 2008; Hare 2011, 2012). A recent external review of the IPHC stock assessment and harvest policy reported that the main problem with the current assessment was the significant retrospective bias (Medley 2008). A concurrent external review (Francis 2008) stated that it can be difficult to decide whether a retrospective trend is of concern and indicates a serious flaw in the stock assessment model structure, or if the retrospective trend is the result of a random pattern of residuals around the observations. The probability of occurrence of a set of consecutive random observations can be calculated by assuming that for each year there is a 50% chance that the estimate of biomass from previous year's stock assessment is revised downward and then multiplying the combined probability for all years with the observed pattern. During the external reviews, data were available through 2007 and the retrospective coastwide fits were only available for three years (2004, 2005, and 2006). By random chance alone the probability of observing a downward revision of the previous year's biomass estimates two years in a row, such as the pattern observed by the external reviewers, is 25%; for five years in a row, such as the pattern observed in the stock assessments through 2008, it is 3%; for eight years in a row, such as the pattern observed in the stock assessment through 2011, the probability by random chance alone is 0.4%.

Stock assessment documents noted the retrospective pattern in the coastwide assessment since 2007, when it was stated that the stock assessment "had not tracked very well for the last few years"

(Clark and Hare 2008a). Subsequent stock assessment documents described the retrospective pattern as relatively small or modest and that the trend of successively lowering all earlier EBio estimates had greatly tapered off, along with a consideration that the retrospective behavior did not weaken the assessment in any way (Hare and Clark 2009, Hare 2010, 2011).

There are alternative approaches to quantify and analyze retrospective bias in stock assessment models (Legault 2009). One approach is the within-model retrospective analysis, done by sequentially removing one year (or different set of years) of data from the latest assessment. This approach is mostly used to diagnose potential sources of retrospective bias. Another approach, the one this report addresses in detail, is the historical retrospective analysis, using the actual annual assessment estimates at the time each assessment was done. This report focuses on historical retrospective analysis and the range of years used reflect the availability of historical annual coastwide stock assessments (2006 to 2011). The historical retrospective analysis is most useful when comparing the performance of management actions and harvest strategy in the face of retrospective revisions of the actual management quantities as originally estimated in each assessment year.

Inspection of the successive historical estimates of exploitable biomass (Fig. 3, top), spawning biomass (Fig. 3, bottom) and total biomass (Fig. 4) extracted from published stock assessments documents shows ongoing retrospective patterns. The magnitude of the retrospective pattern for the last year of the stock assessment's estimated EBio has resulted in downward revisions of the initial EBio estimate of 14% in 2008, 15% in 2009, 18% in 2010 and 25% in 2011 in the first year following the assessment. As an example, the 2009 stock assessment estimated that the 2010 EBio at the beginning of the year was 334 M lb, and consequently, the 2010 yield calculations were based on this 334 M lb estimate of EBio. However, the 2009 stock assessment estimate of EBio in 2010 (334 M lb) was revised down 18% (to 275 M lb) in the 2011 stock assessment. Yield calculations ultimately consist of multiplying target harvest rates times the estimated EBio for the year following the assessment. The 2010 catch has already been taken and is therefore fixed, even if the originally estimated EBio is revised downwards in future assessments. Continual downward revisions of EBio result in a consistent, ongoing upwards revision of realized harvest rates. This retrospective pattern affects the performance of biomass projections conducted following past (Fig. 3) and recent (Valero 2011, 2012) assessments. Biomass projections that were conducted in the recent past consistently indicated a quick turnaround of ongoing biomass declines and a fast biomass increase; however, these projections have been consistently revised downwards and estimated to continue the declining trend by subsequent assessments.

The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. For example, Hare (2011) notes that the revised female spawning biomass time trajectory seems to have dropped slightly below the spawning biomass (SBio) threshold (30% relative to unfished). Given the retrospective bias and resulting overestimation of spawning biomass estimates, the revised spawning biomass trajectory is estimated to have been below the 30% threshold during five consecutive years, 2005 to 2009. Had the female spawning biomass been estimated below 30% at the time, a reduction in the target harvest rate would have been triggered during 2005-2009 following the current harvest control rule (Fig. 5). These target harvest rate reductions (Fig. 5) should have been between 0.186 for 2005 and 0.14 for 2007 (Fig. 5).

Factoring retrospective issues in the harvest strategy

Consistent retrospective bias is indicative of problems in the specification of the stock assessment model (either the model itself or its use of available data). Therefore, conventional model-based measures of uncertainty of management parameters are not realistic because they are based on the structural assumptions of the model being correct (NRC 1998). Consistent retrospective bias can lead to biased management advice and could lead to continued overfishing of stocks, and loss of potential yield (Legault 2009). A direct approach to deal with retrospective biases is to identify the processes responsible for it and to address them in the stock assessment model structure and/or its use of available data. Identifying the ultimate driving processes of retrospective patterns has proven difficult for most stocks in which it is present (NRC 1998, Mohn 1999, Legault 2009), making the provision of management advice in the intervening time challenging.

Alternative approaches that take into account retrospective issues in the provision of management advice have been developed in the fisheries context, including applying adjustment factors based on consistent past retrospective error patterns as a means to correct the estimates used for management (e.g., Showell and Bourbonnais 1994, NRC 1998, Legault and Terceiro 2008). As an example, when original estimates of abundance were estimated to have been 40% above the subsequently revised estimates, current estimates could be adjusted downward by 40% to compensate, assuming that similar bias would also be present in the current year's estimate of abundance. Showell and Burbonnais (1994) applied this approach in the assessment of Scotian shelf silver hake populations and associated stock projections. Although ad hoc, downward adjustment of abundance estimates intended to account for retrospective patterns have been considered a sensible precautionary approach in cases of consistent overestimation of abundance (NRC 1998). Legault and Terceiro (2008) analyzed alternative approaches to adjusting projections for groundfish assessments. The approaches in their analysis included reductions of fishing mortality and downward adjustments to the end of year (or start of projection numbers) produced by the assessment, methods that were considered appropriate to use for projections and were expected to minimize bias in the projections. Accounting for downward revisions of past estimates has been incorporated into recent projections of coastwide biomass for Pacific halibut (Valero 2011, 2012). However, the impact of the retrospective pattern of persistent overestimation of EBio and the resulting underestimation of realized harvest rates have not been incorporated into the IPHC harvest policy. One potential approach is to adjust downward the current target harvest rates by a factor equal to the observed departure between original estimates of EBio and successive downwards revisions. Downward revisions of original estimates for 2006, 2007, 2008, 2009, and 2010 EBio are on the order of 25% to 39% one to five years following the assessment year (Fig. 6). The largest downward revision occurs in the first or second year after initial estimates of EBio (Fig. 6). However, for the available years, declining estimates of EBio have not stabilized and reductions in the estimates are still ongoing. As an example, an earlier version of this analysis used estimates up to the ones provided by the assessment at the end of 2010. The largest one year downward revision of EBio was 18%, and the largest cumulative downward revision was around 30%. Including the latest available assessment (at the end of 2011) brings the largest one year decline to 25% and a cumulative decline of almost 40% from earlier estimates. Therefore, a working value of at least 39% downwards adjustment to the target harvest rate is consistent with the cumulative maximum observed revision to date. Considering that the ongoing decline of EBio estimates since 2006 are without evidence of stabilization, the downwards adjustment could be greater. Downward adjustment of current target harvest rates by 39% would result in revised target harvest rates of 0.131 (down from 0.215) for all of Area 2 and Area 3A and 0.098 (down from 0.161) for all of Area 4 and Area 3B.

Another approach to account for the retrospective bias is to adjust target harvest rates based on departures between estimated realized harvest rates and target harvest rates. This attempts to capture not only departures due to retrospective problems but also due to implementation error of the target harvest rate due, for example, to departures between recommended and accepted catch limits and the application of harvest control rule adjustments such as the recently modified Slow Up-Fast Down. Realized harvest rates from the coastwide assessment with survey partitioned biomass have been estimated around 0.30-0.32 (excluding the most recent and, hence, most uncertain estimates of realized harvest rates) (Fig. 7). Similarly to the non-converged declines in original Ebio estimates, it can be expected that some of the realized harvest rate estimates will continue to be revised upwards. Therefore, a working value of 0.32 is consistent with observed cumulative revisions to date. This would imply realized harvest rates 62% higher than the target. Downward adjustment of current target harvest rates by 50% would result in revised target harvest rates of 0.143 (down from 0.215) for all of Area 2 and Area 3A and 0.107 (down from 0.161) for all of Area 4 and Area 3B.

It is important to keep in mind that these potential modifications to the target harvest rate are not a reduction of the originally intended target harvest rates determined by the simulation work (Clark and Hare 2006, originally 0.2, revised recently to 0.215). Instead, these are adjustments to take into account factors, such as retrospective issues and implementation errors that were not included in the original development of those target harvest rates. If the observed patterns leading to the consistent departure between realized and target rates as well as the ongoing downwards revision of EBio continue, then applying the adjustments is expected to reduce the magnitude of departures between realized and target harvest rates. On the other hand, if the observed retrospective patterns and departures between realized and target rates disappear or change, then the proposed adjustments could be removed (Table 1). Potential outcomes under different decisions regarding adjusting or not adjusting current target rates are illustrated in Table 1. The axis of potential future states on which we have no control are listed as hypotheses on the future retrospective behavior of population estimates. The expected outcomes of making a particular decision under the different hypothesis are described in terms of yield, conservation risk, and potential realizations of harvest rates. For example: if the decision is to adjust target harvest rates and overestimation continues (with associated decline in biomass), the potential outcome is to have lower yields in both short and long terms, but with the expectation of reducing differences between realized and target harvest rates. On the other hand, if the decision is to continue to use status quo target harvest rates and overestimation continues, the outcome expected is the continuation of realized harvest rates higher than target harvest rates. Adjusting target harvest rates in the event of a change in retrospective downward revision of biomass is expected to result in foregone yield in the short term. However, such change in the retrospective pattern would be expected to result in a re-evaluation of adjustments and eventual return to unadjusted target harvest rates.

Biomass projections following estimates at the end of 2011

The methodology and assumptions for the biomass projections are described and illustrated for the initial conditions derived from the assessment at the end of 2010 in Valero (2012). Five-year exploitable and spawning biomass projections were conducted using three scenarios described below. For all scenarios future recruitment is the stock assessment average estimate of numbers at age 6 halibut from 1996 to 2008. Initial conditions are based on population estimates from the WobbleSQ alternative fit of the coastwide stock assessment (Hare 2012). Given unresolved uncertainties on the accuracy of the initial numbers to start the biomass projections and the uncertainty on future trends in recruitment estimates, size-at-age, and performance of target harvest rates these projections should be taken with caution. The goal of the projections is to illustrate the range of uncertainty on trends and status of the stock depending on assumptions on its dynamics and potential management actions. Projections under alternative assumptions, such as those presented in Valero (2011, 2012), result in intermediate biomass projection levels to those presented in this report, which focus on the retrospective bias as the largest uncertainty.

Status quo method (SQ)

Status quo projections follow the basic procedure and assumptions as the method used up to last year's assessment (Hare and Clark 2006, Hare 2011), namely:

i) Size-at-age is assumed to remain the same as that estimated for the last year of the assessment.

ii) A constant realized harvest rate equal to the target harvest rate (HR=0.2).

iii) The initial population numbers are projected without error.

iv) There are no downward revisions of previous recruitment estimates.

Reduced recruitment, size-at-age and initial numbers, status quo target harvest rate ($R_{R,S,N}$_CHR)

This alternative assumes continuing downward revisions of previous cohort strength and declining size-at-age (see Valero 2012), while starting projections at the downward revision of the estimated numbers at age. The numbers-at-age at the beginning of the year 2012 are revised down to account for cumulative downward revisions of the initial numbers-at-age for the projections. In this scenario the initial numbers at age (2012) were revised downwards 40%. Current target harvest rates are used and realized harvest rates are assumed to remain at 0.32, reflecting recent departures between target and realized harvest rates (Fig. 7).

Reduced recruitment, size-at-age and initial numbers, adjusted target harvest rate ($R_{R,S,N}$_AHR)

This scenario is the same as the previous one but uses adjusted target harvest rates to factor in retrospective bias to achieve realized harvest rates of 0.2.

Biomass projection results

Projections under different scenarios are shown in Fig. 8. Projections under status quo assumptions produce similar rapid increases in expected biomass as in projections produced after recent assessments (e.g., Fig. 3). Projections that incorporate continuing declines in size at age, downward revisions of recruitment estimates, and adjusted initial conditions to take into account retrospective bias result in stable or decreasing EBio depending on harvest rate levels (Fig. 8, Top panel). The SBio is estimated to be at 42% of unfished conditions by the assessment at the end of 2011 (Hare 2012). However, correcting the initial conditions for retrospective bias results in SBio to be below the 30% reference point threshold at the start of the projections. Depending on the assumed realized harvest rate levels, SBio could be expected to remain below the 30% biomass reference point threshold or it could reach the 30% threshold by 2017.

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Table 1. Contingency table illustrating the potential effects of different management actions on short and long term yield, future potential management actions and risk under different hypothesis on the retrospective problem. "Adjusted target HR" is the reduced target HR factoring in overestimation of past biomass and departures between target and realized HR. "Status quo target HR" is the currently used target HR.

Retrospective hypothesis	Management action			
	Adjusted target HR		Status quo target HR	
	Short term	Long term	Short term	Long term
Overestimation continues	smaller yield	smaller yield	larger yield	conservation risk higher than target HR
No retrospective issue	smaller yield	smaller yield return to Status quo HR	larger yield	larger yield
Underestimation starts	smaller yield	larger yield return to Status quo HR	larger yield	larger yield lower than target HR

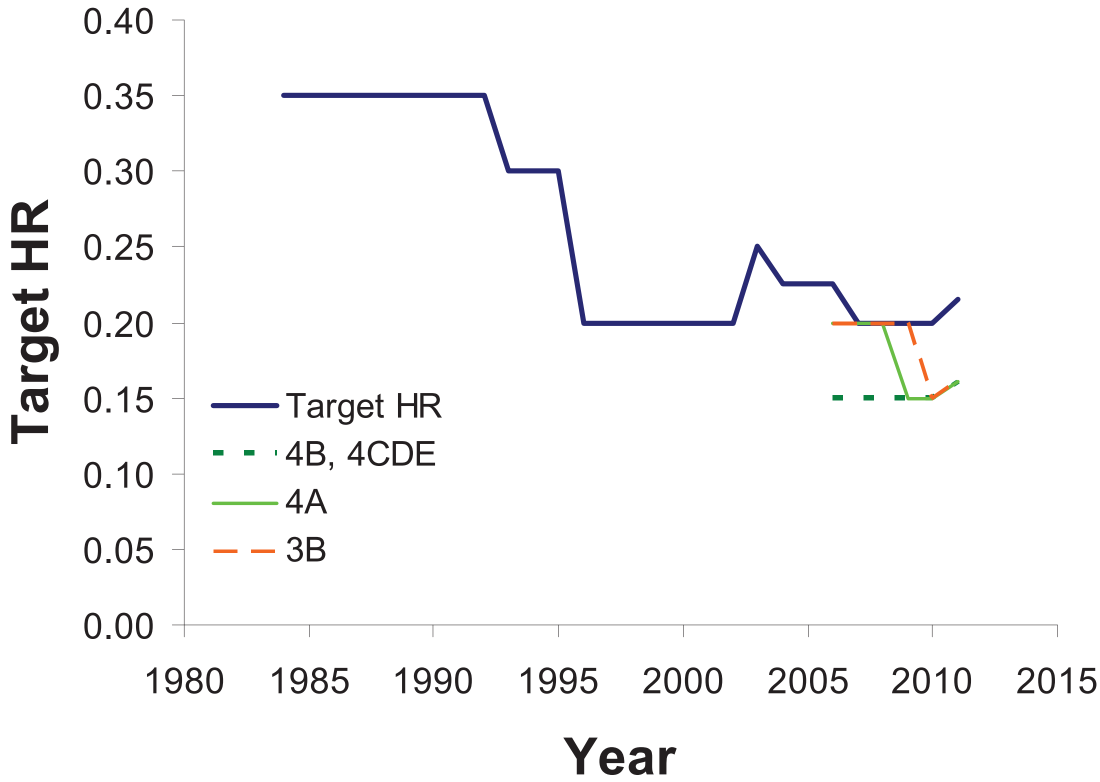
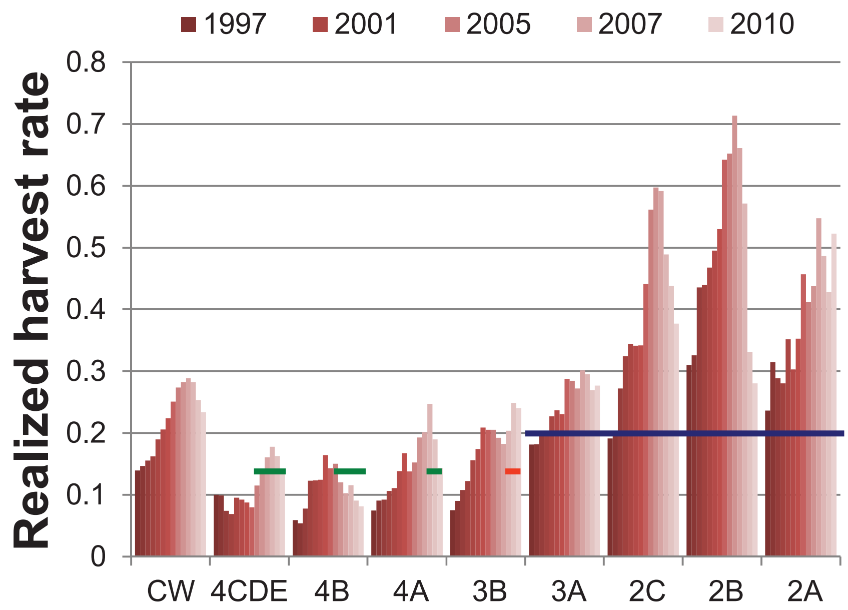


Figure 1. Evolution of target harvest rate levels in the Paci c halibut shery. The blue solid line represents overall target level except for areas of special concern represented by dashed green (4B, 4CDE), solid green (4A) and dashed orange (3B) lines.



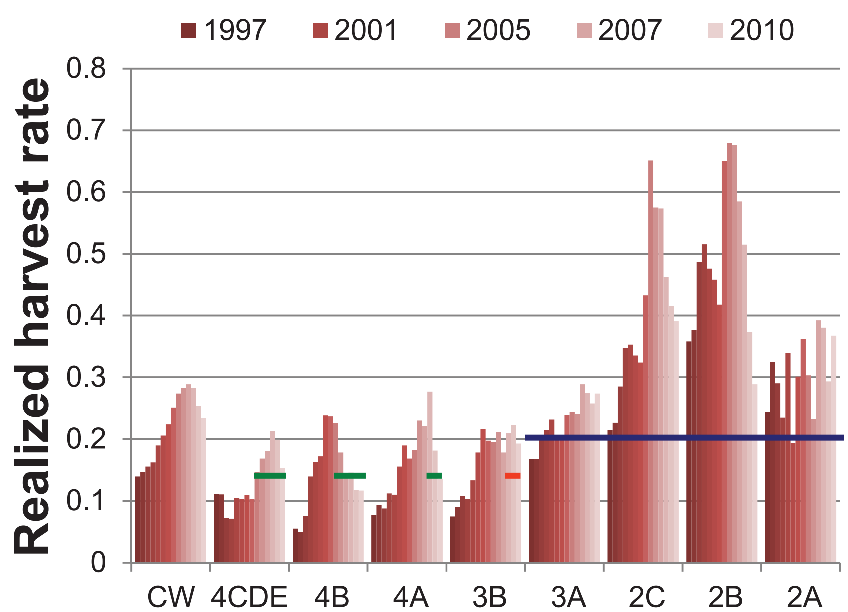


Figure 2. Realized harvest rates estimated from the assessment at the end of 2010 and survey apportionment of biomass, unadjusted (Top) and adjusted for hook competition and survey timing (Bottom). Horizontal lines represent area-speci c target harvest rates.

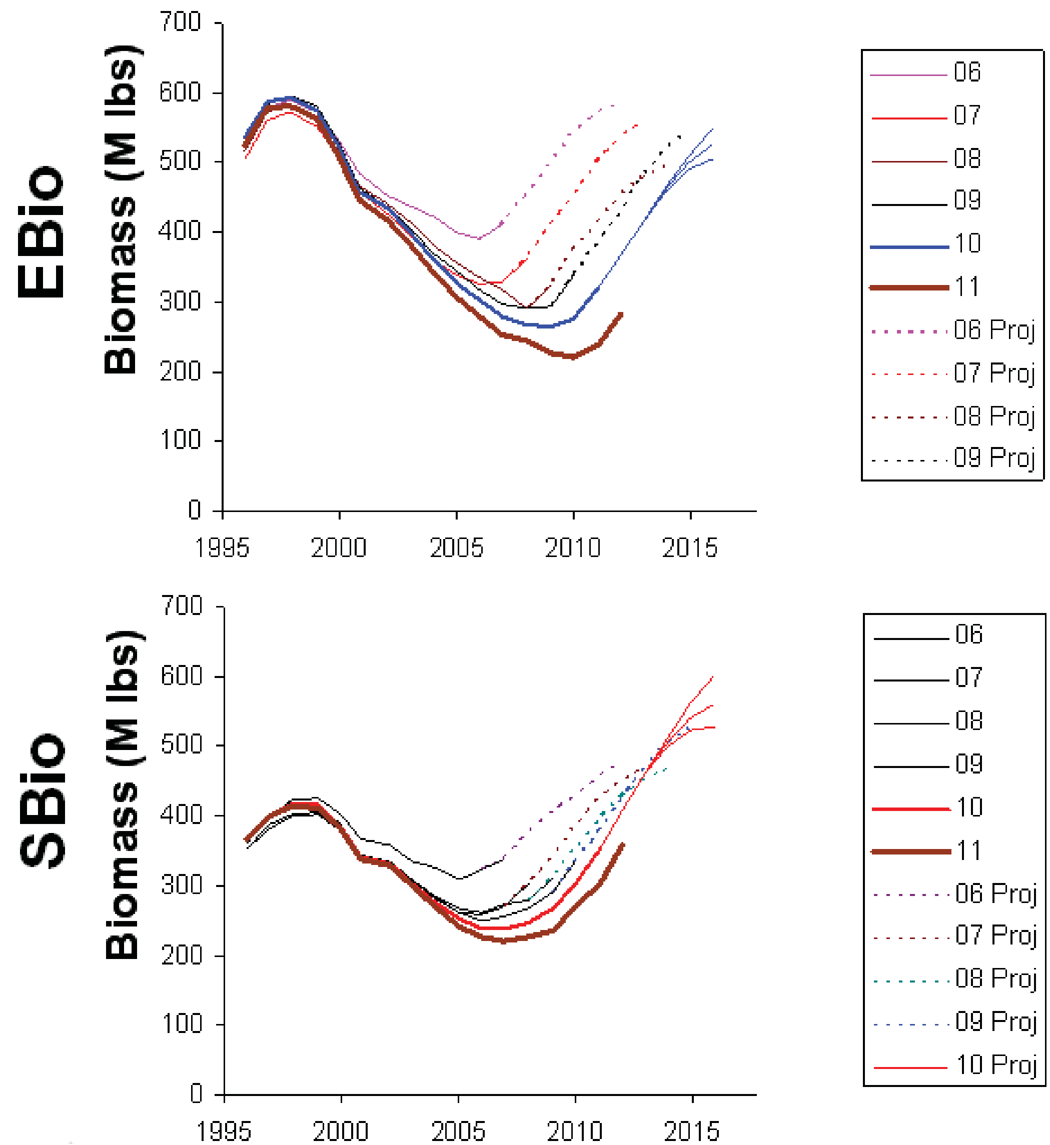


Figure 3. Estimated trends of exploitable biomass (top) and spawning biomass (bottom) for stock assessments at the end of 2006, 2007, 2008, 2009, 2010, and 2011 and the subsequent retrospective downward revisions of through the years 2006 to 2010. Solid lines are estimated trends for the year of the assessment, dashed lines are 5-year projections conducted at the end of each assessment year. Projections after the 2010 end of the year assessment are displayed as thin lines representing high, average and low forecasted recruitment. Time series obtained from Clark and Hare (2006, 2008), Hare and Clark (2008b, 2009), and Hare (2010, 2011, 2012).

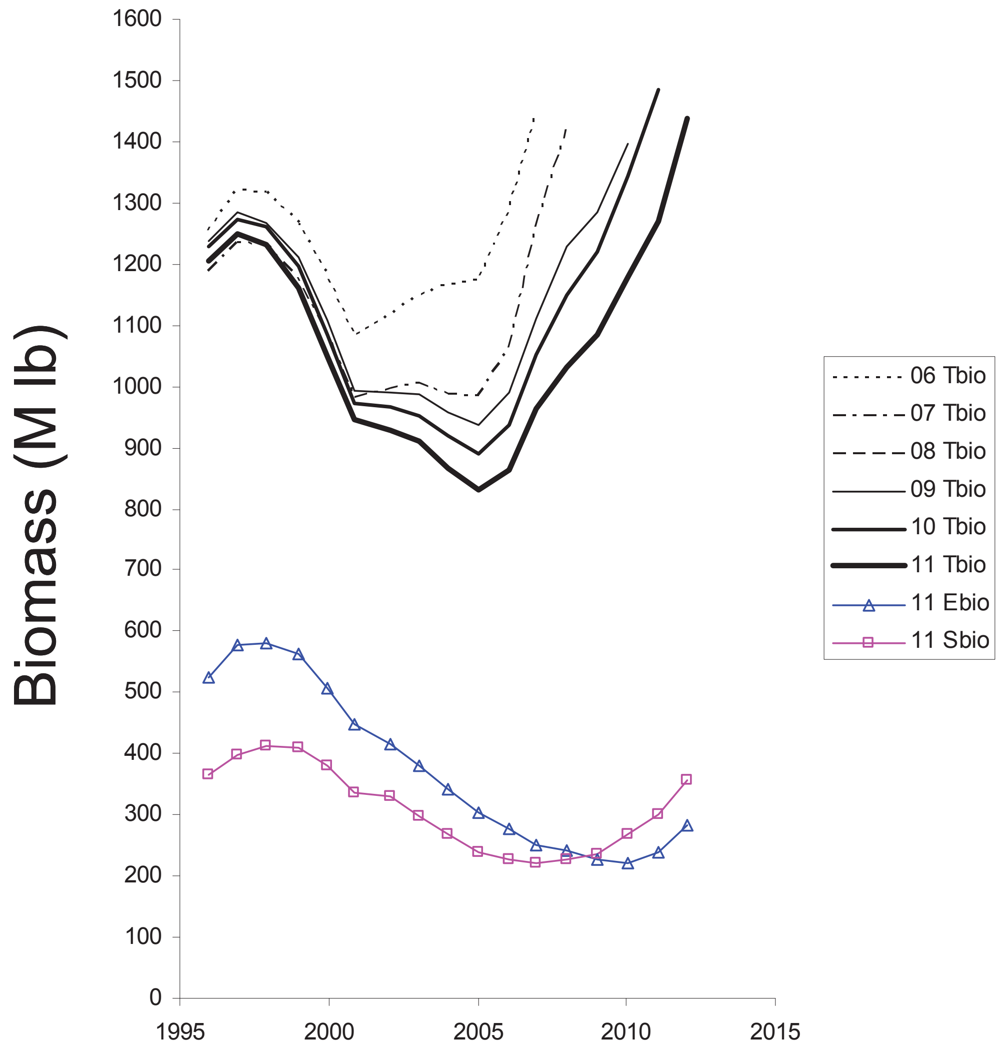


Figure 4. Estimated trends of total biomass of halibut age 8 and older (Tbio) for stock assessments at the end of 2006, 2007, 2009, 2010 and 2011 and the subsequent retrospective downward revisions through the years 2006 to 2010. Exploitable (Ebio) and female spawning (Sbio) biomass as estimated at the end of 2011 presented for reference. Time series obtained from Clark and Hare (2006, 2008), Hare and Clark (2008b, 2009), and Hare (2010, 2011, 2012).

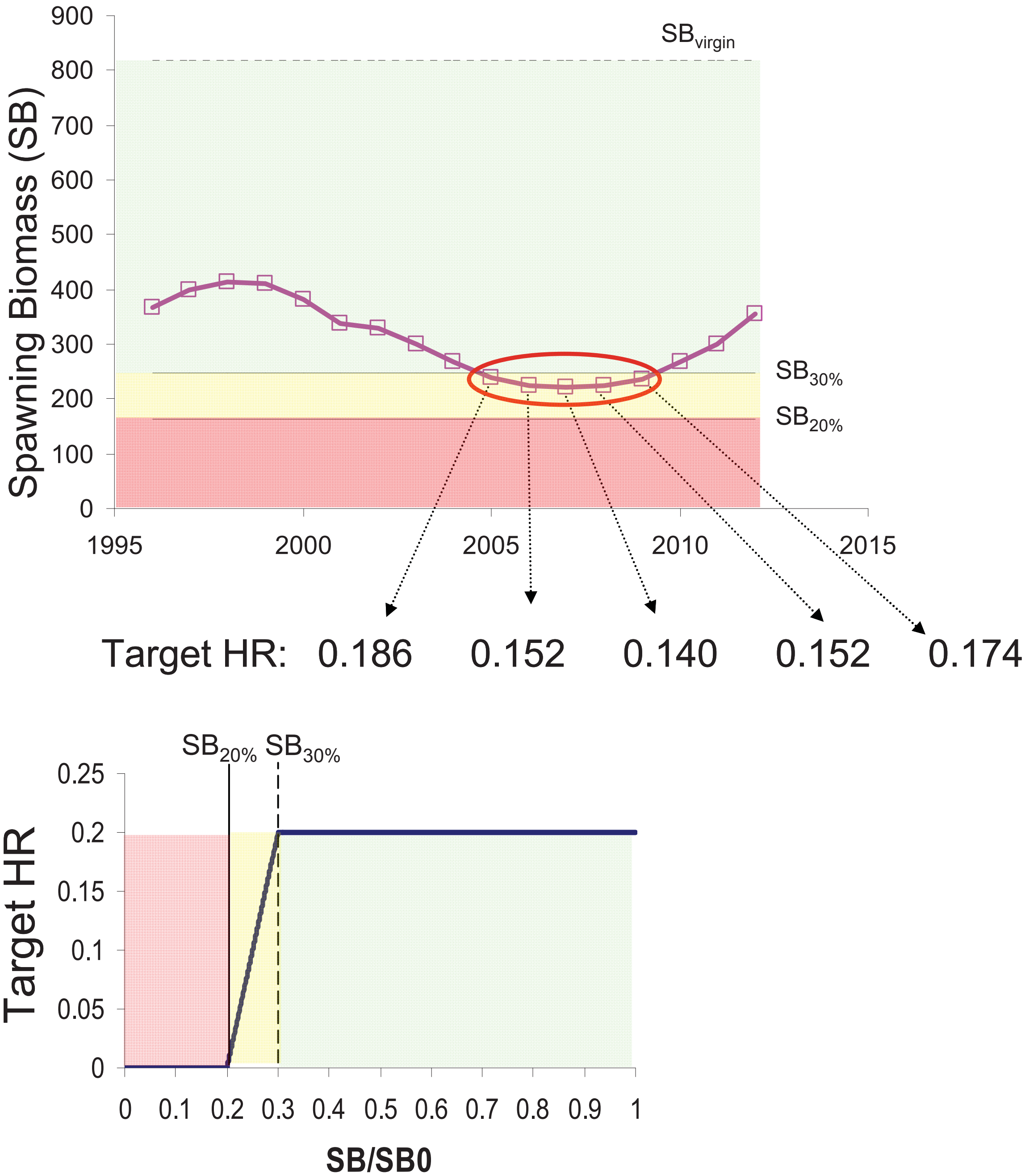


Figure 5. Top panel: Female spawning biomass (SB) estimates (M lb) for 1996 to 2012 as estimated by the stock assessment at the end of 2011 (time series obtained from Hare 2012). Horizontal lines are threshold and limit biomass reference points corresponding to 20% (SB20%) and 30% (SB30%) of estimated un shed female spawning biomass (SB0). Red oval highlights the ve years (2005 to 2009) where SB is retrospectively estimated to have droped below SB30%. Revised target rates (HR) that would have been applied by the current harvest control rule (bottom panel) are shown for each year. Color coding following Valero and Hare (2010).

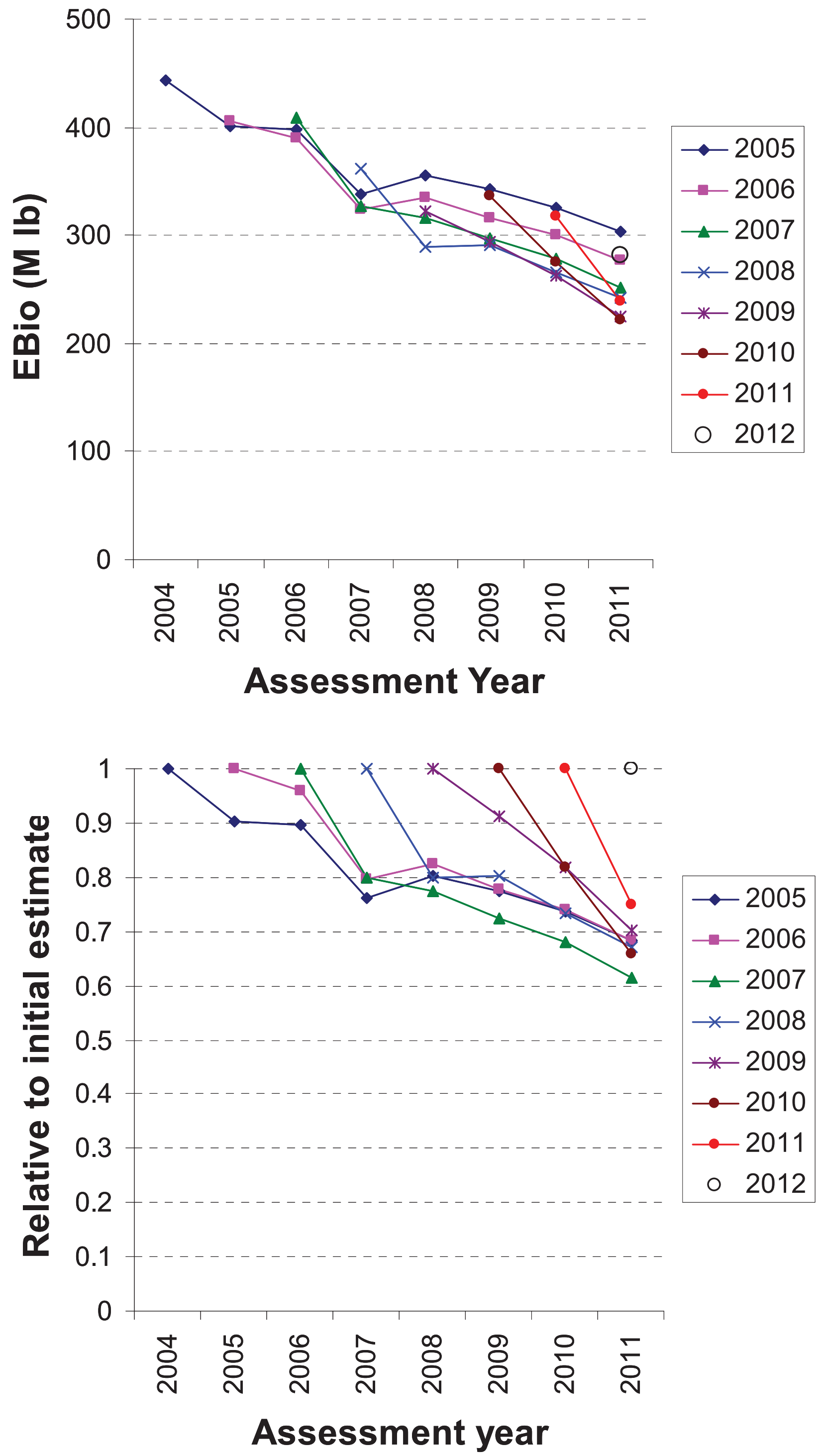


Figure 6. Original estimates of exploitable biomass (EBio) for the years 2005, 2006, 2007, 2008, 2009, 2010 and 2011 and the subsequent retrospective downward revisions through the years 2005 to 2011 as absolute (top panel) and relative to intial values (bottom panel). Time series obtained from Clark and Hare (2006, 2008), Hare and Clark (2008b, 2009), and Hare (2010, 2011, 2012).

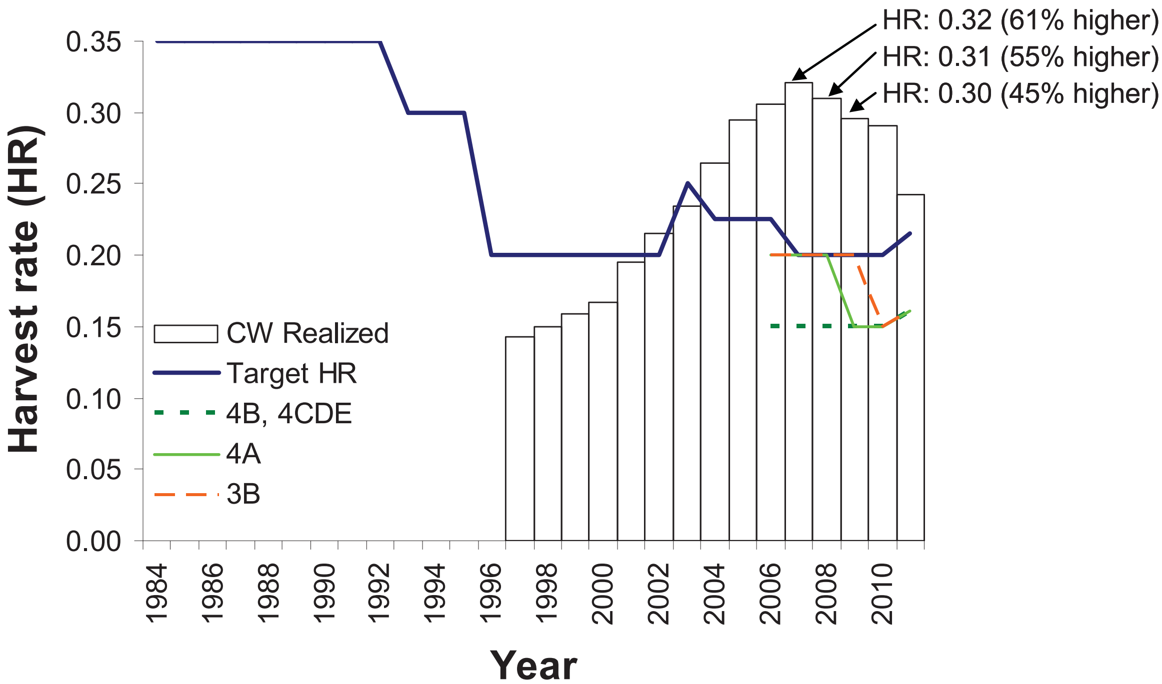
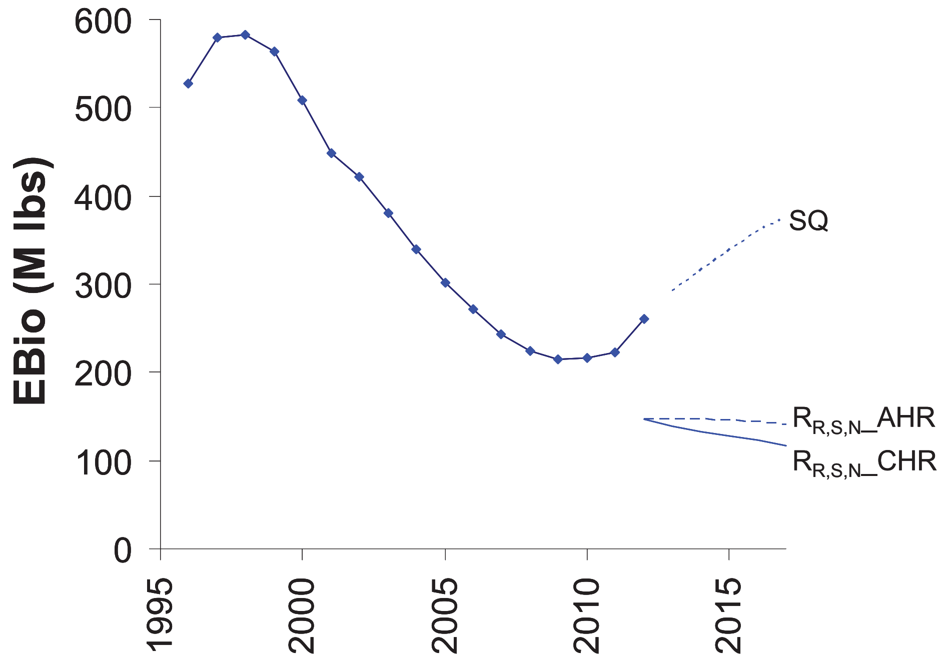


Figure 7. Evolution of target harvest rate levels in the Paci c halibut shery and coastwide (CW) realized harvest rates estimated from the end of the year 2011 stock assessment. The blue solid line represents overall target level except for areas of special concern represented by dashed green (4B, 4CDE), solid green (4A) and dashed orange (3B) lines. Realized harvest rates and the percentage departure from target harvest rate for 2007, 2008 and 2009 are highlighted.



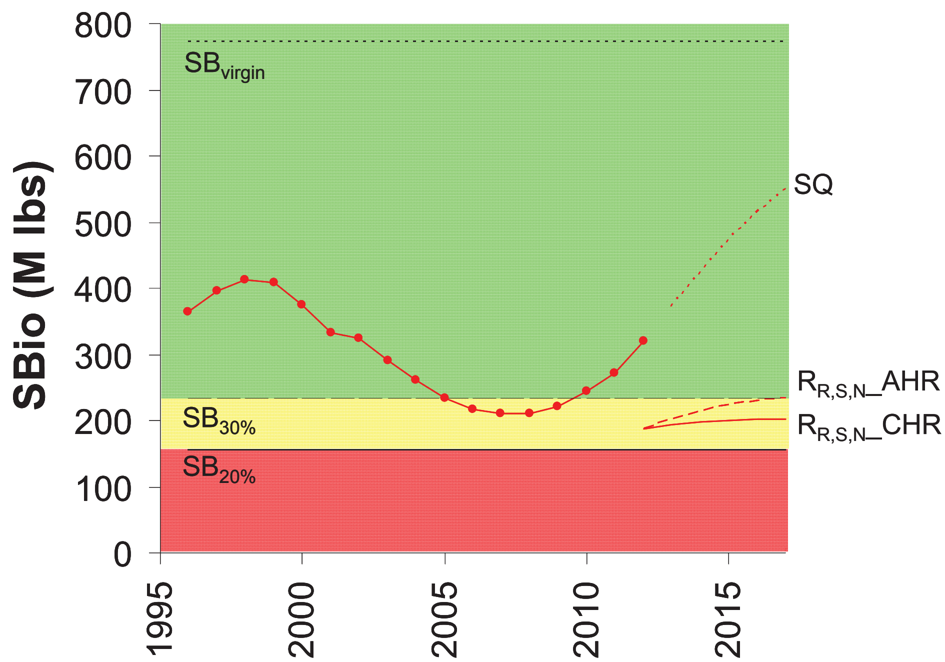


Figure 8. Exploitable (EBio) and spawning (SBio) biomass ve-year projections following the assessment at the end of 2011. Solid lines with solid circles are estimates from WobbleSQ assessment t (Hare 2012), dotted lines are projection under status quo assumptions (SQ). Other projections assume continuation of declines in estimates of past recruitment and size-at-age, and initial numbers reduced to re ect retrospective bias with either adjusted ($R_{R,S,N}$_AHR, dashed lines) or current ($R_{R,S,N}$_CHR, solid lines) target harvest rates.

Progress in the development of a management strategy evaluation for Pacific halibut

Juan L. Valero

Abstract

This report describes the evolution of the harvest strategy for Pacific halibut and the ongoing development of a management strategy evaluation.

Introduction

There are different approaches in the provision of scientific advice for fisheries management. One approach is the assessment-based approach that relies on a regular (usually annual) cycle of evaluation of the status of stocks and determination of "best" estimates of biomass and calculation of quotas based on a predetermined target harvest rate. Target harvest rates can be calculated in different ways depending on specific management goals; among others, maximizing yield (MSY-based), minimizing risk to the stock, coping with fluctuating populations, etc. The early historical emphasis on MSY and optimal target rates has seen a transition into a framework of harvest control rules that includes threshold and limit reference points, and associated target harvest rates (Mace and Sissenwine 2002). This change has been motivated by a transition towards a precautionary approach to fisheries management (FAO 1995) and the realization of the uncertainty associated with assessment model errors, uncertainty around reference points as well as implementation errors, and their combined impact on the ability to conduct successful fisheries management. An alternative approach takes into account a greater spectrum of relevant uncertainties using "feedback control policies" (Mace and Sissenwine 2002). They have been referred as "fisheries control system" (Hilborn 1979), "revised management procedure" (IWC 1994), a "system for evaluating management strategies" (ICES 1994), a "management procedures simulation" (ICCAT 2000), "management procedure approach" (Butterworth 2007), and "management strategy evaluation" or MSE (Smith et al. 1996, Butterworth et al. 2010). Although sometimes used interchangeably, MSE is a framework used to evaluate management procedures. A management procedure (Butterworth et al. 1997) is a set of pre-agreed decision rules that specify what data are to be collected and how the data are to be used to set a total allowable catch (TAC). This set of rules is to be pre-agreed upon by fishery managers, resource users, and scientists (Butterworth and Punt 1999; Parma 2002). The evaluation of alternative management procedures is typically conducted by comparing performance statistics reflecting management objectives and interest of managers, resource users and scientists (Butterworth and Punt, 1999; Parma 2002). Rather than focusing on optimality and best estimates (such as is employed in the assessment-based approach), the goal of MSE is to find robust management alternatives under different biological scenarios and to deal explicitly with the associated uncertainty.

Evolution of the Pacific halibut harvest policy

Pacific halibut in the NE Pacific was fished by Native Americans long before it started to be commercially exploited in 1888. The combination of rapid stock declines and expansion of fishing capacity, capabilities, and the spatial range of the commercial fleet motivated the signing of the halibut convention of 1923, along with the formation of what was to become the IPHC, and the start of a series of fishery regulations for the management of the halibut fishery. In the ensuing years, management of Pacific halibut has relied on different methods for assessing stock trends and status as well as different harvest policy approaches.

The first simulation-based evaluation of alternative management strategies for Pacific halibut was reported by Southward (1968). The simulation approach included biological, fishery, and management model components with the goal of comparing the relative performance of three alternative strategies for managing the fishery. The first strategy was an empirical rule based on trends in commercial CPUE and juvenile abundance, the second was a rule based on potential yield curves (fitting the Schaefer model), and the third was a rule based on yield per recruit analysis. Although not called an MSE and limited to the computing capabilities available at the time, the work included all the major elements of modern-day MSE work. The main result was that the three rules performed similarly, although the Schaefer model was the most unstable and the empirical CPUE-based rule was the cheapest of the three to implement (Southward 1968).

Up to the 1980s estimates of stock status were based on analyses of annual catch and catch-per-unit of effort (CPUE) (Sullivan and McCaughran 1993). During the early 1980s, a period of historically low biomass estimates, annual catch recommendations were calculated as a fraction of estimated annual surplus production in an effort to rebuild stocks (Deriso and Quinn 1985). The stocks were considered rebuilt by 1984 and a constant harvest rate policy has been in place since 1985. The performance of the constant harvest rate strategy was evaluated using Monte Carlo simulations of future stock trajectories (Parma 1991) and retrospective simulation analysis of past stock trajectories (Parma 1993). Alternatives to the assessment-based constant harvest rate strategy were evaluated using a simulated management procedure approach (Parma 2002). Simulations suggested that a management procedure based on a simple delay-difference model could provide stable and adequate yields and perform similarly to a strategy employing a constant harvest rate and constant spawning-biomass-per-recruit (Parma 2002). The constant target harvest rate strategy has continued to this day and is applied to annual estimates of exploitable biomass as defined by the estimated commercial selectivity from a statistical age-structured stock assessment. The target harvest rate has changed over time from a high of 0.35 in 1985 to 0.215 since 2011, except for areas of special concern (due to trends and status of indices) whose target harvest rate has been 0.161 (Hare 2011).

Current target harvest rates have been determined by simulation modeling that incorporated uncertainty in density-dependent growth responses, future levels and distribution of recruitment among areas, stock and environmental relationships, and selectivity curves (Clark and Hare 2006). Uncertainty in the annual stock assessment (other than random observation error on biomass estimates) was not incorporated in the original simulations, nor was management uncertainty such as potential differences between recommended and established catch levels (Clark and Hare 2006). A recent external review of the IPHC stock assessment and harvest policy (Francis 2008) pointed out that assuming that the realized harvest is the same as the target harvest could be potential weakness of the current harvest policy. In response to the external review, auto-correlated errors in the assessment were included in the simulations and it was reported that the effect was relatively minor and was expected to result in a more frequent triggering of target harvest rate reduction (Hare and Clark 2008). An example of realized harvest rate departures from the target harvest rates is the result of the misspecification of closed-area assessments. In summary, area-specific closed-area assessments were biased high because the main assumption, that of a closed population, was violated due to ongoing migration of halibut between regulatory areas. Misspecification in the closed-area stock assessments resulted in realized harvest rates, estimated by recent coastwide stock assessments with survey-partitioned biomass, as much as three times higher than the target in areas 2B and 2C and as low as half the target harvest rate for Area 4 during part of the last decade (Valero 2012a). Estimated coastwide realized harvest rates have increased from a low of 0.14 in 1997, the earliest year estimated by the current stock assessment, to a high of 0.32 in 2007. Following the implementation of the coastwide assessment with survey-partitioned biomass, coastwide realized harvest rates declined to 0.23, as estimated by the assessment at the end of 2010.

Another source of differences between target and realized harvest rates is due to an ongoing retrospective pattern of overestimation of biomass in halibut stock assessments dating back at least to 2004. The retrospective bias has resulted in stock assessment estimates of exploitable biomass (EBio) that show downwards revisions of biomass during successive years of up to 39% of the initial estimate (Valero 2012a). Coastwide realized harvest rates have been up to 62% higher than target harvest rates for some recent years, due in part to the retrospective pattern, and to a lesser degree to implementation errors (actual catches departing from recommendations) or adjustments such as the Slow Up Fast down (SUFD). The performance of the harvest policy relative to reference points is also affected by the retrospective pattern. The revised female spawning biomass time trajectory is estimated to have dropped below the 30% (relative to unfished) threshold for five consecutive years (2005 to 2009). Had the female spawning biomass been estimated at the time to be below the 30% threshold, a reduction in the target harvest rate as low as 0.14 would theoretically have been triggered had the current harvest control rule been followed (Valero 2012a). The pattern of consistent downward revisions of biomass and upward revision of realized harvest rates are still ongoing (no indication of stabilization of earlier biomass estimates) and the extent to which the current harvest policy is robust to the processes described above is still unknown.

Other ongoing processes could affect the performance of the current harvest policy. One is long-term and large-scale (both geographic and in the actual magnitude) changes in size-at-age. Observed size-at-age was low in the 1920s, high in the 1970s and 1980s and has been decreasing for most areas since the mid-1980s. Pacific halibut size-at-age changes have been generally attributed to changes in growth rate (Clark and Hare 2002), although a definite process behind the observed pattern there has not been found to date. Alternative processes could be responsible for the observed pattern, including methodological changes in age determination and the effect of size-selective fishing. Assumptions regarding the process or processes behind the observed changes in size-at-age can have profound implications on the performance of the stock assessment (e.g., in the effect on selectivities) and harvest policy (e.g., in the potential for density-dependent growth and status relative to reference points).

An additional aspect that can affect the performance of the current harvest policy is the spatial scale at which it is applied. The current policy was developed using simulation based on dynamics of what often referred as “core” areas: IPHC Regulatory Areas 2B, 2C and 3A. During the last decade reference points from the harvest policy have changed from a minimum biomass to a threshold ($B_{30\%}$) and limit ($B_{20\%}$) relative to unfished conditions (Clark and Hare 2006) and have changed from being applied at the regulatory area level to a coastwide level (Hare and Clark 2008).

Current assessment-based approach to derive annual catch limits

Pacific halibut stock assessments have been conducted using a coastwide model since 2006, replacing individual regulatory area closed-area assessments that were conducted between 1989 (Sullivan et al. 1990) and 2006 (Clark and Hare 2007). The coastwide model produces a coastwide estimate of exploitable biomass. Since quotas are established for each regulatory area, a method is required for dividing the coastwide biomass estimate. The current method has been to apportion the coastwide exploitable biomass estimate in proportion to the survey index, adjusted for hook competition and survey timing (Hare 2012). This method assumes that the survey index is proportional to abundance and that there are no differences in survey catchability between IPHC regulatory areas (other than the aforementioned adjustments); assumptions that are consistent with the method used to build the coastwide dataset from individual regulatory area datasets (see Clark and Hare 2007). The main steps involved in the annual process to derive catch limits are outlined in Figure 1. Since the change to coastwide assessment and survey apportionment of biomass, two IPHC sponsored Biomass Apportionment Workshops have been held (IPHC 2009, 2010, Valero and Hare 2010a) in order to provide a forum to discuss pros and cons of this apportionment method and evaluate potential alternatives. The coastwide stock assessment and survey-based partition of biomass has been accepted as a whole by the IPHC, and this approach has been used for each management cycle since 2007. In spite of this, there is ongoing discussion among the IPHC's constituency regarding the validity of its assumptions and its merits relative to alternative approaches.

Development of a management strategy evaluation for Pacific Halibut

A management strategy evaluation (MSE) framework can provide a formal way to evaluate the performance of the current harvest strategy to different types and levels of uncertainty. It can also be used to evaluate different management procedures that could be considered as alternatives to the current management approach. Decisions regarding the selection and evaluation of alternative strategies are informed by testing of alternative candidates against a series of pre-agreed performance indicators that reflect management goals. One of most important components of the MSE process is the construction of simulation models, called operating models, that describe potential past and future scenarios for the dynamics of the stock and the fishery and that includes key uncertainties. Other components of the MSE approach are a conditioning module, a projection module, and an evaluation module, as illustrated in Figure 2 and described below.

Operating models

The goal of the operating models is to describe population and fishery dynamics under alternative hypothesis and model formulations to capture the real (statistical and structural) uncertainty. One of the operating models currently in development is an expansion of the first two versions of IPHC widgets (Valero and Hare 2009, 2010a). The expanded model versions incorporate alternative migration patterns for juveniles and adults, such as structuring migration by age, sex, maturity and site fidelity. Expanded models also allow for alternative spatial structure in growth and spawning stock/recruitment relationships, as well as different selectivity and catchability types. Other operating models explicitly incorporate alternative size-at-age dynamics. The first version of operating models using alternative size-at-age dynamics was a one-area model that has been expanded to a multiple-area model with migration. Another set of operating models are based on incorporating historical data into stock assessment analysis using the Stock Synthesis framework (see next section). Operating models are currently being conditioned to different time spans of available data: recent (1996 to present; used in the coastwide current stock assessment) and historical data (allowing for a variety of different time spans to be considered, extending as far back as 1888, depending on data availability for the processes of interest); see Figures 3 and 4.

Conditioning

The goal of the conditioning component of an MSE is to condition the operating models on available historic data in order to be consistent with the historic dynamics of the stock. It is important to note that the conditioning of operating models is not the same as conducting a full stock assessment. The focus of the conditioning component is not in finding the best assessment of the stock, but rather in making sure that the operating models are consistent with historical data. This is an important distinction since operating models often include processes for which we may not have relevant data to fit. For example, we may have operating models that focus on potential climate impacts on individual growth. Even if we may not have relevant data to provide a definitive description and fit to the process we still want to have operating models that incorporate such an effect in a way that is consistent with historic data on the dynamics of the stock. In other MSE projects underway in the fisheries community, the conditioning of operating models has been done using a variety of approaches. Three alternative approaches are: 1) using recent stock assessments, 2) using all available data, and, 3) incorporating expert opinion. The choice of the type of conditioning used depends on the hypothesis to be tested and the focus of the operating model, as well as the data that the models are being conditioned upon.

The conditioning of operating models for Pacific halibut described in the previous section used SS3 (Stock Synthesis version 3). Stock Synthesis (Methot 2000, 2011) is a state of the art generalized framework for modeling fish stocks. Stock Synthesis has been extensively reviewed and widely used in the US and international fisheries community for stock assessments including tunas (Maunder and Silva 2011), flatfishes (Stewart 2008), Pacific hake (Stewart et al. 2011) and a variety of other groundfish (see Lee et al. 2011). It has the flexibility to model different types and levels of complexity of population dynamics in relationship to the quantity and quality of available data and hypotheses about the dynamics of the resource and the fishery. At this stage, the Pacific halibut population is assumed to be a single coastwide stock along the Pacific coast of the United States and Canada. The model dynamics were two-sex and used either sex specific (survey) or sex combined (commercial fishery) age compositions, depending on data availability. The modeled period includes the years 1888-2010 (i.e., up to the last year of available data). Data type and years available are summarized in Figure 4. The model used all removals from 1888 structured in four fisheries (Commercial, Sport and Subsistence, Bycatch, and Wastage) and the IPHC survey (Figs. 3 and 4). In its current version, growth was estimated internally in the model and selectivities were modeled as a function of age, allowing for changes over time to take into account changes in hook type and changes in minimum size limit in the commercial fishery. Changes in ageing methods from surface age to break and burn were incorporated into the model following methods described in Clark (2004). Commercial catchability is allowed to have a non-linear relationship with abundance but survey catchability is assumed constant and proportional to abundance. A Beverton-Holt stock recruitment relationship is used, with a fixed and relatively high steepness value (0.85) and a relatively large variability allowed to recruitment deviations (sigmaR = 0.6).

The model produced good fits to historical and recent available data under the specifications described above. Fits to historically observed commercial weight per unit of effort (WPUE) and survey WPUE are shown in Figures 5 and 6, respectively. Model fits to commercial age composition for both sexes combined from 1935 to 1970 are shown in Figure 7 (see Valero 2012c for additional figures) and fits to sex-specific survey age composition from 1997 to 2010 are shown in Figure 8. Time series of recruitment estimates and 95% confidence intervals are shown in Figure 9; the largest estimated recruitment year corresponds to 1987, followed by 1983 and 1977. The Beverton-Holt spawning stock recruitment relationship is currently used in the model (see Valero 2012c for details), but additional spawning stock recruitment relationships are under analysis, including other functional forms such as Ricker, environmental covariates, and different recruitment erasEstimated time series of female spawning biomass with 95% confidence intervals are shown in Figure 10. The estimated unfished level and its confidence interval are in the range of recent values used as part of the current harvest policy, although the later have been based on estimates of recent recruitment (from 1996 onwards, excluding the most recent estimated years) and a spawning biomass per recruit ratio from an unproductive regime (see Hare 2012). The time series of female spawning biomass estimated here is similar in its trajectory to that estimated by Parma (2002) for years 1974 to 2000 (Fig. 11). The different timing of the estimated SBio increase between models could be attributable to the treatment of changes from J to C hook in the early 1980s and its effect on assumed selectivity and catchability of commercial fishing gear. Parma (2002) also conducted 10-year projections, which are consistent in trajectory and biomass levels to the estimates of the conditioning model (Fig. 11). Time series of SBio estimates from the conditioning model and recent stock assessments conducted between 2006 and 2011 have similar declining trajectories for the earliest estimated years of recent assessments. However, the last estimated years of each recent assessment indicate a reversing SBio trend and a rapid estimated increase, which contrast with the consistent declining trend estimated by the conditioning model (Fig. 11). The five-year projections following recent assessment years also contrast with downward revisions and continuation of declining SBio trend in subsequent recent stock assessments, as described in Valero (2012b,c); the downwards revised trend for earlier estimated years is close to that estimated by the conditioning model fits and those projected by Parma (2002) (Fig. 11). Similar patterns of differences emerge when comparing times series of total biomass of halibut ages 8 and older (8+), as estimated by the conditioning model and recent stock assessments (Fig. 12). Although estimated 8+ time series are similar in trajectory and biomass levels for the early part of recent assessments, the conditioning model estimates a continuing decline while recent assessments estimate a change in trend followed by a rapid increase that is revised downwards in subsequent assessments.

Projection

The goal of the projection component is to re-create all steps involved in the annual management cycle (Fig. 2). This includes how catches are taken from the conditioned operating models (as described in previous sections), what data to collect, how to use the data to determine stock status and trends, and how to determine next year catches and any other relevant management actions. For evaluation purposes this process is not only repeated over several years during a pre-specified projection time, but it is also repeated many times to incorporate different types of uncertainty in the process. The approach used here takes advantage of the parametric bootstrapping component of the Stock Synthesis model. This component allows one to simulate data sets that are generated based on characteristics of the real data and the likelihood functions used in the model. This approach has been used recently to explore the ability of different stock assessment models to estimate natural mortality (Lee et al. 2011).

Evaluation

The evaluation component summarizes results of simulations based on performance indicators of alternative management strategies. Performance indicators reflect management goals and will be instrumental in the evaluation, comparison and eventual selection of alternative management strategies. Common indicators include measures of yield, conservation risk, stability and others. Additional specific performance indicators could be identified via consultation of stakeholders involved in the process.

Summary and future steps

The development of an MSE is a time-intensive enterprise that requires involvement, consultation, and agreement among all interested parties, from scientist, managers and resource users. The development and implementation of MSE is an active area of work worldwide that typically involves the steps listed below (modified from Kolody and Anganuzzi 2010), although not necessarily always in the following order, with the steps frequently being iteratively revised. Below each step is a brief statement regarding the present state of completion of each step with respect to the current MSE:

1) *De ne objectives and performance metrics*.
    Where we are now: Objectives and metrics are only available for the *status quo* harvest strategy. The level and type of stakeholder participation to define objectives and metrics still need to be discussed and determined.
2) *Develop candidate harvest strategies and harvest control rules*.
    Where we are now: Current candidates need to be discussed and expanded.
3) *Develop operating models and condition them to historic data.*
    Where we are now: A set of operating models is under development and conditioning.
4) *Simulation test of candidate harvest strategies.*
    Where we are now: Awaiting previous steps.
5) *Select harvest strategy*.
    Where we are now: Awaiting previous steps.
6) *Implement harvest strategy.*
    Where we are now: Awaiting previous steps.

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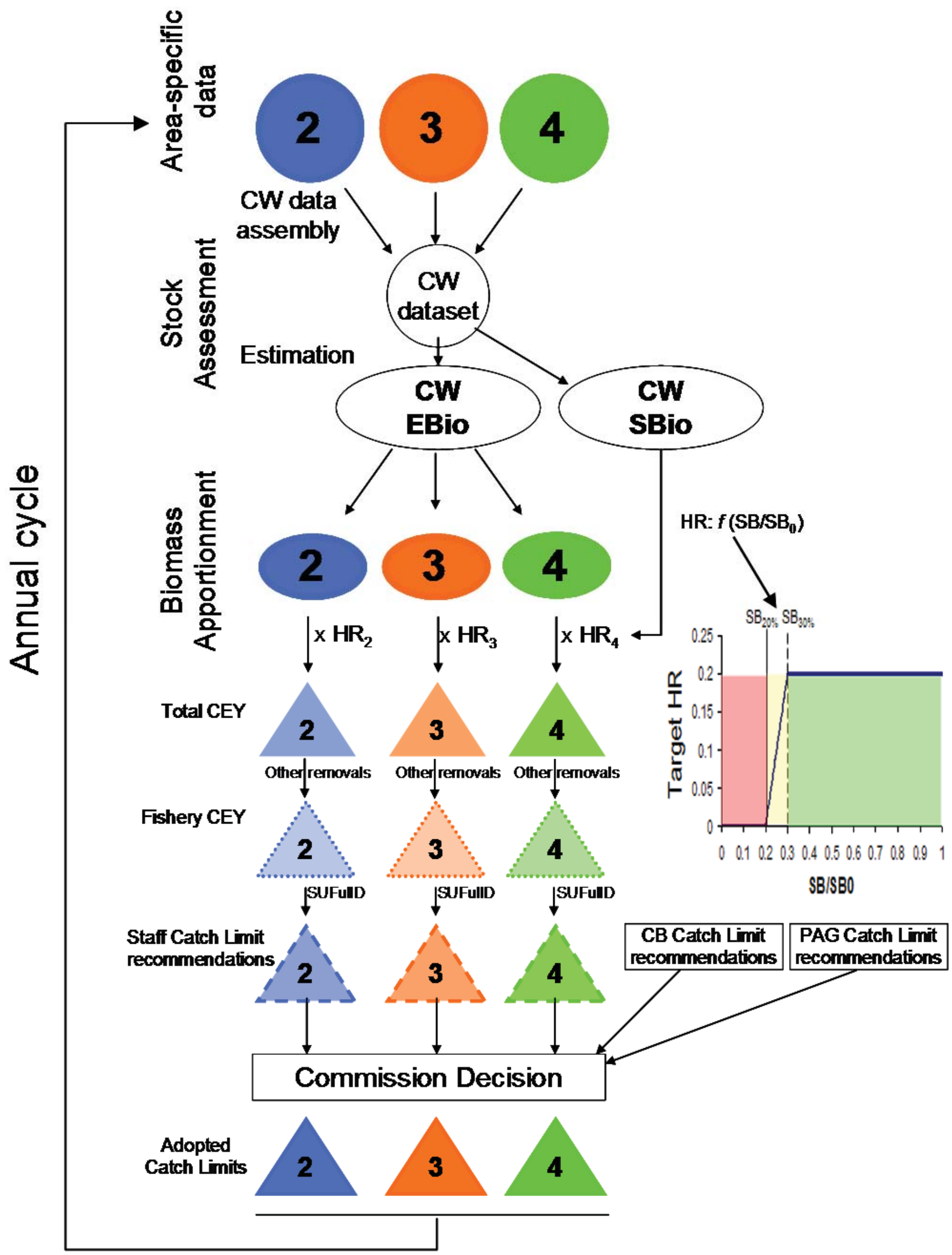

Figure 1. Schematic representation of current annual cycle to derive CEY recommendations based on a coastwide (CW) assessment and a survey-based apportionment of exploitable biomass (EBio). "SB": female spawning biomass; "SB0": estimated un shed SBio; "$SB_{20\%}$ and "$SB_{30\%}$": 20% and 30%, respectively, of estimated un shed SBio; "CB": Conference Board; "PAG": Processor Advisory Group; "SUFullD": Slow Up, Full Down adjustment. Ovals represent biomass estimates, other area-speci c data are used to assemble the CW dataset, such as length and age compositions, etc; triangles represent CEY estimates. The schematic is simpli ed to three hypothetical areas.

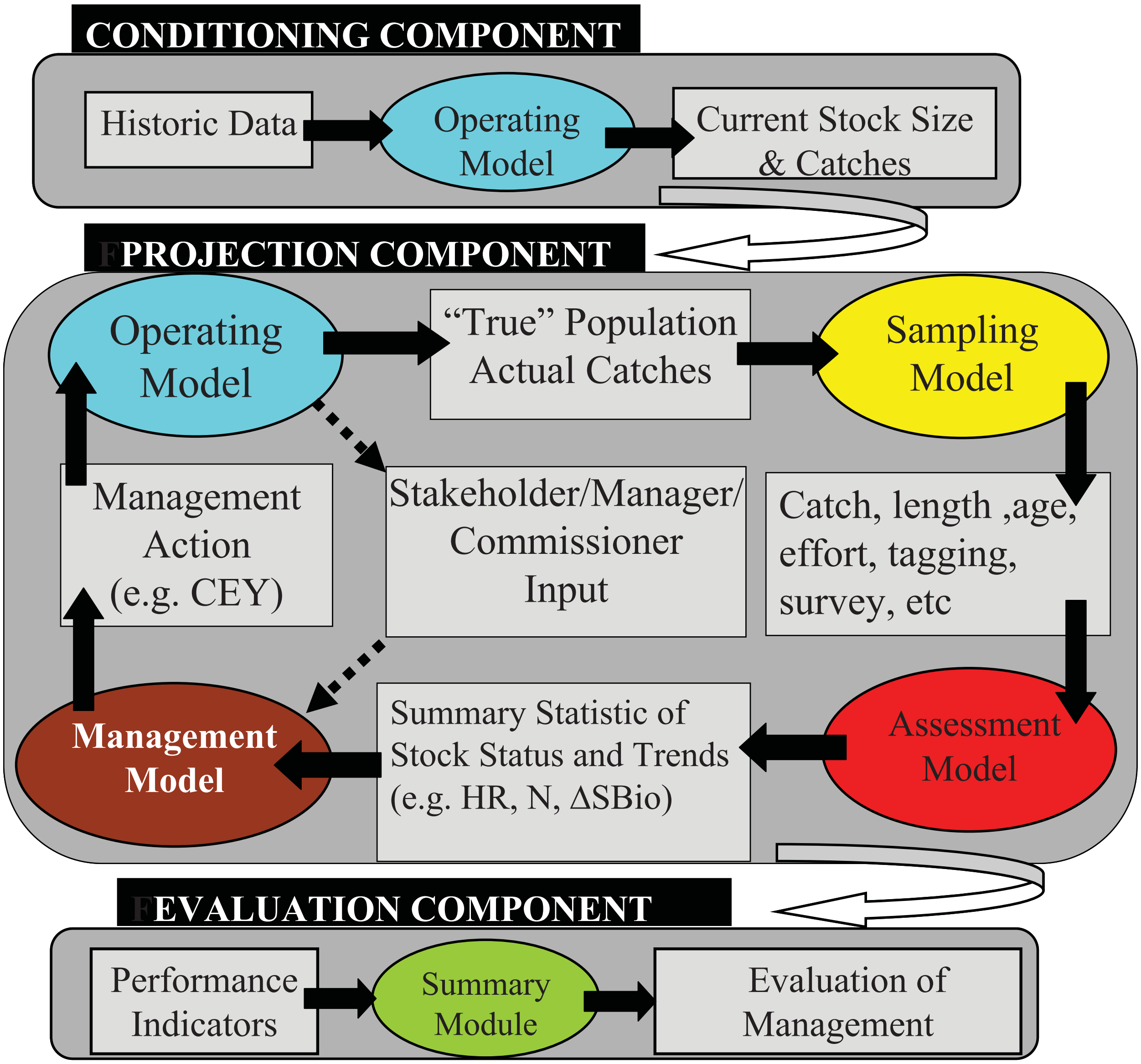

Figure 2. Schematic of the main components of a Management Strategy Evaluation (MSE).

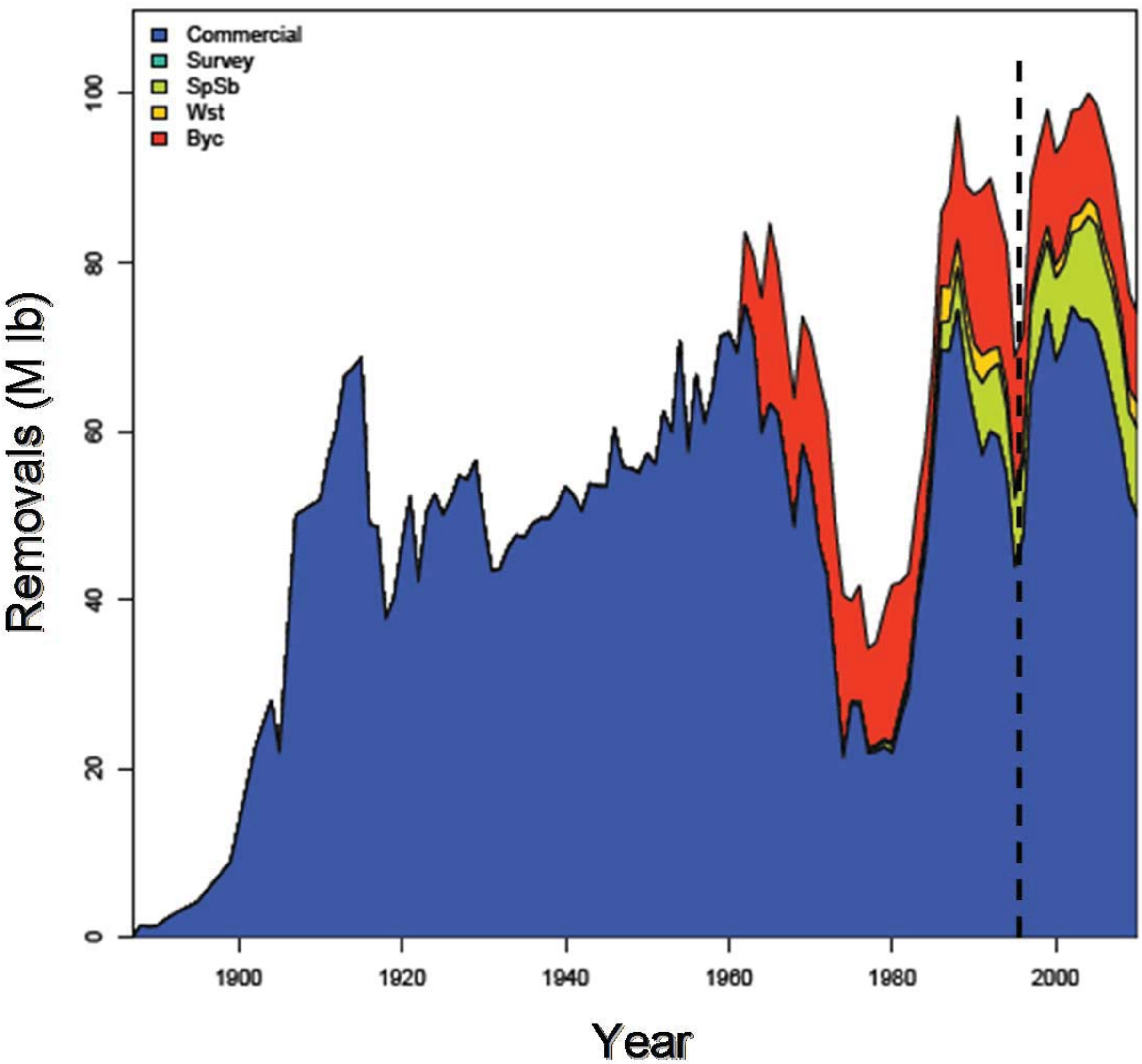

Figure 3. Coastwide total Paci c halibut removals from the beginning of the commercial shery in 1888 to 2010 in millions of pounds (M lb). Removal components are Commercial, Survey, Sport and Personal (SpSb), Wastage (Wst), and Bycatch (Byc). All removals are used for the historical conditioning of the model, the vertical dashed line is year 1996 which is the beginning of the data used for the current IPHC stock assessment.

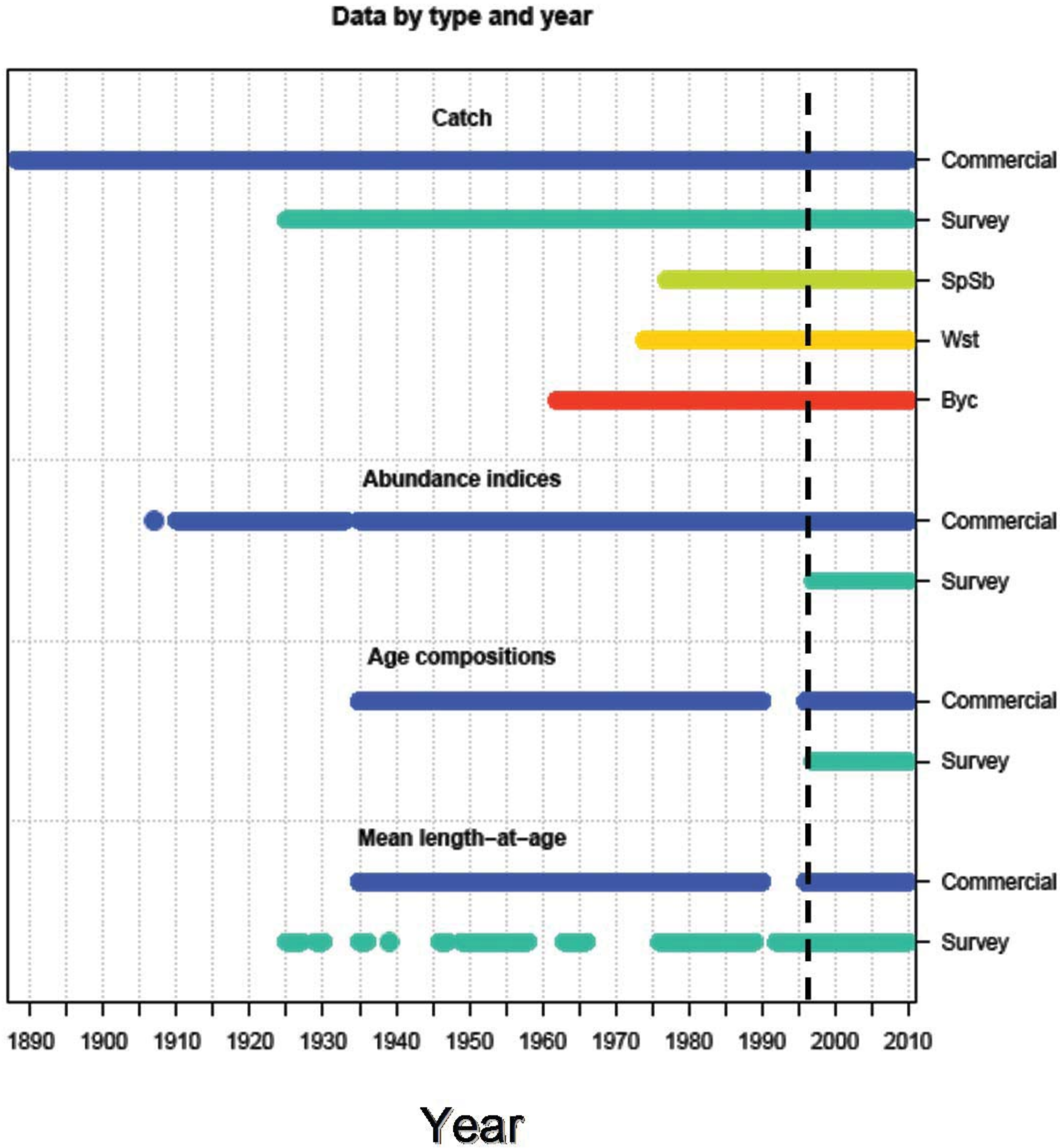

Figure 4. Overview of data sources used in the conditioning model for Paci c halibut, 1888 to 2010. All available data were used for the historical conditioning of the model, the vertical dashed line is year 1996 which is the beginning of the data used for the current IPHC stock assessment.

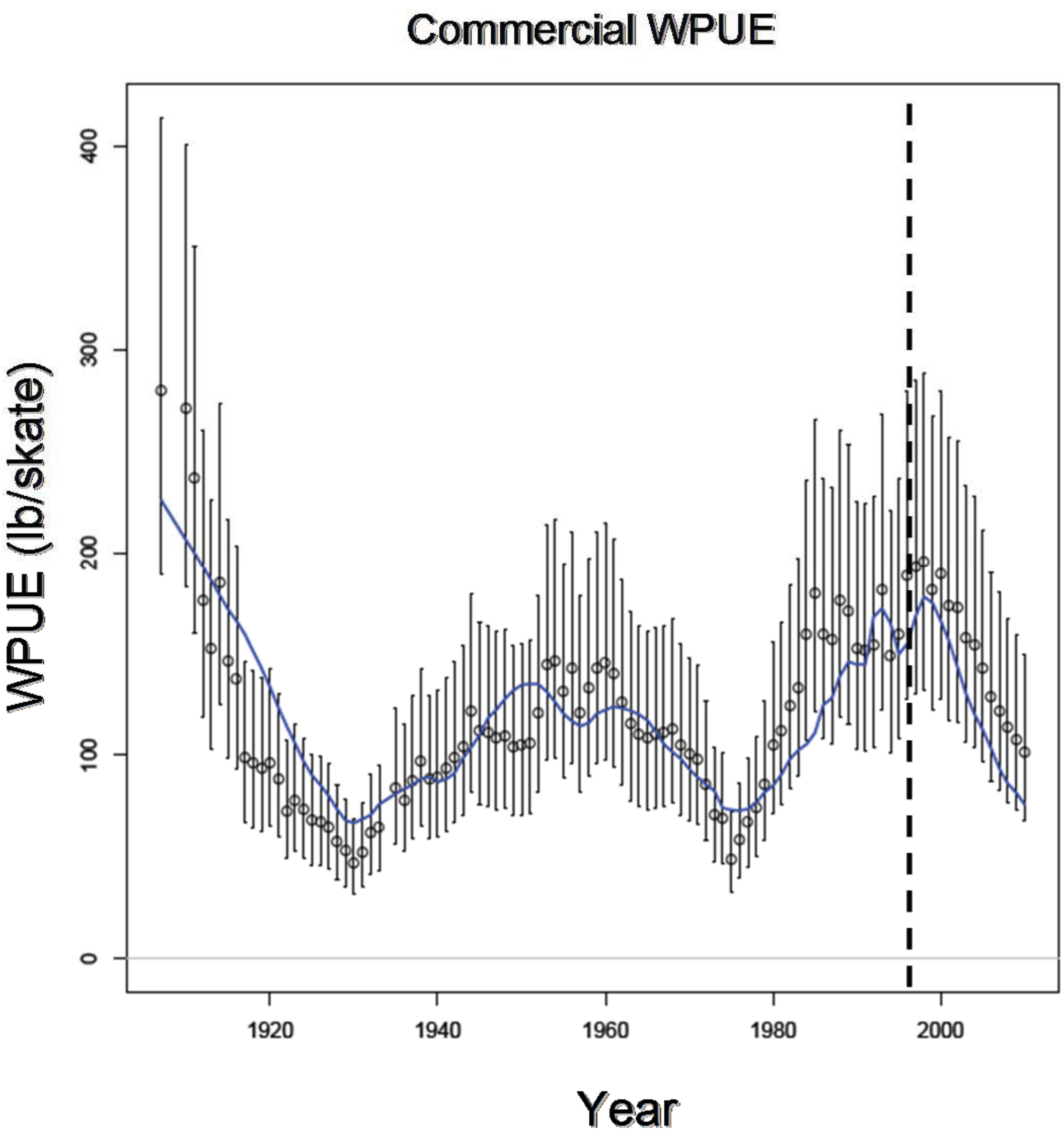

Figure 5. Commercial Paci c halibut weight per unit of effort (WPUE) in pounds per skate and conditioning model t (blue line). All available WPUE data were used for the historical conditioning of the model presented here; the vertical dashed line is year 1996 which is the beginning of the data used for the current IPHC stock assessment.

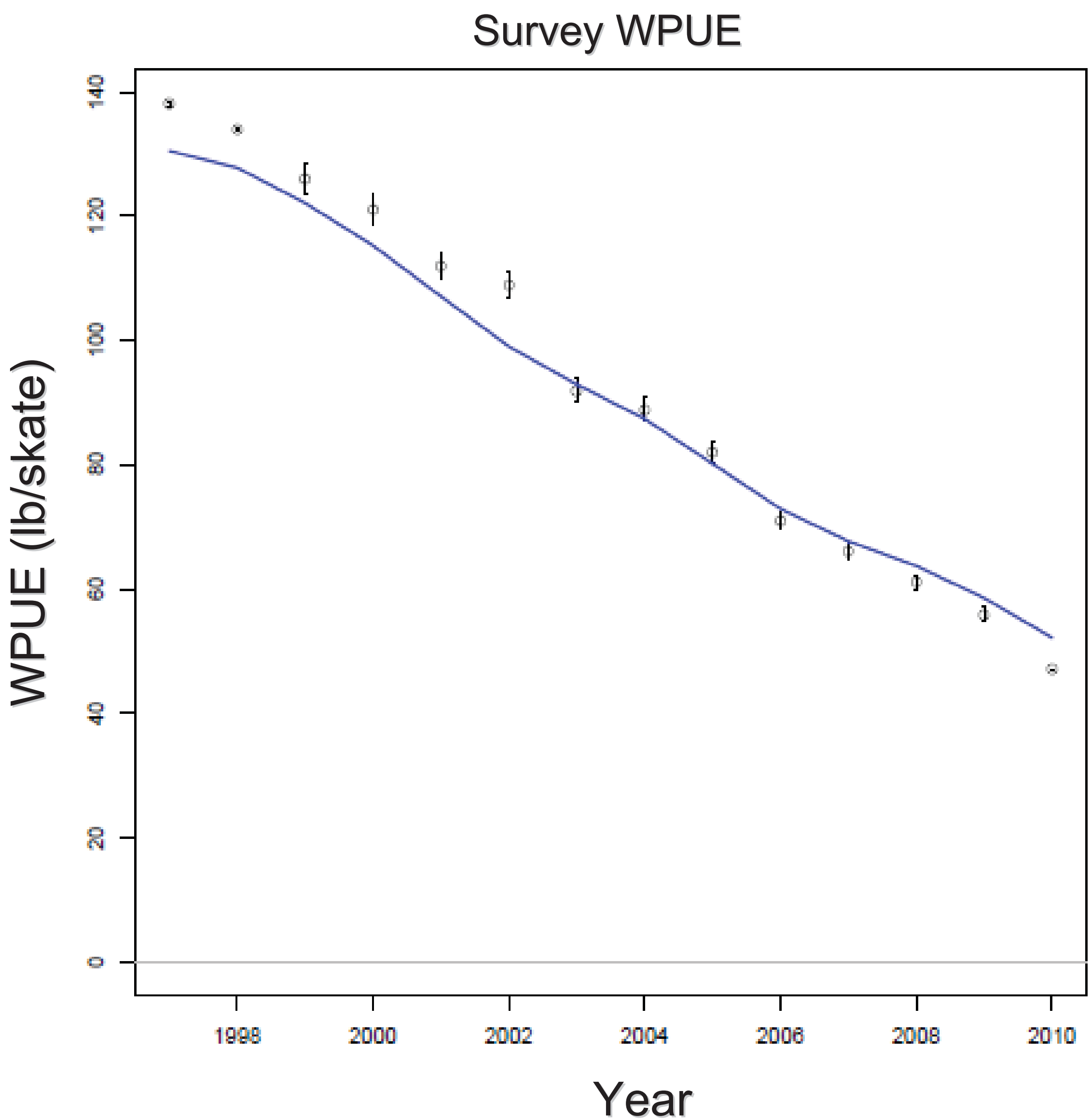

Figure 6. Survey weight per unit of effort (WPUE) of Paci c halibut in pounds per skate and current conditioning model t (blue line).

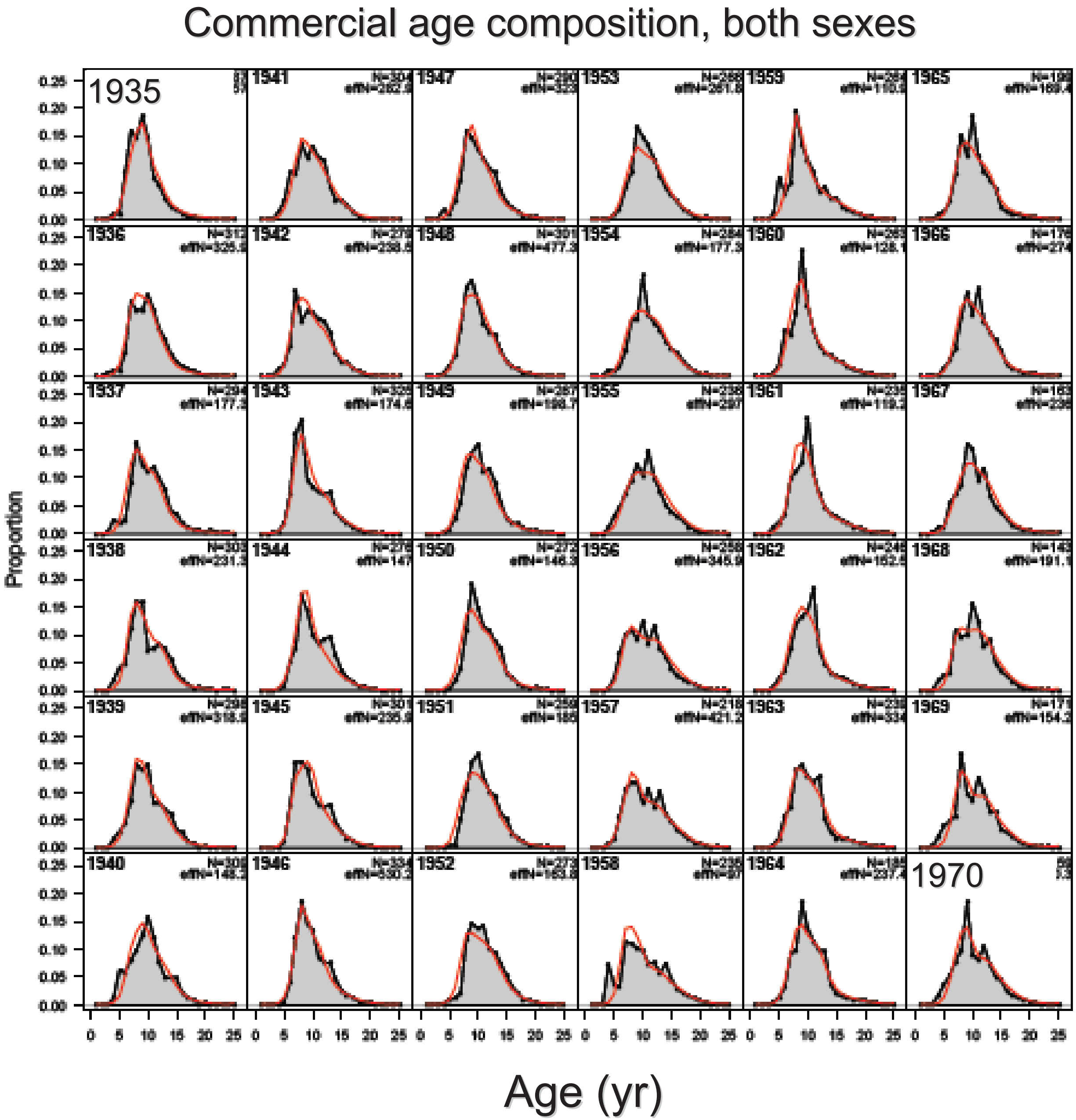

Figure 7. Conditioning model fit (red line) to the observed Pacific halibut commercial age composition data from 1935 to 1970, both sexes combined. Additional fits in Valero (2012c).

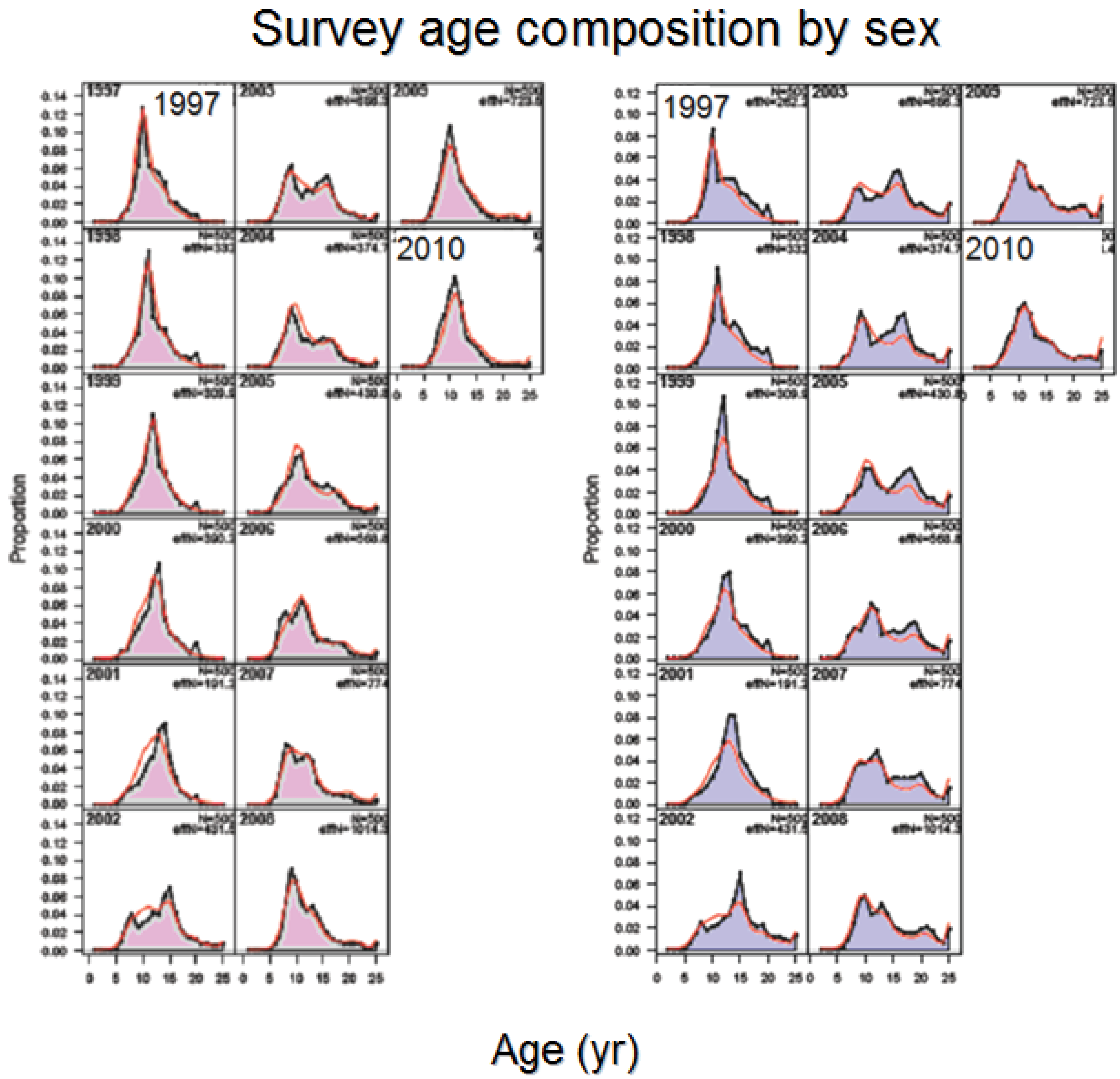

Figure 8. Conditioning model t (red line) to the observed Paci c halibut survey age composition data for females (pink, left panels) and males (blue, right panels) from 1997 to 2010.

Figure 9. Time series of age 0 Paci c halibut recruit estimates with 95% con dence intervals (CI).

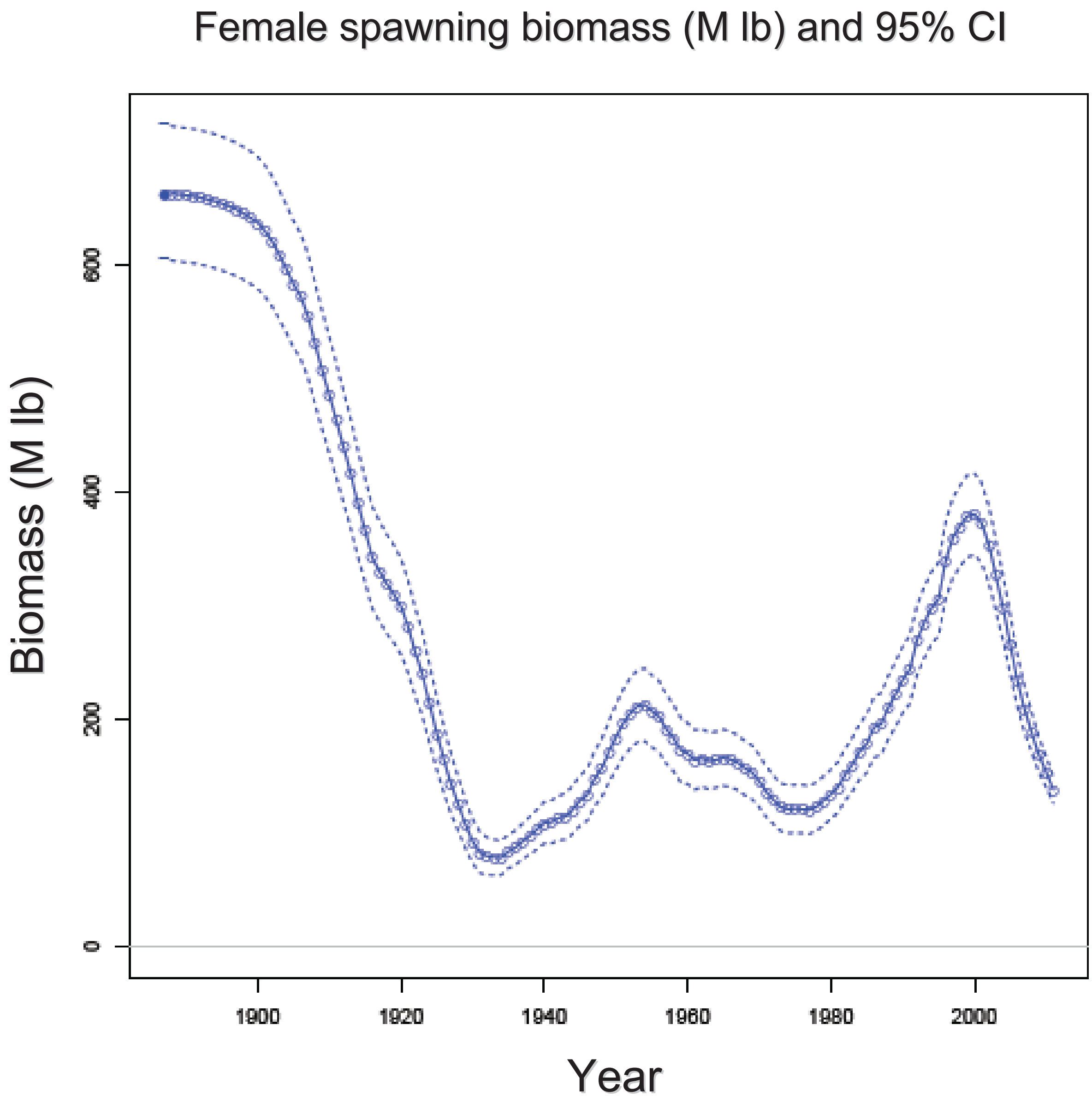

Figure 10. Estimated Paci c halibut female spawning biomass in millions of pounds (M lb) with 95% con dence intervals.

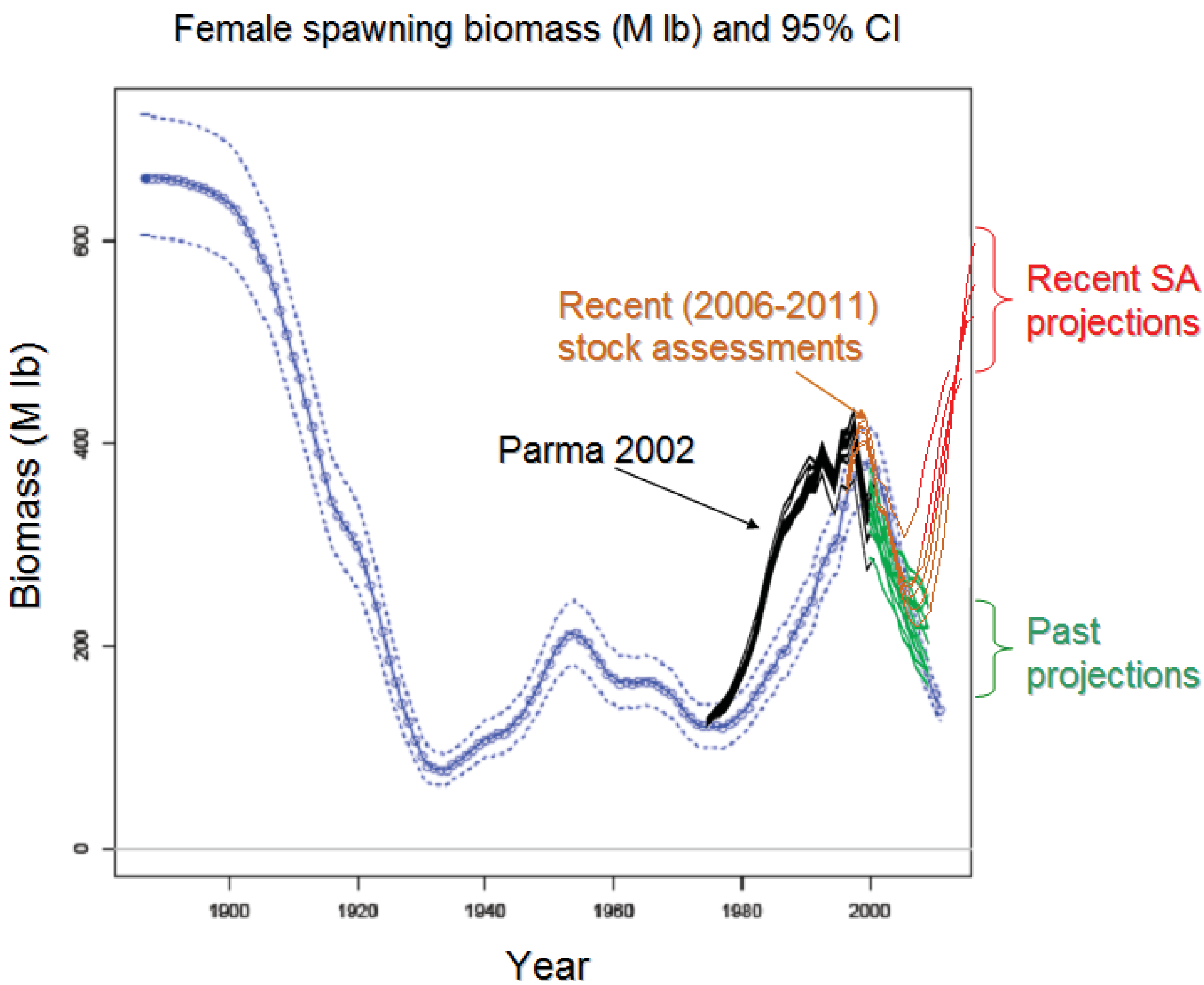

Figure 11. Estimated Paci c halibut female spawning biomass (blue line with open circles) in millions of pounds (M lb) with 95% con dence intervals. Black lines are female spawning biomass estimates between 1974 and 2000 and green lines are subsequent 10-year projections conducted by Parma (2002). Brown lines are female spawning biomass estimates between 1996 and 2011 as estimated by IPHC stock assessments at the end of 2006, 2007, 2008, 2009, 2010, and 2011 and the subsequent retrospective downward revisions through the years 2006 to 2010. Red lines are 5-year projections conducted at the end of each assessment year. Time series were obtained from Clark and Hare (2006, 2008), Hare and Clark (2008, 2009), and Hare (2010, 2011, 2012). See electronic version for colors, and Valero (2012c) for additional gures.

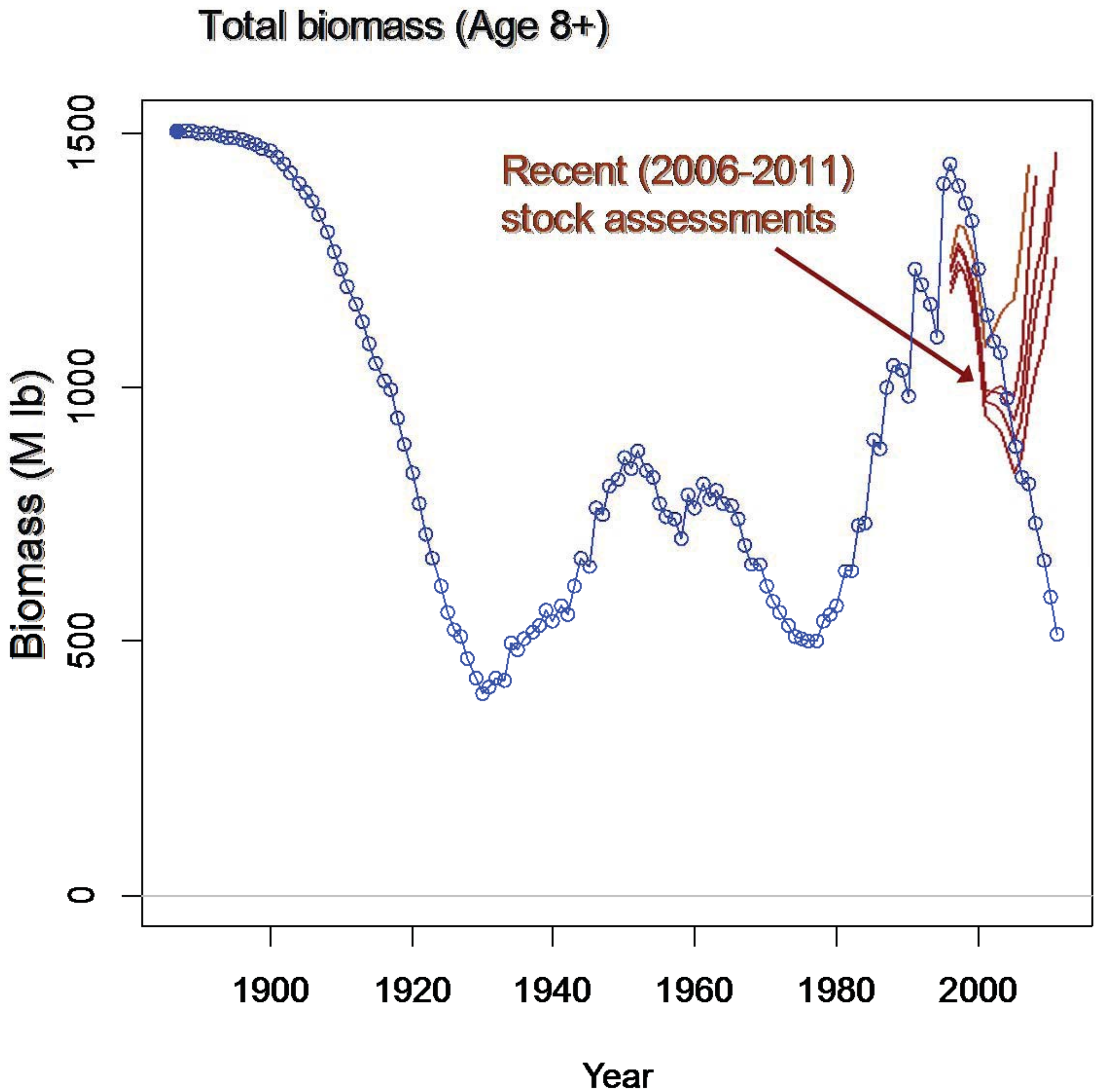

Figure 12. Estimated total biomass of Paci c halibut age 8 and older (8+, blue line with open circles) in millions of pounds (M lb). Brown lines are age 8+ biomass estimates between 1996 and 2011 as estimated by IPHC stock assessments at the end of 2006, 2007, 2008, 2009, 2010, and 2011 and the subsequent retrospective downward revisions through the years 2006 to 2010. Time series for recent assessments were obtained from Clark and Hare (2006, 2008), Hare and Clark (2008, 2009), and Hare (2010, 2011, 2012). See electronic version for colors.

Assessment of the Pacific halibut stock at the end of 2011

Steven R. Hare

Abstract

Since 2006, the IPHC stock assessment model has been fitted to a coastwide dataset to estimate total exploitable biomass. Coastwide exploitable biomass at the beginning of 2012 is estimated to be 260 M lbs, down from the end of 2010 estimate of 317 M lbs. The model variant chosen for the assessment this year differs from the production version of the past few years. Termed "WobbleSQ" (as opposed to the earlier "Trendless"), its treatment of survey q (catchability) is the only difference between the two models. The downward revision reflects weaker recruitment of the 1989-1997 cohorts, revised WPUE indices based on late-season data in 2010, and the ongoing retrospective behavior shown in the model. Female spawning biomass is estimated at 319 million pounds at the start of 2012, a decline of nearly 9% over the beginning of 2011 estimate of 350 million pounds. The female spawning biomass shows somewhat lesser retrospective behavior, possibly lending credence to our belief that the ongoing decline in size at age, which strongly affects selectivity-at-age, is one of the root causes of the retrospective behavior. Trawl estimates of abundance are similar to assessment estimates in most areas, and also provide evidence that while exploitable biomass and numbers continue to decline, the total biomass and number of halibut remains level, or slightly increasing. The coastwide exploitable biomass was apportioned among regulatory areas in accordance with survey estimates of relative abundance, modified by adjustments for hook competition and survey timing. Weighting of the survey indices follows a Kalman filter analysis, resulting in weights of 75:20:5 for the last three years.

Introduction

Each year the International Pacific Halibut Commission (IPHC) staff assesses the abundance and potential yield of Pacific halibut using all available data from the commercial and sport fisheries, other removals, and scientific surveys (Appendix A). A biologically determined level for total removals from each regulatory area is calculated by applying a fixed harvest rate to the estimate of exploitable biomass in that area. This level is called the "constant exploitation yield" or CEY for that area in the coming year. The corresponding level for catches in directed fisheries subject to allocation is called the fishery CEY. It comprises the commercial setline catch in all areas plus the sport catch in Area 2B, and the sport plus ceremonial and subsistence catches in Area 2A. It is calculated by subtracting from the total CEY an estimate of all unallocated removals - bycatch of halibut over 26 inches in length (hereafter, "O26"), wastage of O26 fish in the halibut fishery, fish taken for personal use, and sport catch except in Areas 2A and 2B. In 2010, a change was made in the method by which under 32 inch (U32) bycatch and commercial wastage was accounted for in determination of fishery CEY (Hare 2011a). Until 2010 all U32 bycatch and wastage mortality (BAWM) had been accounted for in the determination of the target harvest rate, which had been set at 0.20 for Area 2A, 2B, 2C and 3A and 0.15 in area 3B and 4. The new accounting methodology directly deducts BAWM between 26 and 32 inches (O26U32) from total CEY to determine fishery CEY. The new target harvest rates accompanying this change were set at 0.215 and 0.161, replacing the old values of .20 and 0.15, respectively. Staff recommendations for catch limits in each area are based on the estimates of fishery CEY but may be higher or lower depending on a number of statistical, biological, and policy considerations. Similarly, the Commission's final quota decisions form the management targets for the coming year and are based on the staff's recommendations but may be higher or lower.

For many years, the staff assessed the stock in each regulatory area by fitting a model to the data from that area (Appendix B). This procedure relied on the assumption that the stock of fish of catchable size in each area was closed, meaning that net migration was negligible. A growing body of evidence from both the assessments (Clark and Hare 2007) and a mark-recapture experiment (Webster and Clark 2007, Webster 2010) showed that there is a continuing and predominantly eastward migration of catchable fish from the western area (Areas 3 and 4) to the eastern side (Area 2). The effect of this unaccounted for migration on the closed-area stock assessments was to produce underestimates of abundance in the western areas and overestimates in the eastern areas. To some extent that had almost certainly been the case for some time, meaning that exploitation rates were well above the target level in Area 2 and a disproportionate share of the catches had been taken from there.

In order to obtain an unbiased estimate of the total exploitable biomass (EBio), beginning with the 2006 assessment, the staff built a coastwide data set and fitted the standard assessment model to it. Exploitable biomass in each regulatory area was estimated by partitioning, or apportioning, the total EBio in proportion to an estimate of stock distribution derived from the IPHC setline survey catch rates (weight per unit effort, or WPUE). Specifically, an index of abundance in each area was calculated by weighting survey WPUE by total bottom area between 0 and 400 fm (Hare et al. 2010). The logic of this apportionment is that survey WPUE can be regarded as a fishery-independent, consistent and relatively unbiased index of density, so multiplying it by bottom area gives a quantity proportional to total abundance. Beginning in 2009 two adjustments to the index for each area, one based on hook competition and the other on survey timing, were computed for use in biomass apportionment (Webster and Hare 2011). The staff's Catch Limit Recommendations are based on use of both adjustments. New in 2010 was a change to the weighting which has been used for the last several years of survey WPUE. Based on a statistical analysis of relative variability within a year compared to variability between years (Webster 2011), the new weighting places far more emphasis on the most recent year than was the case previously. The new "Kalman" weights are in the ratio of 75:20:5 for the past three years WPUE values (after adjusting for hook competition and survey timing). The estimated proportion in each area is then the adjusted and weighted index value for that area divided by the sum of the adjusted and weighted index values.

An alteration to the method by which individual regulatory area data are weighted to produce the coastwide dataset was implemented this year. Two types of data weighting are used, depending on the data type: "area-weighting" and "abundance-weighting" (Clark and Hare 2007). Area weighting uses the relative amount of bottom area to weight the individual datasets; WPUE time series are an example of data for which area-weighting is appropriate. Abundance weighting refers to the weighted-average of area specific data with weights computed as bottom area times survey NPUE (number of fish per unit effort). Age/sex compositions and mean length at age/sex are data for which abundance-weighting is appropriate. Until this year, all weighting used the 0-400 fm bottom areas and unadjusted survey NPUEs. This year, four different combinations of bottom area and survey adjustments were used, each matched to the apportionment choices used at the estimation of regulatory area EBio distribution stage (for determination of total CEY). The apportionment scenarios involved using either 0-400 fm or 20-275 fm definitions of bottom area, as well as using (or not using) the survey hook correction and survey timing adjustments. The differential weightings produce coastwide datasets that differ slightly and therefore produce slightly different model fits. The output of greatest concern – EBio – varied by a maximum of 1-2% among the different data weightings. The weighting, and that used in the Catch Limit Recommendations, is that adopted by the Commission in 2010 and uses the 0-400 fm bottom area definition and averaged survey WPUE adjusted for hook competition and survey timing.

Changes to the assessment and apportionment in 2011

The following summarizes changes, additions, and updates to the 2011 assessment and apportionment procedures, compared to the previous halibut assessment (Hare 2011b)

- 2011 survey, commercial, bycatch, sport, personal use, and wastage data added
- The Area 2B survey WPUE was modified slightly by removing, from the mid-1990s, stations on Dogfish Bank, which are outside the area where the current survey design is implemented (Webster and Hare 2012)
- Swept area estimates of Total (TBio) and Exploitable Biomass (EBio) from independent trawl surveys are updated for several regulatory areas.
- A definition of bottom area, reflecting the present survey design, of 20-275 fathoms was used as an alternative apportionment scheme
- Weighting of the regulatory area input datasets in constructing the coastwide dataset now reflects the combination of WPUE adjustments and choice of bottom area used for different apportionment schemes

Observations from the survey, commercial and other fisheries

The IPHC collects data from a variety of sources to characterize the fishery, status and population trends in all regulatory areas, and assist in fitting a population assessment model. Some of the more important datasets are summarized herein.

Halibut removals

Total removals from the halibut populations come from five categories: commercial catch (IPHC survey catch is included in this category), sport catch, bycatch (from a variety of fisheries targeting species other than halibut), personal use, and wastage from the commercial fishery. Bycatch and wastage are subdivided into O26 and U26 components as the U26 components are not used for purposes of determining fishery CEY (they are factored into the harvest rate). Detailed descriptions of each category are contained in the Fishery Removals section of the annual Report of Assessment and Research Activities (Gilroy et al. 2012, Gilroy and Hare 2012, Williams 2012a,b,c). The 2011 regulatory area total removals are illustrated in Figure 1, coastwide total removals from 1935 to 2011 are illustrated in Figure 2, and regulatory area total removals for 1974-2011 are illustrated in Figure 3 (and listed in Appendix Tables A1-A8). On a coastwide basis, total removals are at their lowest level since 1984 and commercial removals at their lowest point since 1983. For temporal context, total removals are about 40% below the peak of the 1990s and about double the lowest value seen in the late 1970s. The pattern of changes between the mid-1980s removals and 2011 removals has been quite different among regulatory areas, however.

De nition of bottom area

The definition of halibut habitat is important to the process of apportioning coastwide biomass. It also plays a role in weighting various regulatory area datasets to construct the coastwide dataset used in fitting the stock assessment (Clark and Hare 2007). Until 2009, halibut habitat was defined as all bottom area between 0 and 300 fathoms. While the setline survey restricts stations to a range of 20-275 fm, the mean density estimates are applied to the larger habitat definition. A recent review of commercial landings revealed that commercial fishing for halibut is increasingly operating in waters deeper than 300 fm (Hare et al. 2010). Correspondingly, beginning in 2010, staff expanded the definition of halibut habitat to 400 fm. In 2009, for the first time, the Area 4 island stations (termed Area "4I") were indexed separately from the Area 4D edge and the Area 4 continental shelf. However, as the station density differs between the Pribilof Island stations (termed "Area 4IC") and the St. Matthews Island stations (termed "Area 4ID"), they are now indexed separately. It is conceivable that applying density estimates from the narrower, surveyed range of 20-275 fm to the broader, defined habitat, range of 0-400 fm results in a bias that differs by area. Staff designed and conducted an expanded survey in Area 2A in 2011 to better understand the operational constraints involved with operating the standard survey in both shallower (10-20 fm) and deeper (20-275 fm) waters (Webster et al. 2012). The bottom area computations and totals are described in Hare et al. (2010) and the square nautical miles of habitat are listed in Table A9.

Treatment of Area 4CDE

Due to its large size and relatively low density of halibut, Area 4CDE does not have a grid of setline survey stations across its entire range. Since 2000, the IPHC setline survey has included 48 stations along the 4D Edge at depths between 75 and 275 fm. Since 2006, a total of 29 stations have been surveyed annually around the Pribilof Islands and St. Matthew Island. Extensive use is also made of the data from the NMFS annual Eastern Bering Sea trawl survey. Finally, a unique grid survey, comprised of 82 stations including matching a subset of the NMFS trawl survey stations, was carried out in 2006 over the southern Eastern Bering Sea shelf (Soderlund et al. 2007). Finally, a unique grid survey, comprised of 82 stations was carried out in 2006 over the southern Eastern Bering Sea shelf (Soderlund et al. 2007).

To construct a comprehensive and representative dataset for Area 4CDE, five subareas are indexed and then weighted by bottom area to compute indices of interest, similar to those computed for the other regulatory areas. The 4D Edge, with 48 setline survey stations, covers 15,313 nmi^2. Beginning in 2009, the 4CDE island stations were used to index the bottom area around the islands, and are separated into two groups. The first are the stations around the Pribilof Islands, operationally (though not officially) referred to as Area 4IC, which comprise 2,094 nmi^2. The other stations, around St. Matthew Island are operationally referred to Area 4ID and comprise 1,925 nmi^2. The reason for separating the groups of islands is that the station density differs; Area 4IC islands are on an approximately 7 nmi^2 grid, while the Area 4ID stations are on a 10 nmi^2 grid. The Bering Sea flats comprise the remainder of the Area 4CDE and, as of 2009, extend northwards to 65.5°N - though constrained on the western boundary by the International dateline. This region is operationally (again, not officially) split into Area 4N, which represented 59,499 nmi^2 and Area 4S, which represents 141,103 nmi^2. The areas differ slightly from the 2009 values as a result of the new NMFS northern shelf survey (discussed below). The boundaries for the five Area 4CDE areas are illustrated in Figure 4. Density estimates for the five areas all rely on surveys - Areas 4D

Edge, 4IC and 4ID on the IPHC setline survey; Areas 4S and 4N on trawl surveys as discussed in the next section.

NMFS and ADF&G trawl surveys

Bering Sea

Every year, the IPHC places a sampler aboard the National Marine Fisheries Service (NMFS) Eastern Bering Sea (EBS) groundfish/crab trawl survey. The sampler collects biological data on the halibut catches, taking lengths of almost all halibut caught and selecting a subsample for aging. The 2011 effort is described in Sadorus and Lauth (2012). The catch rate of halibut (all sizes) on the NMFS EBS trawl survey is illustrated in Figure 5. Due to the high cost, and very low catch rate, of setline surveying halibut in the EBS, the IPHC does not conduct the Standardized Stock Assessment (SSA) grid survey in that region. While the IPHC survey does operate along the Area 4D shelf edge, that region is not indicative of densities and trends across the broad shelf. For the purposes of apportionment, it is vital that a measure of density for the EBS shelf be derived each year, and the NMFS groundfish trawl survey is leveraged to allow just such an estimate. The traditional NMFS survey (i.e., as operated from 1982-present) generates swept area estimates of abundance for the southern part of the EBS shelf (equivalent to operational IPHC area 4S). In 2006, the IPHC added 100 extra stations to the SSA grid survey and placed these across the shelf in conjunction with a subset of the NMFS stations to get an estimate of shelf-wide density (Soderlund et al. 2007). In that year, mean density was estimated to be 18.1 pounds per standardized survey skate. It is important to note that the value of 18.1 represented a weighted average of a value of 16.8 lbs for the shelf and 76 lbs/skate for the 4I stations. Starting in 2009, we have used the value of 16.8 lbs/skate as the standard O32 halibut density for Area 4S in 2006. Beginning in 2010, Area 4S comprises the part of the shelf covered by the traditional NMFS EBS shelf survey (see Fig. 4) and thus includes the southern parts of IPHC Areas 4D and 4E. This differs from the definition of Area 4S utilized in 2009. The reason for the change is that starting in 2010 the NMFS expanded the EBS trawl survey north to 65.5 °N and covering the entire remainder of the EBS shelf. Part of the expanded NMFS survey region was previously included with Area 4S but is now included as part of Area 4N (discussed below).

The 2006 setline estimate of Area 4S density is tied to the NMFS trawl survey to provide an annually varying estimate based on the following approach. From the NMFS trawl survey we obtain swept-area estimates of abundance at length. We then apply the stock assessment estimated survey selectivity at length schedule to the full catch to provide an index of survey catch rate, comparable to the SSA survey fishing gear. Figure 6 illustrates how the length frequency distribution resulting from this treatment of trawl survey data compares to the actual length frequencies collected in the 2006 IPHC special EBS setline survey. In this manner we are able to obtain, for a small fraction of the cost it would take to survey the southern EBS with a setline survey, a highly reliable index of halibut abundance across the EBS flats. Figure 7 provides an illustration of the time trend in abundance estimated from the trawl survey. In 2008, the index was at its lowest point since the mid-1980s, but the subsequent two years showed an increase of more than 50% over the 2008 value, before declining 20% this year. Figure 8 provides an illustration of the size composition of the Area 4S EBio. The index of total halibut biomass has been increasing steadily since 2002, and had reached its highest level in the history of the trawl survey in 2010, before dropping 4% in

2011. The length frequency data indicate very large numbers of U32 fish across the southern EBS shelf (Fig. 9).

In 2009, the EBS shelf area north of 61°N was added to the definition of halibut habitat in Area 4CDE. However, as this northern shelf undoubtedly has a different (i.e., much lower) halibut density than the southern shelf, a different means of estimating density needed to be established. Fortunately, there has been an approximately triennial trawl survey, conducted in a similar manner to the 4S survey with a similar net, in the greater Norton Sound area since 1976. The survey was conducted by NMFS until 1991 and since then by the Alaska Department of Fish and Game (ADF&G). In all, there have been surveys conducted in 1976, 1979, 1982, 1985, 1988, 1991, 1996, 1999, 2002, 2006, and 2008. There has been no formal analysis of the halibut data from the survey; however, ADF&G provided us with the raw catch rate (WPUE) data at all stations fished each year. The survey has been conducted each time in a core area (indicated by the Norton Sound outline in Figure 4) as well as opportunistic stations often well away from Norton Sound. In 2009, in order to create a consistent index for Area 4N across years, we selected just the stations within the core area and calculated a simple mean value and its standard error (Fig. 10a). This index has units of kg of halibut per km^2 area swept. As there are no sample data, we are unable to derive an O32 index similar to that derived from the NMFS trawl survey. To create a density index comparable to the other IPHC areas (i.e., O32 lbs/standard skate), we proceeded in the following manner.

1. Compute mean density (and standard error) for each Norton Sound ("Area 4N") survey year
2. Compute mean density in NMFS southern shelf trawl survey ("Area 4S") for the same years and in the same units.
3. Regress the square root transform of 4N density on the square root transform of the 4S density and use the regression parameters to estimate density in the unsurveyed years for 4N
4. Transform the estimates back to their original scale and retain the actual survey values in the years a survey was conducted in 4N (rather than use the predicted values)
5. Construct a standard IPHC density index (lbs/skate) by multiplying the 4S index by the ratio of the 4N trawl density index to the 4S trawl density index.
6. Compute average density for survey stations within the Norton Sound core area for the 2010 expanded NMFS trawl survey.
7. Scale the Norton Sound WPUE time series by the ratio of the full 2010 NMFS expanded survey density to the Norton Sound core area average density. In 2010, average density in the Norton Sound core area was 136.0 kg/km^2 while average density across the entire expanded survey area was 119.0 kg/km^2, resulting in a scalar of 0.875 applied to the Norton Sound WPUE index.

This procedure relies on several assumptions, most stringently that density trends in 4N and 4S, as well as in the Norton Sound core area and 4N, vary synchronously. Consideration of the years with actual survey data shows this to be a reasonable assumption and the square root transform down weights the single very large 4N data point of 1996 to achieve a closer match. The end result (Fig. 10b) is a density estimate comparable to the other IPHC areas. In general, 4N density averages 1/3rd to 1/10th of 4S density. As 4S is more than twice as large as 4N, the relative amount of overall added biomass to 4S is relatively minor (Fig. 10c). More importantly, all halibut are accounted for in Area 4CDE up to 65.5°N.

Gulf of Alaska/Aleutian Islands

Additionally, in 2011 the NMFS also operated their biennial Gulf of Alaska survey (Sadorus and Paulsson 2012, Figs. 11a-c). The triennial Aleutian Islands survey was not conducted this year, however it is used in a comparison of NMFS trawl and IPHC assessment biomass estimates (discussed later). In the Gulf of Alaska, swept area estimates of total biomass and total numbers of halibut (Fig. 12) showed a decline from the high levels seen in the 2009 survey. The large confidence intervals preclude determination of a statically significant trend but appear to indicate relatively level total abundance over the 1993-2011 time period. Trends in Gulf of Alaska exploitable biomass and exploitable numbers are, however, much more evident (Fig. 13). Area 3B has declined steadily since the peak in 1999, while 3A has declined steadily since the peak there in 2003. Due to the difficulty of trawling in many parts of 2C, it is questionable how representative of halibut abundance the trawl survey is for that region.

Alaska trawl swept-area estimates of abundance

The swept-area estimates of abundance derived from the three NMFS trawl surveys (Bering Sea, Gulf of Alaska, Aleutian Islands) are a valuable independent indicator of long-term trends in halibut biomass. While the survey regions do not correspond precisely to IPHC regulatory areas nor are the trawl surveys each conducted in all years, nevertheless it is useful to illustrate the abundance trends. Figure 12 illustrates the trawl swept area estimates of total numbers and total biomass, assembled into IPHC regulatory areas. Details of the area compilations and illustration of EBio trends are contained later in the document, in the section comparing assessment and trawl abundance estimates.

IPHC setline survey

The current SSA survey has been conducted since 1996 in almost all areas and in all years. A triangular design was used in 1996 and 1997, with the current 10 nmi regular grid used from 1998 to the present. Areas and years not surveyed are: the Eastern Bering Sea shelf which was surveyed only in 2006; Area 2A which was not surveyed in 1996, 1998, and 2000, the Area 4D edge which was not surveyed in 1996, 1998 and 1999, and Area 4A and 4B which were not surveyed in 1996. Setline surveys were conducted in Areas 2B, 2C, and 3A on a semi-regular basis between 1977 and 1986 before being discontinued for a decade. The surveys prior to 1984 used “J” hooks while all surveys from 1984 onwards were based on use of “C” hooks. In its current configuration, stations are placed on a 10-nautical mile grid between depths of 20 and 275 fm, resulting in a total of approximately 1280 stations. The 2011 SSA survey is fully described in White et al. (2012). A key indicator of stock status in each regulatory area is the weight of O32 halibut caught per standardized skate, termed the survey WPUE (Fig. 13 and Appendix Tables A9a and A9b). Survey WPUE has declined by over 50% on a coastwide basis over the past 10 years. While the rate of decline has differed among areas, there has been a substantial decrease in WPUE in all areas, indicative of a consistent coastwide decline in exploitable biomass. As described earlier, Area 4CDE is assembled from five subareas. The derived WPUE indices from each of those areas are each weighted by its respective bottom area to construct the single Area 4CDE WPUE time series shown in Figure 14. Note that this particular representation uses the 0-400 fm bottom area definition to compute the weighted average values for Area 4CDE as well as the coastwide Total value. A different perspective on the trend over time of survey catch of halibut is provided in

Figure 15; this figure shows the trend in total numbers caught on the setline survey (per unit effort, NPUE).

The survey catch of halibut is sampled to obtain biological information about the stock including sex and age distribution and is described in Forsberg (2012a). The 2011 age distributions for males, females, and sexes combined for all regulatory areas are plotted in Figure 16. The age structure of the population is of considerable interest for a variety of reasons. These distributions indicate the relative abundance of fish available to the fishery, relative contributions to the female spawning biomass, etc. In 2011 as in the last several years, there is a general tendency for an older age structure in the western areas, relative to the eastern areas. In particular, the lack of fish older than 20 years is noted for Area 2. Areas 3B and 4A present somewhat anomalous age distributions in that they more closely resemble Area 2 than Area 3A or most Area 4 distributions. At least part of the explanation for the higher number of young fish may be that the settlement of juveniles from Gulf-wide spawning occurs primarily in these areas. In 2009, a reduced harvest rate was (of 0.15) was implemented in Area 3B in part based on the more truncated age distribution. Survey age-specific catch rates (Fig. 17) provide a means of gauging historic year class strength. Note that the age-specific catch rates are affected by the change in size at age, thus the survey indexes numbers of fish selected to the gear and not necessarily total numbers of fish in the population compared across years. The very strong 1987 and 1988 classes are readily apparent in Figure 17. Optimistically, it appears that the 1999 and 2000 year classes are now entering the survey catch at the larger rates the assessment model has been predicting the last few years. The declining size at age is likely responsible for the delay in recruiting to the survey and it may still be a few years before these two year classes enter the commercial fishery in proportion to their overall numbers in the population.

Commercial shery

The second major component of the annual IPHC data collection is sampling the commercial catch. The port sampling program is detailed in Erikson and MacTavish (2012) and age sampling in Forsberg (2012b). From commercial fishing logs, commercial CPUE is computed for each regulatory area (Fig. 18 and Appendix Table A10). As with the survey WPUE, there has been a consistent coastwide decline in commercial WPUE though not quite as pronounced. This is not unexpected however, as commercial fishers tend to move their effort to maintain their catch rate, whereas the survey maintains the same fishing locations every year. Approximately 1500 otoliths are collected and aged from each regulatory area (smaller samples in Areas 2A and 4B). Because commercially-caught halibut are gutted at sea, the sex of halibut is unknown when sampled at the port of landing. A statistical methodology has been developed, based on sex ratio at length in survey catches, to parse out male and female proportions at age (see Clark 2004). The estimated sex and age composition of the commercial catch, by regulatory area, is illustrated in Figure 20. It is important to note that the distribution of ages for the total (sexes combined) is not statistically estimated (the distribution represents the otolith readings); it is the sex-specific distributions that are statistically derived. As with the survey age samples, the fish in Area 2 are, on average, several years younger than fish caught in Areas 3 and 4. Here, as well, Area 3B (but not Area 4A) is anomalous in that the average age of fish is closer to the Area 2 average.

Part of the coastwide decline in exploitable biomass can be attributed to a decline in size at age. For a given number of halibut in the population, a smaller size at age results in a smaller cumulative biomass. Figure 20a shows how the average weights of halibut in survey and commercial catches have changed over the past 12 years. Average weight has declined by 25% in the survey catches and 33% in the commercial catches. While the decline could be due to a decline in average age of the fish in the catches (since younger fish are smaller), Figure 21b shows this has not been the case, as average ages in both the survey and commercial catch have not declined at nearly the same rate. Trends, by regulatory area, in average age and average weight are illustrated in Figure 21.

Lost yield from U32 bycatch

In 2009, a methodology was developed to estimate yield loss from bycatch in the non-directed fisheries (Hare 2010). Bycatch, which is unsexed but for which length samples are available, was partitioned into age and sex components and a life history simulation model then produced estimates of how much yield was lost to the directed commercial fishery, in units of pound of lost yield per pound of U32 bycatch. The yield loss ratio in general is around one pound per pound but varies by regulatory area, depending both on the size of the bycatch when taken as well as the size at age of halibut when taken in the commercial fishery. Figure 22 updates the lost yield computations from Hare (2010). Neither these, nor the previous calculations in Hare (2010) factored migration into the estimates, which has the effect of "spreading" the lost yield downstream from the area of capture. Work on evaluating the effect of migration on downstream distribution of lost yield is reported in Valero and Hare (2010 and 2011).

Description of the assessment model

The current halibut assessment model has remained essentially unchanged since 2003. It has been thoroughly described in an IPHC Scientific Report (Clark and Hare 2006) and was subjected to a peer review by two external scientists from the Center for Independent Experts (IPHC 2008). Since the Commission's acceptance of a coastwide stock assessment model, much of the focus of the staff and the industry is now on how the coastwide estimate of exploitable biomass is apportioned among regulatory areas. For both these reasons, the assessment model for 2011 is identical to that used for the last several assessments. In the interest of brevity, little discussion is presented here of the model itself. Interested readers are referred to Clark and Hare (2006, 2007, and 2008) for full details.

The IPHC assessment model is age- and sex-structured. Commercial and survey selectivities are both estimated as piecewise linear functions of observed mean length at age/sex in survey catches. (There is a 32-inch minimum size limit in the commercial fishery.) Commercial catchability, i.e., q, is typically allowed to vary from year to year with a penalty of 0.03 on log differences. Some variation in survey catchability between years has been allowed in production fits since 2006. The model is fitted to commercial and survey catch at age/sex and CPUE.

Until 2006, estimates of halibut abundance were made using closed-area models for all areas except Areas 2A and 4CDE. Area 2A leveraged the Area 2B assessment and relative survey WPUE, while Area 4CDE relied upon the NMFS EBS trawl estimates of swept area abundance. The closed-area models are not considered reliable due to violation of the closed-population assumption. Due both to time constraints, as well as lack of confidence, we no longer fit or produce biomass estimates from the closed area models. The coastwide model has considerable more flexibility than the closed-area models, including sex-specific catchability (generally termed "q"), selectivity, and natural mortality parameters; it is fitted to CPUE (WPUE and NPUE) at age/sex (rather than just total CPUE), uses weaker selectivity smoothing, and neutral data weighting.

Finally, and perhaps most importantly, the coastwide data set is far less noisy than the closed area datasets and fits to the data provide more confidence in the results than was the case for closed-area model results.

Alternative model fits

As has been done the past few years, several variants of the basic assessment model were fitted. Differences among most of the models concerned how survey and commercial catchability were parameterized. An additional model was fitted that excluded commercial CPUE, and is considered similar to many of the NMFS groundfish assessment models. The models are summarized as such:

(Trendless, also referred to as Base 2010) Survey q is allowed to vary annually, subject to a penalty on the amount of variation, but has an additional requirement that a regression of estimated survey catchability on year have zero slope. This was the selected production model since between 2007 and 2010.

(Vanilla, Alt. 1) Survey q constant: catchability is a single fixed (though estimated) value in all years.

(WobbleSQ, Alt. 2) Survey q drift: survey catchability estimated for each year, but (new this year) was allowed to drift freely. This resulted in a better fit, and lower EBio estimate (by 10 million pounds) than placing a penalty on the amount of "wobble", as was done the last few years.

(NMFS, Alt. 3) Survey q trendless drift (i.e., Base2010 model) but Commercial CPUE is disregarded.

(CAGEAN, Alt. 4) This is similar to the old IPHC CAGEAN model. Only commercial data are fitted and commercial q is allowed to drift.

Table 1 shows features of the Base2010 model fits as well as the alternatives. The differing trends in survey and commercial q are illustrated in Figure 23. The best fit, indicated by a ΔAIC score of zero is Alternative 2 (WobbleSQ) model. The next best fit is provided by the production model used the past four years, the survey q trendless drift (Base2010) model. The three other model fits are significantly worse. The range of exploitable biomass estimates produced by the five models is relatively narrow: 260 to 289 M lbs, a considerably lower range than produced by the 2010 assessment model variants which produced a range of 266 to 330 M lbs. In a departure from last year, the WobbleSQ model was allowed to have an unconstrained survey q. In previous years, the amount of drift in survey q was controlled by a penalty on year-to-year relative changes. Because the WobbleSQ model has consistently differed from the Trendless model in the time trajectory of survey q, we opted to allow the extra freedom in the parameter. The resulting model fit was superior to one with the usual constraint on survey q (lower AIC of 10) and produced an estimate of EBio of 260 M lbs, compared to a value of 270 M lbs for the constrained version of WobbleSQ.

In previous years, we have selected the Trendless model as the basis for apportionment, despite the fact that WobbleSQ was generally the better fitting model (as measured by AIC). In the 2011 assessment, Trendless was only two AIC points higher than WobbleSQ so it was retained since a difference of two is not large enough to eliminate a model from contention. Further, the argument that has long been made is that a great deal of effort goes into standardizing the survey and we have no ancillary indications of long-term changes in the catchability of the survey. However, the superior fit of the unconstrained WobbleSQ model, and its more conservative estimate of EBio, tips the scale in favor of using WobbleSQ as the production model for the 2012 Catch Limit Recommendations. In the interest of completeness and comparability, all biomass and yield calculations are done for both the WobbleSQ and Trendless models.

As part of the work to identify the cause of the retrospective behavior of the halibut assessment model (discussed below), a large number of variants of both models were fitted. A total of 16 different variants, each involving the change of a single model parameter or data weighting, were fitted and the resulting estimates of EBio and SBio tabulated. The point of the exercise, besides attempting to identify the cause of the retrospective behavior, was to illustrate the sensitivity of the model to different parameterizations and illustrate the amount of uncertainty that is due to model structure. The 16 variants are listed, and briefly described, in Table 2. The range of EBios for the 16 variants was considerably broader than the range of EBios for the five main candidate models.

Effect of the 2011 data on abundance estimates

Coastwide survey WPUE declined by 5% and commercial WPUE increased by 1% from 2010 to 2011 (Figs. 12 and 16; Appendix A tables A9 and A10). It must be noted, however, that the 2010 commercial WPUE value was revised downward from a value of 232 pounds/skate to a value of 210 pounds/skate as a result of including late arriving data not available at the time the dataset was locked for the 2010 assessment. This single change caused the Base2010 estimate of EBio of 317 M lbs to be revised downwards to a value of 292 M lbs. The 2011 assessment further reduces the estimate of EBio at the beginning of 2011 to 245 M lbs. The EBio estimate from the Trendless (Base2010) at the beginning of 2012 is then estimated to be 288 M lbs, for a total downward revision of 9% between the (original) 2011 beginning of year estimate and the 2012 beginning of year estimate. As noted earlier, the staff's recommended model this year is the WobbleSQ model and the sequence of revised EBios for this model is as follows: The original beginning of year EBio (from the 2010 assessment) was 295 M lbs, which was revised downwards to 267 M lbs with the 2010 dataset update. The 2011 assessment further revises that value downwards to 223 M lbs which compares to an estimated value of 260 M lbs for the beginning of 2012. Table 3 contains a summary of these changes. Note the estimated biomasses for beginning of year 2012 assume no size at age change between 2011 and 2012, an assumption which may well not hold true given the ongoing decline in size at age.

Evaluation of the assessment

Quality of ts

The WobbleSQ model fits survey NPUE at sex/age (Fig. 24), commercial catch at age (Fig. 25) and commercial NPUE at sex/age (Fig. 26) very well. There is no apparent pattern to the residuals from the fits, although the model initially underestimates slightly the early strength of the 1987 year class. The model fits the increasing number of fish aged 25 and older, particularly males, which are appearing in both the survey and commercial catches. The very low growth rate for male halibut means that many are not recruiting to the fishery until they are older than 25. This "plus" group is poised to increase even more in the new few years as the remains of the very large 1987 and 1988 year classes reach 25 years of age. The series of total survey and commercial NPUE and WPUE are also predicted closely (Fig. 27, middle panel).

Coastwide estimates of recruitment, exploitable biomass and spawning biomass

Exploitable biomass (EBio) at the beginning of 2012 is estimated to be 260 million pounds and female spawning biomass (SBio) is estimated to be 319 million pounds. Estimated EBio is down by about 18% from the beginning of year 2011, while SBio is about 9% lower than the 2011 beginning of year value estimated in the 2010 assessment. Note that the beginning of year 2011 values and the beginning of year 2012 values derive from different variants of model, which accounts for some of the inter-year decline (the inter-year decline for the same model as used for the 2010 assessment was 9%). EBio and SBio are both estimated to have declined continuously between 1998 and 2007 (Fig. 27, top right panel). EBio continued to decline until 2009, the model estimates that both are now on the increase, with SBio bottoming out in 2007 and EBio bottoming out in 2009. This differs slightly from the 2010 assessment in terms of when the turnarounds in decline for both EBio and SBio began. This point is discussed more fully in the Retrospective Performance section. Recruitment (measured as age-eight fish in the year of assessment) has varied between 7 and 33 million halibut since the 1988 year class, with a mean of 17.9 million. The 1989 to 1997 year classes, presently 14 to 22 years old and the main target of the commercial fishery for the past several years, are all estimated to have been below average, with several of the year classes substantially below average (Fig. 27, top left panel). The sharply declining biomass over the past decade has resulted from these small year classes, in combination with reduced growth rates, replacing earlier year classes that were much larger, especially the 1987 and 1988 year classes. The projected increase in 2012 biomasses can be attributed, in large part, to the incoming 1998 through 2003 year classes that are estimated to be well above average, particularly the 1999 and 2000 year classes. The extent to which these year classes will contribute to EBio over the next few years depends on the growth rate which, as has been frequently noted, continues to decline.

The annual stock assessment produces an estimate of the total number of male and female halibut, ages 6 and older, in the ocean (Fig. 28, top panel). The time series of abundance shown in Figure 28 illustrates the strength of the celebrated 1987, and to a lesser extent 1988, year classes. As was the case in last year's assessment, the current assessment indicates that three large year classes – 1998, 1999, and 2000 – have entered the exploitable biomass and should be the largest contributors to the EBio and catch over the next few years. Presently, all three year classes are estimated to be nearly as large – in terms of numbers – as the 1987 and 1988 year classes but we caution that their strength is not well determined and note that retrospective downward revisions of initial estimates are common to this class of models. However, it is important to note that size at age is much smaller now than it was 20 years ago. This has two important ramifications – first it means that the three strong year classes are only just beginning to reach the exploitable size range and, therefore, their true numbers in the population are still quite uncertain. Second, it also means that for a given number of halibut, their collective biomass will be far smaller than the 1987 and 1988 year classes (Fig. 28, bottom panel). Currently, a large fraction of males never reach the minimum size limit and thus never enter the exploitable biomass. It remains to be seen just how these year classes will develop into the exploitable component of the stock.

The estimated age composition of the coastwide spawning biomass shows a broad range of ages, including a 4% contribution by females age 20 and older (Fig. 29). While the age distribution is certainly truncated due to the size-selective effects of fishing, it is encouraging that production of eggs is not confined to a narrow range of ages and should ensure that adequate reproductive potential remains in the ocean for the foreseeable future. On an area-by-area basis, there are some departures from this pattern, particularly in Areas 2 and 3B which show a lower percentage of older females (See the Area summaries section).

Estimates of uncertainty

There are a number of ways of estimating the uncertainty associated with a given model fit and biomass estimate. They are all unsatisfactory in that they are conditioned on the correctness of the model when in fact it is the choice of one model over another that is the major source of uncertainty in assessments. This is well illustrated by the difference in area-specific biomass estimates between the coastwide and closed-area fits of the IPHC model as reported in past years.

One standard method of illustrating uncertainty around an estimate, for a given model, is the likelihood profile. The bottom panels in Figure 27 show the likelihood profiles for both the exploitable biomass as well as the female spawning biomass for the WobbleSQ model. The 95% confidence interval (C.I.) for EBio is 187 to 342 million pounds, while the 95% C.I. for the female spawning biomass is 228 to 423 million pounds. Confidence intervals for the recruitment estimates were also computed and are plotted with the recruitment estimates (Fig. 27, top panel). For comparison purposes, the 95% C.I. for the alternative model fits described above are plotted in Fig. 30. The means of both EBio and SBio for all the alternative model fits lie within the 95% C.I. of the WobbleSQ (production) model estimates.

In addition to the standard variants, this year an additional 16 variants were fitted as part of an ongoing attempt to diagnose the cause of the production model's retrospective behavior (discussed below). The 16 variants involved changing a single parameter, or data or penalty, but keeping all other aspects of the model the same. The resultant EBio and SBio estimates are plotted as numbered circles on Figure 30. The same set of 16 variants was also run using the Trendless (Base2010) model as the base model (Fig. 31). While the exercise yielded no insight to the cause of the retrospective behavior, it does help to further illustrate the level of uncertainty that is associated with a biomass estimate from a stock assessment model. In particular, natural mortality can wield a large influence on biomass estimates and, in the case of both the WobbleSQ and Trendless models, yields a substantially lower estimate of EBio.

Retrospective performance

Each year's model fit estimates the abundance and other parameters for all years in the data series. One hopes that the present assessment will closely match the biomass trajectory estimated by the previous year's assessment. To the extent that it does not, the assessment is said to have poor retrospective performance.

Halibut assessments have exhibited retrospective behavior going back to the 1980s and the original catch-at-age model, CAGEAN (Deriso et al. 1983). The current assessment model, developed in 2003, has shown various levels of retrospective behavior since its development (Clark and Hare 2006). For the last several years, the assessment has revised downward the previous several years' exploitable biomass estimates (Fig. 32a), meaning that biomass was overestimated then and may be overestimated now if the cause of the retrospective problem lies somewhere within the model. There is some precedent for that; the assessment models in use in the mid-1990s and the early 2000s showed strong retrospective patterns that turned out to be the result of mis-specified selectivity (age- rather than length-based). There is also the possibility that the retrospective pattern is caused in some way by the external estimation of the sex composition of the commercial catch, or by the internal prediction of surface age compositions prior to 2002 through the application of an age misclassification matrix (Clark and Hare 2006). Note that the retrospective behavior of the female spawning biomass is smaller than that for the EBio (Fig. 32b), indicating that the source of the behavior may be more closely linked to estimated numbers of males, whose selectivity at age has declined along with size-at-age.

Problems of this sort with the assessment machinery would manifest themselves as systematic revisions of the estimated relative strength of the year-classes present in the stock. That was true of the retrospective patterns caused by the misspecification of selectivity in the past: incoming year-classes would at first be estimated as weak because catch rates were low, but the real reason was low selectivity rather than low abundance. When they were later caught in large numbers, the estimates of relative year-class strength increased. The retrospective estimates of year class strength are plotted in Figure 32c. There is evidence of a systematic revision of estimates of year class strength as the 1994 through 2000 year class have all trended downward for the last five assessments. The pattern was not as strong for previous cohorts and may have changed somewhat starting with the 2001 year class but these are more uncertain than the earlier year classes due to fewer years of observation and estimation.

In 2007, a check was made using a blind projection of the assessment from 2004 to 2007. Year-class strengths and other parameters from the 2004 assessment, along with just the catches from 2005-2007 which are needed to estimate fishing mortality, were used to project the 2007 age structure and then compared to the 2007 observed age structure. That projection demonstrated that the retrospective behavior appears to be caused solely by the data and not by the assessment model (Clark and Hare 2008). The magnitude of the retrospective pattern from earlier assessments has varied over the last few years. In 2009, the downward adjustment of earlier EBio assessments appeared to have relaxed, however the three subsequent assessments have seen a resumption and even an increase in the retrospective behavior.

Causes of retrospective behavior are notoriously difficult to diagnose (Legault 2009). In the case of halibut, it appears to result from lower NPUE catch rates than expected, given the estimated mortality rate. This could be due, for example, to a trend in natural (or undocumented fishing) mortality, or a trend in catchability. The catchability explanation seems less likely, however, given that a model which allows catchability to have a trend produces assessment estimates that differ little from models with tightly constrained catchability. In fact, all the usual variants of the production model that is fitted each year show a very similar retrospective pattern. We consider it most likely that the retrospective behavior continues to derive in part from the still declining growth rates. Each year, a new set of size at age data is collected and used to smooth earlier estimates of size at age. The addition of smaller sizes at age results in a reduction of the earlier estimated weights at age thus lowering EBio for the same number of fish. More important however is that as growth slows, fewer fish of the same age are selected to the gear and their lack of appearance in expected numbers forces the model to revise recruitment estimates to match the observed survey and commercial catch rates. The difference in retrospective behavior for the EBio vs. the SBio lends some credence to the growth rate change as the prime factor in the retrospective behavior. To summarize, there is ongoing retrospective behavior in the halibut assessment. The magnitude of the behavior showed no signs of slowing this year and the trend of successively lowering all earlier EBio estimates has continued. In response, the staff has continually recommended lower catch limits. A detailed summary of the past and present magnitude of the retrospective behavior, and its effect on realized harvest rate and harvest policy is contained in Valero (2012b).

Retrospective behavior in halibut assessment models has a long history with little resolution, or diagnosis, of the source. Work in the next year will focus intently on attempting to resolve the source and it is anticipated that collaborative work with other assessment scientists will be conducted. Whether the present model and/or data issues are identified, there remains the possibility that an entirely new model should be developed. Another possibility to consider is basing catch limit recommendations on indicators other than the assessment estimate of biomass. Work along these lines is currently in development (Valero 2012a), in the form of a Management Strategy Evaluation

Harvest policy and status relative to reference points

The IPHC has developed, refined, and utilized a constant harvest rate policy since the 1980's. The policy was fully described in Clark and Hare (2006) and further modified as described in Hare and Clark (2008), and Hare (2011b). Stated succinctly, the policy was initially designed to harvest 20% of the coastwide exploitable biomass when the spawning biomass is estimated to be above 30% of the unfished level. The harvest rate is linearly decreased towards a rate of zero as the spawning biomass approaches 20% of the unfished level. This combination of harvest rate and precautionary levels of biomass protection have, in simulation studies, provided a large fraction of maximum available yield while minimizing risk to the spawning biomass. Following the CIE review of the assessment and harvest policy (Francis 2008, Medley 2008), the simulations on which the harvest policy was based were modified to incorporate "assessment error" (Hare and Clark 2008). This was implemented by adding autocorrelated error in estimation of the SBio, and having the harvest rates set according to the "perceived" state, as opposed to the "true" state, of the SBio. This form of robustification of the harvest policy is designed to protect the stock in the common situation where assessments tend to consistently too high or too low for a sequence of years, which corresponds to the current situation regarding the halibut assessment. For precautionary purposes, several areas (Area 3B and westwards) have had their target harvest rate reduced to 15%.

Since the early 2000s, and similar to many fisheries management agencies, the harvest policy has incorporated a measure designed to avoid rapid increases or decreases in catch limits, which can arise from a variety of factors including true changes in stock level as well as perceived changes resulting from changes in the assessment model. The adjustment, termed "Slow Up Fast Down (SUFastD)" is based on a target harvest rate of 20% but the realized rate differs due to the adjustment (Hare and Clark 2008). The SUFD approach is somewhat different from similar phased-change policies of other agencies in that it is asymmetric around the target value, i.e., the catch limit responds more strongly to estimated decreases in biomass than to estimated increases. This occurs for two reasons: first, the assessment generally has a better information base for estimating decreasing biomass compared with increasing biomass; and second, such an asymmetric policy follows the Precautionary Approach.

Beginning with the 2011 Catch Limit Recommendations, the staff modified the SUFastD quota adjustment to a SUFullD adjustment. The basis for the adjustment is described in Hare (2011a) and is summarized, briefly, as follows. The initial simulations that gave support to the SUFastD did not capture the current conditions faced by the stock over the past several years. Since implementation of the SUFastD adjustment, EBio has been in a constant downward trajectory. As removals have been in excess of 20% of EBio and each subsequent EBio estimate was lower than the previous year's estimate, the target harvest rate could never be met as only 50% of the intended reduction in removals was taken. Additionally, size-at-age of halibut has continued to decline and this always affects performance of the adjustment. Staff Catch Limit Recommendations (CLRs) this year, as they were in 2010, are based on a SUFullD adjustment, i.e., one third of potential increases are taken and 100% of decreases are taken.

The unfished female spawning biomass ($B_{unfished}$) is computed by multiplying spawning biomass per recruit (SBR, from an unproductive regime) times average coastwide age-six recruitment (from an unproductive regime). The recruitment scaling uses the ratio of high to low recruitments based on long term recruitment estimates from Areas 2B, 2C, and 3A and applied to the current coastwide average recruitment (Clark and Hare 2006), which we believe to represent a productive regime. The SBR value, computed from Area 2B/2C/3A size at age data from the 1960s and 1970s is 118.5 lbs per age-six recruit. Average coastwide recruitment for the 1990-2002 year classes (computed at age-six) is 20.39 million, and the estimate of unproductive regime average recruitment is 6.48 million recruits. This gives a $B_{unfished}$ of 768 million pounds, a B_{20} of 154 million, a B_{30} of 230 million pounds, and the 2012 female spawning biomass value of 319 million pounds establishes $B_{current}$ as 42% of $B_{unfished}$ (Fig. 34, top panel), down slightly from the 2011 beginning of year estimate of $B_{current}$ of 43%. The revised trajectory of SBio suggests that the female spawning biomass did drop below the B_{30} level between 2006 and 2009, which, had it been so estimated at the time, would have triggered a reduction in the harvest rate. On an annually estimated basis, however, the initially estimated stock size has not been that low; it is only retrospectively that the revised estimate of spawning biomass is estimated to have gone below to the reference point threshold. One problem with this method of establishing reference points is that the threshold and limit are dynamic, changing each year as the estimate of average recruitment changes.

In addition to monitoring the status of the female spawning biomass relative to reference points, success at achieving the harvest rate is also documented (Fig. 34, lower panel). The target harvest rate over the past decade for halibut has generally been 0.20. Exceptions include a briefly increased rate to 0.225 and 0.25 between 2004 and 2006, and a lowered rate of 0.15 in Areas 3B and 4. In 2011, the target harvest rates were set at 0.215 (Areas and 3A) and 0.161 (Areas 3B and 4); however, it is important to note that these were not actual target harvest rate increases. These new rates reflected a change in the method by which O26U32 bycatch and wastage are accounted for in determining fishery CEY (Hare 2011a). On a coastwide basis, however, recent realized harvest rates have hovered around 0.25 (Fig. 35). A sizable portion of this above-target harvest rate comes from the retrospective revision of exploitable biomass estimates. Thus, while the intended rate has been around 0.20, with staff recommended catch limits based on such a rate, a retrospective downwards revision of early exploitable biomass estimates, when combined with unchanged estimates of total removals generates higher realized harvest rates (Valero 2012b).

Estimates of realized harvest rate among individual regulatory areas require use of an apportionment method to calculate the underlying exploitable biomass. The apportionment method used by the staff uses survey timing and hook competition adjustments to the (0-400 fm) bottom area-weighted survey WPUE, which are then time-averaged using Kalman weights (discussed below) for apportionment purposes. The adjusted and Kalman-weighted WPUE time series is used in most of our data comparisons, e.g., WPUE trends over time, comparisons with trawl estimates of abundance, etc. The adjusted and Kalman-weighted survey WPUEs are used to apportion biomass to estimate recent realized harvest rates (described below). Realized harvest rates (Fig. 35) tend to increase from west (below or at the target harvest rate during the last decade) to east (up to three times above target for a number of years during the last decade in Areas 2B and 2C) though the eastern area realized harvest rates have declined sharply towards the target harvest rate during the last few years, in part due to lower catch limits. Also, until last year, another portion of the above-target performance resulted from the SUFastD adjustment which prevented catch limits dropping fully to the target level indicated by contemporary estimates of exploitable biomass, in those areas where declines in catch limits were proposed.

A detailed summary of the past and present magnitude of the retrospective behavior, and its effect on realized harvest rate is contained in Valero (2012b). Under the assumption that the retrospective revision of current biomass estimates will match that of the past five years, a methodology to revise applied harvest rates to current biomass estimates was developed. In essence, if the contemporary biomass estimates are eventually revised downwards 40%, the applied harvest rates would be revised downwards by the same magnitude, to values of 0.131 (from 0.215) and 0.098 (from 0.161). Yield tables using both sets of harvest rates have been prepared and are presented in the Yield section below. However, more analysis of the effect of both existing measures and alternative adjustments is required and will be undertaken in 2012.

Comparison of assessment and trawl survey estimates of EBio

The NMFS and Canadian Department of Fisheries and Oceans conduct bottom trawl surveys annually to triennially across most of the continental shelf of the U.S. west coast, British Columbia and Alaska. One method of possibly validating the coastwide assessment (and biomass partitioning) is to compare estimates produced by the two independent methods. We were able to obtain swept area estimates of abundance at length from trawl surveys that covered IPHC Areas 2C westward to Area 4CDE. For Area 2B halibut are not sampled in the trawl survey and, in 2A too few halibut are caught to produce reliable estimates of abundance, thus no comparisons are made for those two areas.

The NMFS conducts an annual survey on the Eastern Bering Sea shelf, a triennial survey in the Aleutian Islands and a biennial survey in the Gulf of Alaska. The NMFS trawl surveys do not precisely match IPHC regulatory areas. However, common areas can be generally defined:

Area 2C: NMFS GOA survey area Southeast matches IPHC Area 2C. Note that there is much rough/untrawlable ground in this region.
Area 3A: NMGS GOA regions Yakutat + Kodiak
Area 3B: NMFS GOA regions Chirikof + the eastern 70% of Shumagin
Area 4A: NMFS GOA Shumagin (western 30%) + AI region 799 + AI region 5699 (eastern 30%) + EBS region 50.
Area 4B: NMFS AI regions - 299 - 5699 (western 30%)
Area 4CDE: EBS regions - region 50.

Estimates of commercially exploitable biomass (i.e., the usual EBio) can be derived by applying the commercial selectivity curve to the swept area estimates of numbers at length and then applying the IPHC length weight relationship. For this comparison, the IPHC assessment estimates of EBio are partitioned among areas using the adjusted bottom-weighted survey WPUE index. The results are illustrated in Figure 36.

The agreement between the trawl and assessment estimates of abundance is surprisingly good for most of the areas. Areas 4A, 4B, and 4CDE are within a few percent of each other over the past few surveys. In Area 3A and 3B, the trends are generally captured though the trawl estimates of abundance tend to be lower by about a third. Area 2C, as anticipated provides the worst match. It is important to keep in mind the independence of the two estimates. The only commonality between them is use of a selectivity curve to derive EBio, and use of the NMFS survey to generate a density estimate for the shelf region. The assessment estimates incorporate assumptions and estimates of factors such as catchability, natural mortality, survey apportionment, etc. The trawl estimates make an assumption about the effective area swept by the survey trawl and assumes a capture probability value of 1.0 for all sizes encountered. This latter assumption may be one reason the Area 3A and 3B trawl estimates are lower if larger halibut are able to escape the trawl and thus be under-represented in the swept area estimates.

Finally, the trawl data may provide some evidence as regards the preponderance of smaller halibut, though the wide confidence intervals indicate that individual year estimates, and likely trends, are uncertain. The large number of small halibut in the Bering Sea was earlier discussed and illustrated in Figure 9. In Figures 37 (Area 3A) and 38 (Area 3B), we show the swept area estimates of numbers by 10 cm length class in the central Gulf. The 2009 NMFS trawl survey showed an unprecedented number of halibut in the 50-70 cm range. The 2011 values have subsided from the 2009 peak but the broad confidence intervals (see Figure 12) do not suggest a significant change in total biomass. The point is that over the past 15 years, total biomass in the Gulf has shown little trend, however since the larger fraction of the biomass now comes from smaller halibut, it follows that the total number of halibut has increased, or at least remained level. As (or, perhaps, if) those millions of smaller halibut grow, we should see a steady increase in EBio predicted by the coastwide assessment.

Apportioning the coastwide biomass among regulatory areas

The staff believes that survey WPUE-based apportionment is the most objective and consistent method of estimating the biomass distribution among areas and therefore the best distribution of total CEY to achieve the IPHC's goal of proportional harvest among areas (see Webster et al. 2011 for a discussion of alternatives). The validity of the survey WPUE apportioning requires that survey catchability – the relationship between density and WPUE – be roughly equal among areas. Over the past few years, several checks for area differences in catchability were made (Clark 2008a, Clark 2008b, Clark 2008c, Webster 2009) but results were inconclusive in determining differences. This year, the two same factors used in 2010 for adjusting survey WPUE were considered. Methodologies and analyses of both factors - in isolation and in combination - are contained in Webster and Hare (2011), and results updated for this year are illustrated in Figure 39. A brief summary of the rationale behind the two factors is presented below but details, are not repeated here - see Webster and Hare 2011. Following (potential) adjustment of the annual survey WPUE values, the IPHC has usually averaged the last few years' of values to smooth out annual variation in the survey. Starting last year, a weighting scheme based on a Kalman filter approach was adopted by staff as a superior and statistically-sound methodology (Webster 2011). This approach derives directly from discussions at the Commission's 2010 Annual Meeting and a request of staff by the Commission.

The apportionment of biomass results in a level of EBio for each regulatory area. Staff CLRs are based on the fishery CEY in each area. The fishery CEY is calculated by subtracting "other removals" from the total CEY, which itself is calculated by multiplying the area-specific target harvest rate and the area-specific EBio. Until last year, other removals had been comprised of O32 bycatch, O32 wastage, sport catch (except in Areas 2A and 2B where it is part of the fishery CEY), and personal use/subsistence (except in Area 2A, where it is part of the fishery CEY). As of 2011, bycatch and wastage mortality (BAWM) under 32 inches in length but over 26 inches (O26U32) are included in the fishery CEY calculations. U26 BAWM is, at present, still accounted for in determination of the target harvest rate. The effect of directly accounting for O26U32 BAWM was to increase the target harvest rate to 0.215 in Areas 2 and 3A and to 0.161 in Areas 3B and 4. The analysis upon which the change in O26U32 BAWM was based is given in Hare (2011a).

Adjustment factors

Hook competition. Catchability of halibut is affected by the presence of other bait takers, a process known as hook competition. If the average number of baits available to halibut varies substantially among regions, this might be a reason to adjust survey WPUE. To compute this adjustment, the return of baits by regulatory area is summed from survey data.

Timing of setline survey. The survey is designed to measure EBio at approximately the midpoint of the year in each regulatory area. Necessarily, the timing varies due to survey logistics. The timing of removals (commercial, sport and subsistence fishing, bycatch, wastage) also varies, even more substantially, among areas. It can be reasoned that an area where more of the annual removals are taken prior to our survey would “see” a smaller EBio than an otherwise identical situation where the other removals had not yet occurred. To compute this adjustment, we estimate the midpoint of the survey as well as fraction of removals prior to that time.

Bottom-area weighting factor

The IPHC setline survey operates on a 10 nautical mile grid in all IPHC regulatory areas, except for the broad shelf in Area 4CDE. Halibut are distributed, however, in both shallower and deeper waters. The choice of which bottom area definition to use is relatively subjective; both are biased. The broader definition (0-400 fm) assumes halibut density in 0-20 and 275-400 fm is the same as in the surveyed depths of 20-275 fms, an assumption that is almost certainly incorrect, at least for some areas. The narrower definition (20-275 fm) gives no credit for biomass distribution for areas that have larger areas in the shallower and deeper regions, areas in which commercial fishing is documented to occur. Staff recommendation is to use the broader area definition, applied equally to all areas, largely because fishing is known to occur in these depths in at least most of these areas. Initial work on potentially expanding the survey, at least periodically, to shallower and deeper regions is discussed in Webster et al. (2012). The relative amount of bottom area for the two definitions is listed below.

	2A	2B	2C	3A	3B	4A	4B	4CDE
0-400 fm	3.6%	7.5%	3.7%	12.4%	7.5%	5.0%	5.0%	55.5%
20-275 fm	3.7%	8.1%	4.1%	14.3%	8.7%	5.8%	4.0%	51.3%

Time-averaging methods of adjusting survey WPUE

A detailed statistical analysis was conducted last year to determine whether the default three year equal weighting method that had been used by the IPHC to weight recent survey WPUEs was optimal (Webster 2011). The results show that, in fact, the most recent year’s survey should be disproportionally weighted compared to earlier years. This result derives from the relative variances within an area in a given year compared to interannual variance. Areas with a large number of stations, such as Area 3A and 2C should, in a statistical sense, give almost no weight to any but the most recent year's WPUE value. However, several areas with greater coefficients of variation, should still give some weight to the previous couple of years. Rather than utilize a different set of weights for each area, when the weights can vary somewhat depending on the period of years considered, we selected the weighting scheme (from Area 2A) which was most inclusive of previous years' data. That scheme results in weights of 75:20:5 (recent year first).

Raw, adjusted and time-averaged survey WPUE

For the purposes of weighting individual area regulatory datasets and apportioning EBio, the adjustments and weights described above are applied to the raw survey WPUE. The result of applying these corrections is illustrated in Figure 40. This particular figure reflects use of both adjustments and the 0-400 fm bottom area definition.

Methods of apportioning biomass and computing shery CEY

Compared to the last several years, the options for apportioning biomass among regulatory areas this year is limited: there are just four options. The four options are as follows:

1. 0-400 fm bottom area weighting; no WPUE adjustments
2. 0-400 fm bottom area weighting; survey WPUE adjustments for hook competition and survey timing
3. 20-275 fm bottom area weighting; no survey WPUE adjustments
4. 20-275 fm bottom area weighting; survey WPUE adjustments for hook competition and survey timing

The regulatory area apportionments for these four options are listed in Table 4. As in 2010, the staff recommends Option 2, which has been the basis for CLRs for the past three years.

The staff recommendation is the highlighted line in all the tables referencing apportionment. After determination of the fishery CEY, staff CLRs are based on one other consideration – the "Slow Up Full Down" adjustment, which was adopted last year by the Commission as a means of limiting rapid increases in catch limits, while also acting in a precautionary sense to fully accept decreases in in catch limits.

Area-apportioned biomass, total, and fishery constant exploitation yields

Area apportionment of EBio has four possibilities, corresponding to the apportionment percentages listed in Table 4. As noted earlier, the choice of apportionment option has a small effect on the estimated coast EBio, thus adding an extra bit of variability in the estimated amount of EBio in each regulatory area. Tables 5 and 6 list the estimated EBios in each area; Table 5 has the EBios for the preferred WobbleSQ model, while Table 6 contains the values for the Trendless (Base 2010) model.

Following apportioning of biomass, total CEY is computed by multiplying each regulatory area EBio by the target harvest rate for that area: 0.215 for Areas 2 and 3A, 0.161 for Areas 3B and 4. The next step is then to deduct "Other Removals" in order to compute fishery CEY, and the final step is to apply a SUFullD adjustment to any catch limits slated in increase the following year. Tables for all quantities were prepared for the preferred WobbleSQ model (Table 7) and for the Trendless/Base2010 model (Table 8), and also included a summary of the change from the 2011 catch limits.

As discussed in the Retrospective and Harvest Policy sections, an alternative set of applied harvest rates was developed (Valero 2012b) as one means of pre-emptively accounting for the ongoing retrospective behavior of both models. Those alternative harvest rates – 0.134 for Areas 2 and 3A and 0.098 for Areas 3B and 4 – give rise to a second set of tables of total CEY, fishery CEY, SUFullD and change from 2011 catch limits. The tables for the WobbleSQ model are in Table 9; the tables for Trendless/Base2010 are in Table 10. Finally, a comparison between the 2011 and 2012 EBios and fishery CEYs is given in Table 11.

Area summaries

The coastwide assessment indicates that the exploitable biomass of halibut has declined approximately 60% over the past decade. This declining trend is seen in almost all of the area-specific survey and commercial WPUE indices, though with turnarounds apparently beginning in several areas. But the breadth and reasons behind the trends vary by area. The following is a region by region discussion of the trends and grouping of diagnostic plots to assess the past and present removals, stock trends, and prospects for each area. For each of the areas, six plots are illustrated. These include the following:

1. Total removals – illustrated by category (commercial catch, sport, etc.)
2. Abundance indices – these include the raw and adjusted/weighted survey WPUE indices and the Coastwide assessment with adjusted/weighted survey partitioning.
3. 2011 age structure of the survey catch.
4. Surplus production. Stated simply, surplus production is the amount of total catch that, when taken exactly, keeps the exploitable biomass at the same level from one year to the next. If the biomass increases, then total catch (termed "removals") was less than surplus production. If the biomass declines, then removals were greater than surplus production. Removals exceeding surplus production can lead to long-term declines in biomass; stock building results from taking less than surplus production.
5. WPUE and effort – Long-term trends in commercial fishing effort and WPUE.
6. 2011 age structure of the commercial catch.

Taken in total, these indicators convey a comprehensive picture for each area and serve as a helpful reference when discussing each regulatory area.

Area 2

Areas 2A, 2B and 2C indices are illustrated in Figures 41, 42, and 43, respectively. Between 1997 and 2006, total removals were stable in all three areas, averaging 1.6 million pounds in Area 2A, 13.5 million pounds in Area 2B, and 12.4 million pounds in Area 2C. Removals declined sharply between 2007 and 2011, in response to the change from closed-area to coastwide assessment and the resultant revised view of relative halibut abundance in Area 2. Bycatch of U32 fish in Area 2, and subsequent lost yield to CEY, is estimated to be rather low, however yield lost due to "upstream" bycatch of U32 halibut is estimated to be much greater than yield lost due to "local" U32 bycatch (Valero and Hare 2011). Deductions to total CEY for O26 bycatch in Area 2A still represent a sizable portion of total removals, whereas O26 bycatch in Areas 2B and 2C is relatively low. Surplus production estimates suggest that removals exceeded surplus production in Area 2 for most of the past decade, though in Area 2B surplus production has exceeded removals for the past four years. Commercial effort steadily increased in Area 2A for almost a decade but dropped sharply in 2009 and again in 2010, but showed a rebound in 2011. In Areas 2B and 2C commercial effort has steadily declined for the past five to six years.

The main indices of abundance all suggest a steady decline in biomass from the mid-1990s to the mid/late 2000s change to the coastwide assessment. Area 2A saw in 2009 a drop to the lowest survey WPUE on record, which had followed a drop of 50% from 2008, to an average survey catch of 8 pounds of O32 halibut per standard skate. In 2010, survey WPUE doubled, but it was still the third lowest value on record, however it increased again in 2011 to the highest unadjusted value since 2004. It should be noted that Area 2A is generally the area most affected by survey WPUE adjustments and the adjusted 2011 value actually declined slightly from the adjusted 2010 value. The 15-year trend in Area 2B survey WPUE is more complex than in the rest of Area 2. The 2008-2010 period saw an average of around 88 lbs/skate which is similar to values seen between 1998 and 2004, and is 50% higher than the series low values in 2006 and 2007. In 2011, however, survey WPUE receded 10% from the 2010 value. However, between 1995 and 1997, Area 2B survey WPUE averaged almost 150 lbs skate, a high level that was re-examined this year (Webster and Hare 2012) and found to be authentic. Area 2C, which declined from an average survey WPUE of around 250 lbs/skate in the late 1990s, seems to have stabilized following years of steep quota cuts and, for the first time, had the highest survey WPUE of any IPHC regulatory area (136 lbs/skate). Commercial WPUE tells basically the same story as survey WPUE for Areas 2A and 2C. Area 2B commercial WPUE was the highest on record and has increased for four straight years.

Survey partitioning of the coastwide biomass suggests that the beginning of year 2012 EBio is up in Areas 2A and 2C, and down in 2B from 2011 values. What is still a strong concern to staff is the generally much younger age structure of fish caught in Area 2. Mean age is around 11 years of age, with little difference between males and females. In particular, the catch of females is concentrated on ages where maturity at age is low thus removing females from the population before many have the opportunity to contribute to the spawning biomass.

All the indices are consistent with a picture of a steadily declining exploitable biomass up to at least 2007. The reasons for the decline are likely twofold. The first is the passing through of the two very large year classes of 1987 and 1988. Every assessment over the past decade has shown that those two year classes were very strong in comparison to the surrounding year classes. Now that those two year classes are 20 years old, their contribution to the exploitable biomass and catches has sharply declined and the drop in biomass was to be expected as they are replaced by year classes of lesser magnitude. Secondly, realized harvest rates were substantially higher than the target rate of 20%, and for a few years were in excess of 50% (of EBio, not total biomass). Harvest rates have been brought down sharply from peak levels in Area 2B (almost 80% in the years before the change to the coastwide assessment) but less so in Areas 2A and 2C.

Removals have been generally larger than surplus production and that stalled rebuilding of regional stocks. The reduced removals now appear to have arrested decline of the regional biomass and, across all of Area 2, it appears a rebuilding to higher levels may have begun. While all areas appear stabilized, they remain at relatively low levels that limit available yield. There are multiple signs that two or three large year classes are set to enter the exploitable biomass, though this is dependent both on reducing harvest rates that are above target as well as on the growth rate.

On that score, it is encouraging that removals have been brought down over the past few years. Realized harvest rates remain slightly above target in all of Area 2 but are closer to target than at any time in the past decade.

Area 3

Areas 3A and 3B indices are illustrated in Figures 44 and 45, respectively. While these two areas occupy the current central area of distribution of the halibut stock, they have substantially different exploitation and biomass histories over the past 10-20 years.

Area 3A removals, both the total as well as the individual components (commercial, sport, bycatch) were relatively stable from the mid-1980s to the mid-2000s., but have been steadily decreased the past four years. Commercial effort has also seen relatively little variation in the past 15-20 years. During the past decade when WPUE indices were falling sharply coastwide, Area 3A generally showed the most stability. However, Area 3A survey WPUE has declined for five consecutive years, before showing a slight increase in 2011 of 3% from the low value of 117 lbs/skate in 2010. This value is about 40% of the level seen in the late 1990s. Commercial WPUE is also at its lowest point since the change from "J" to "C" hooks in 1984 and is at about 66% of its late 1990s level. Paralleling the declines in survey and commercial WPUE, EBio has declined steadily in 3A since 2005.

Area 3B saw a large increase in removals beginning in 1996 which peaked in 2002; removals have dropped sharply since. Commercial fishing effort more than tripled in the seven years after 1996 and then declined modestly over the past four years, before increasing again beginning in 2008 and continuing through 2010 and then dropping slightly in 2011. The rapid increase in removals during the late 1990s was intentional following implementation of the regular assessment survey and was never believed to be sustainable. We estimate that removals greatly exceeded surplus production between 1998 and at least 2007. Commercial and survey WPUE are at 25% and 19%, respectively, of their average level between 1997 and 1999. Area 3A has a much broader spectrum of ages in the population than is seen in Area 2. Average age for females in survey catches is 13 and for males is 16 years of age. Area 3B, however, is more similar to Area 2 in age distribution than to Area 3A.

For a long time, Area 3A had the appearance of being the most stable of the IPHC regulatory areas. The area has been fully exploited for many decades and there is a wealth of data detailing its population dynamics. The area also sits at the current center of halibut distribution and it appears that emigration is roughly equal to immigration. Like Area 2, Area 3A benefited from the very large year classes of 1987 and 1988 and the slow decline in exploitable biomass is the result of those year classes dying off. The biomass remains the largest of any of the regulatory areas; however the sharp declines of the past several years are a sign that exploitation rates have been too high, though we are not yet considering Area 3A as an "area of particular concern". The modest increase in WPUE this year may, or may not, indicate an arrest of the decline. Should this trend reversal not persist, we may reconsider applying that designation. Until the biomass decline has ended, recommended catch limits will trend downwards in Area 3A.

The situation in Area 3B is one that has concerned us for several years. Area 3B was relatively lightly fished until the mid-1990s. With the introduction of a regular survey, quotas were incrementally increased from 4 million pounds to a high of 17 million pounds. Predictably, catch rates declined steadily. Our view of Area 3B was that the area had an accumulated "surplus" biomass that could be (and was) taken but the level of catches was not sustainable. Removals were brought down to around 10 million pounds however the WPUE indices continue to drop sharply. The level of commercial effort expended to take the CEY is near an all-time high and has been increasing. The age distribution of the population is not broad and reflects one of an area fished at a much higher rate than is sustainable, or where both recruitment and emigration are also high. Like Area 4, Area 3B is a net (though smaller) exporter of halibut as emigration is larger than immigration. It is paramount that the ongoing decline in Area 3B be arrested - until that is accomplished, the true level of productivity in Area 3B cannot be estimated. Lowering the harvest rate in Area 3B (to 0.15 from 0.20 in 2010) was a precautionary move and one that has seen success in Area 4.

Area 4

Areas 4A, 4B, and 4CDE indices are illustrated in Figures 46, 47, and 48, respectively. The three areas have roughly similar commercial exploitation histories over the past decade and show generally similar trends. In all three areas, commercial catches increased from around 1.5 million pounds to around 4-5 million pounds between 1996 and 2001. All three areas have since declined to 2-3 million pounds though the trajectories differ. The target harvest rate is currently 0.161 in all of Area 4, with the change from 0.20 beginning in 2004 in 4B, 2006 in 4CDE and 2008 in 4A. Commercial effort mirrored the rise in removals from 1996-2001, however the drop in effort was not nearly as sharp as the drop in catches, and the drop in commercial WPUE is evident in the time series. Survey WPUE declined around 70% between the mid1990s and mid-2000s. All three areas have shown increases in recent years, with the turnarounds occurring immediately after the cut in the harvest rate in each area. All three areas, however, showed a decline in 2011, though Area 4B's decline was slight (1%). The recent leveling of WPUE, which reflect a slowing of the decline in EBio as estimated by the coastwide assessment, is evidence that the western portion of the stock, which is a net exporter of halibut, is best served by a lower harvest rate than that in the eastern areas. As the stock builds up, removals will also increase. There is evidence in both the assessment and the NMFS trawl surveys that large numbers of halibut, in the 50-80 cm size range, are found in Area 4 and should add substantially to the exploitable biomass over the next several years, assuming these fish grow into the O32 size range.

There are a couple of other observations that should be made about Area 4. The biggest concern, as regards productivity and sustainability of halibut, is the level of bycatch mortality. Most of the O32 bycatch in Area 4 most likely affects future yield within Area 4 itself. Over the past decade, O32 bycatch has averaged 3-4 million pounds resulting in an annual yield loss comparable to that level. On the other hand, U32 bycatch - which has also been on the order of 3-4 million pounds annually - results in a greater yield loss due to its smaller size and large numbers of killed halibut. Some potentially large fraction of yield loss, however, is to areas "downstream" of Area 4 given migration of fish beyond at which they become vulnerable to fishing (Valero and Hare 2011). For most of the 2000s, removals exceeded surplus production in all three subareas of Area 4. It would appear that situation has reversed though it is probably too early to make a definitive declaration. Encouragingly, the age distributions in Area 4 are the broadest of any of the IPHC regulatory areas. Thus, Area 4 not only contributes to the spawning biomass in a ratio exceeding its removals, it is also a reservoir of older females which can be a valuable commodity for a fish population.

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Table 1. Alternative coastwide model ts. The AIC value is in relative units compared to the model with the lowest AIC score.

Model	Number of parameters	Δ AIC	Exploitable Biomass (Mlb)	Spawning Biomass (Mlb)
Trendless (Base2010)	187	+20	288	352
Vanilla (Alt. 1)	173	+334	262	315
WobbleSQ (Alt. 2)	187	0	260	319
NMFS (Alt. 3)	171	+129	289	358
CAGEAN (Alt. 4)	145	+127	266	306

Table 2. Sixteen variants of the assessment model, tted to illustrate the effect of structural uncertainty on estimates of EBio.

Variant	Description
1	Freely estimate M for both sexes
2	Fix M at 0.15 for both sexes
3	Fit to Bycatch LFs – note Hessian not positive definite for this fit
4	Commercial q drift tolerance set at 0.01
5	Commercial q drift tolerance set at 0.05
6	Commercial q drift tolerance set at 50 (i.e., unconstrained)
7	Survey q drift tolerance set at 0.01
8	Survey q drift tolerance set at 0.1
9	Turn off robust estimation
10	Turn off variance scaling
11	Sex-specific CPUE lambda set to 0
12	Total CPUE lambda set to 0
13	Unisex parameters
14	Domed survey selectivity
15	Bycatch total not predicted
16	Bycatch level doubled in input data

Table 3. Effect of the 2010 and 2011 data on coastwide abundance estimates.

Model	2011 ebio 2010 assessment Data as of 11/10	2011 ebio 2010 assessment Data as of 11/11	2011 ebio 2011 assessment Data as of 11/11	2012 ebio 2011 assessment Data as of 11/11
Trendless (Base 2010)	318	292	245	288
WobbleSQ (Alt. 2)	295	267	223	260

Table 4. Shares of exploitable biomass by area according to various apportionment methods.

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	1.9%	13.4%	10.5%	32.9%	13.7%	6.9%	7.6%	13.2%	100.0%
0-400	Timing/Hook	2.4%	13.4%	10.5%	35.4%	15.8%	5.7%	5.5%	11.3%	100.0%
20-275	None	1.7%	13.2%	10.5%	34.5%	14.5%	7.2%	5.6%	12.8%	100.0%
20-275	Timing/Hook	2.2%	13.1%	10.5%	36.8%	16.7%	6.0%	4.0%	10.7%	100.0%

Table 5. Exploitable biomass by area according to various apportionment methods for the preferred WobbleSQ model.

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	4.907	35.052	27.411	86.218	35.831	18.001	19.936	34.644	262.000
0-400	Timing/Hook	6.148	34.904	27.279	91.997	41.167	14.856	14.251	29.397	260.000
20-275	None	4.443	33.586	26.729	87.858	36.969	18.349	14.319	32.746	255.000
20-275	Timing/Hook	5.617	33.393	26.561	93.550	42.445	15.134	10.193	27.108	254.000

Table 6. Exploitable biomass by area according to various apportionment methods for the Base2010 (Trendless) model.

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	5.319	37.995	29.713	93.458	38.840	19.513	21.610	37.553	284.000
0-400	Timing/Hook	6.810	38.663	30.216	101.905	45.601	16.456	15.786	32.563	288.000
20-275	None	4.931	37.274	29.664	97.505	41.029	20.363	15.891	36.342	283.000
20-275	Timing/Hook	6.280	37.337	29.698	104.599	47.458	16.921	11.397	30.310	284.000

Table 7. Estimates of 2012 Total CEY, Other Removals, Fishery CEY, SUFullD Catch Limits and the percentage change from the 2011 Catch Limits, for the Wobble SQ model using harvest rates of 0.215 (Areas 2 and 3A) and 0.161 (Areas 3B and 4).

2012 Total CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	1.055	7.536	5.893	18.537	5.778	2.903	3.215	5.586	50.503
0-400	Timing/Hook	1.322	7.504	5.865	19.779	6.638	2.395	2.298	4.740	50.543
20-275	None	0.955	7.221	5.747	18.889	5.961	2.959	2.309	5.280	49.322
20-275	Timing/Hook	1.208	7.179	5.711	20.113	6.844	2.440	1.644	4.371	49.510

2012 Other Removals

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.174	0.871	2.653	7.492	1.568	0.828	0.429	2.275	16.290
0-400	Timing/Hook	0.174	0.871	2.653	7.861	1.568	0.828	0.429	2.275	16.659
20-275	None	0.174	0.871	2.510	7.492	1.568	0.828	0.429	2.275	16.147
20-275	Timing/Hook	0.174	0.871	2.510	7.861	1.568	0.828	0.429	2.275	16.516

2012 Fishery CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.881	6.665	3.240	11.045	4.210	2.075	2.786	3.311	34.213
0-400	Timing/Hook	1.148	6.633	3.212	11.918	5.070	1.567	1.869	2.465	33.884
20-275	None	0.781	6.350	3.237	11.397	4.393	2.131	1.880	3.005	33.175
20-275	Timing/Hook	1.034	6.308	3.201	12.252	5.276	1.612	1.215	2.096	32.994

2012 SUFullD

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.881	6.665	2.633	11.045	4.210	2.075	2.382	3.311	33.202
0-400	Timing/Hook	0.989	6.633	2.624	11.918	5.070	1.567	1.869	2.465	33.137
20-275	None	0.781	6.350	2.632	11.397	4.393	2.131	1.880	3.005	32.570
20-275	Timing/Hook	0.951	6.308	2.620	12.252	5.276	1.612	1.215	2.096	32.331

Change from 2011 Catch Limits

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	-3.2%	-12.9%	13.0%	-23.1%	-43.9%	-13.9%	9.3%	-11.0%	-19.2%
0-400	Timing/Hook	8.7%	-13.3%	12.6%	-17.0%	-32.5%	-35.0%	-14.3%	-33.7%	-19.3%
20-275	None	-14.1%	-17.0%	13.0%	-20.6%	-41.5%	-11.6%	-13.8%	-19.2%	-20.7%
20-275	Timing/Hook	4.5%	-17.5%	12.5%	-14.7%	-29.7%	-33.1%	-44.3%	-43.6%	-21.3%

Table 8. Estimates of 2012 Total CEY, Other Removals, Fishery CEY, SUFullD Catch Limits and the percentage change from the 2011 Catch Limits, for the Base2010 (Trendless) model using harvest rates of 0.215 (Areas 2 and 3A) and 0.161 (Areas 3B and 4).

2012 Total CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	1.144	8.169	6.388	20.093	6.263	3.146	3.485	6.055	54.744
0-400	Timing/Hook	1.464	8.313	6.497	21.910	7.353	2.653	2.546	5.251	55.986
20-275	None	1.060	8.014	6.378	20.964	6.616	3.284	2.562	5.860	54.738
20-275	Timing/Hook	1.350	8.027	6.385	22.489	7.653	2.729	1.838	4.888	55.358

2012 Other Removals

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.174	0.871	2.653	7.861	1.568	0.828	0.429	2.275	16.659
0-400	Timing/Hook	0.174	0.871	2.653	8.408	1.568	0.828	0.429	2.275	17.206
20-275	None	0.174	0.871	2.653	7.861	1.568	0.828	0.429	2.275	16.659
20-275	Timing/Hook	0.174	0.871	2.653	8.408	1.568	0.828	0.429	2.275	17.206

2012 Fishery CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.970	7.298	3.735	12.232	4.695	2.318	3.056	3.780	38.085
0-400	Timing/Hook	1.290	7.442	3.844	13.502	5.785	1.825	2.117	2.976	38.780
20-275	None	0.886	7.143	3.725	13.103	5.048	2.456	2.133	3.585	38.079
20-275	Timing/Hook	1.176	7.156	3.732	14.081	6.085	1.901	1.409	2.613	38.152

2012 SUFullD

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.930	7.298	2.798	12.232	4.695	2.318	2.472	3.740	36.484
0-400	Timing/Hook	1.037	7.442	2.835	13.502	5.785	1.825	2.117	2.976	37.517
20-275	None	0.886	7.143	2.795	13.103	5.048	2.425	2.133	3.585	37.118
20-275	Timing/Hook	0.999	7.156	2.797	14.081	6.085	1.901	1.409	2.613	37.040

Change from 2011 Catch Limits

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	2.2%	-4.6%	20.1%	-14.8%	-37.5%	-3.8%	13.4%	0.5%	-11.2%
0-400	Timing/Hook	13.9%	-2.7%	21.7%	-6.0%	-23.0%	-24.3%	-2.9%	-20.0%	-8.7%
20-275	None	-2.6%	-6.6%	20.0%	-8.8%	-32.8%	0.6%	-2.1%	-3.6%	-9.6%
20-275	Timing/Hook	9.8%	-6.5%	20.1%	-1.9%	-19.0%	-21.1%	-35.4%	-29.8%	-9.8%

Table 9. Estimates of 2012 Total CEY, Other Removals, Fishery CEY, SUFullD Catch Limits and the percentage change from the 2011 Catch Limits, for the Wobble SQ model using harvest rates of 0.131 (Areas 2 and 3A) and 0.098 (Areas 3B and 4).

2012 Total CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.697	4.977	3.892	12.243	3.806	1.912	2.118	3.680	33.326
0-400	Timing/Hook	0.892	5.065	3.958	13.350	4.469	1.613	1.547	3.191	34.085
20-275	None	0.646	4.883	3.886	12.773	4.021	1.996	1.557	3.562	33.323
20-275	Timing/Hook	0.823	4.891	3.890	13.703	4.651	1.658	1.117	2.970	33.703

2012 Other Removals

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
0-400	Timing/Hook	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
20-275	None	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
20-275	Timing/Hook	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421

2012 Fishery CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.523	4.106	1.382	5.477	2.238	1.084	1.689	1.405	17.905
0-400	Timing/Hook	0.718	4.194	1.448	6.584	2.901	0.785	1.118	0.916	18.664
20-275	None	0.472	4.012	1.376	6.007	2.453	1.168	1.128	1.287	17.902
20-275	Timing/Hook	0.649	4.020	1.380	6.937	3.083	0.830	0.688	0.695	18.282

2012 SUFullD

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.523	4.106	1.382	5.477	2.238	1.084	1.689	1.405	17.905
0-400	Timing/Hook	0.718	4.194	1.448	6.584	2.901	0.785	1.118	0.916	18.664
20-275	None	0.472	4.012	1.376	6.007	2.453	1.168	1.128	1.287	17.902
20-275	Timing/Hook	0.649	4.020	1.380	6.937	3.083	0.830	0.688	0.695	18.282

Change from 2011 Catch Limits

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	-42.6%	-46.3%	-40.7%	-61.9%	-70.2%	-55.0%	-22.5%	-62.2%	-56.4%
0-400	Timing/Hook	-21.1%	-45.2%	-37.8%	-54.2%	-61.4%	-67.4%	-48.7%	-75.4%	-54.6%
20-275	None	-48.1%	-47.6%	-40.9%	-58.2%	-67.3%	-51.6%	-48.2%	-65.4%	-56.4%
20-275	Timing/Hook	-28.7%	-47.4%	-40.8%	-51.7%	-58.9%	-65.5%	-68.4%	-81.3%	-55.5%

Table 10. Estimates of 2012 Total CEY, Other Removals, Fishery CEY, SUFullD Catch Limits and the percentage change from the 2011 Catch Limits, for the Wobble SQ model using alternative harvest rates of 0.131 (Areas 2 and 3A) and 0.098 (Areas 3B and 4).

2012 Total CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.643	4.592	3.591	11.295	3.511	1.764	1.954	3.395	30.744
0-400	Timing/Hook	0.805	4.572	3.574	12.052	4.034	1.456	1.397	2.881	30.771
20-275	None	0.582	4.400	3.502	11.509	3.623	1.798	1.403	3.209	30.026
20-275	Timing/Hook	0.736	4.374	3.479	12.255	4.160	1.483	0.999	2.657	30.143

2012 Other Removals

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
0-400	Timing/Hook	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
20-275	None	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421
20-275	Timing/Hook	0.174	0.871	2.510	6.766	1.568	0.828	0.429	2.275	15.421

2012 Fishery CEY

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.469	3.721	1.081	4.529	1.943	0.936	1.525	1.120	15.323
0-400	Timing/Hook	0.631	3.701	1.064	5.286	2.466	0.628	0.968	0.606	15.350
20-275	None	0.408	3.529	0.992	4.743	2.055	0.970	0.974	0.934	14.605
20-275	Timing/Hook	0.562	3.503	0.969	5.489	2.592	0.655	0.570	0.382	14.722

2012 SUFullD

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	0.469	3.721	1.081	4.529	1.943	0.936	1.525	1.120	15.323
0-400	Timing/Hook	0.631	3.701	1.064	5.286	2.466	0.628	0.968	0.606	15.350
20-275	None	0.408	3.529	0.992	4.743	2.055	0.970	0.974	0.934	14.605
20-275	Timing/Hook	0.562	3.503	0.969	5.489	2.592	0.655	0.570	0.382	14.722

Change from 2011 Catch Limits

Weighting	Adjustment	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
0-400	None	-48.5%	-51.4%	-53.6%	-68.5%	-74.1%	-61.2%	-30.1%	-69.9%	-62.7%
0-400	Timing/Hook	-30.6%	-51.6%	-54.4%	-63.2%	-67.2%	-73.9%	-55.6%	-83.7%	-62.6%
20-275	None	-55.2%	-53.9%	-57.4%	-67.0%	-72.6%	-59.7%	-55.3%	-74.9%	-64.4%
20-275	Timing/Hook	-38.3%	-54.2%	-58.4%	-61.8%	-65.5%	-72.8%	-73.9%	-89.7%	-64.2%

Table 11. Estimates of 2012 exploitable biomass and CEY from the 2011 assessment.

	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4A	Area 4B	Area 4CDE	Total
Coastwide assessment [1]									
2012 exploitable biomass	6.148	34.904	27.279	91.997	41.167	14.856	14.251	29.397	260.000
Proportion of total	0.024	0.134	0.105	0.354	0.158	0.057	0.055	0.113	1.000
Harvest rate	0.215	0.215	0.215	0.16125	0.16125	0.16125	0.16125	0.16125	<0.215
Total CEY	1.322	7.504	5.865	19.779	6.638	2.395	2.298	4.740	50.543
Other removals [2, 3]	0.174	0.871	2.653	7.861	1.568	0.828	0.429	2.275	16.659
2012 shery CEY [2]	**1.148**	**6.633**	**3.212**	**11.918**	**5.070**	**1.567**	**1.869**	**2.465**	**33.884**

Notes:

[1] "Coastwide assessment" refers to the coastwide model fit with survey apportionment of the total biomass estimate among regulatory areas, and corrected for estimated rates of hook competition and survey timing.

[2] "Other removals" comprise O32 and U32/O26 wastage, O32 and U32/O26 bycatch, personal use, and in most areas sport catch. In Areas 2A and 2B sport catch is included in fishery CEY rather than in other removals.

[3] Assumes GHL of 0.931 M lbs. in Area 2C and 3.103 M lbs. in Area 3A.

Table 12. Estimates of 2011 exploitable biomass and CEY from the 2010 assessment (2010 RARA, p. 115).

	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4A	Area 4B	Area 4CDE	Total
Coastwide assessment [1]									
2011 exploitable biomass	2.997	38.250	23.874	109.841	48.066	23.583	26.992	43.397	317.000
Proportion of total	0.021	0.129	0.079	0.345	0.181	0.067	0.051	0.127	1.000
Harvest rate	0.215	0.215	0.215	0.16125	0.16125	0.16125	0.16125	0.16125	<0.215
Total CEY	1.426	8.792	5.386	23.520	9.242	3.426	2.603	6.502	60.897
Other removals [2]	0.476	0.848	3.057	9.162	1.734	0.858	0.394	2.515	19.044
2011 shery CEY [2]	**0.950**	**7.944**	**2.329**	**14.358**	**7.509**	**2.568**	**2.208**	**3.987**	**41.853**
2010 catch limit	**0.910**	**7.650**	**2.330**	**14.360**	**7.510**	**2.410**	**2.180**	**3.720**	**41.070**

Notes:

[1] "Coastwide assessment" refers to the coastwide model fit with survey apportionment of the total biomass estimate among regulatory areas.

[2] "Other removals" comprise O32 and U32/O26 wastage, O32 and U32/O26 bycatch, personal use, and in most areas sport catch. In Areas 2A and 2B sport catch is included in fishery CEY rather than in other removals.

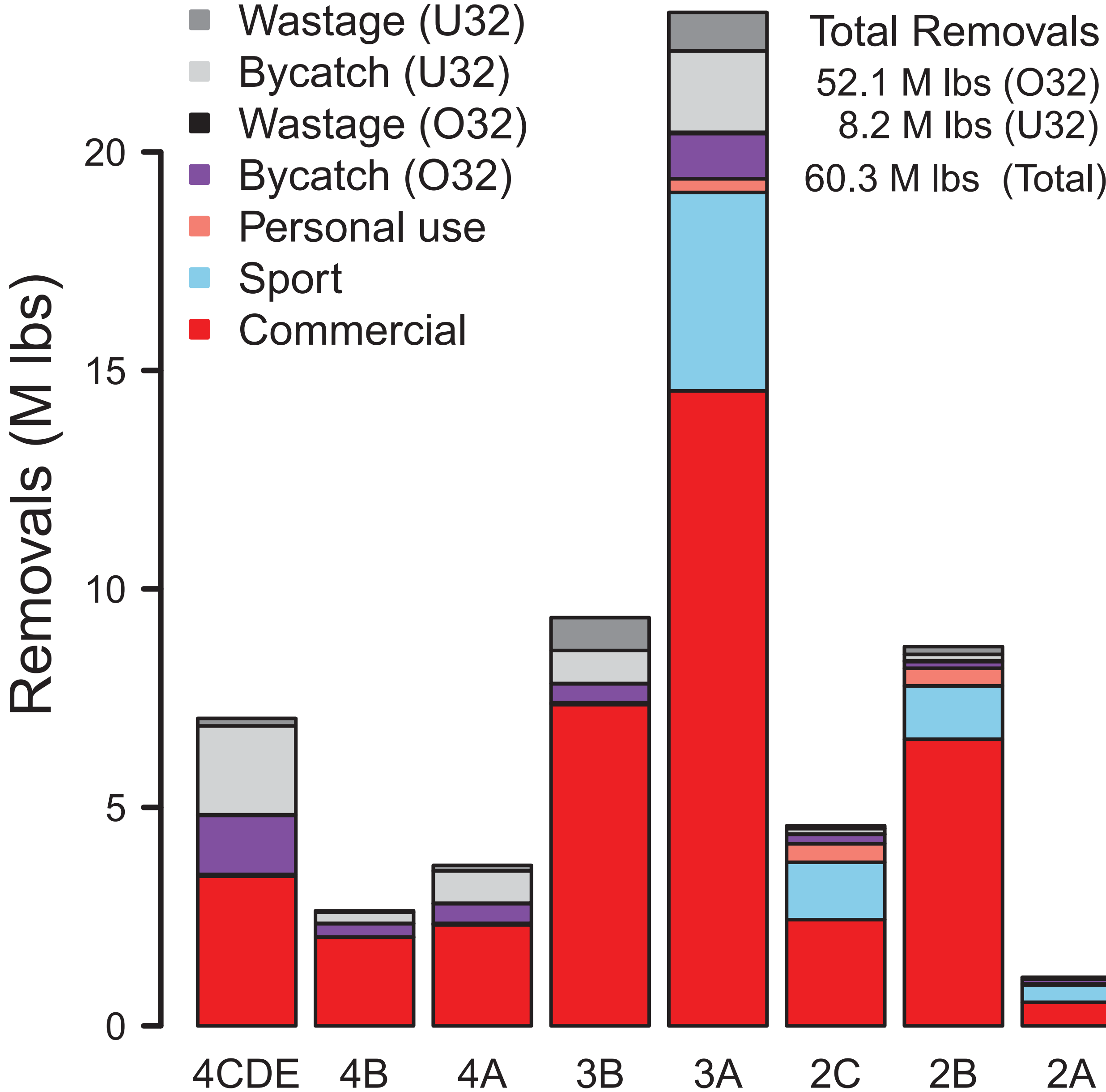


Figure 1. Total removals by type and regulatory area for 2011.

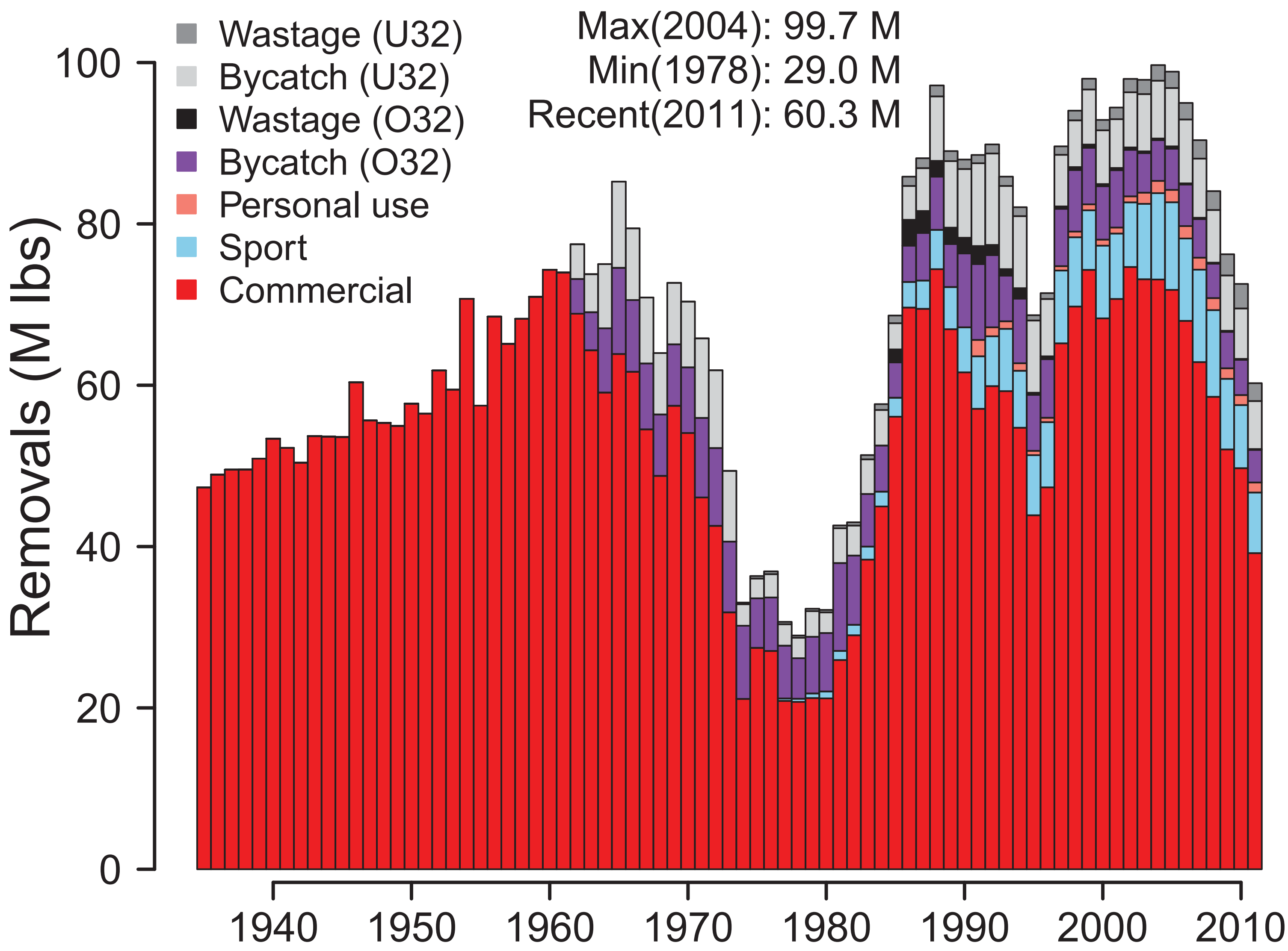


Figure 2. Total removals coastwide for the period 1935-2011. Year and amount of minimum, maximum, and most recent removals are also listed.

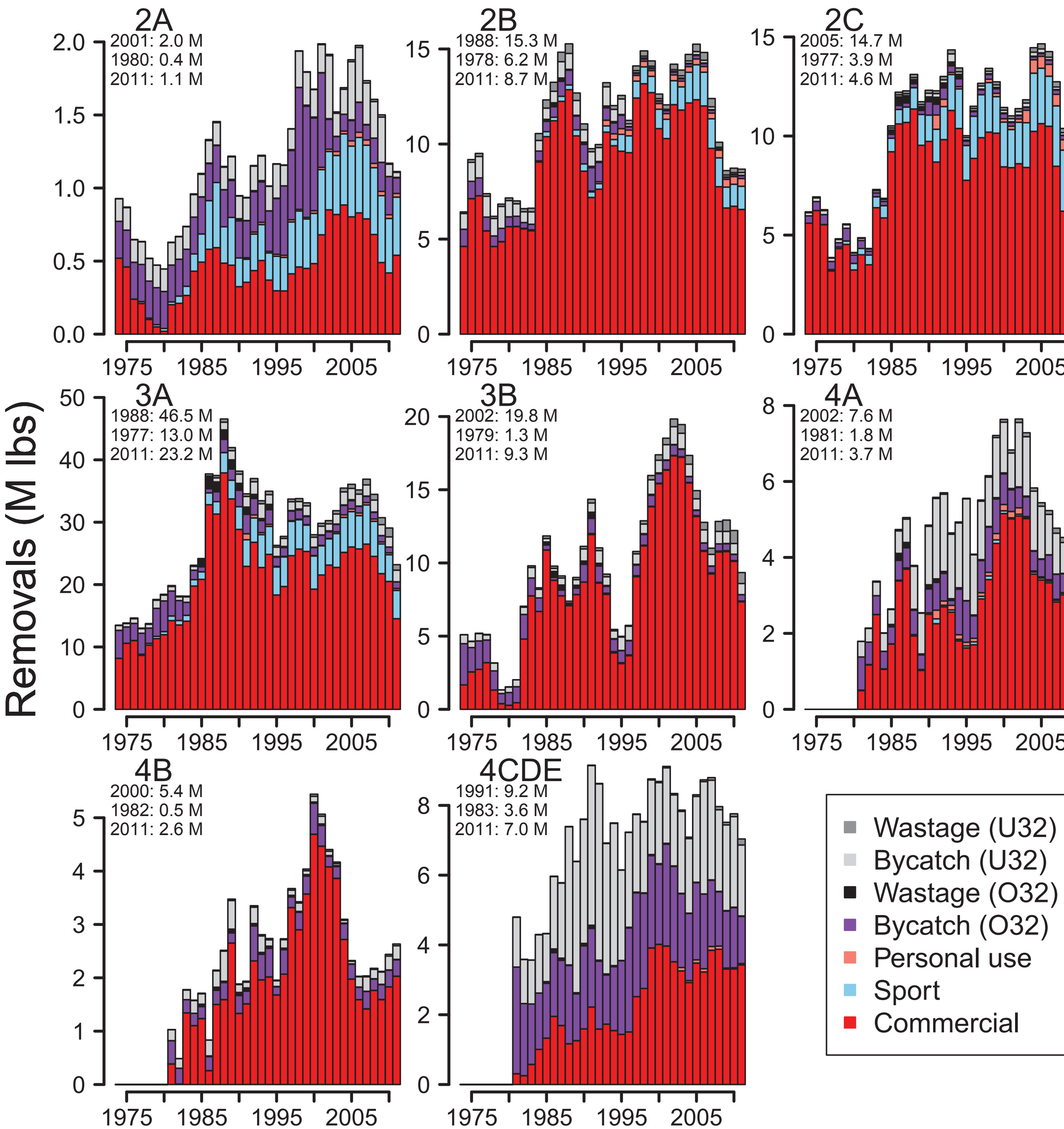


Figure 3. Total removals of halibut, by Regulatory Area, 1974-2011. Year and amount of minimum, maximum, and most recent removals are listed in the upper left corner for each regulatory area.

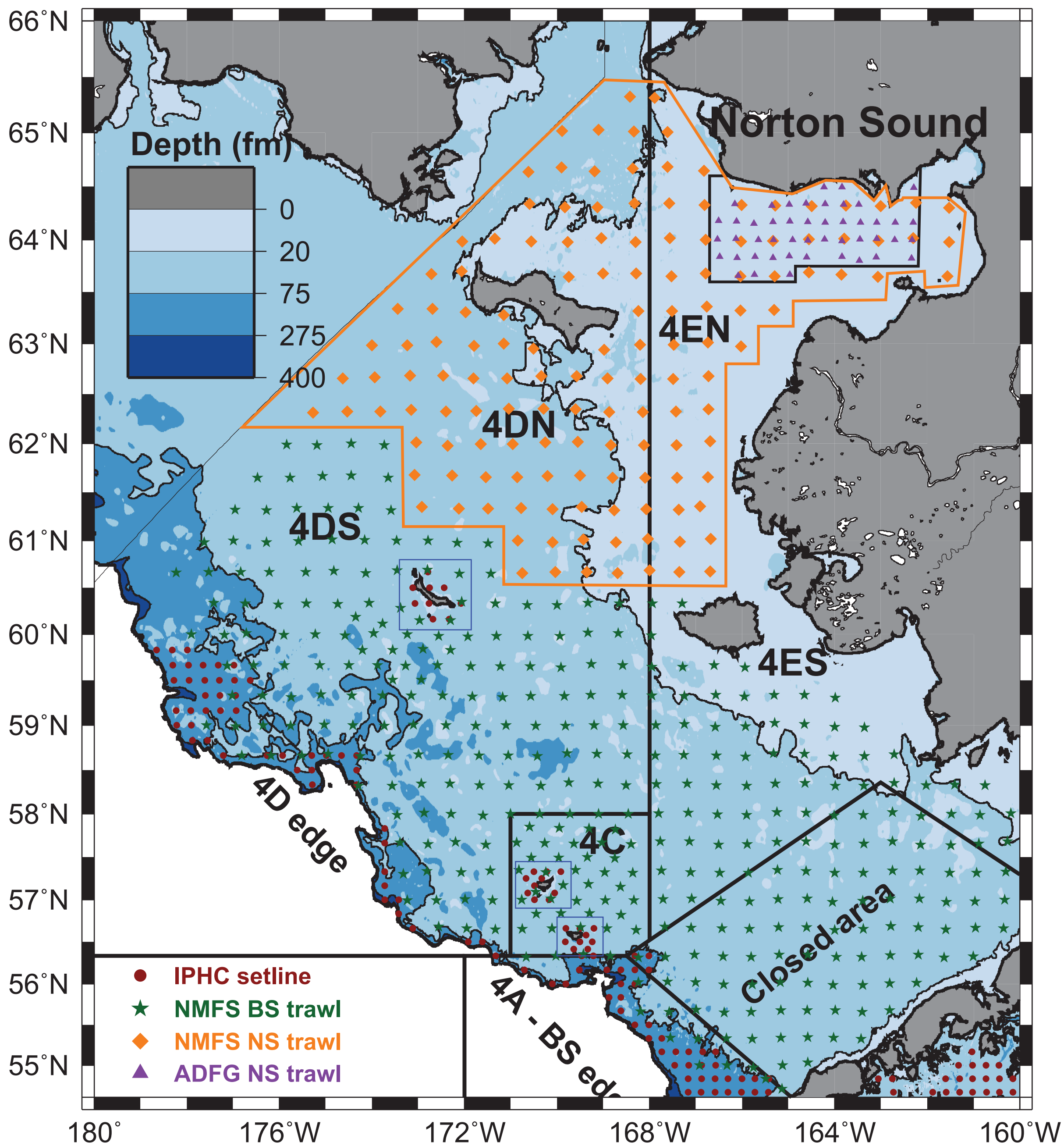


Figure 4. Summary of information sources and subareas utilized to construct a dataset for Area 4CDE. See text for details.

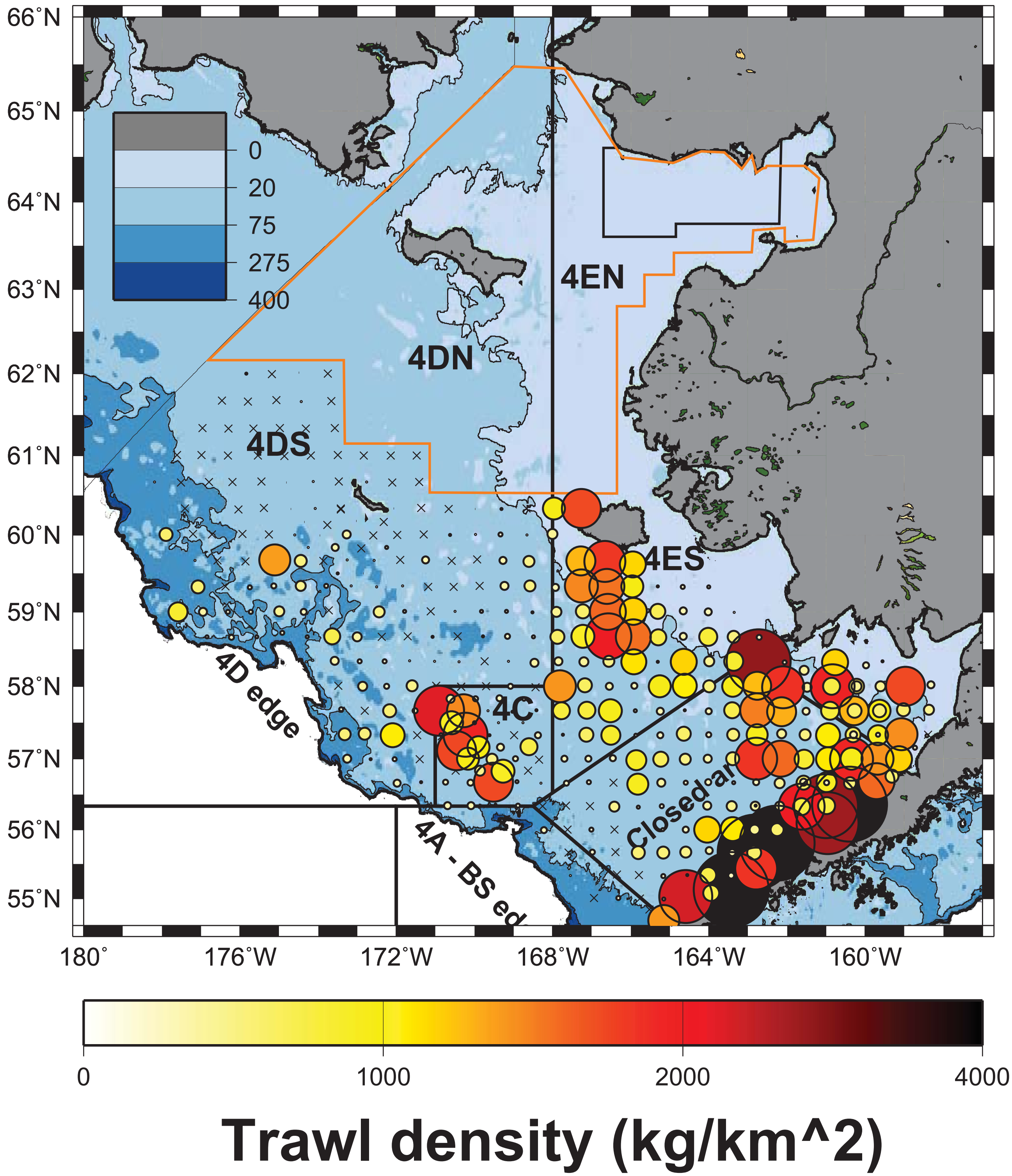


Figure 5. Catch rates of halibut (all sizes) at survey stations in the 2011 NMFS expanded Eastern Bering Sea trawl survey. The size of the circles is proportional to catch rate (kg/km^2) and conveys the same information as the coloring of the circles. Stations with zero catch are indicated by an "x".

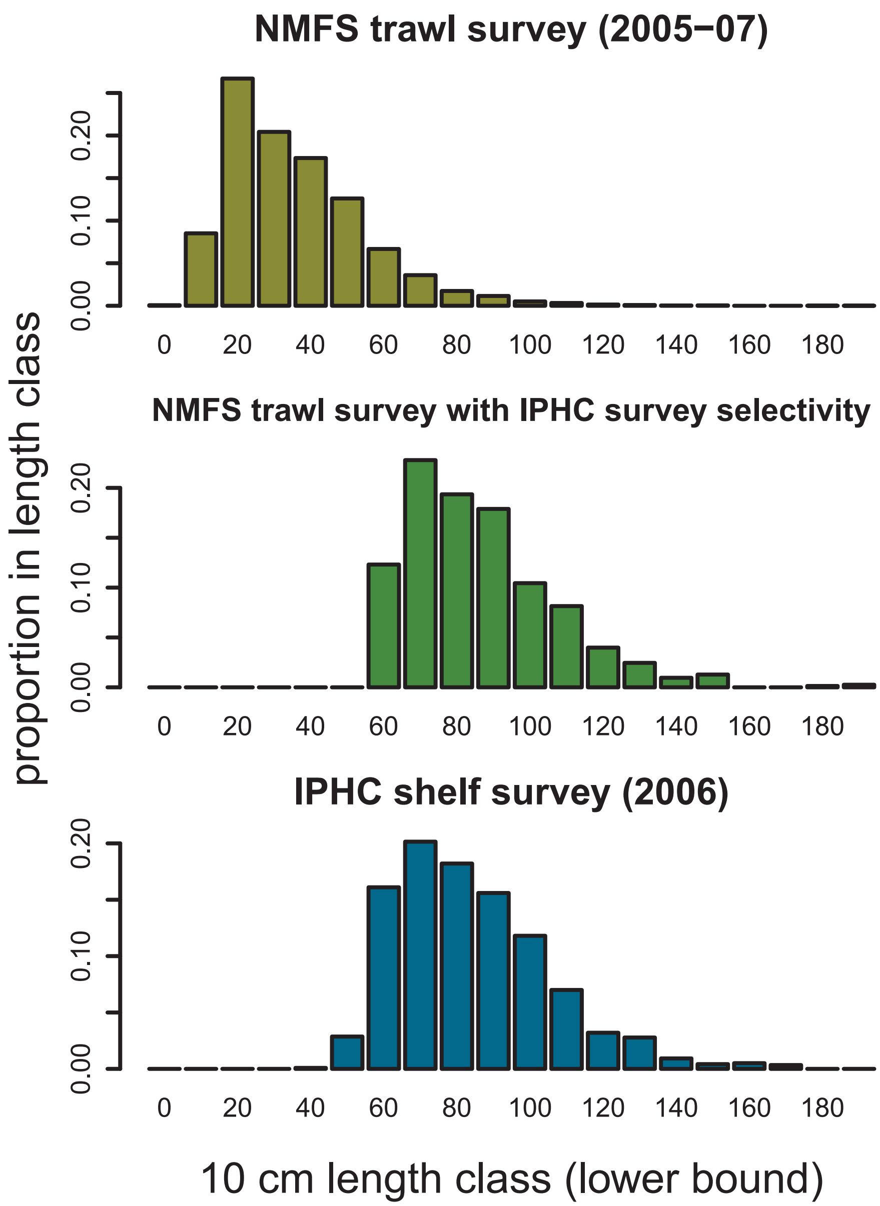


Figure 6. Comparison of NMFS trawl survey and IPHC length frequency compositions. The top panel shows the length frequency composition for all halibut caught by the NMFS trawl gear for years 2005-7. The middle panel shows the frequency distribution of lengths after the IPHC setline selectivity curve is applied to raw counts. The bottom panel illustrates the length composition of halibut in the 2006 IPHC shelf survey.

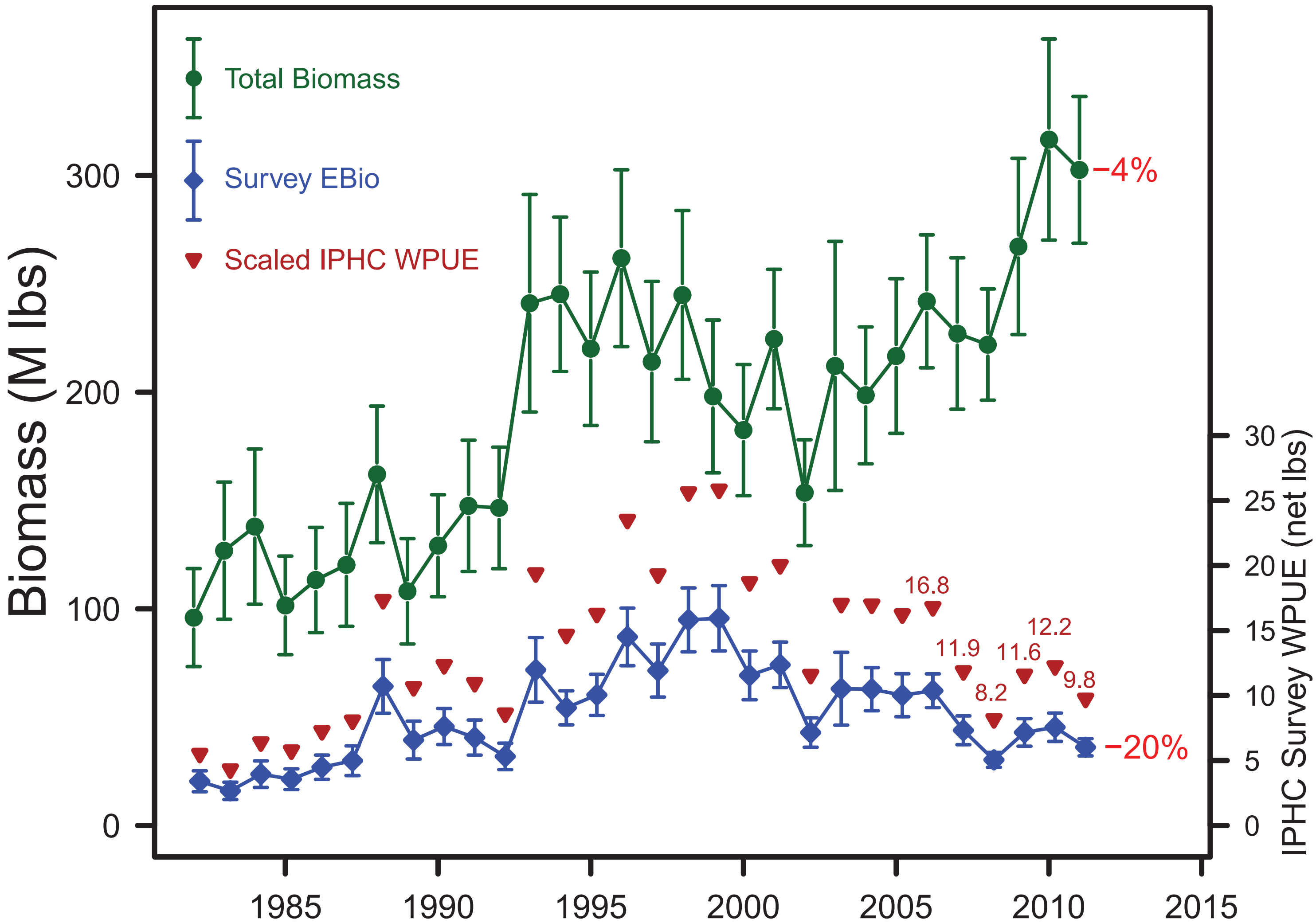


Figure 7. Swept-area estimates of halibut abundance from the NMFS EBS trawl survey. The red dots and error bars represent mean and 95% con dence interval for the total abundance; the blue diamonds are error bars representing mean and 95% con dence interval for abundance with survey selectivity applied to the total biomass (termed survey EBio). The inverted purple triangles represent the estimated density of O32 halibut (per standardized skate of gear) across the shelf; this index is scaled to the survey EBio trend (see text for full details). The percentages show the change in the index values from 2010 to 2011.

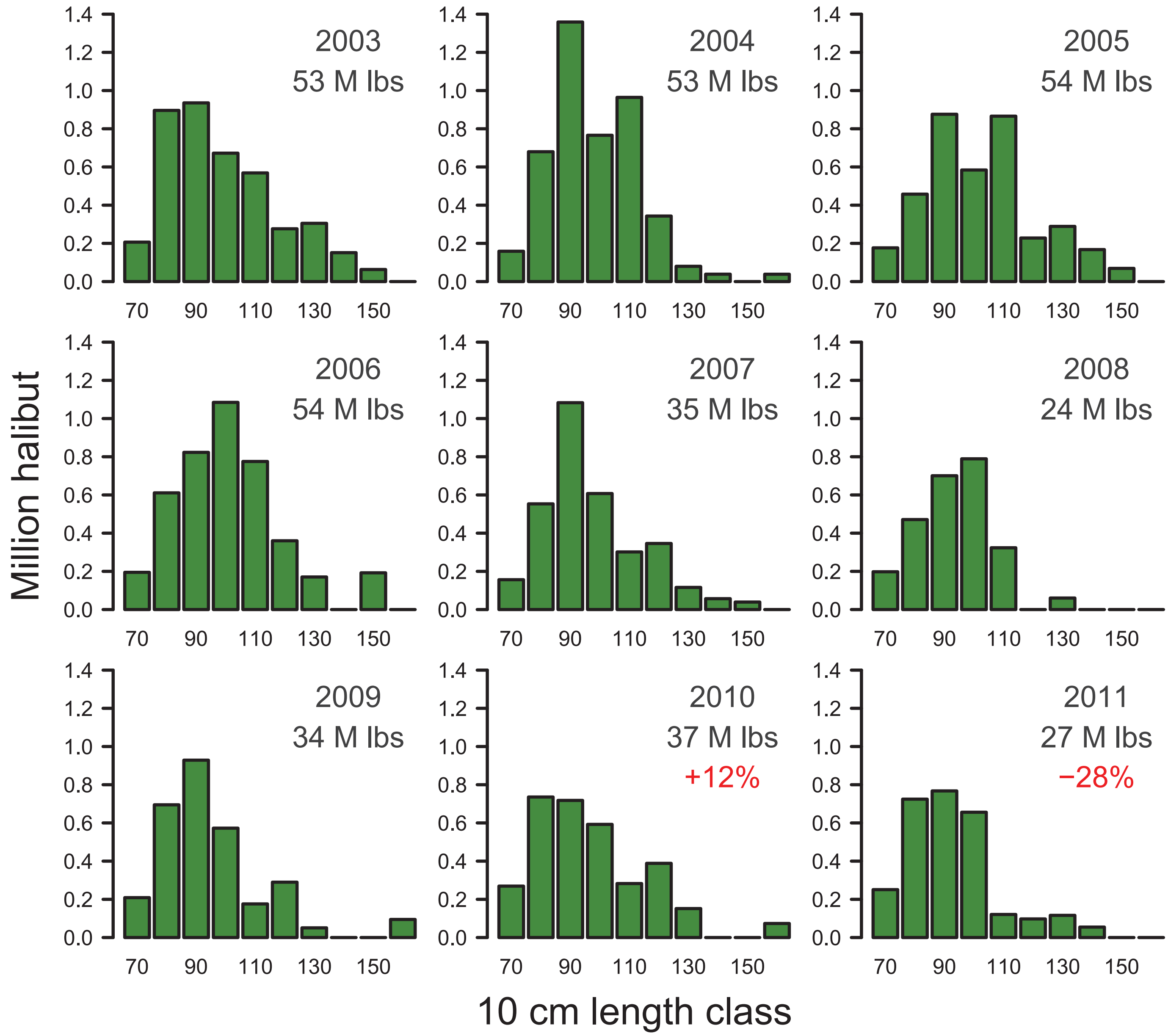


Figure 8. Swept area estimates of halibut EBio, by 10-cm length interval, in the NMFS EBS trawl survey for the years 2002 to 2010. Increases in estimated EBio over the previous year are indicated in the 2010 and 2011 plots. Exploitable numbers of halibut are illustrated by the darker bars. The percentages show the change in the index values from 2009 to 2010.

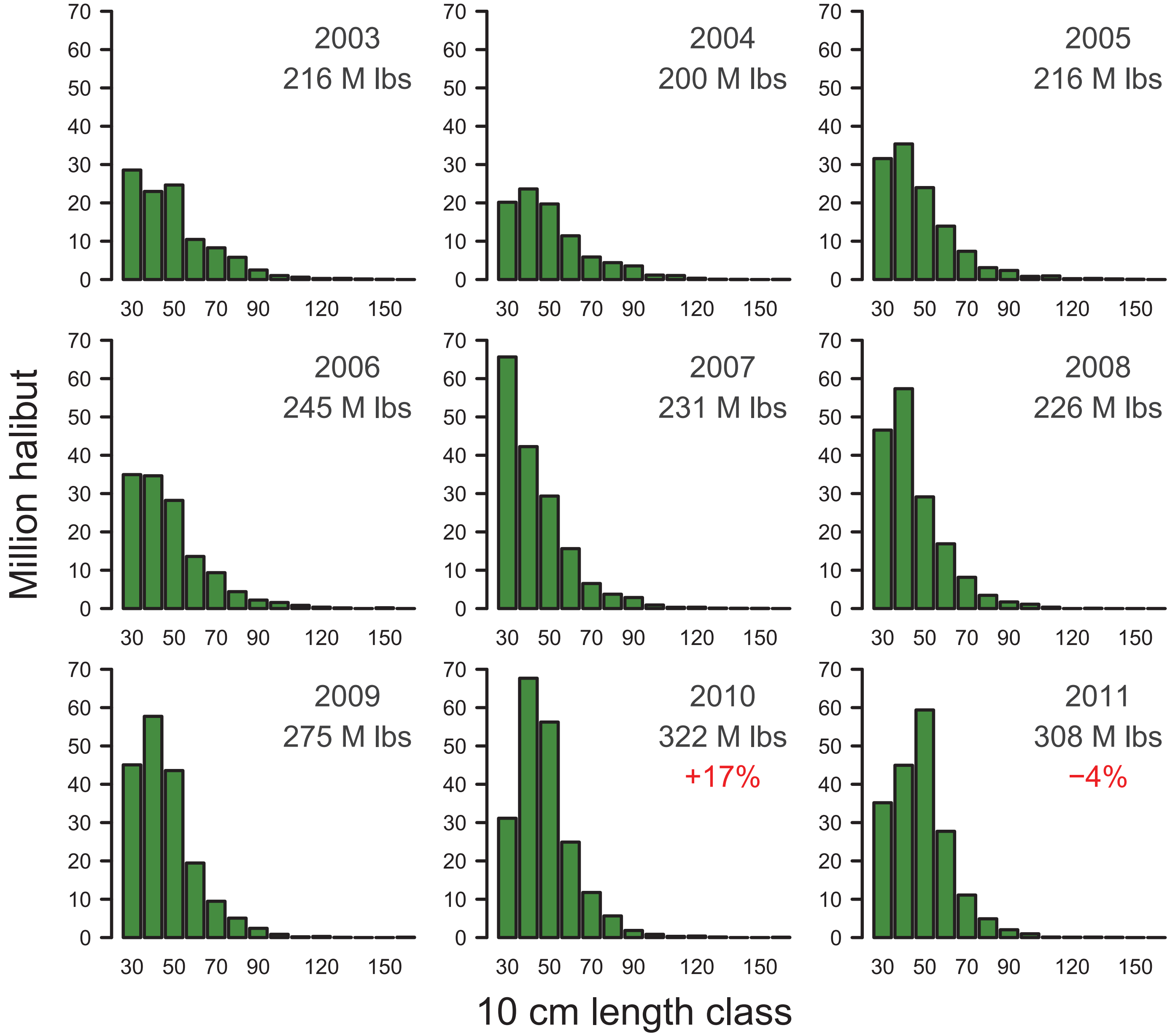


Figure 9. Swept area estimates of halibut TBio, by 10-cm length interval, in the NMFS EBS trawl survey for the years 2002 to 2011. Changes in estimated EBio over the previous year are indicated in the 2010 and 2011 plots.

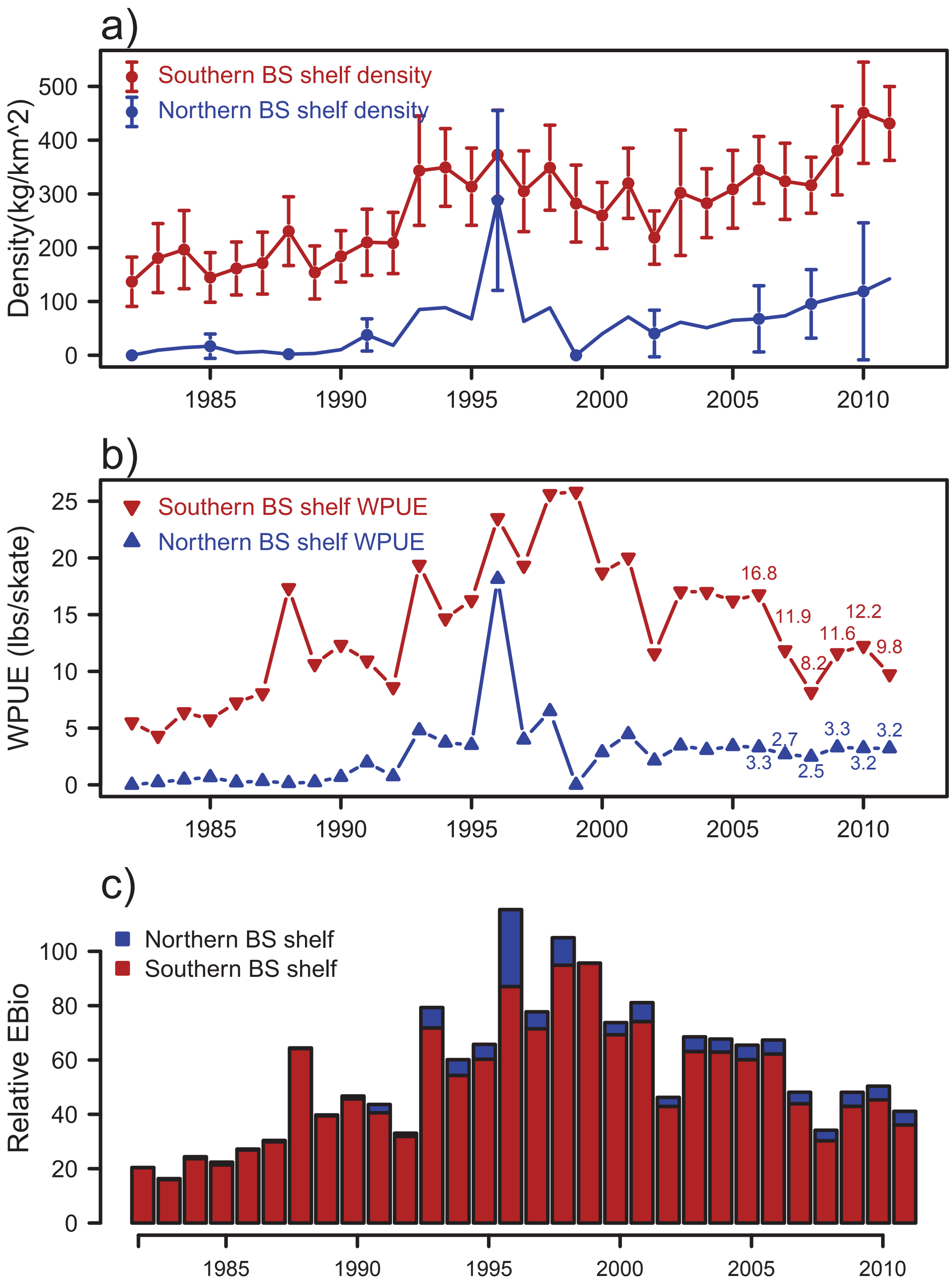


Figure 10. Time series used to construct an estimate of halibut biomass in the northern shelf region of Area 4CDE, termed Area 4N. See text for details.

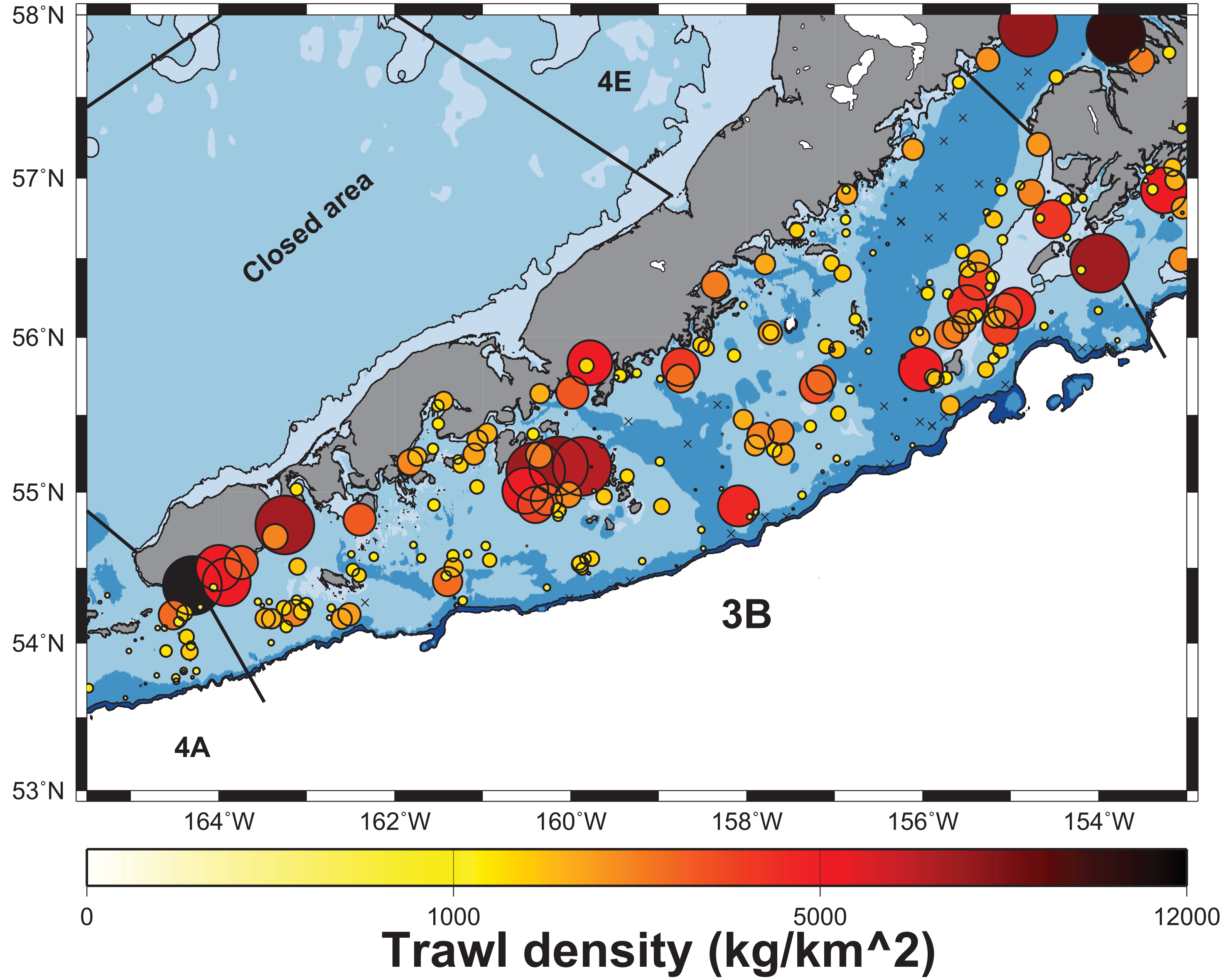


Figure 11a. Catch rates of halibut (all sizes) at survey stations in the 2011 NMFS biennial Gulf of Alaska trawl survey in the vicinity IPHC Area 3B. The size of the circles is proportional to catch rate (kg/km²) and conveys the same information as the coloring of the circles. Stations with zero catch are indicated by an "x".

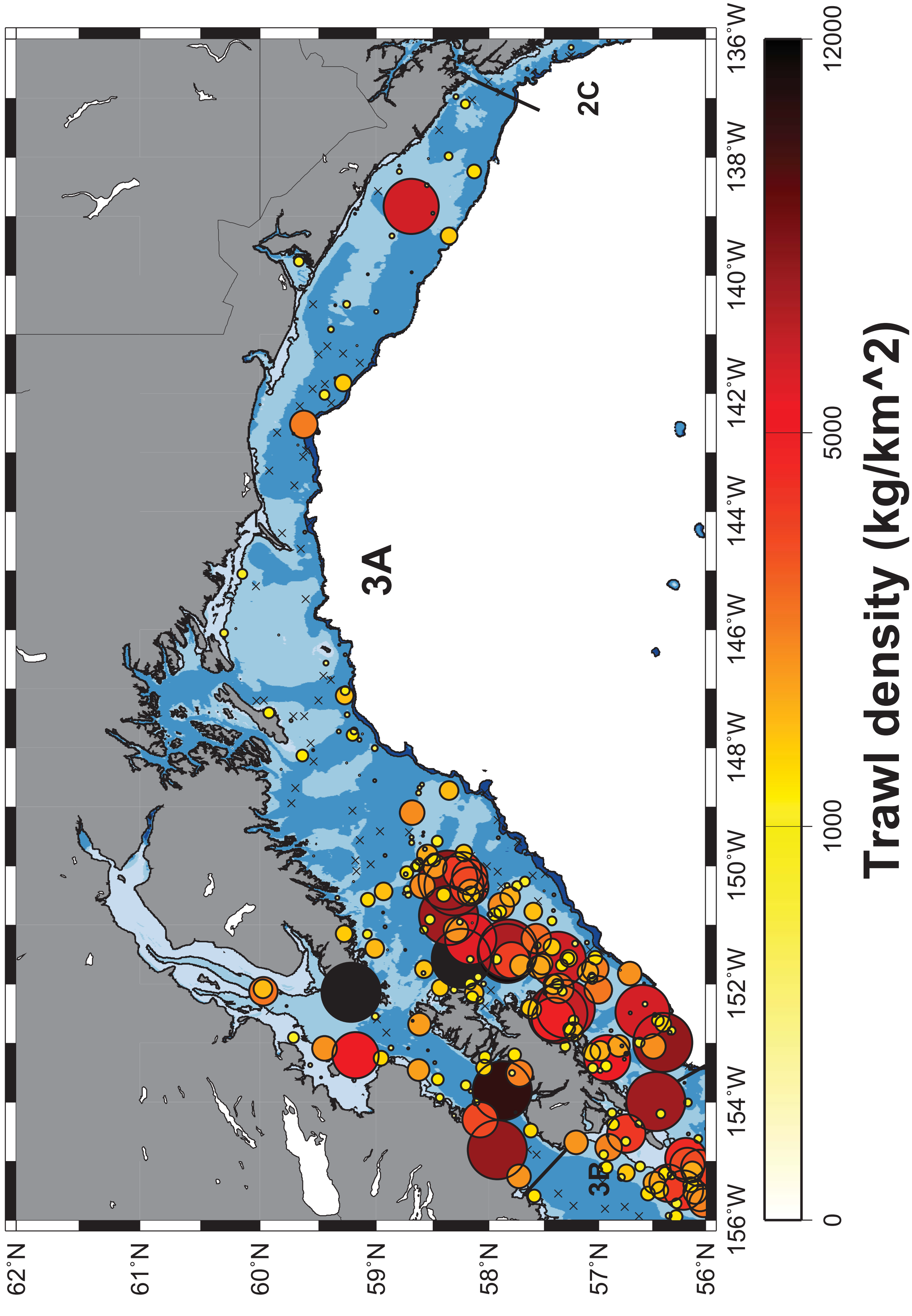


Figure 11b. Same as Figure 11a, but for IPHC Area 3A.

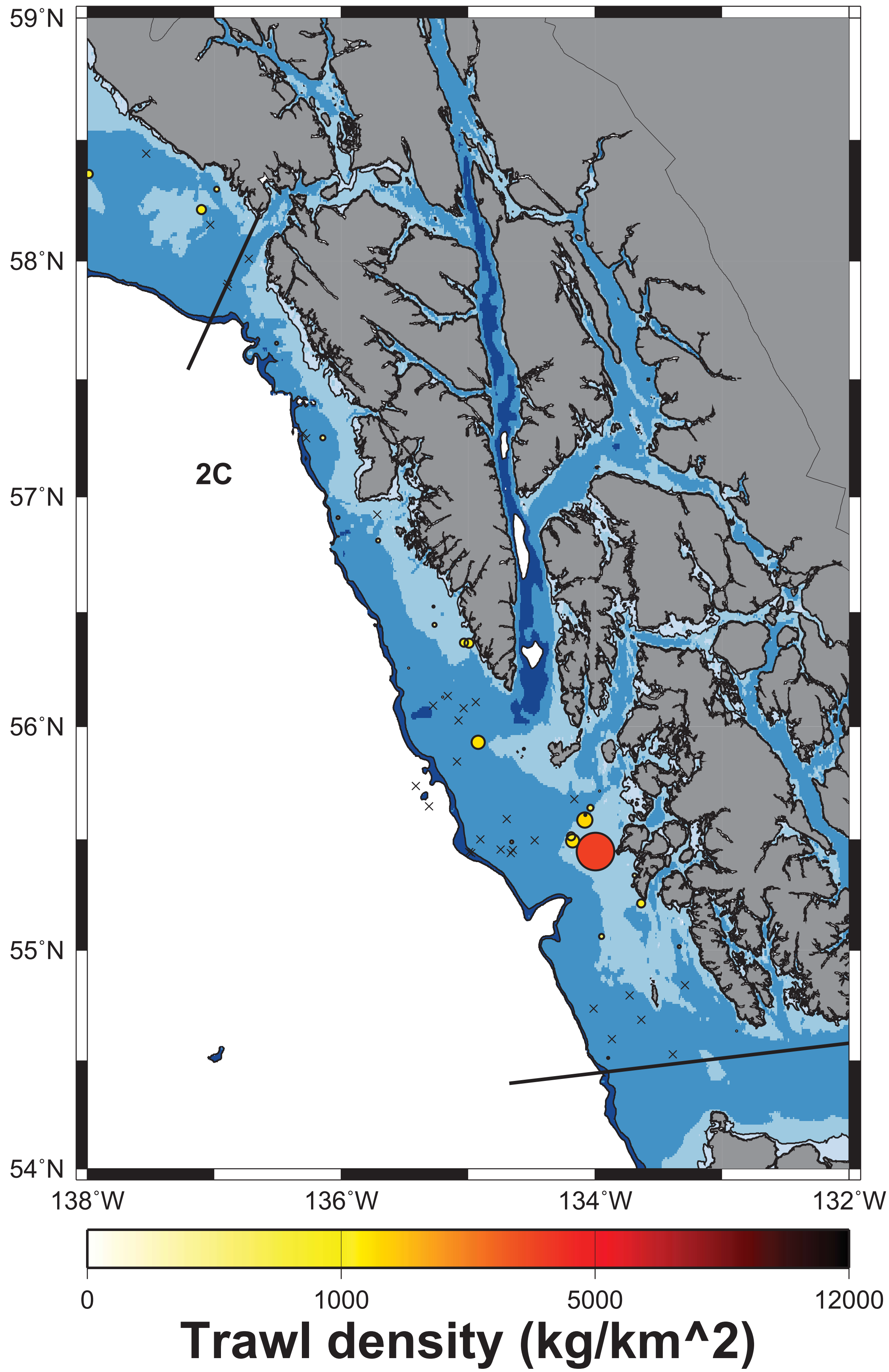


Figure 11c. Same as Figure 11a, but for IPHC Area 2C.

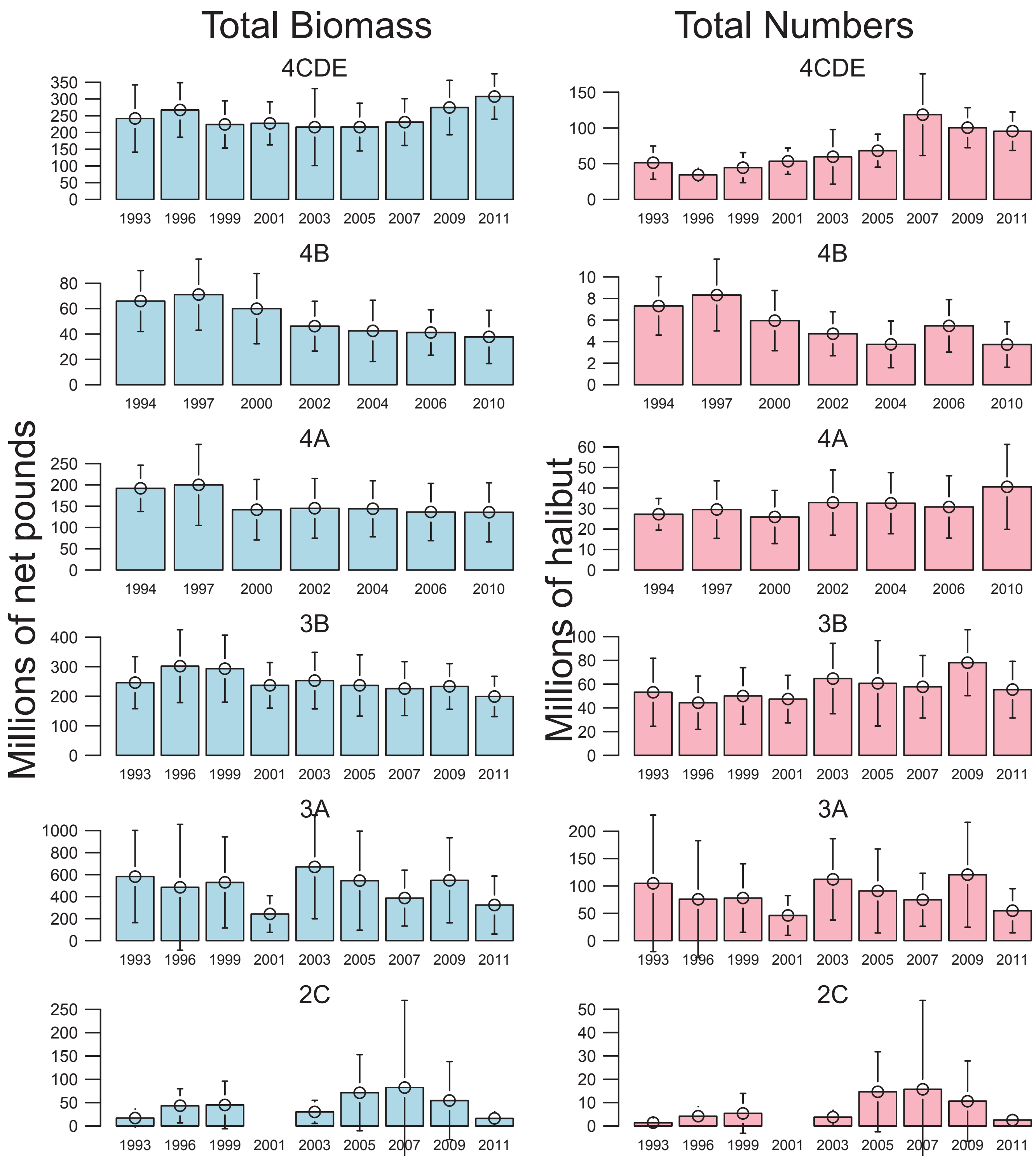


Figure 12. Swept area estimates of total biomass and total numbers of halibut in IPHC Areas 4CDE to 2C.

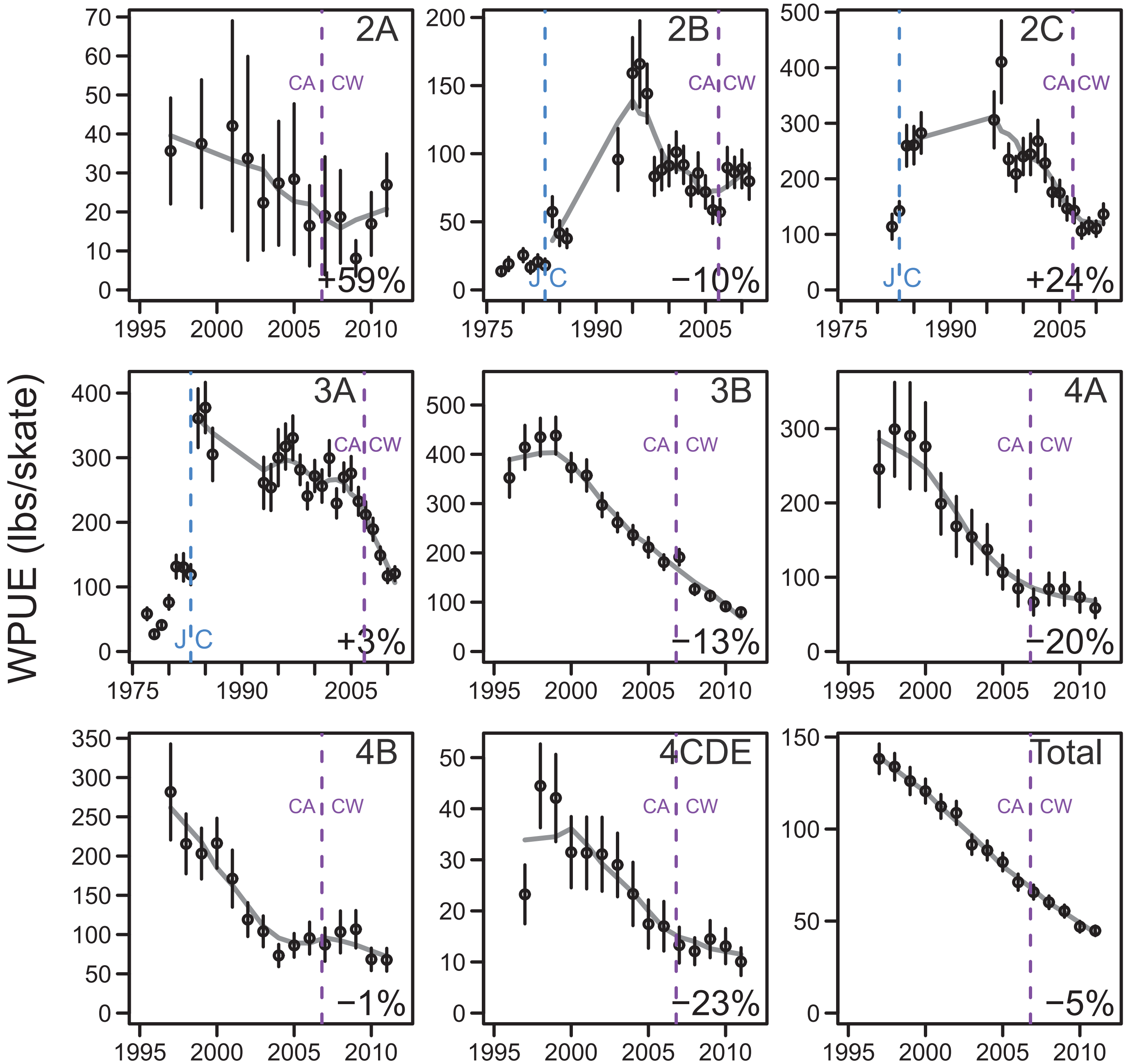


Figure 13. Survey WPUE (weight of O32 halibut per standardized skate of gear) by regulatory area. The dots indicate the area-wide average; the vertical bars represent +/ 2 standard errors of the mean. The thick line is a smoother to illustrate trend; it is not an assessment model tted to the WPUE data. The total is computed by area-weighting the individual area WPUE time series. Note that the timeline for Areas 2B, 2C, and 3A differ from the other areas and extends back to 1975. The data points prior to 1984 are from the "J" hook era. The dashed vertical line indicates the change from closed area (CA) to coastwide (CW) assessment. The percentages show the change in the index values from 2010 to 2011.

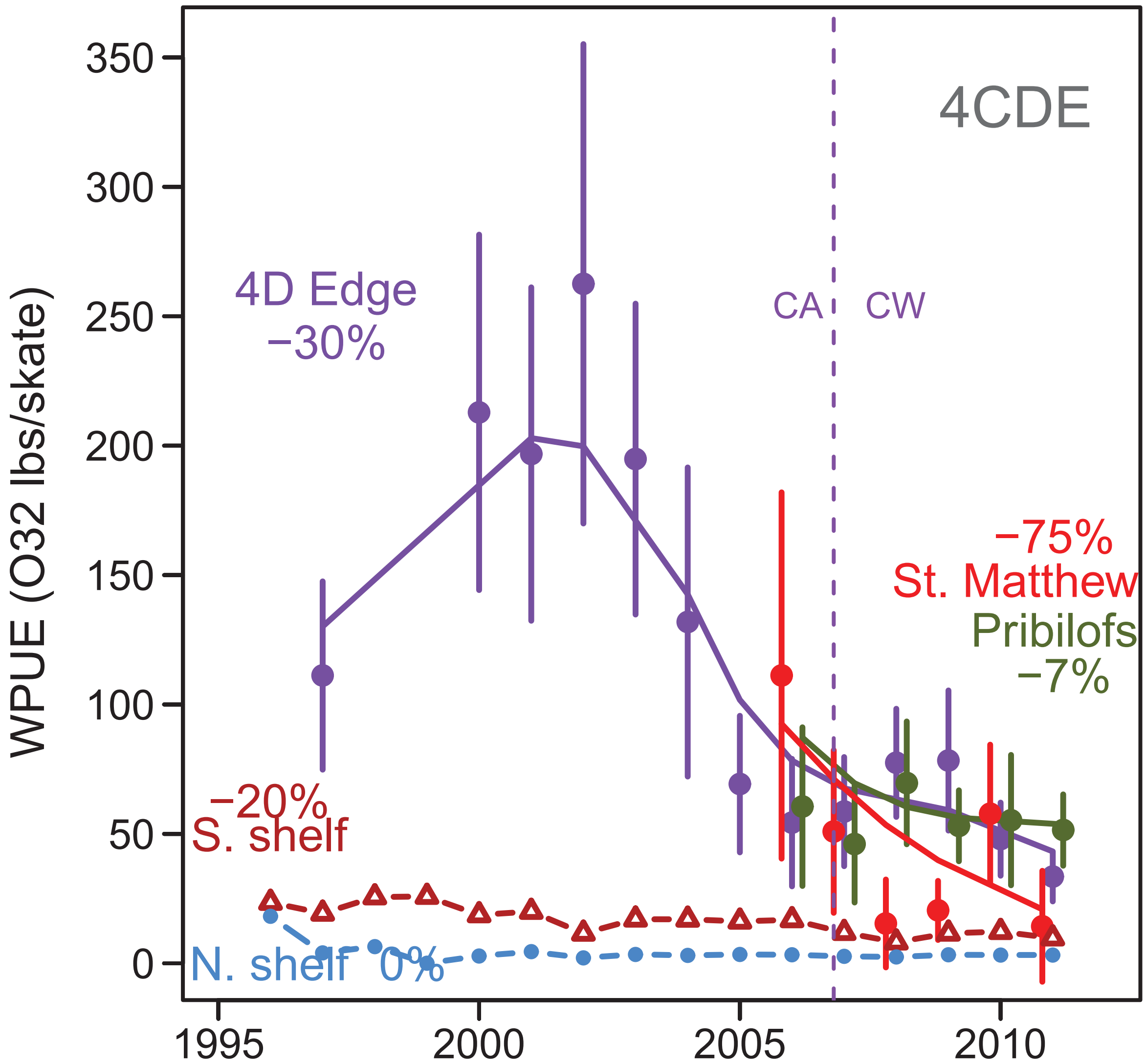


Figure 14. The ve subarea components used to construct the WPUE survey index for Area 4CDE. The dashed vertical line indicates the change from closed area (CA) to coastwide (CW) assessment. The percentages show the change in the index values from 2010 to 2011.

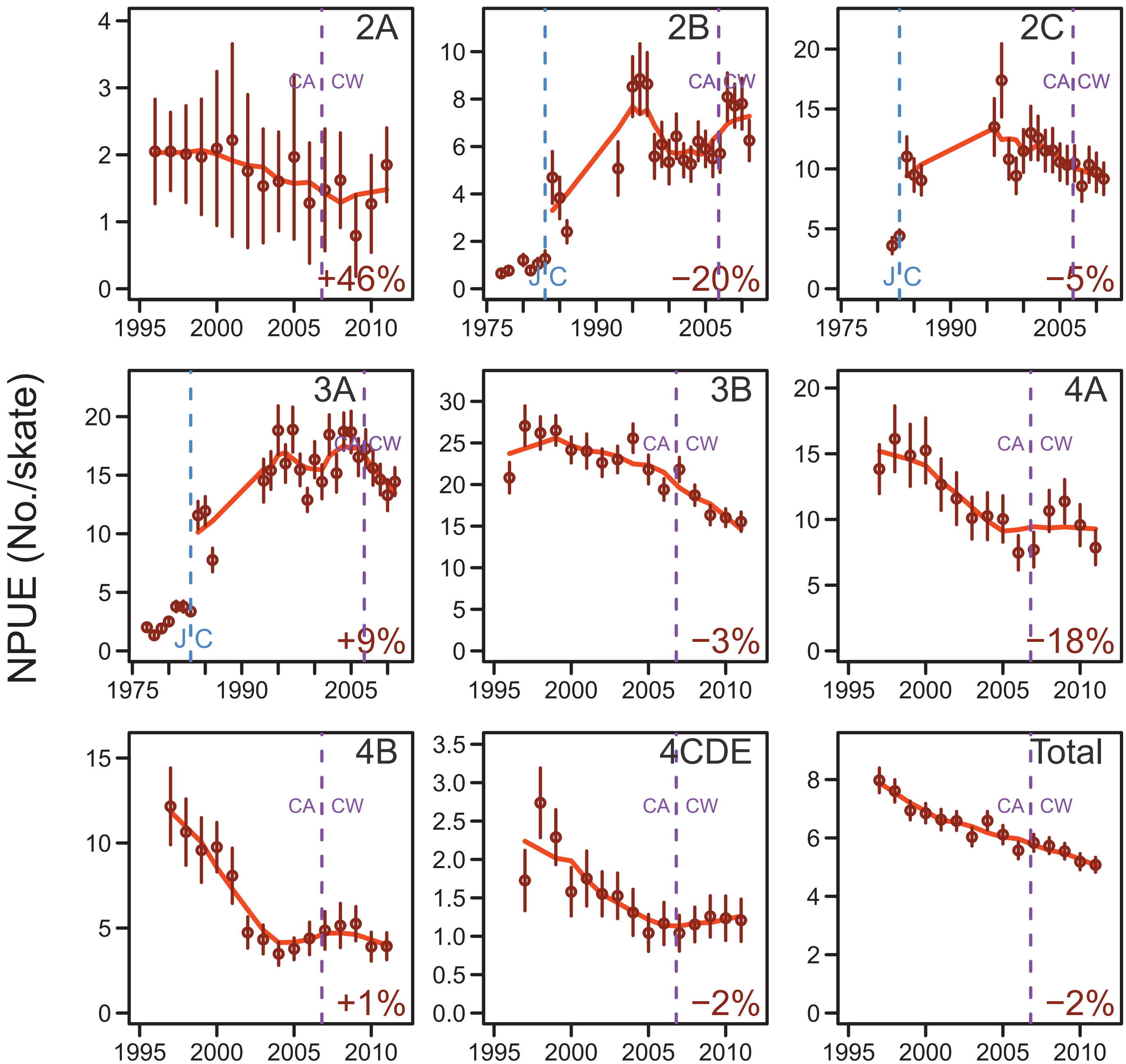


Figure 15. Survey NPUE (total number of halibut (all sizes) per standardized skate of gear) by regulatory area. The dots indicate the area-wide average; the vertical bars represent +/ 2 standard errors of the mean. The thick line is a smoother to illustrate trend; it is not an assessment model tted to the NPUE data. The total is computed by area-weighting the individual area NPUE time series. Note that the timeline for Areas 2B, 2C, and 3A differ from the other areas and extends back to 1975. The data points prior to 1984 are from the "J" hook era. The percentages show the change in the index values from 2010 to 2011.

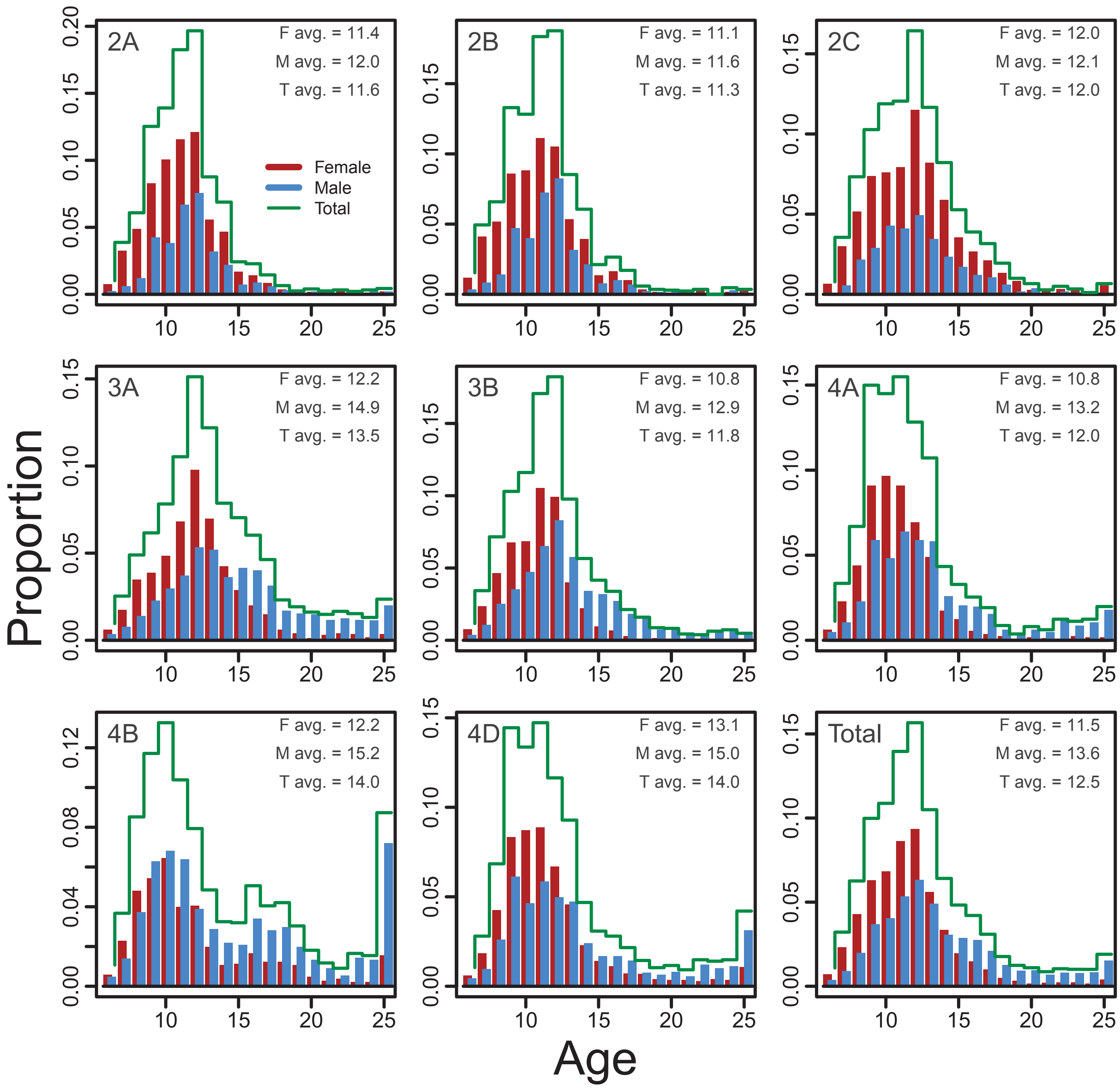


Figure 16. Regulatory area sex and age compositions from halibut taken in the 2011 IPHC stock assessment survey. Proportions are shown for females (red bars), males (blue bars) and sexes combined (green line). Average age is also shown, with "T" indicating Total (sexes combined).

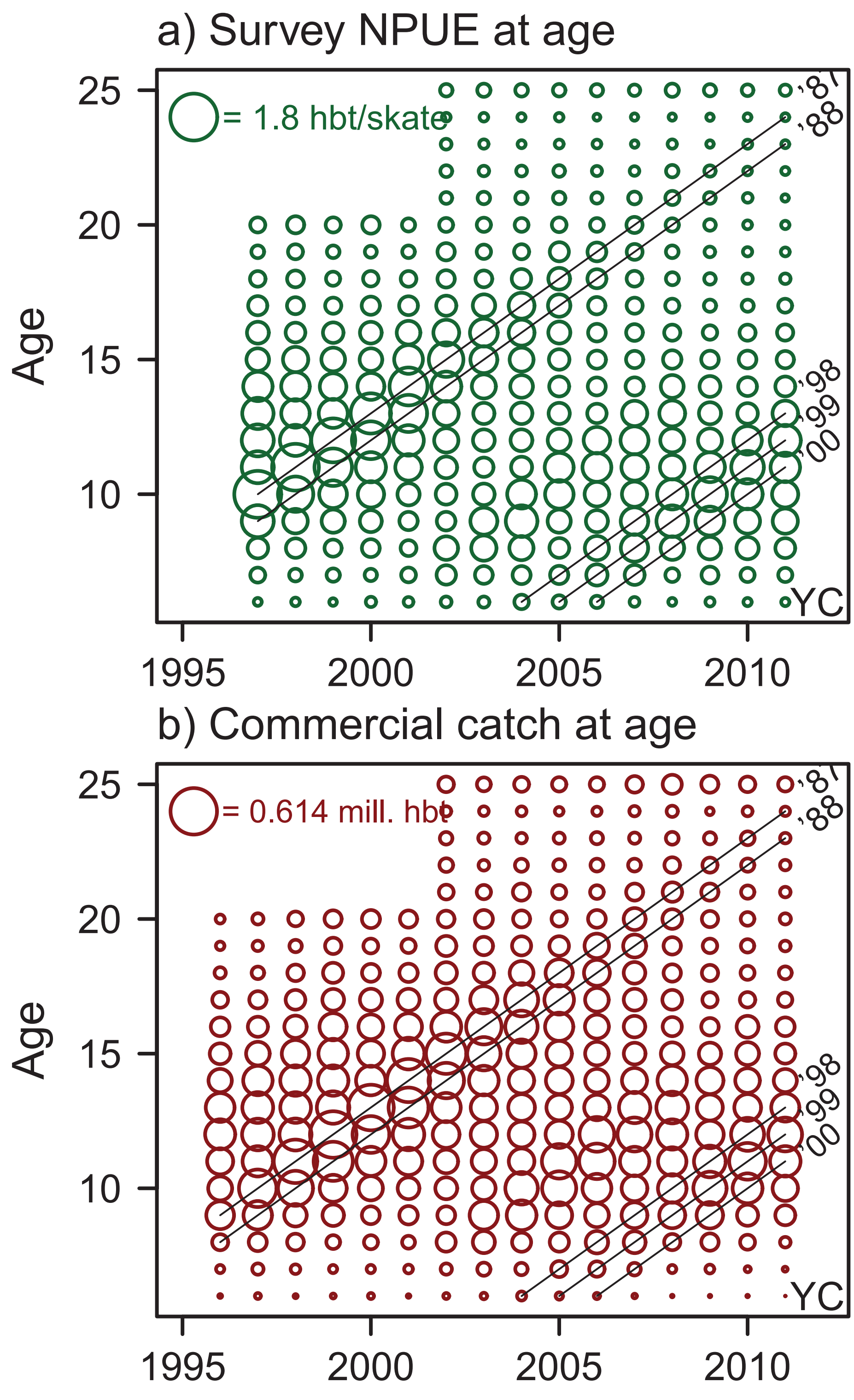


Figure 17. Bubble plots showing age-speci c survey catch rate of halibut (both sexes combined, panel a), and catch at age (both sexes combined) in the commercial shery (panel b).

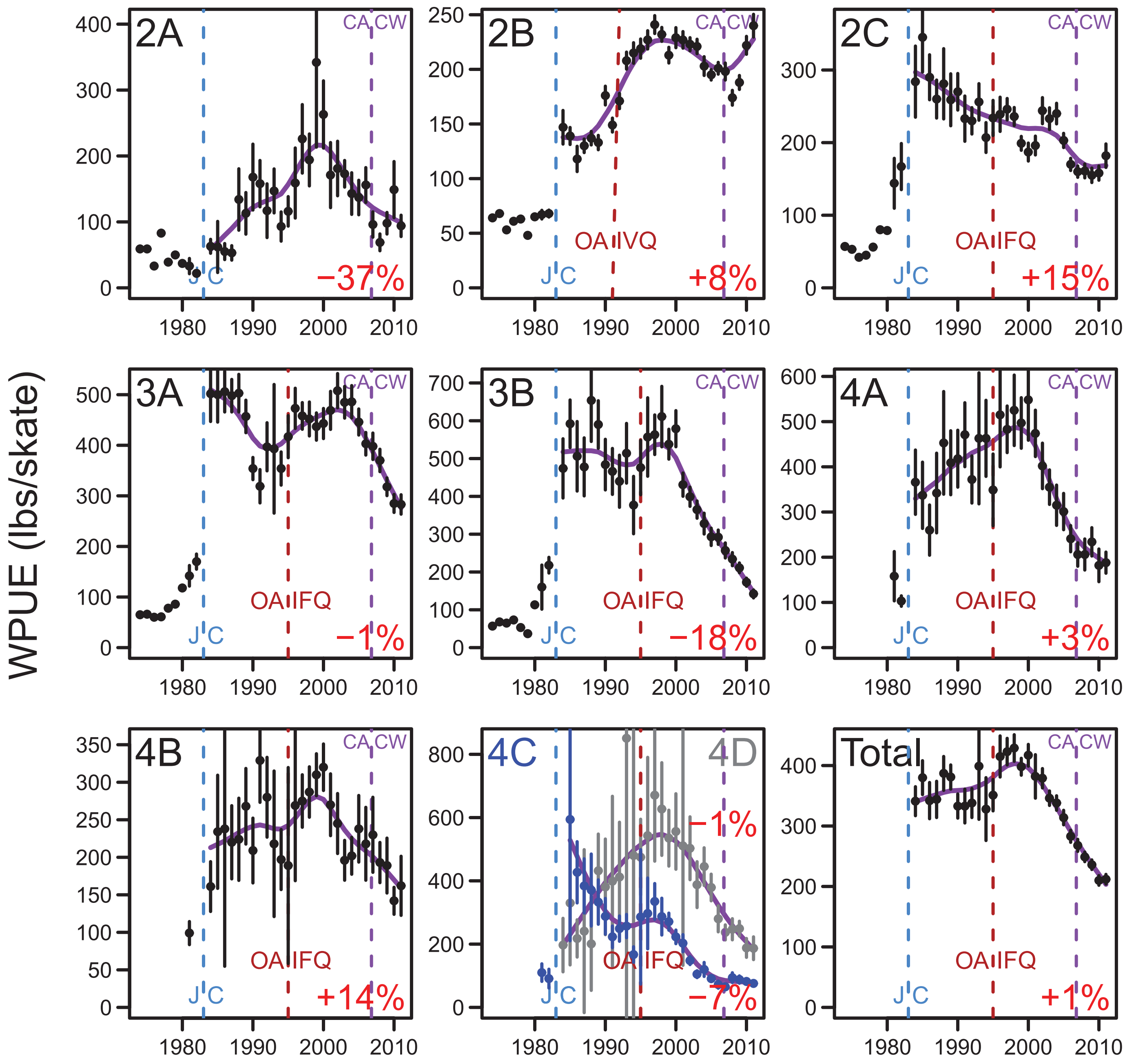


Figure 18. Commercial WPUE by regulatory area. The dots indicate the area-wide average; the vertical bars represent +/ 2 standard errors of the mean. The gray/green line is a smoother to illustrate trend; it is not an assessment model t to the CPUE data. The total is computed by area-weighting the individual area WPUE time series. The dashed vertical lines indicate transitions between J and C hook, between open access (OA) and Individual Vessel Quotas in Area 2B, and between open access and Individual Fishing Quotas in Areas 2C, 3, and 4. The percentages show the change in the index values from 2010 to 2011.

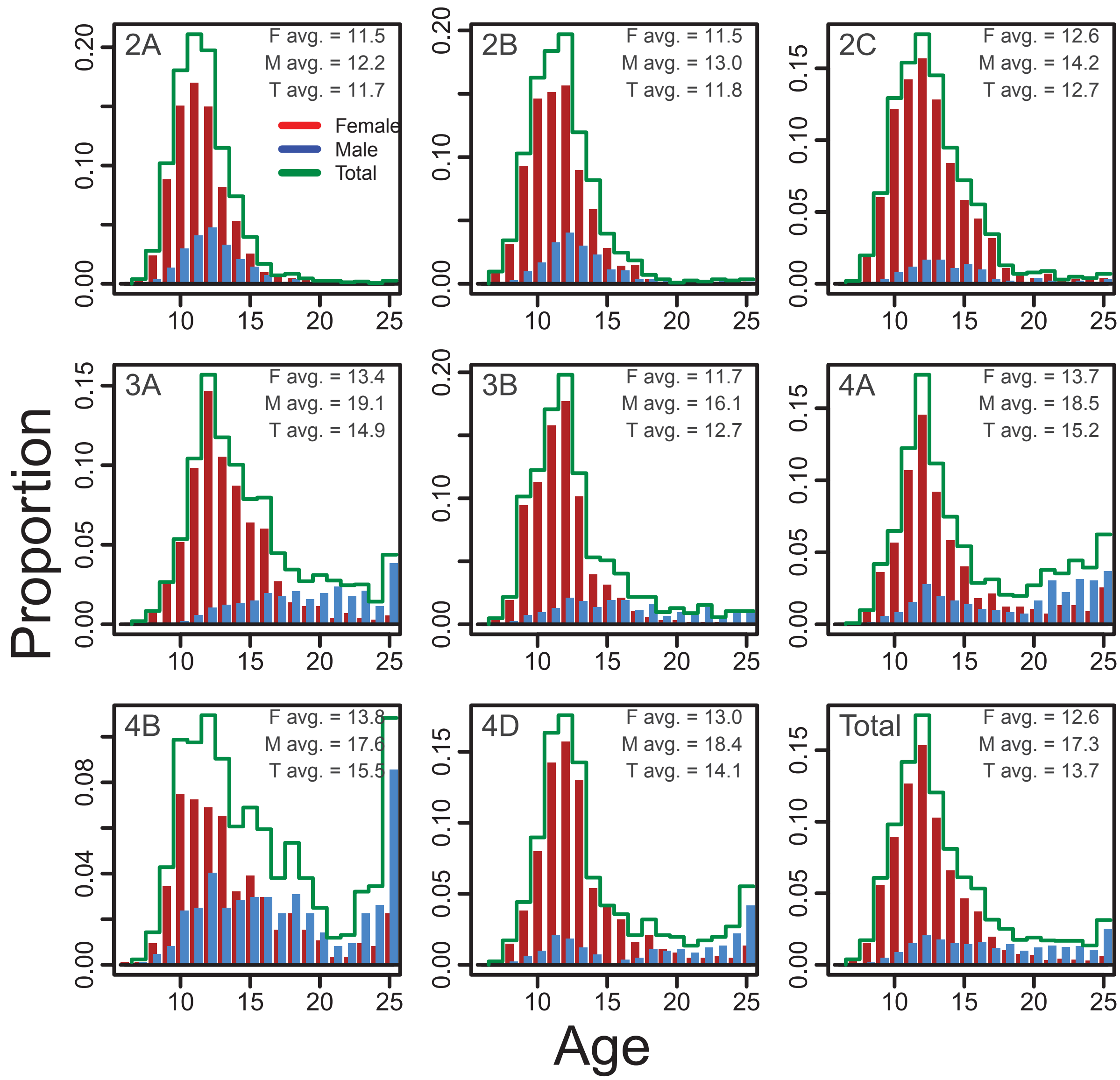


Figure 19. Regulatory area sex and age compositions from halibut sampled from commercial landings. Proportions are shown for females (red bars), males (blue bars) and sexes combined (green line). Average age is also shown, with "T" indicating Total (sexes combined).

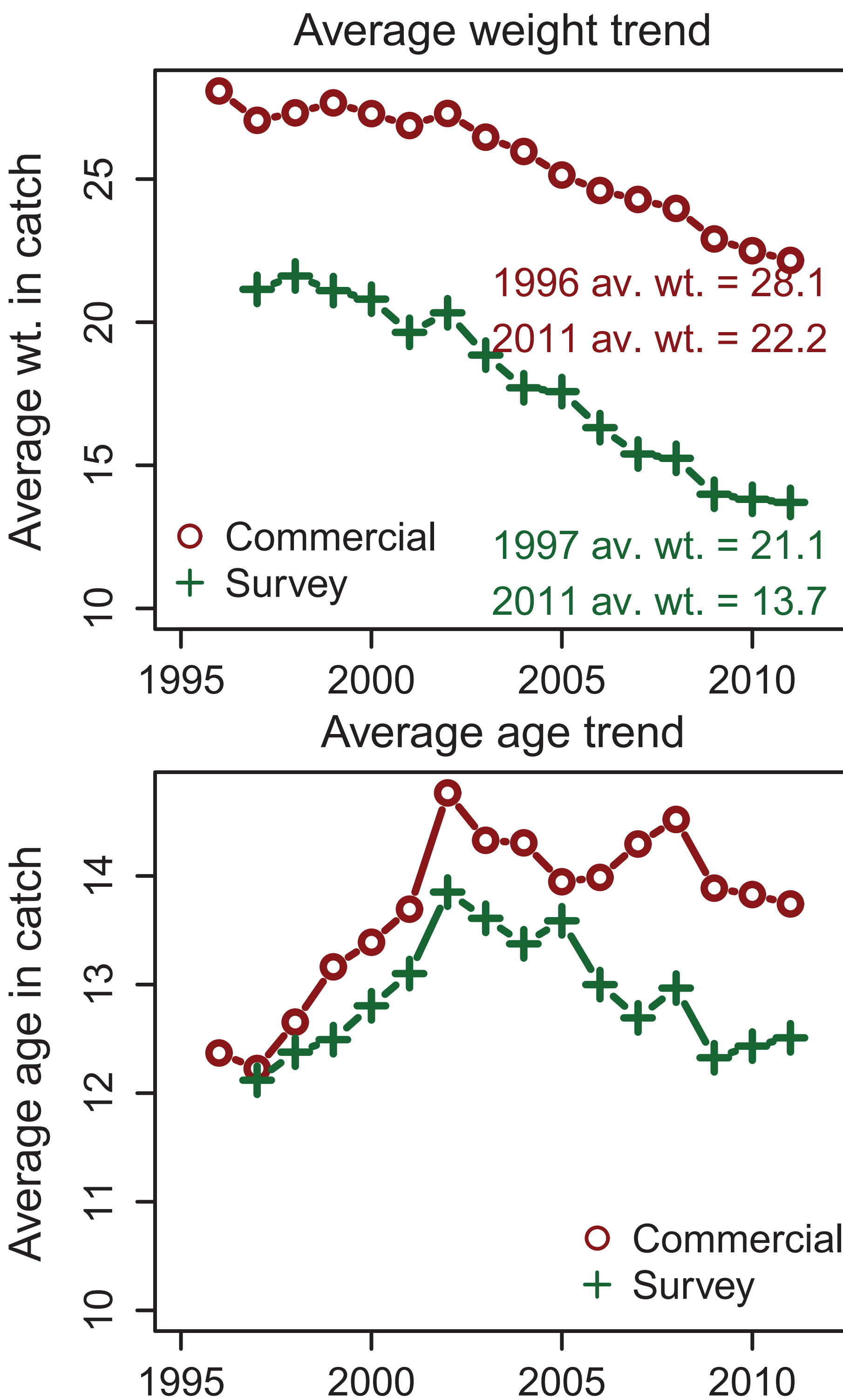


Figure 20. Average weight (panel a) and average weight (panel b) trends for the coastwide halibut stock for 1996 to 2011.

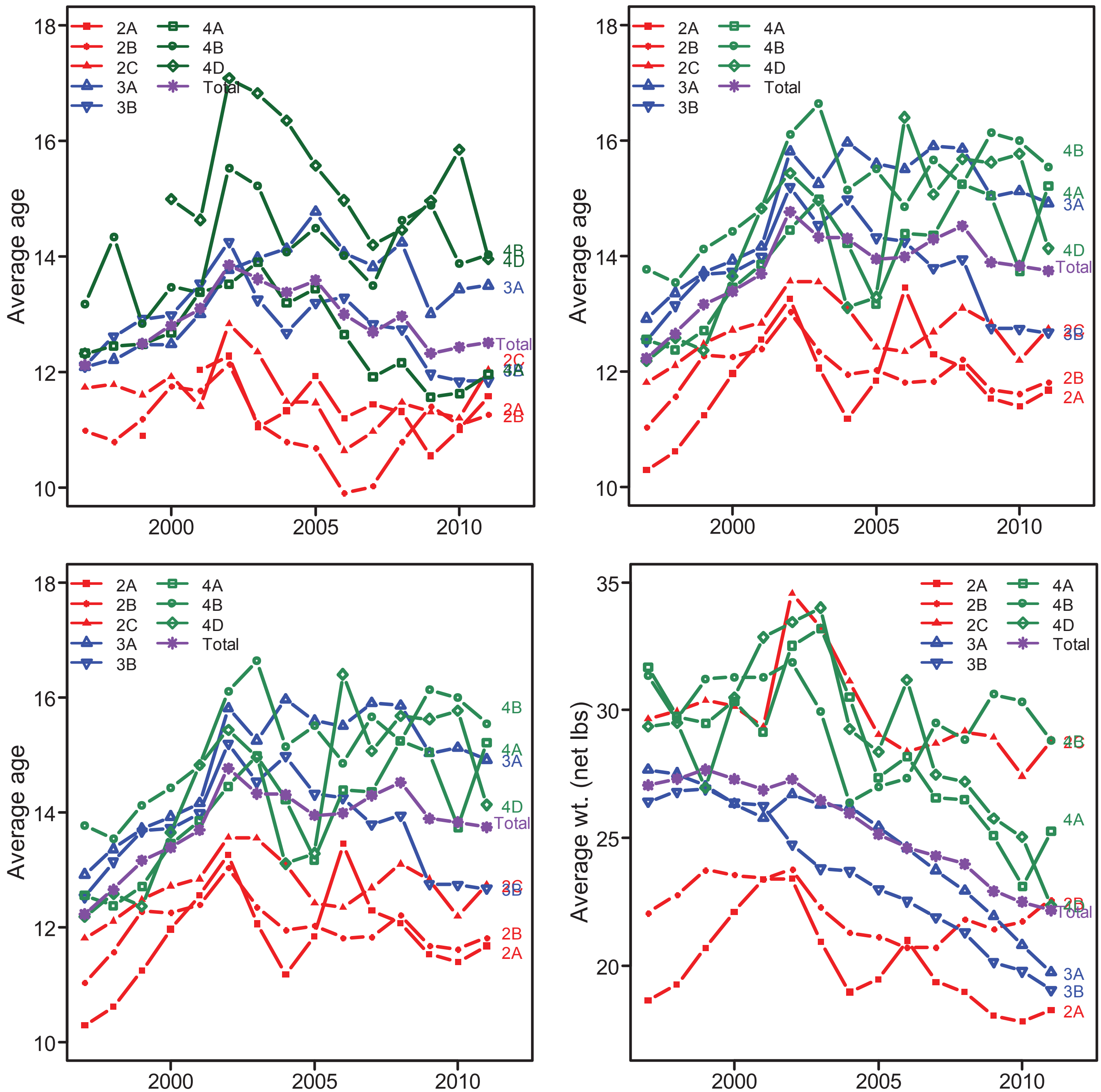


Figure 21. Trends in average age (top panels) and average weight (bottom panels) in survey catches (left panels) and commercial catches (right panels).

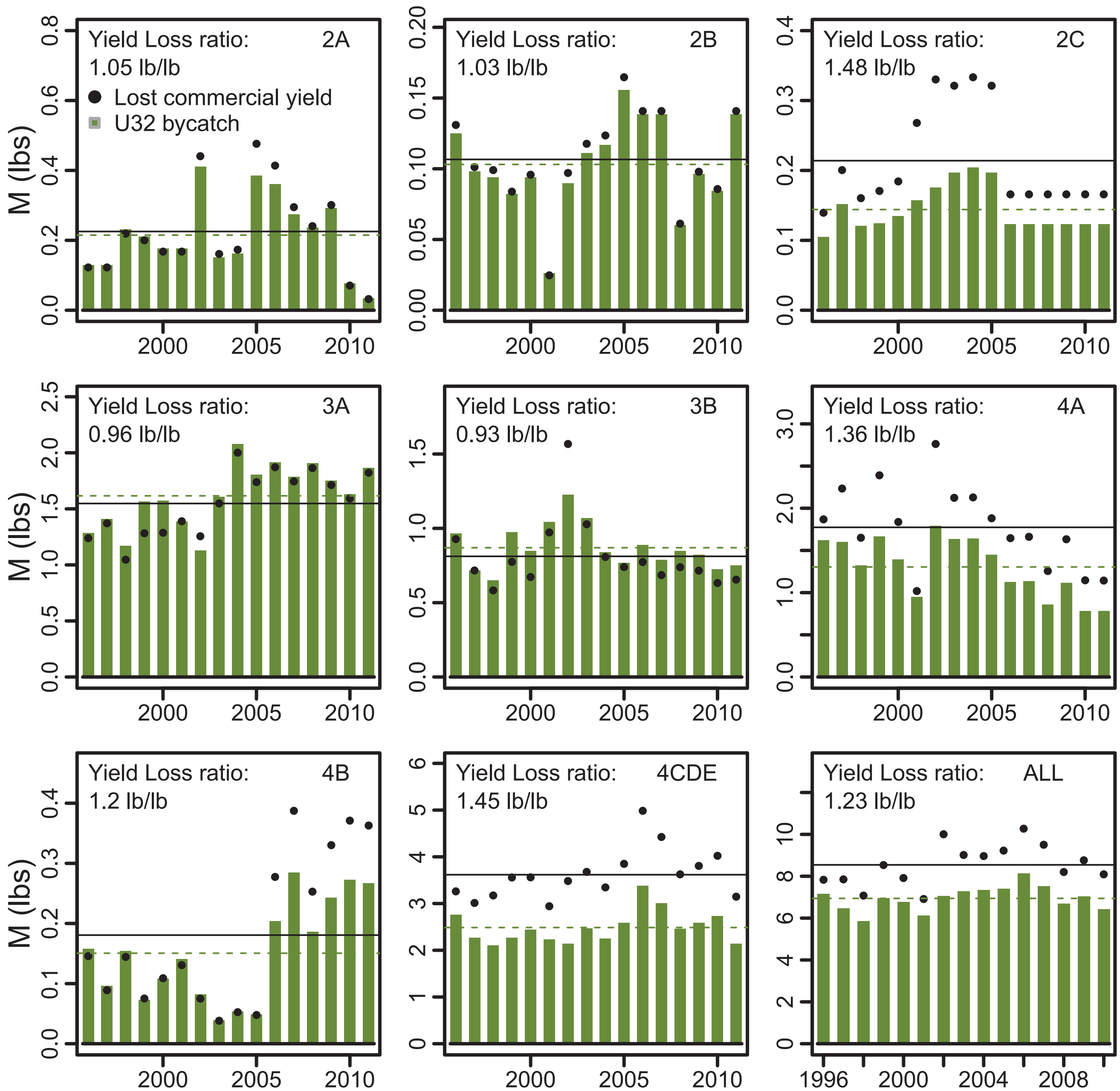
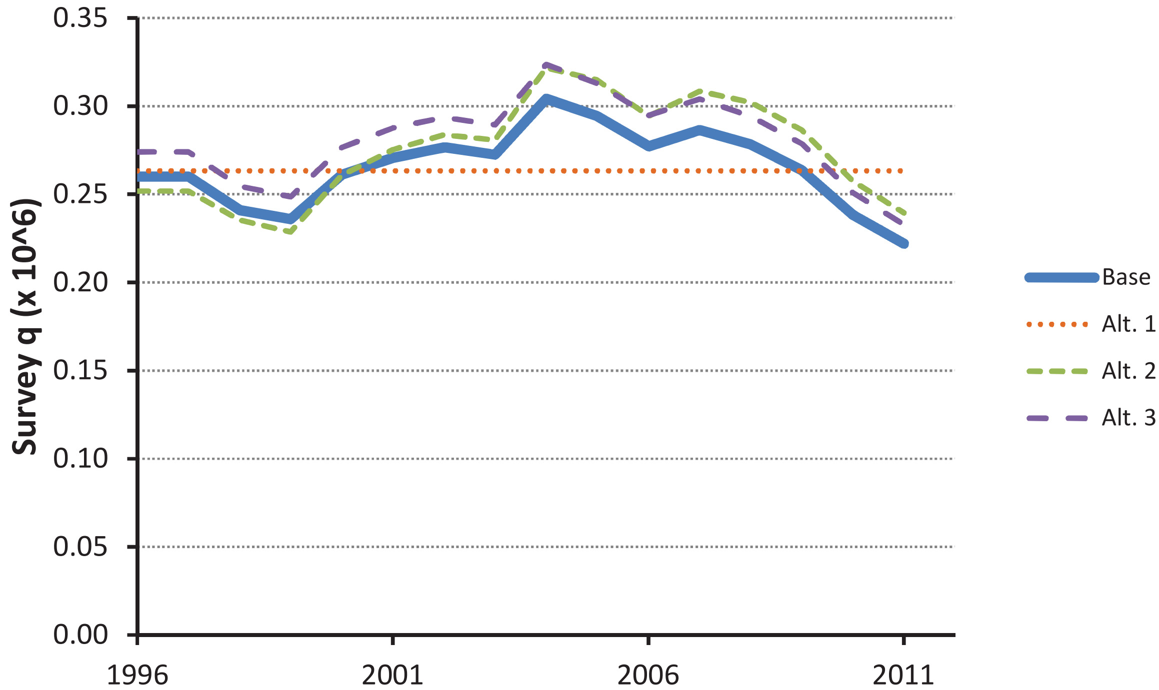


Figure 22. Illustration of impact of under-32 inch bycatch on future yield by regulatory area, without accounting for migration. The bars show estimated annual bycatch mortality, dots show estimated lost yield. Lost yield is estimated using growth models developed individually for each regulatory area. The dashed horizontal line is the average U32 bycatch over the 1996-2011 period; the solid horizontal line is the average yield loss over the same time frame.



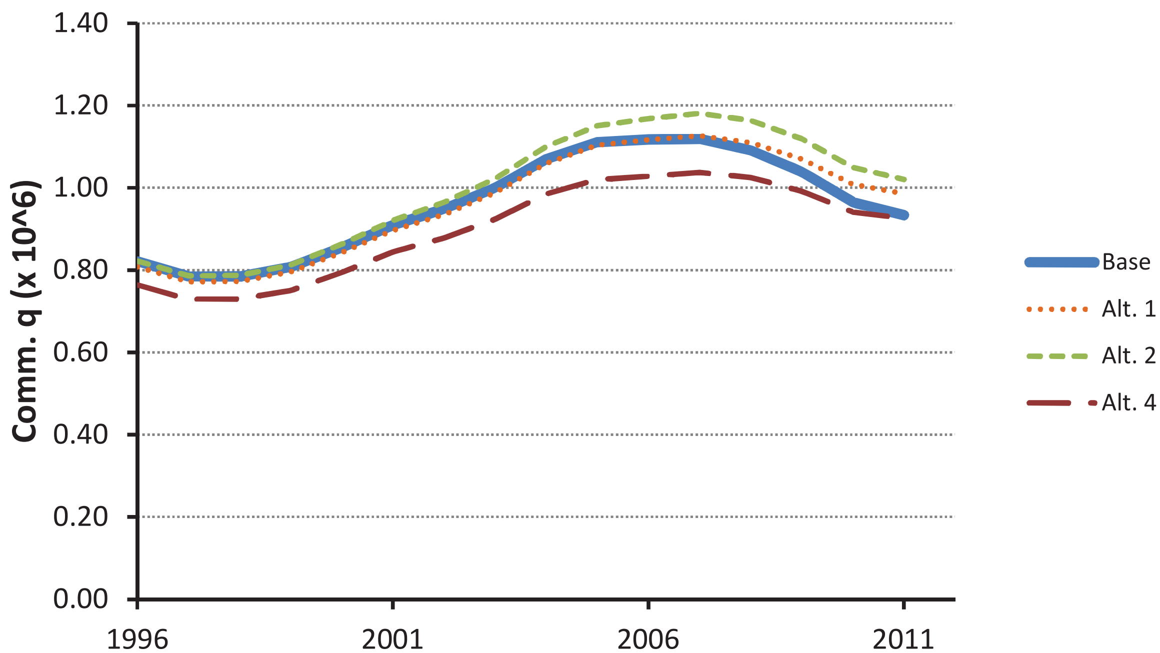


Figure 23. Illustration of time trends in survey and commercial "q" (catchability) among the Base and four Alternative assessment models. See text for details.

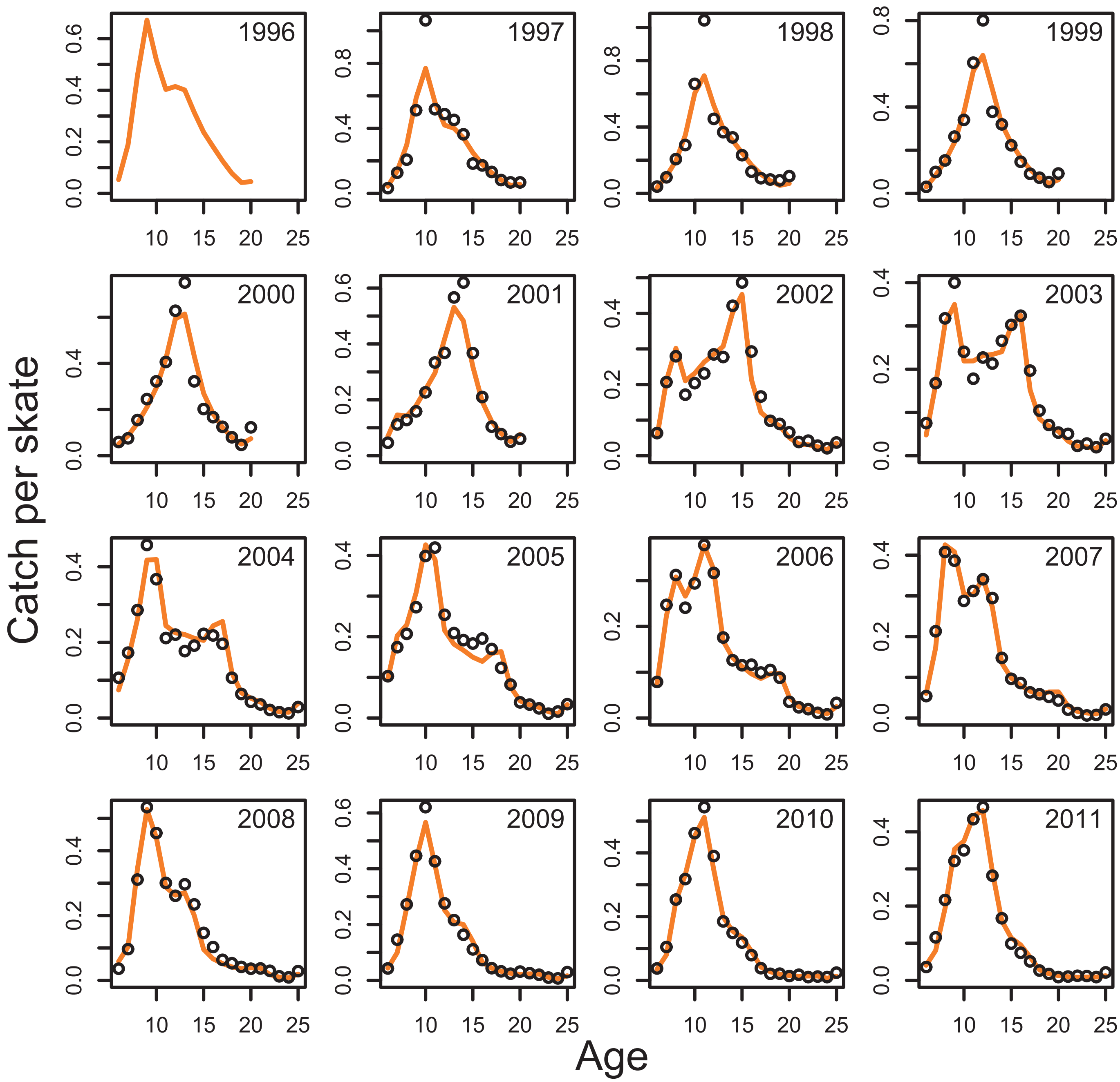


Figure 24a. Observed (points) and predicted (lines) survey NPUE at age of females in the 2011 coastwide model t.

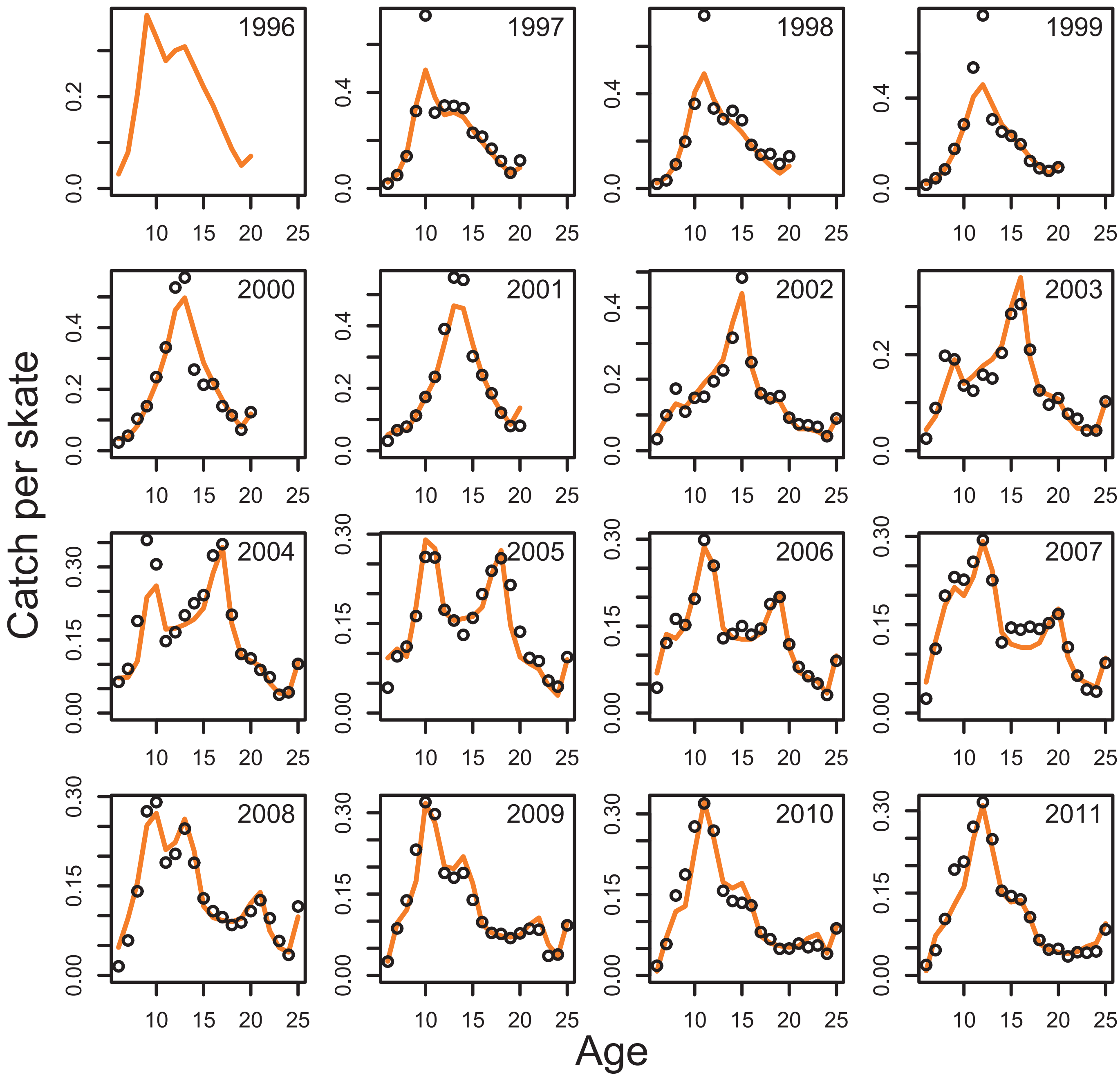


Figure 24b. Observed (points) and predicted (lines) survey NPUE at age of males in the 2011 coastwide model t.

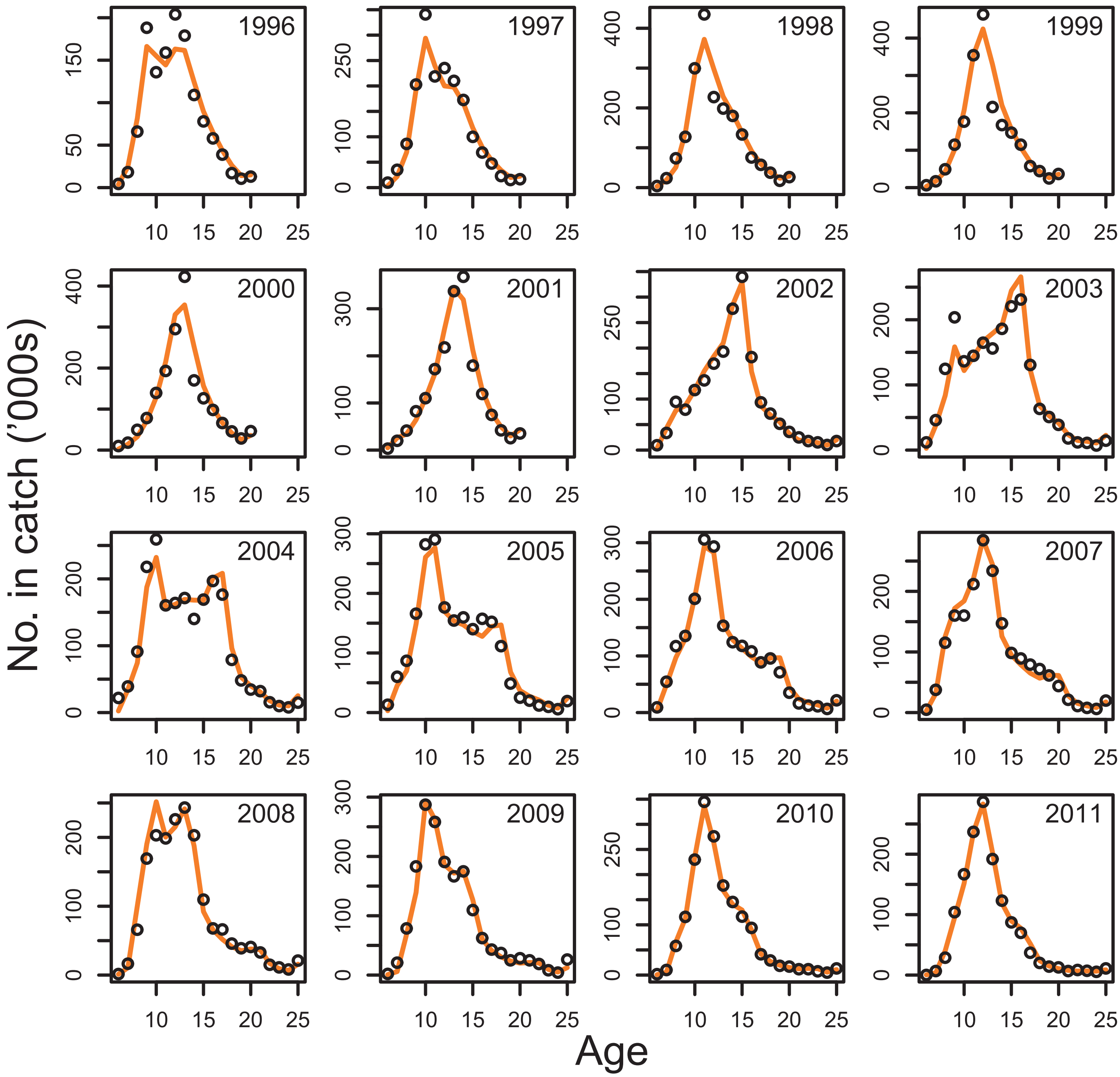


Figure 25a. Observed (points) and predicted (lines) commercial catch at age of females in the 2011 coastwide model t.

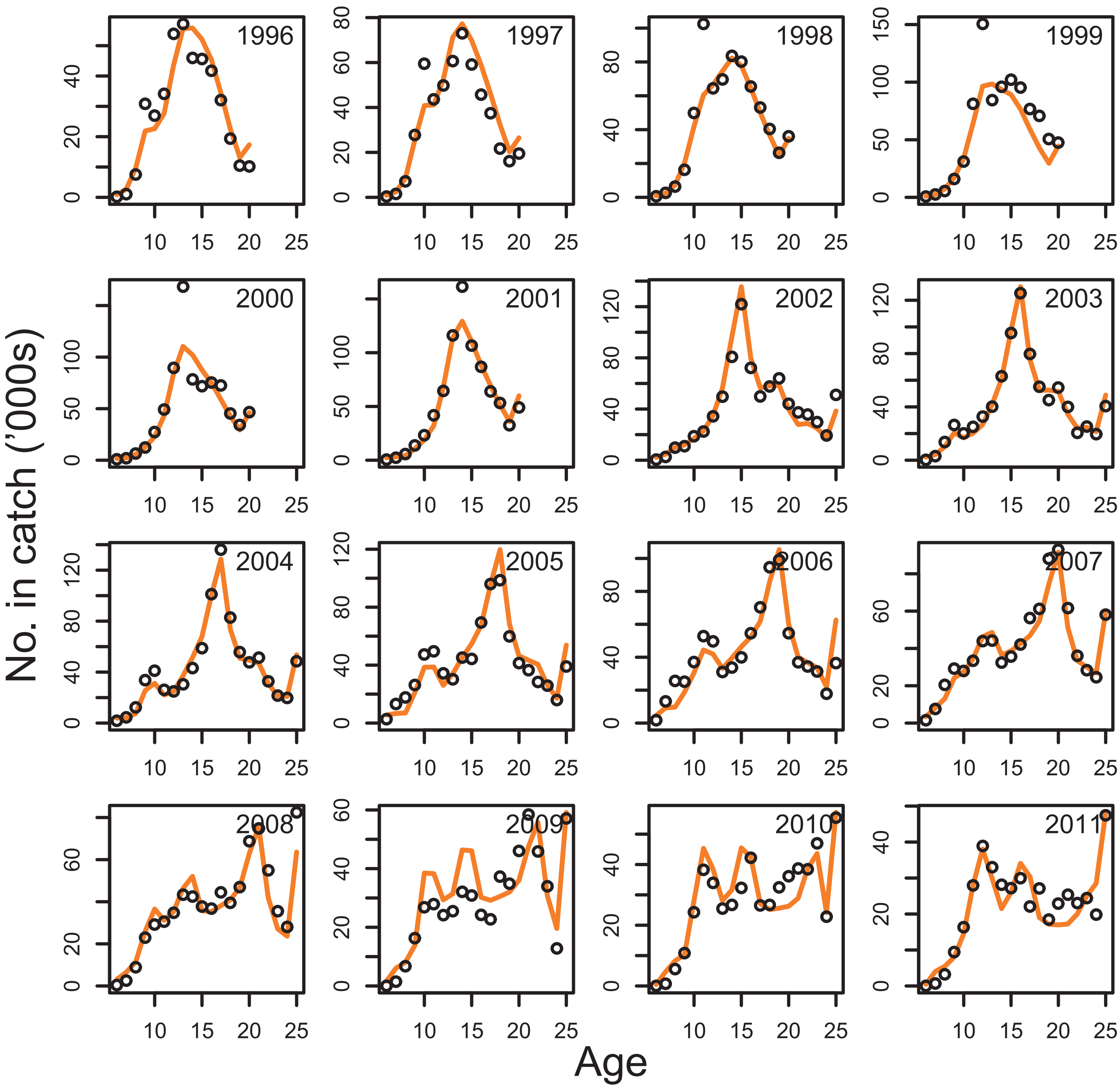


Figure 25b. Observed (points) and predicted (lines) commercial catch at age of males in the 2011 coastwide model t.

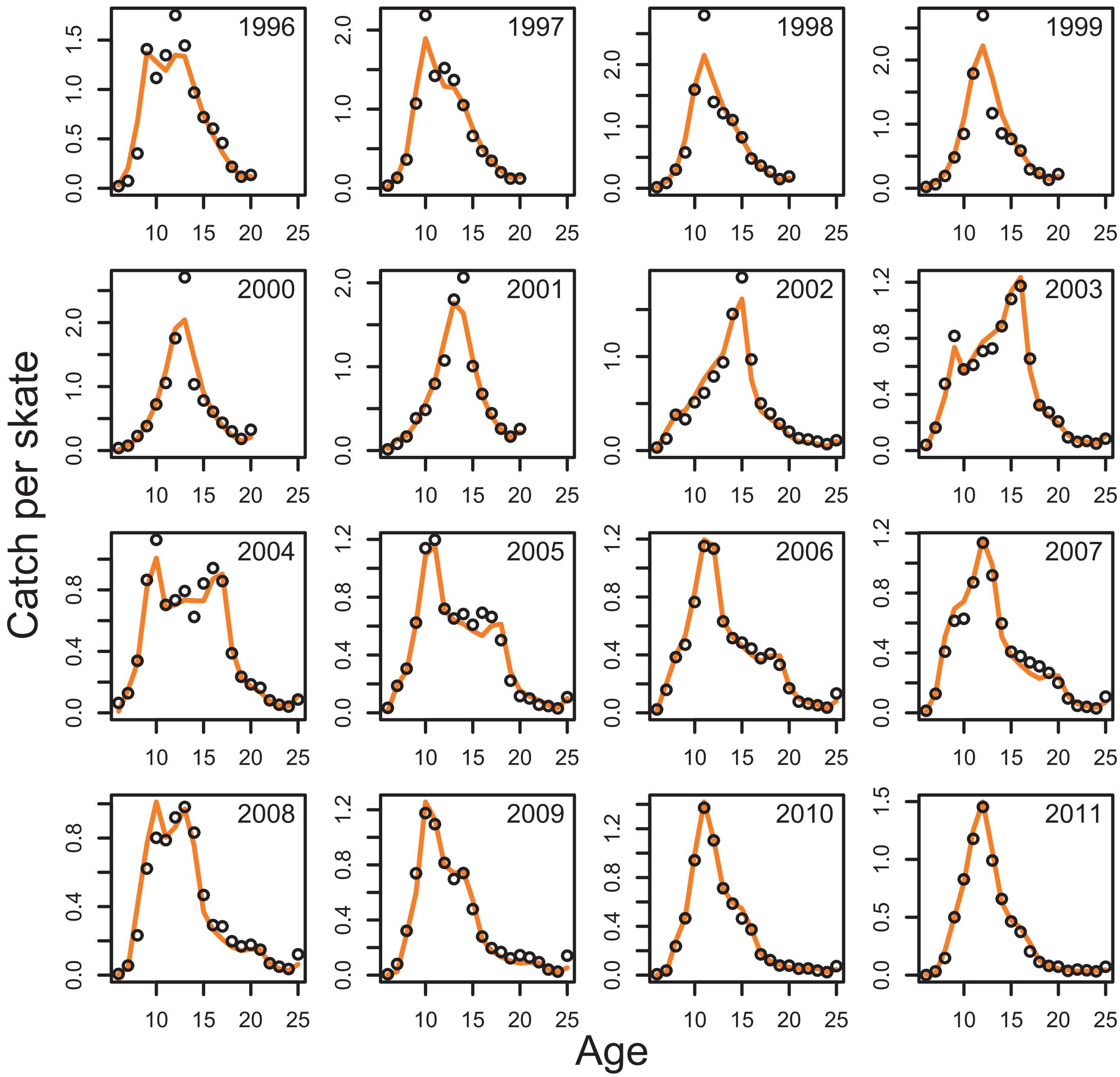


Figure 26a. Observed (points) and predicted (lines) commercial NPUE at age of females in the 2011 coastwide model   t.

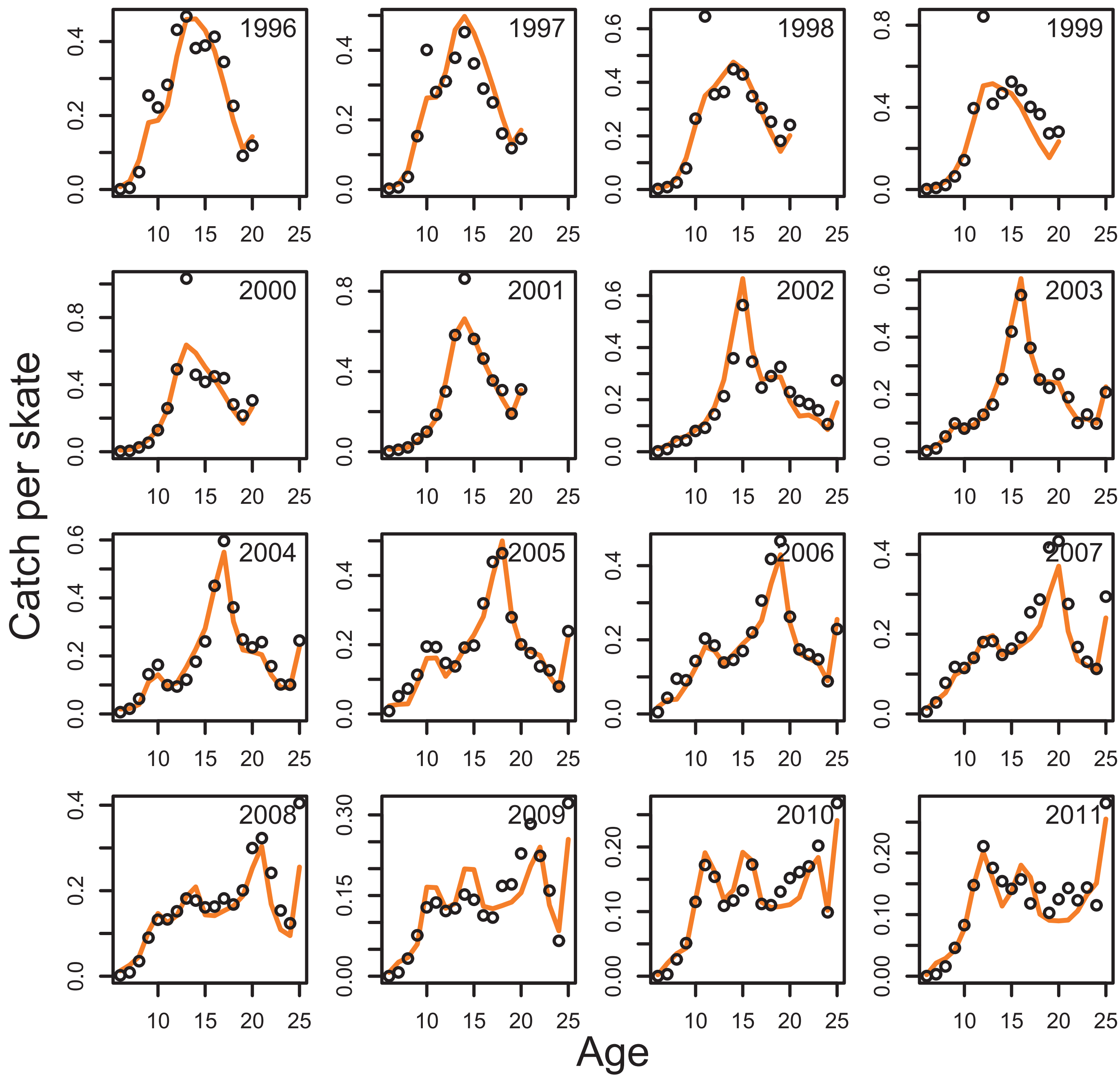


Figure 26b. Observed (points) and predicted (lines) commercial NPUE at age of males in the 2011 coastwide model t.

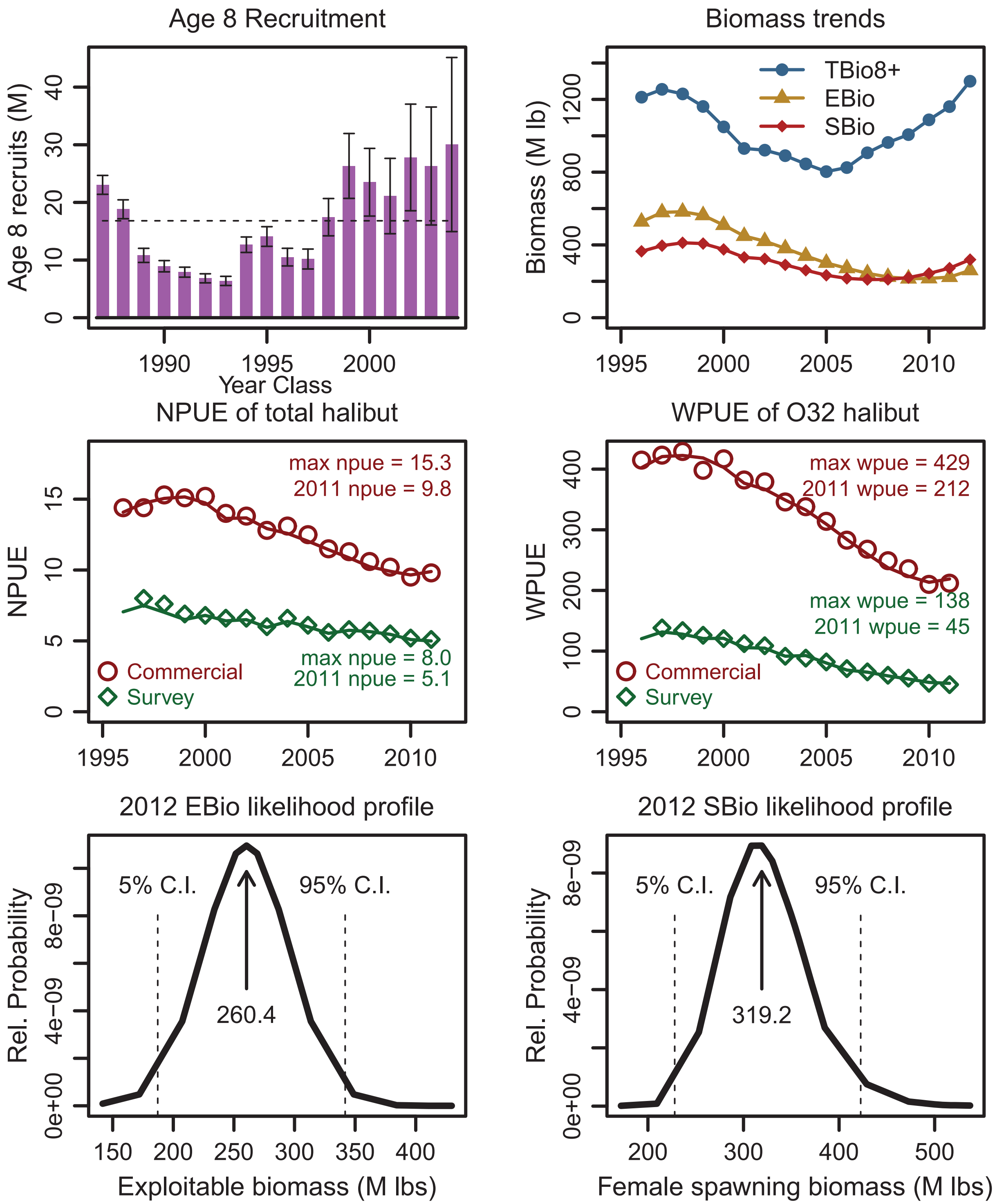
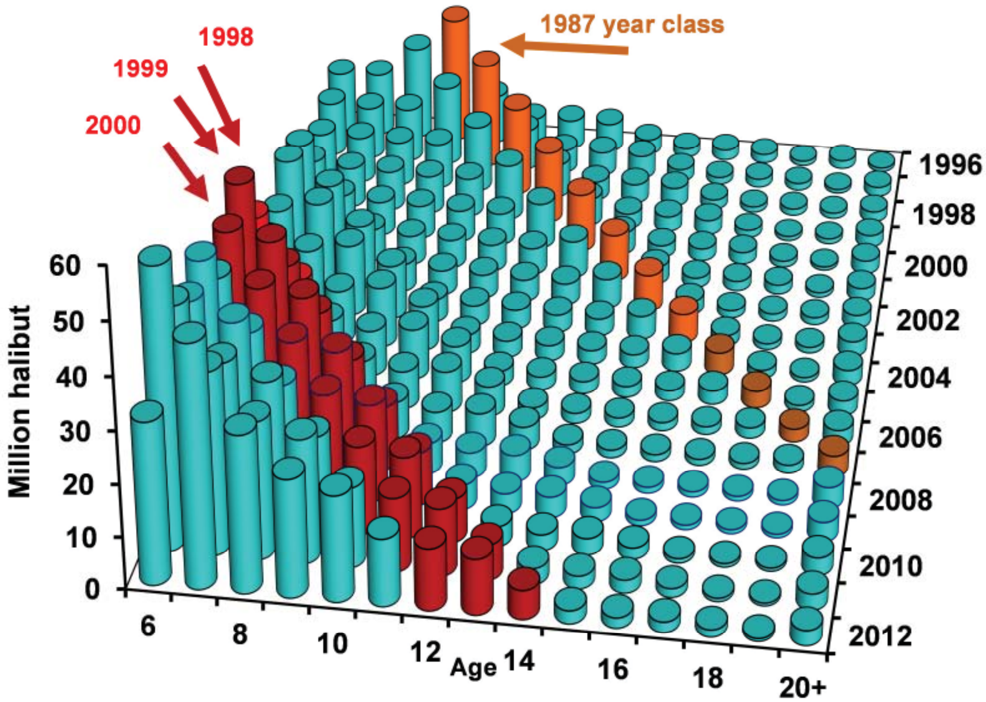


Figure 27. Features of the 2011 halibut coastwide assessment (WobbleSQ variant).

a) **Total numbers in the population**



b) **Exploitable biomass in the population**

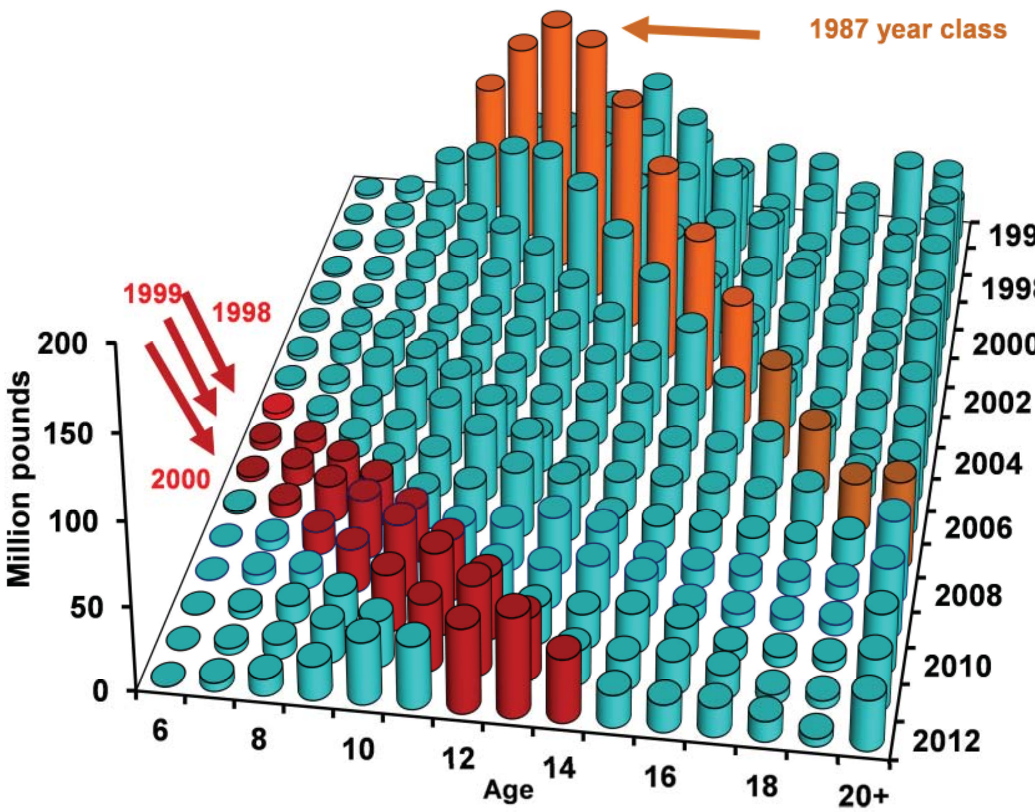


Figure 28. Coastwide population estimates in total numbers of halibut (panel a) and as EBio (panel b). Several large year classes are highlighted.

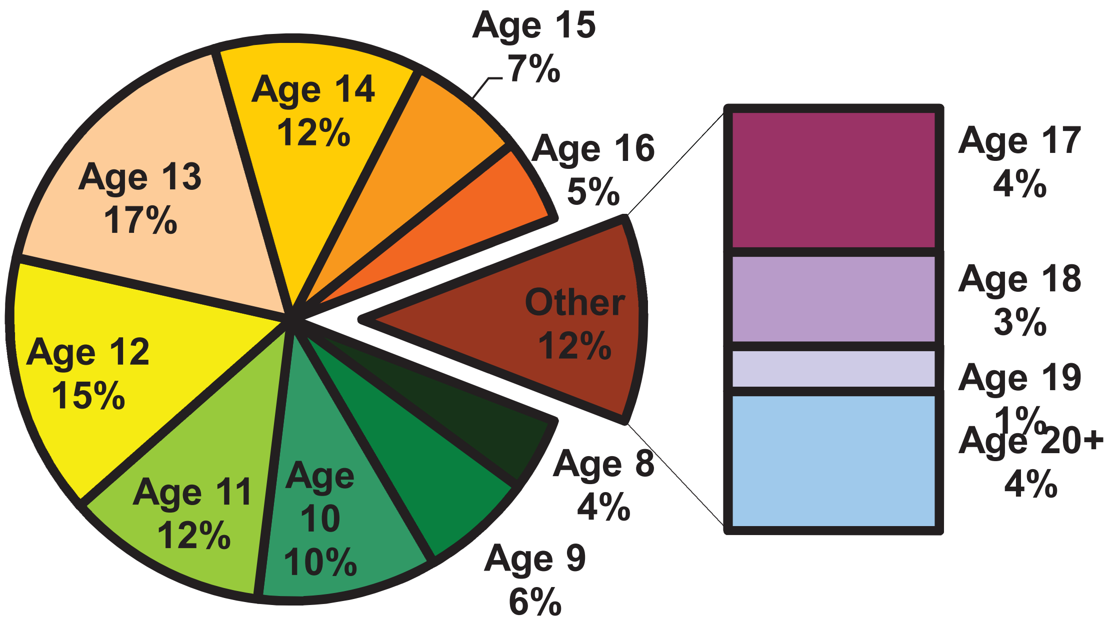


Figure 29. Estimated current age composition of the 2011 halibut female spawning biomass.

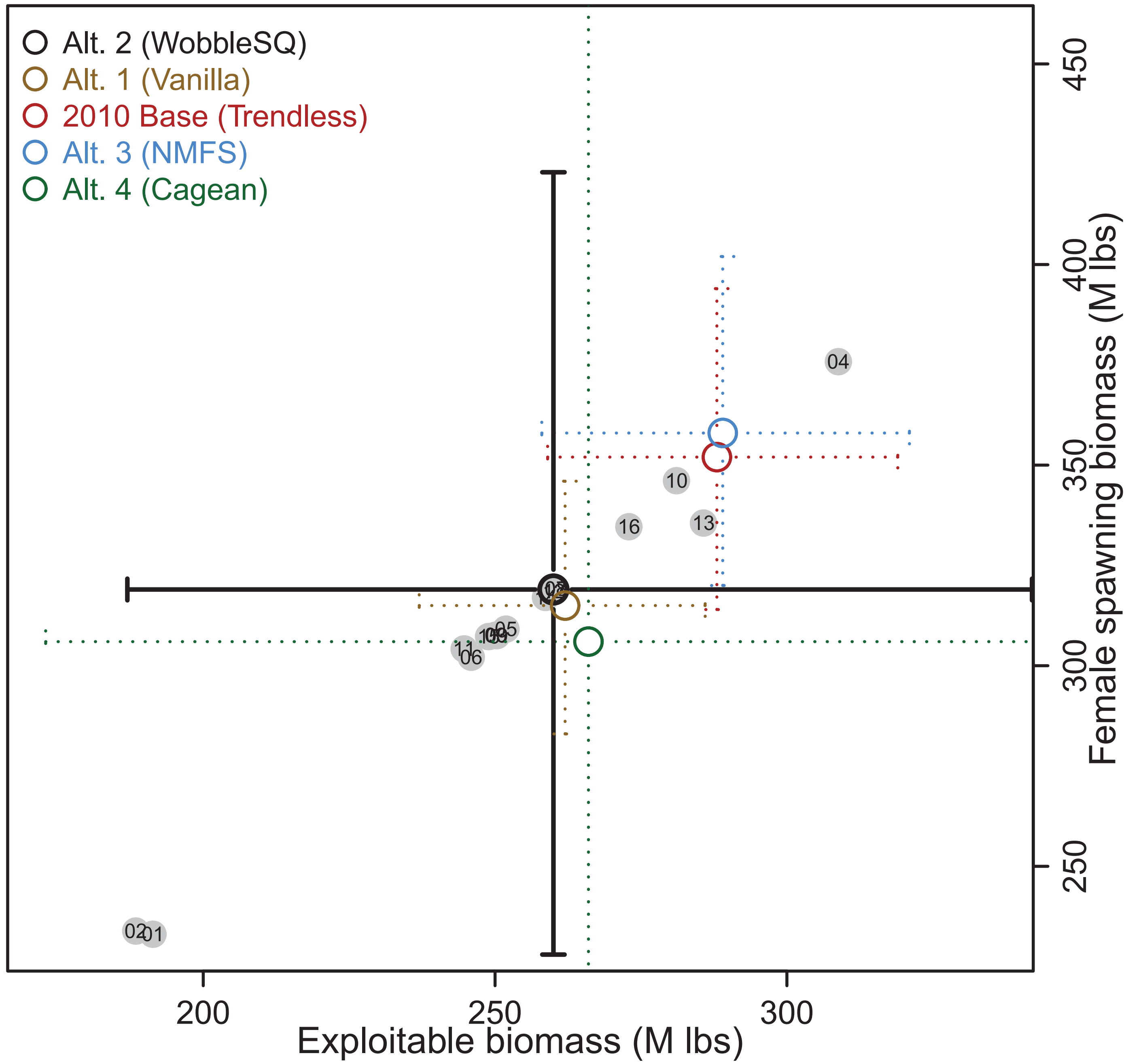


Figure 30. Illustration of maximum likelihood estimates (circles) for EBio and SBio for various model fits. The 95% percent asymptotic confidence intervals for the likelihood profiles are shown by the end caps of the horizontal and vertical bars extending from the circles. In this plot, the 16 alternative model fits are with the WobbleSQ model as the focus. See text for details.

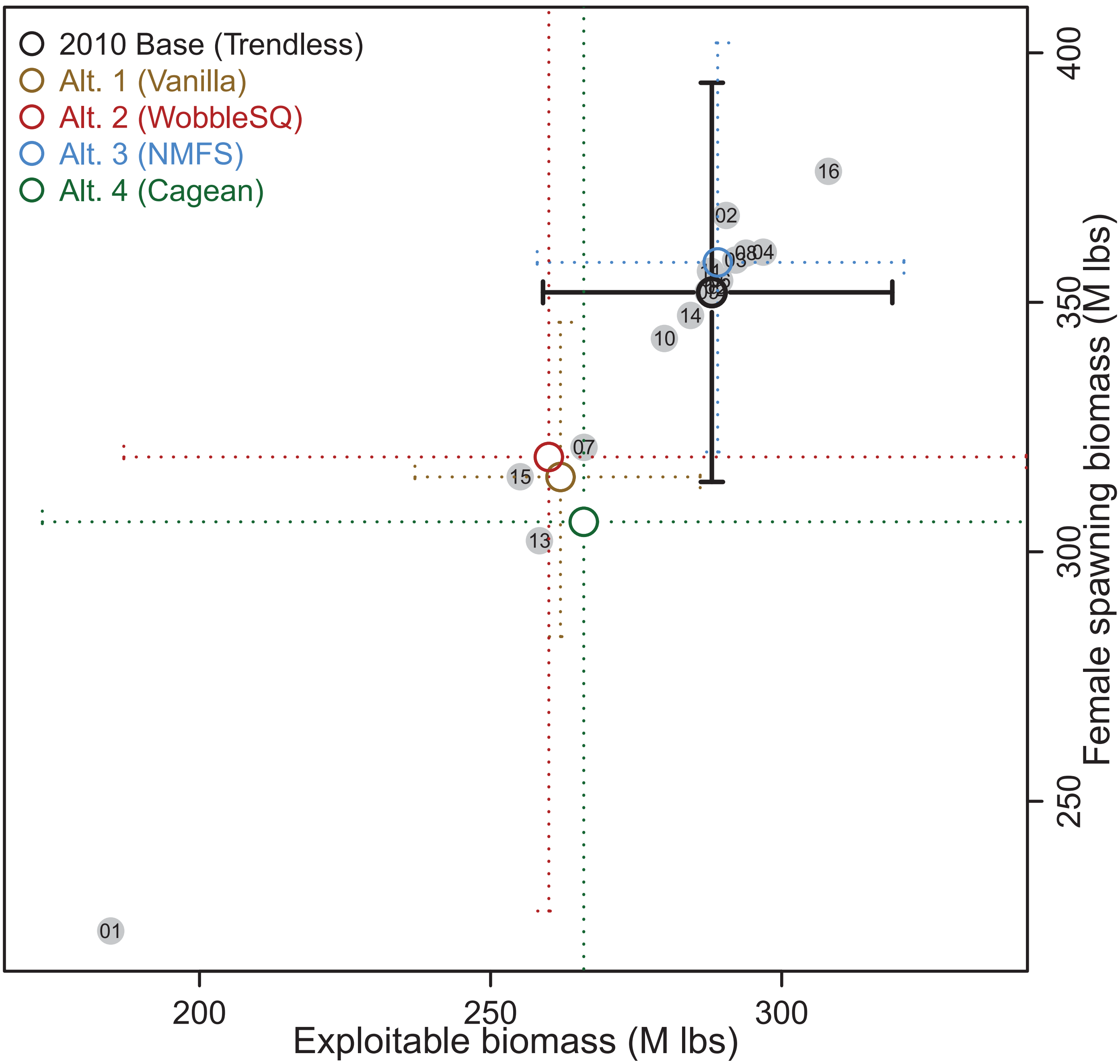


Figure 31. Same as Figure 31, but with Trendless model as the focus. See text for details.

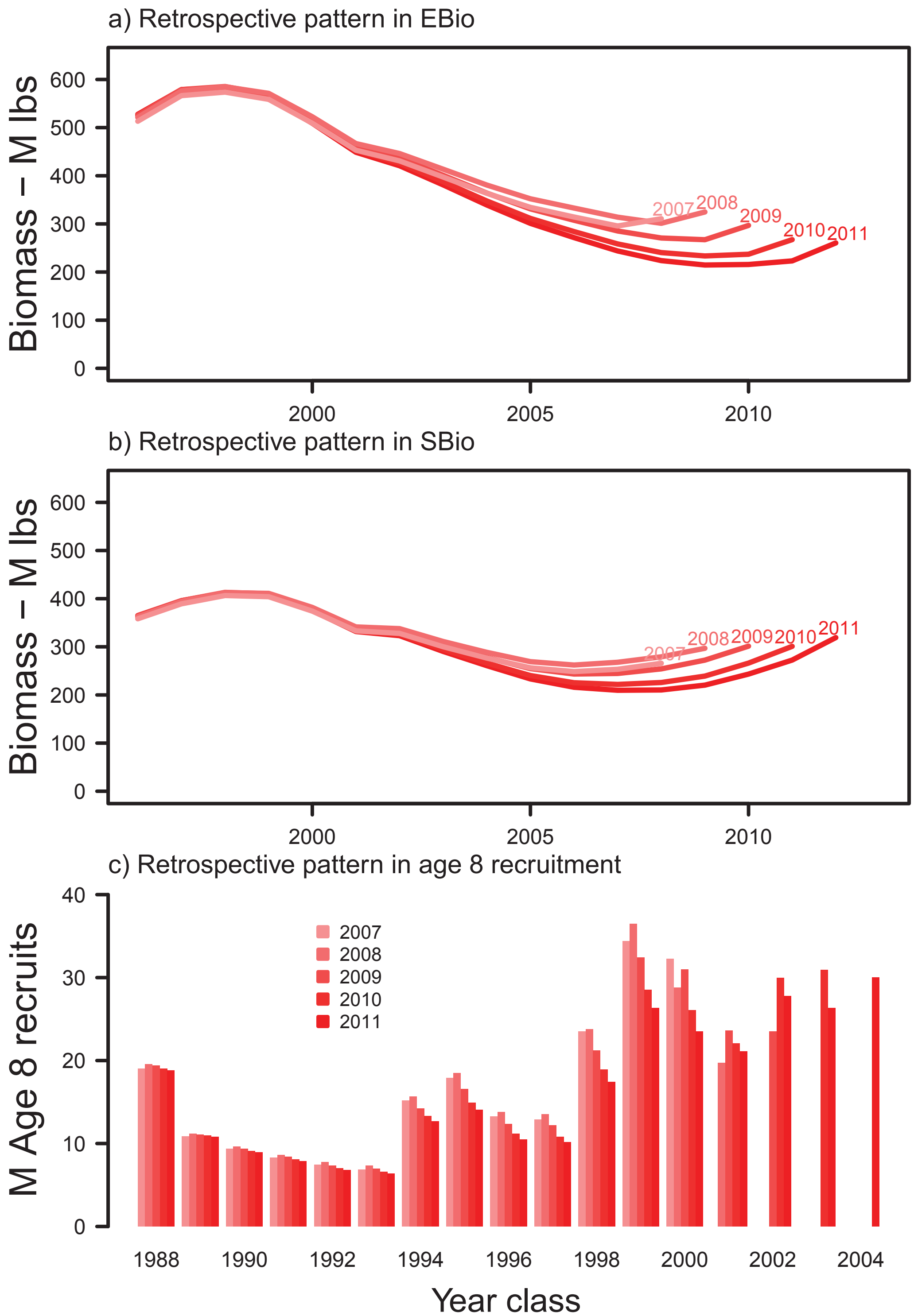


Figure 32. Retrospective behavior of the WobbleSQ 2011 halibut assessment model. The top panel illustrates the effect on estimates of EBio by sequentially removing years of data. The middle panel illustrates the effect on estimation of female spawning biomass and the bottom panel illustrates the effect on age eight recruitment. Note that the most recent year class (2004) is only estimated in the 2011 assessment, the 2003 year class in the 2010 and 2011 assessments, and so on. The x-axis is year for the biomass plots and year class for the recruitment plot.

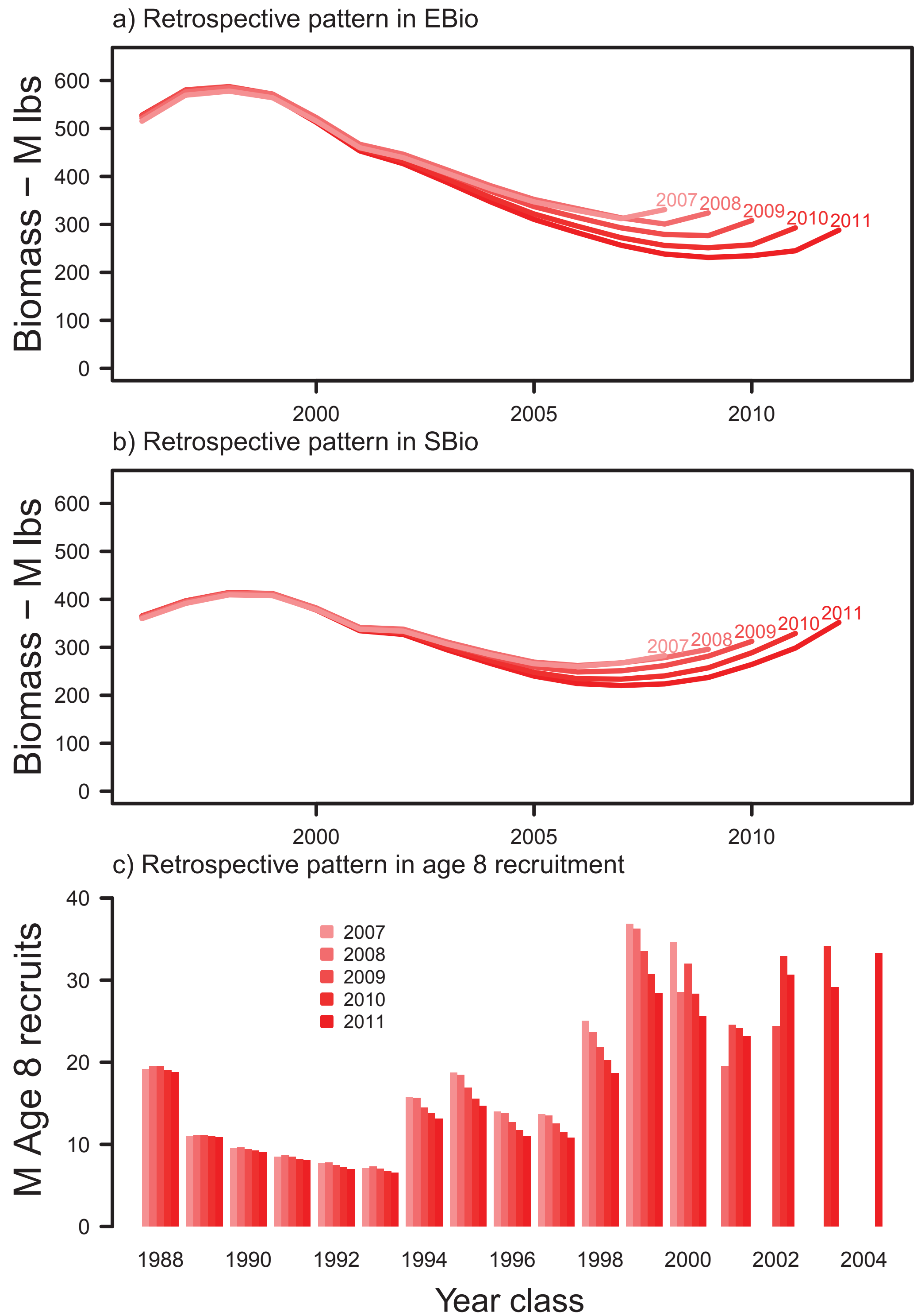


Figure 33. Same as Figure 32, but retrospective behavior of the Base2010 (Trendless) halibut assessment model.

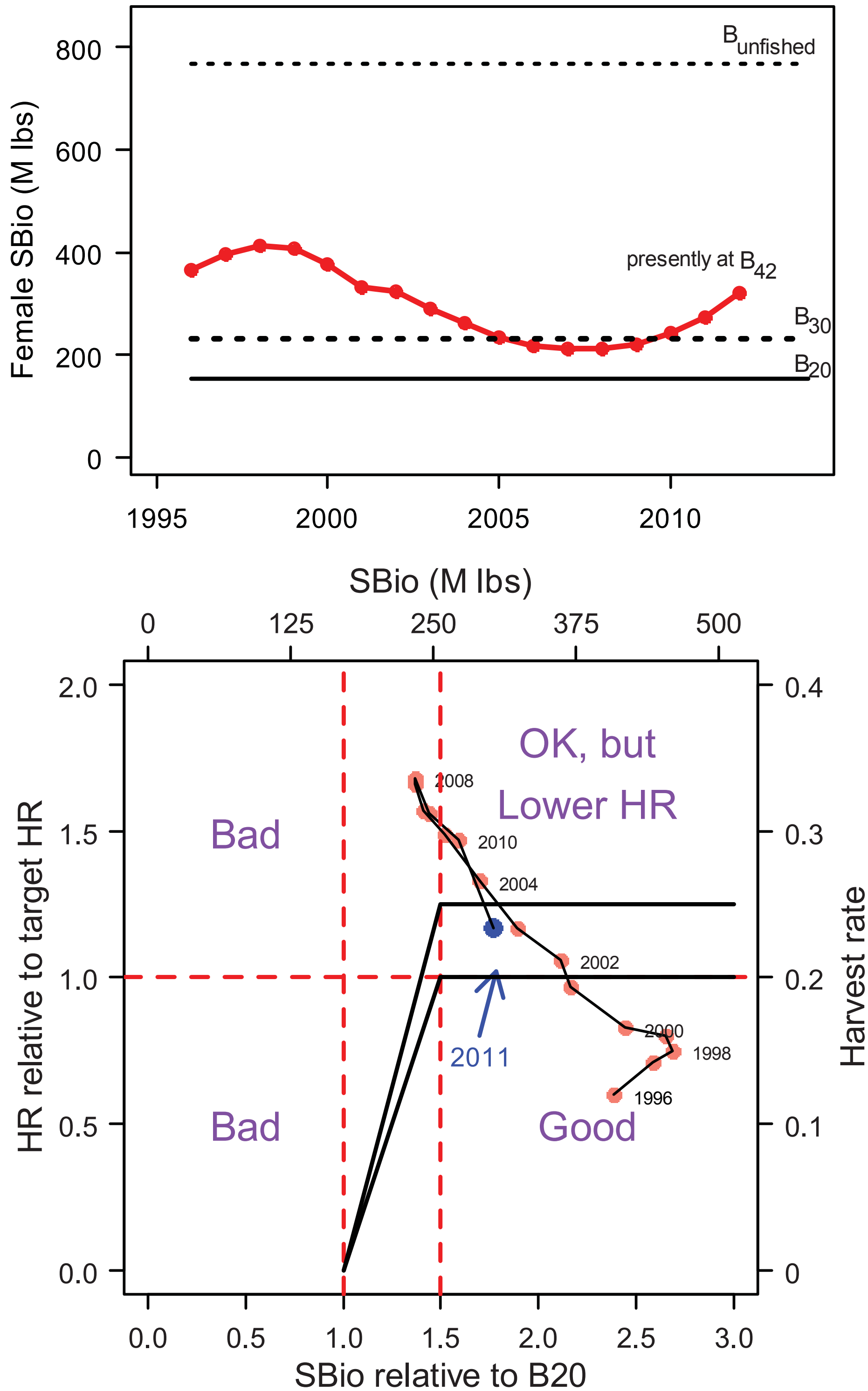


Figure 34. Trend and status of halibut management relative to reference points. Upper panel shows trajectory of female spawning biomass (SBio) relative to B_{20} and B_{30}, which are 20% and 30%, respectively of SBio$_{un\ shed}$ The lower panel plots the same data , relative to B20 along the x-axis and and the vertical axis illustrates realized harvest rate relative to a target harvest rate of 0.20 (value of 1.0) and the previous target harvest rate of 0.25 (value of 1.25).

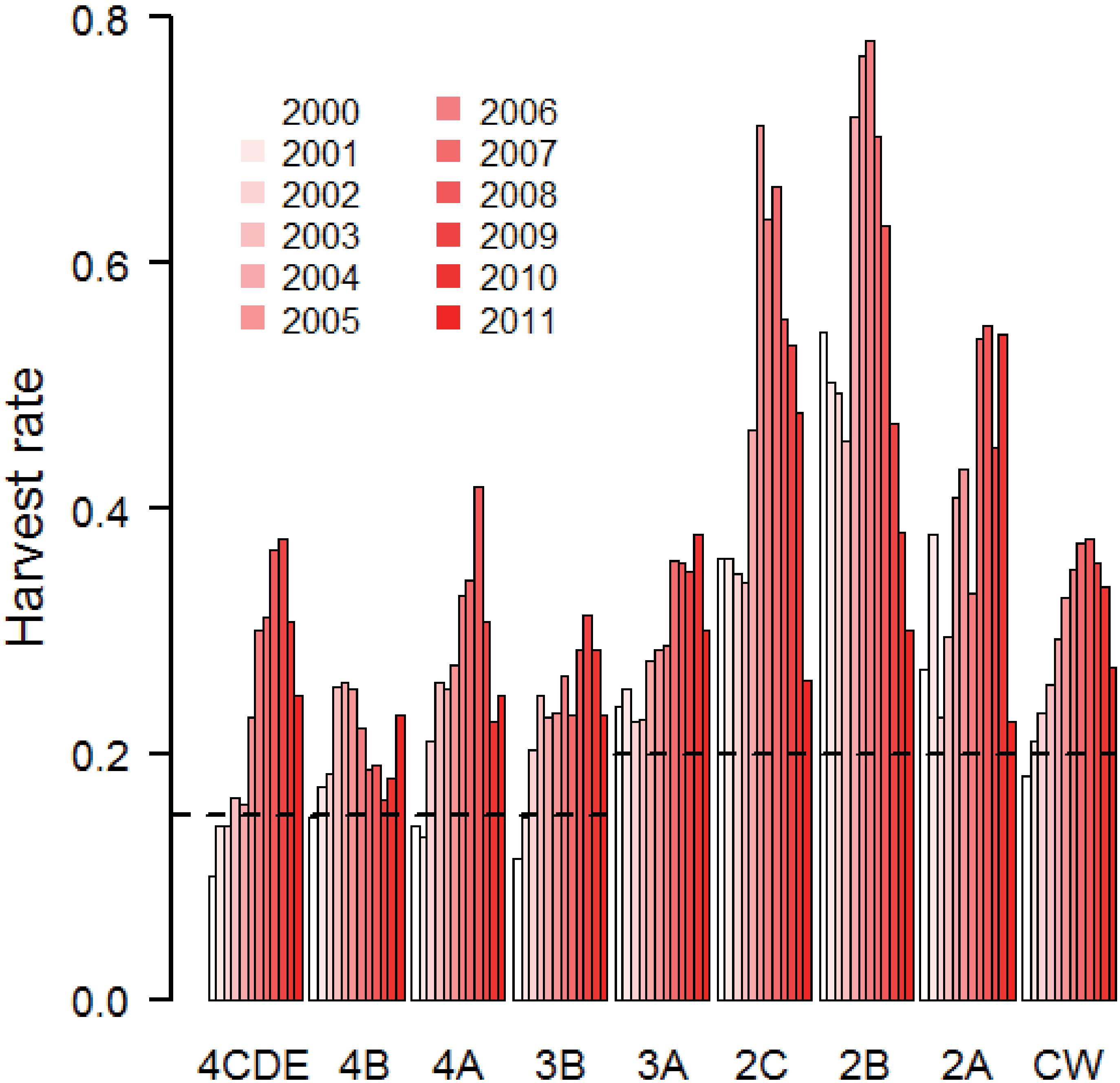


Figure 35. Summary of estimated realized harvest rates from the coastwide assessment, using adjusted and weighted survey WPUE to partition biomass among areas.

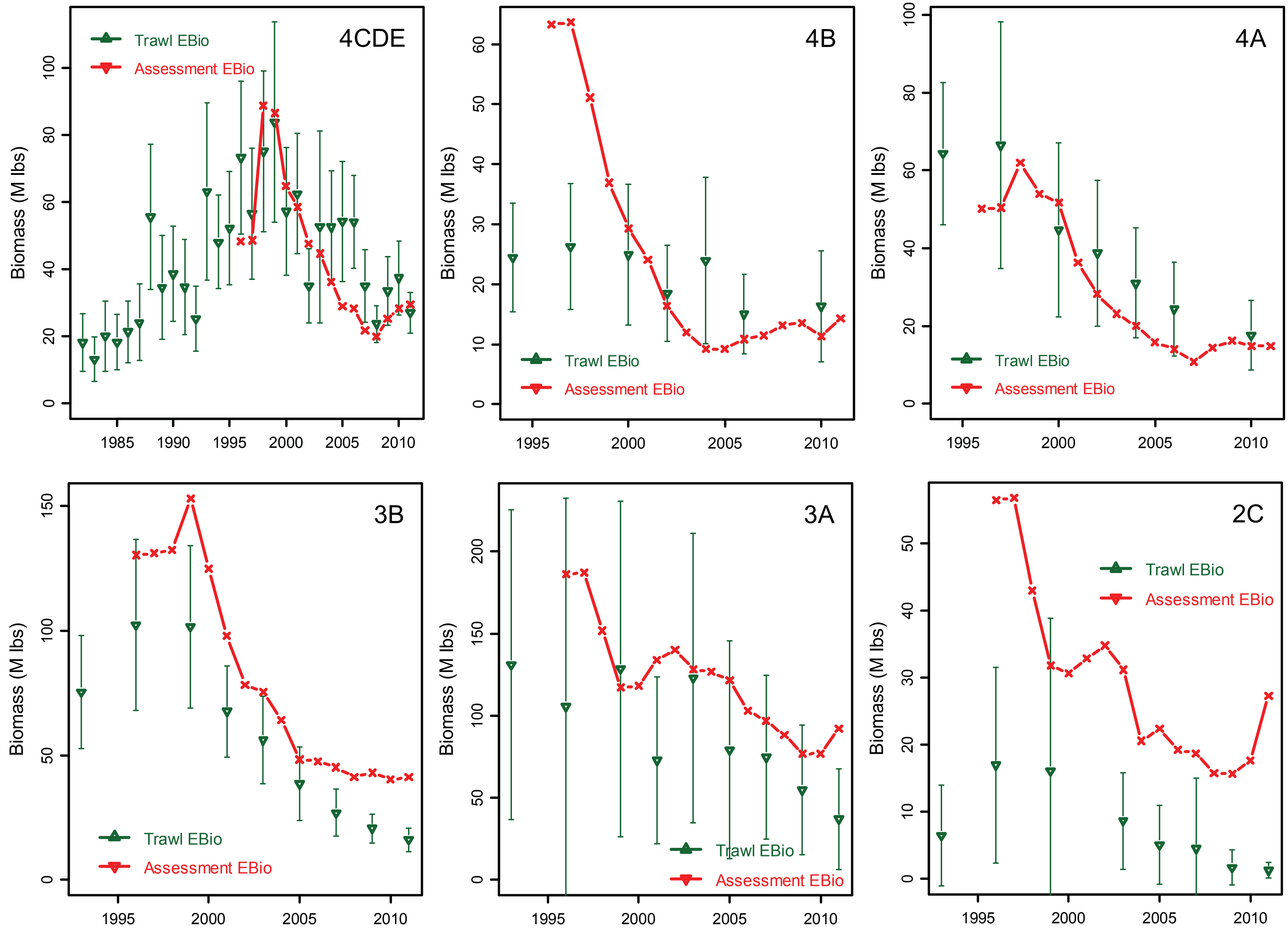


Figure 36. Comparison of IPHC assessment estimates (using adjusted survey WPUE) and NMFS swept area estimates of EBio.

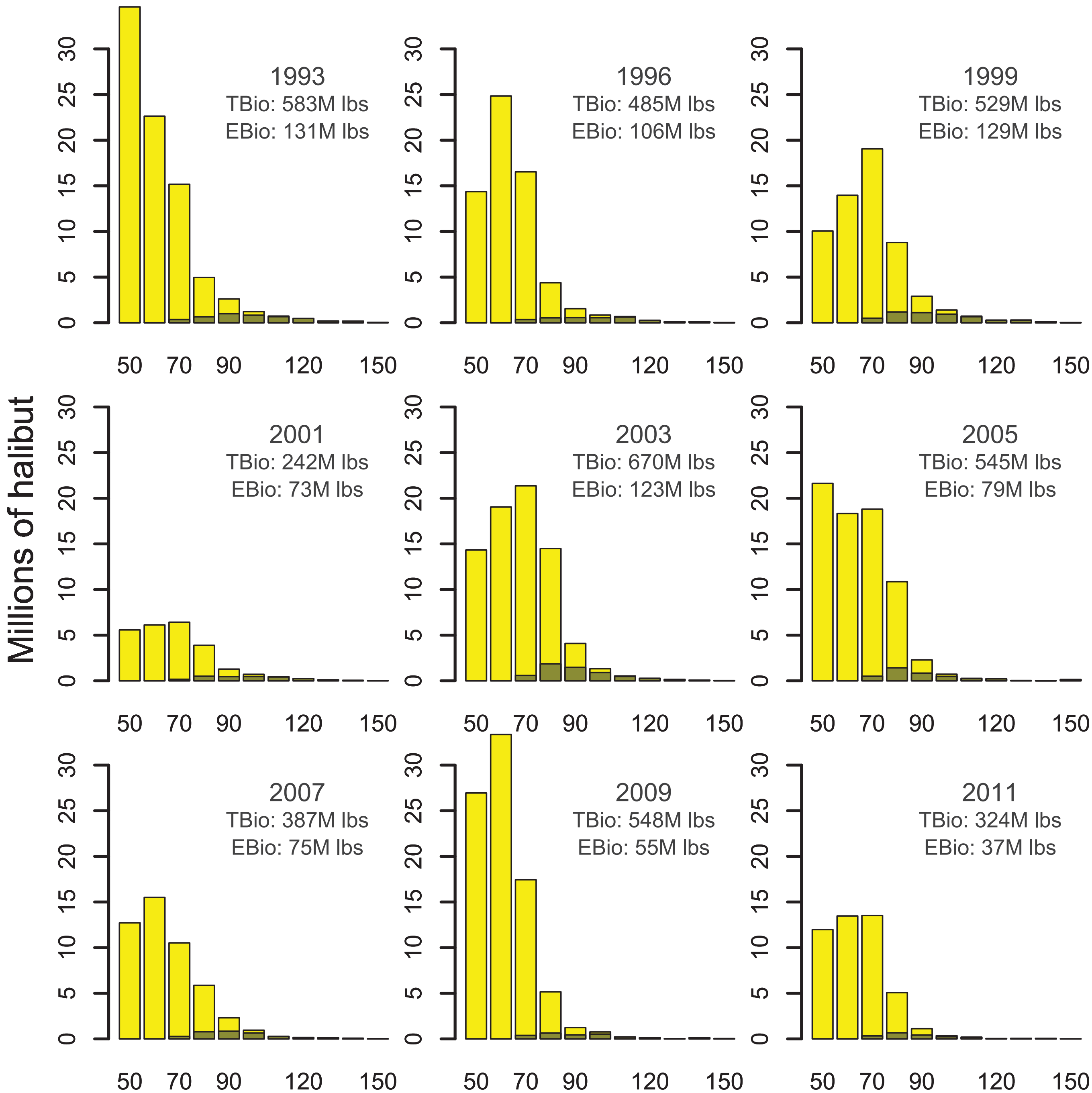


Figure 37. Swept area estimates of halibut in IPHC regulatory Area 3A, by 10-cm length interval, in the NMFS EBS trawl survey for the years 1993 to 2011. Values for total (TBio) and Exploitable (EBio) biomass estimated by the survey are also listed. Exploitable numbers of halibut are illustrated by the darker bars.

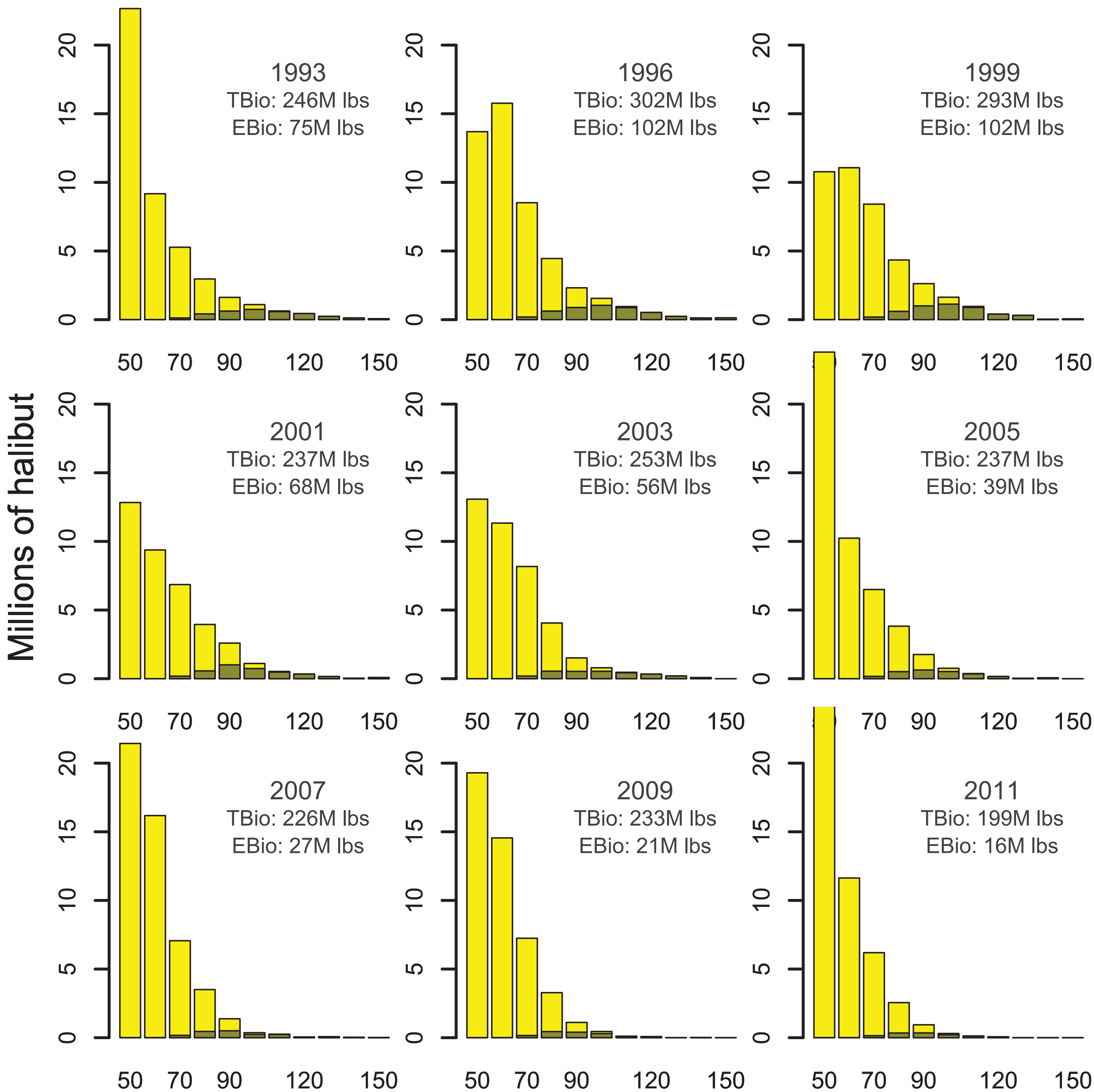


Figure 38. Same as Figure 34, but for IPHC regulatory area 3B.

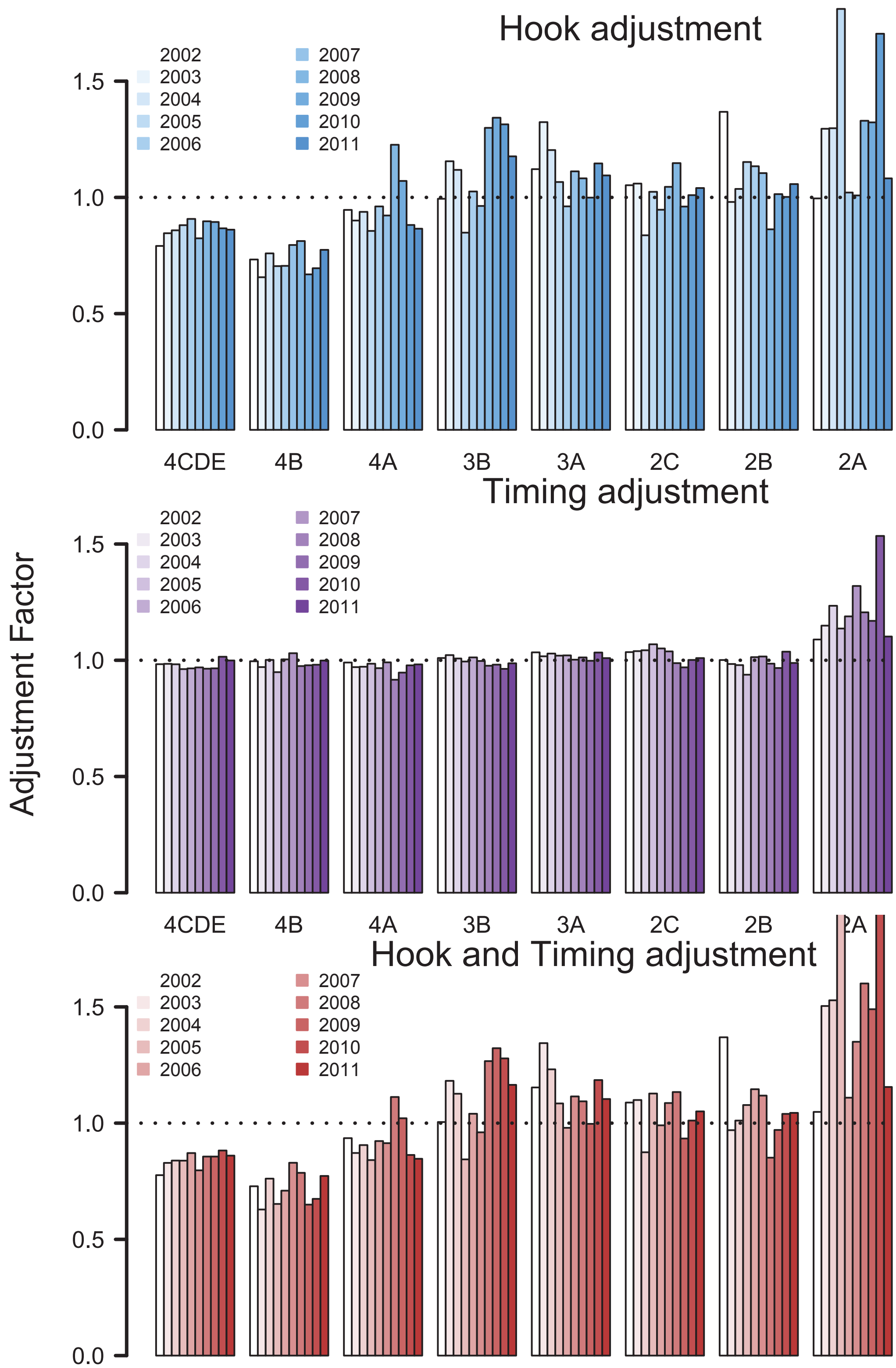


Figure 39. Illustration of the adjustments to survey WPUE for hook competition (top panel), survey timing (middle panel) and the two factors in combination (bottom panel).

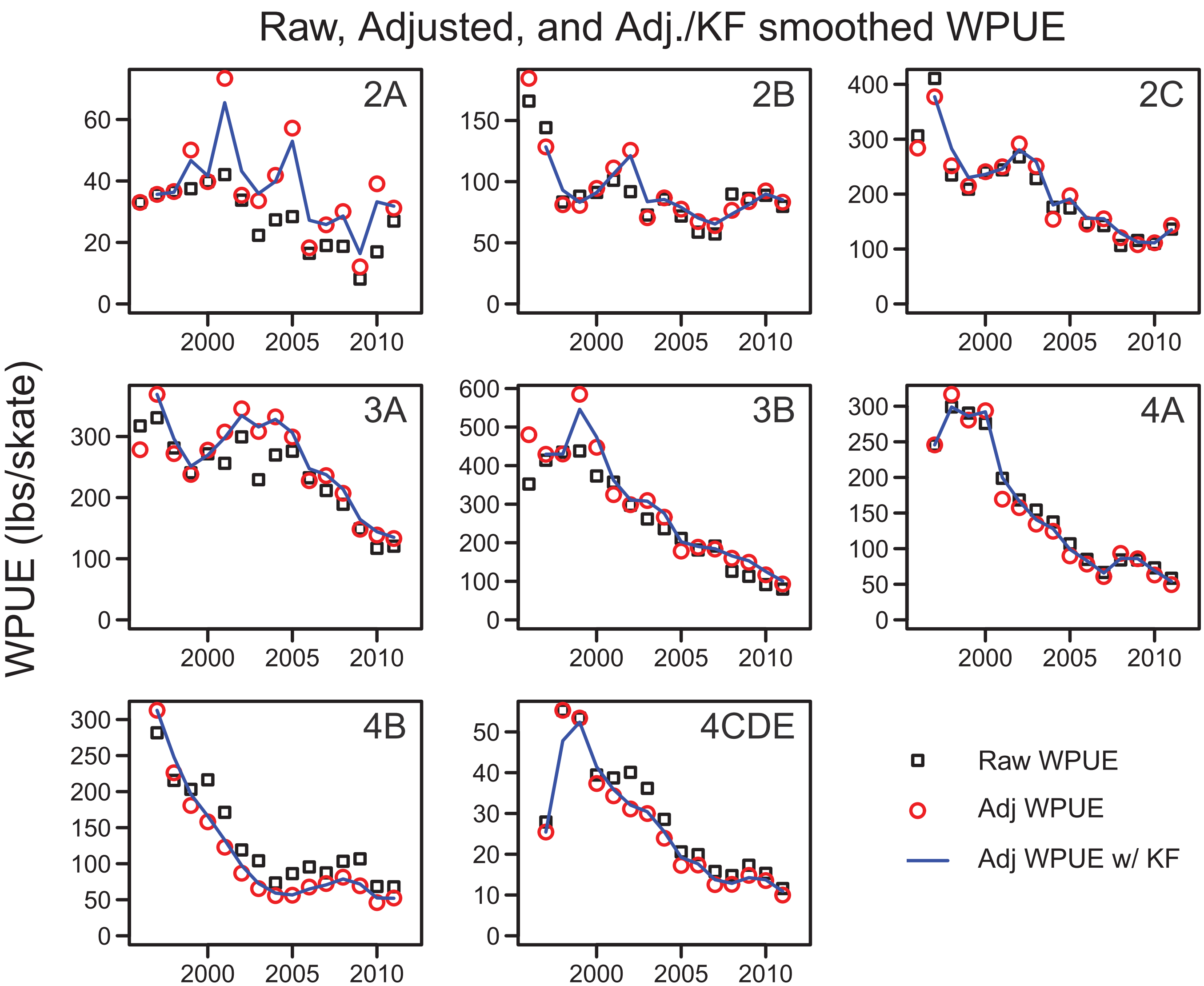


Figure 40. Illustration of the effect of adjusting survey WPUE for the effects of hook competition and survey timing and using Kalman-weights to time-average the adjusted values. This particular illustration used the 0-400 fm bottom area de nition.

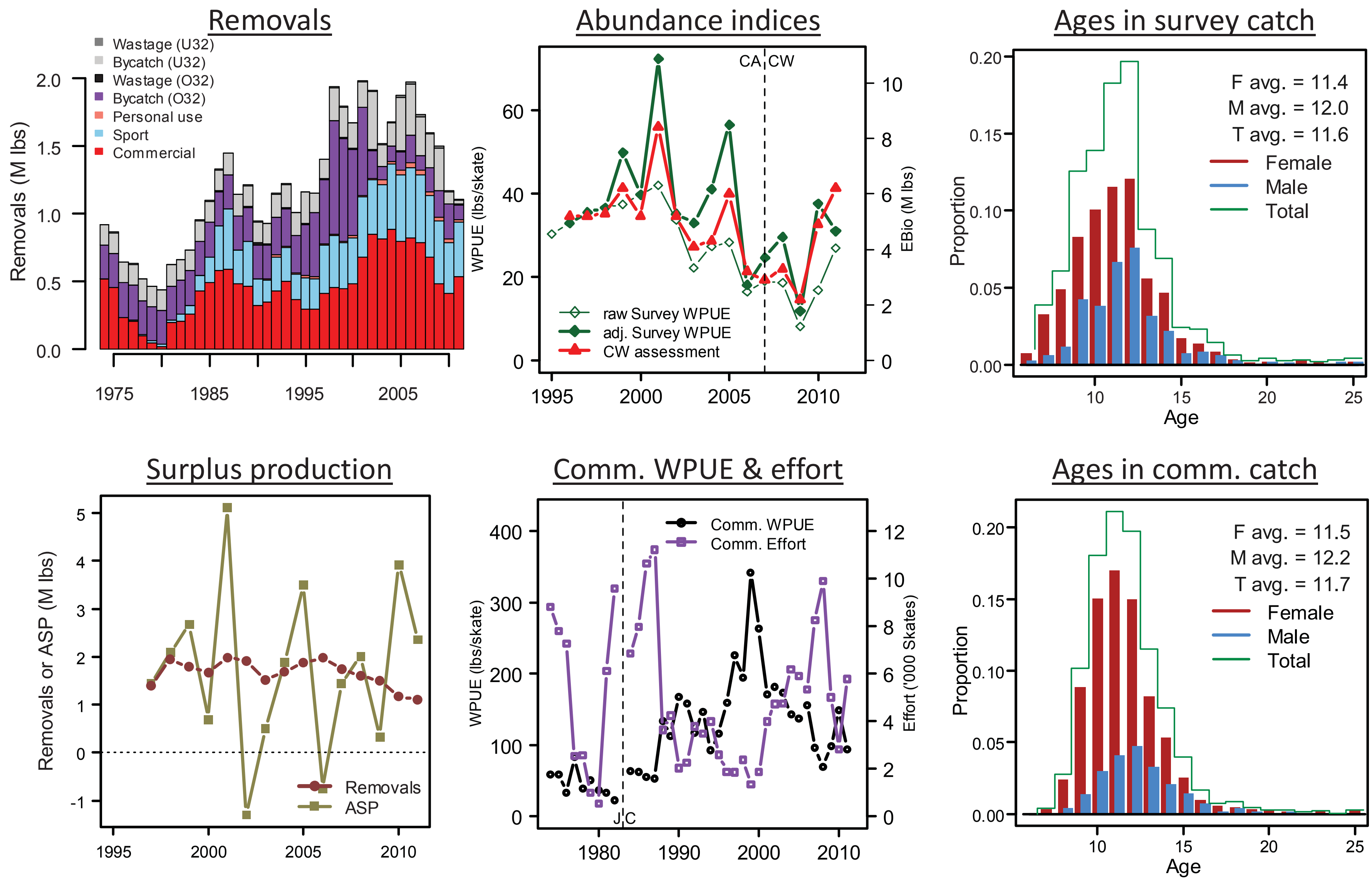


Figure 41. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 2A.

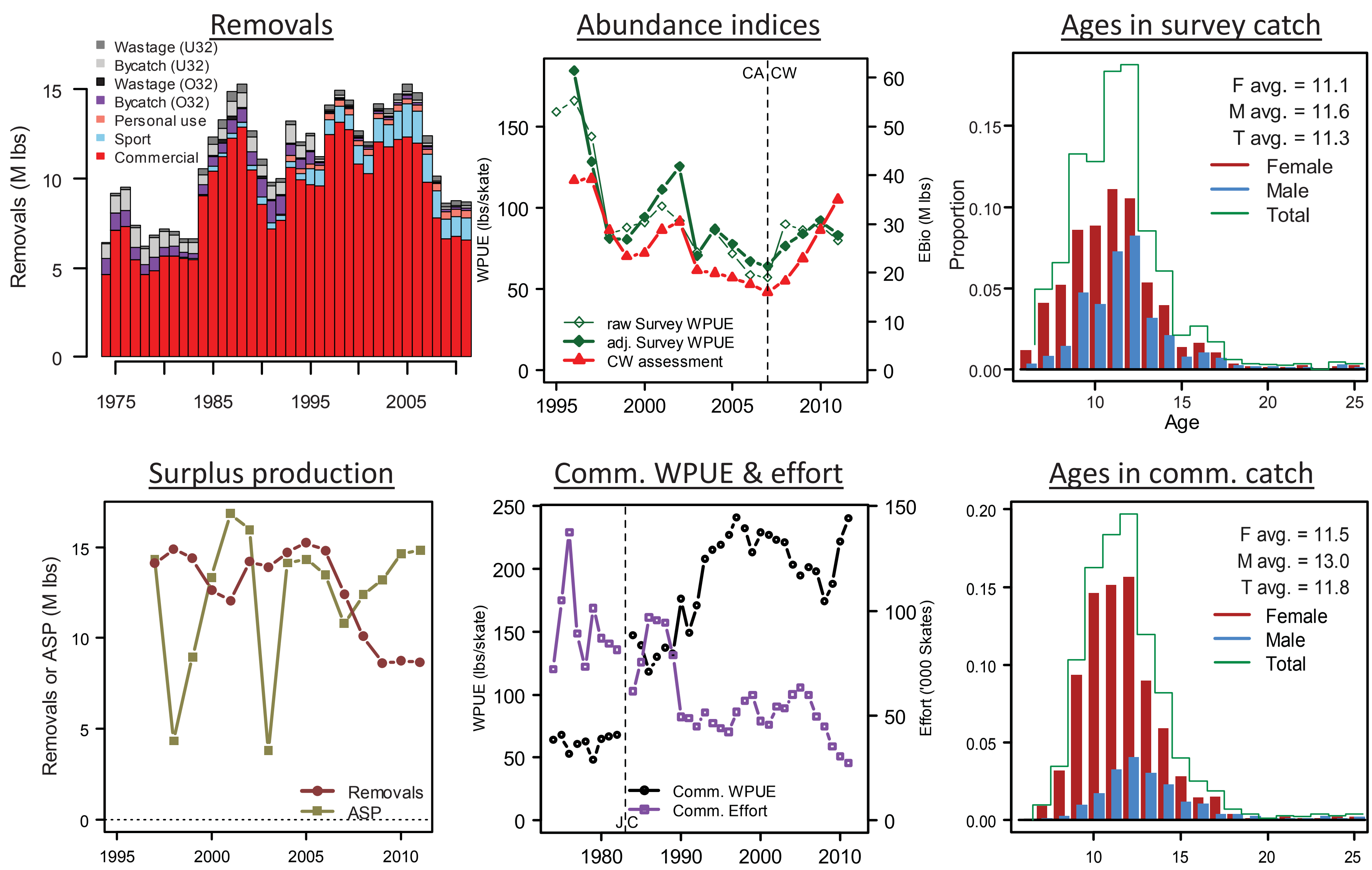


Figure 42. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 2B.

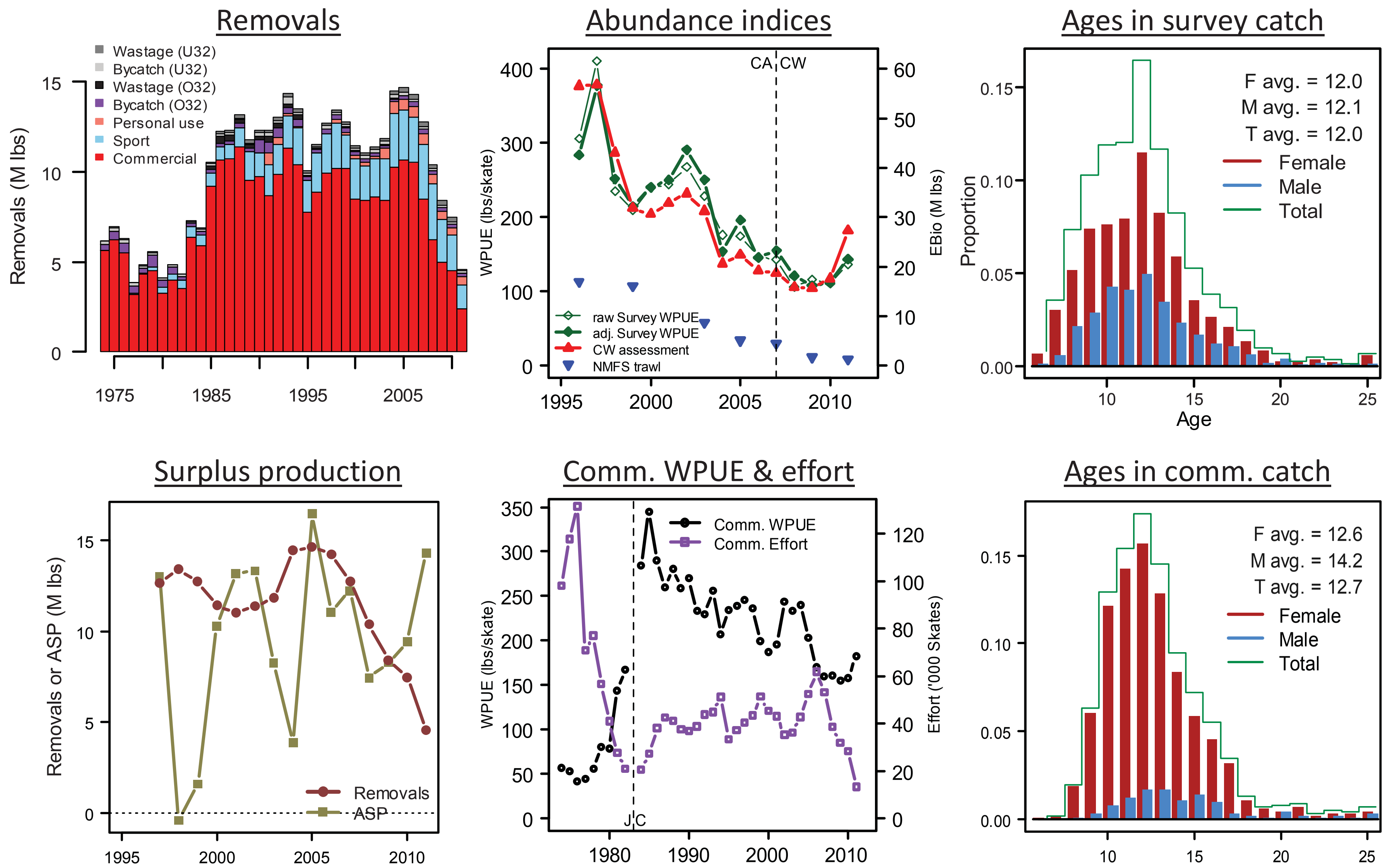


Figure 43. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 2C.

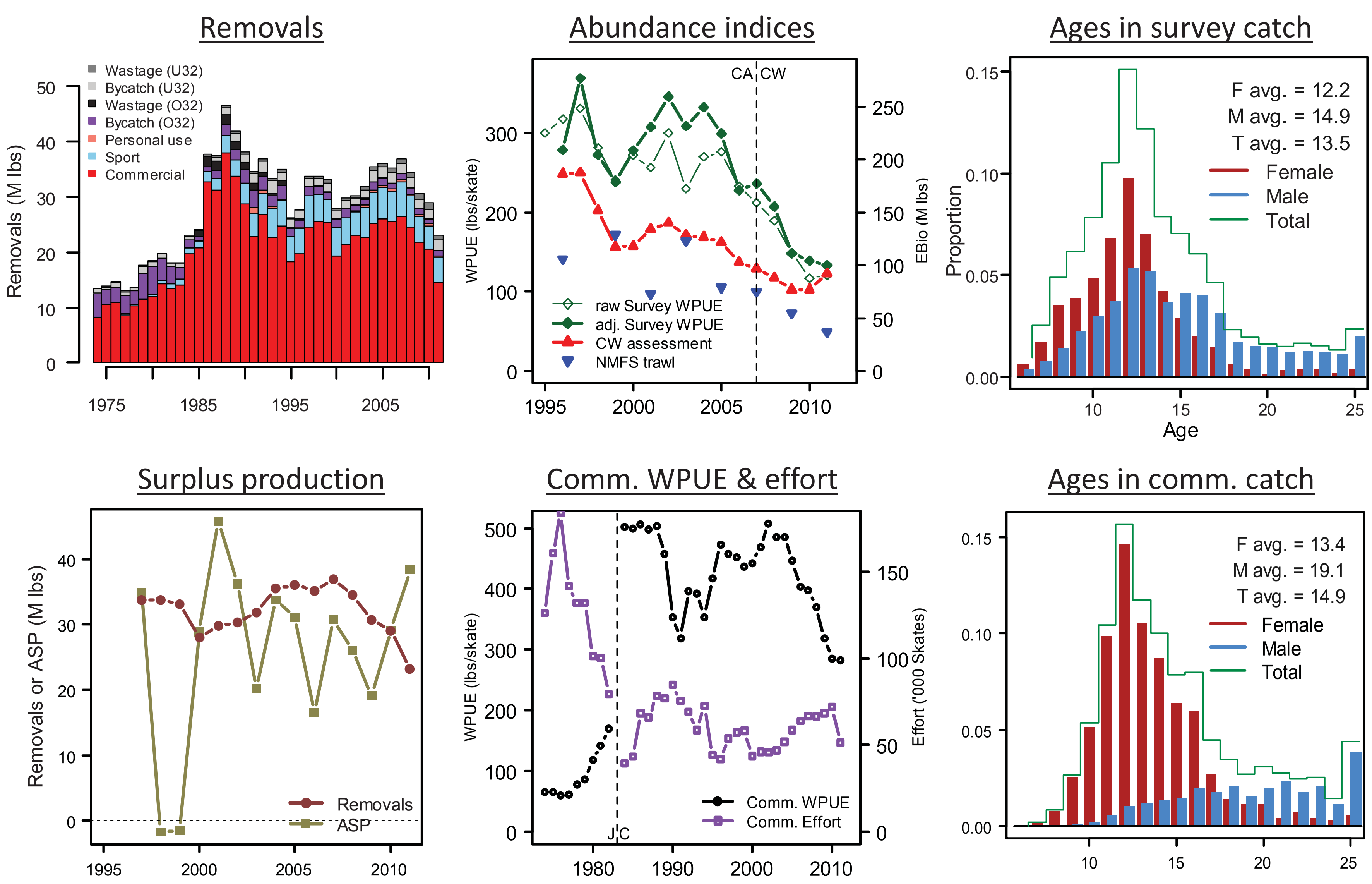


Figure 44. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 3A.

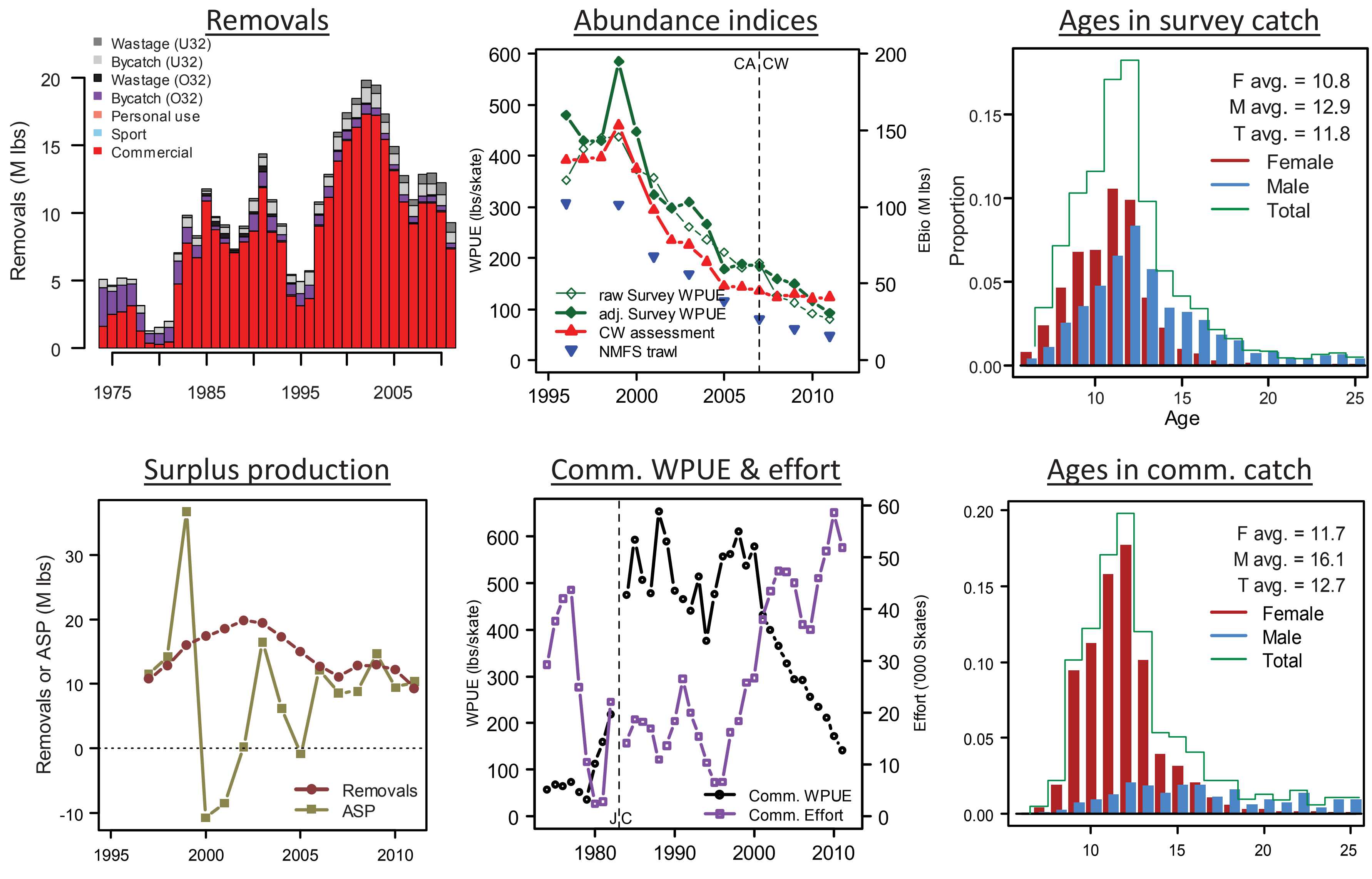


Figure 45. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 3B.

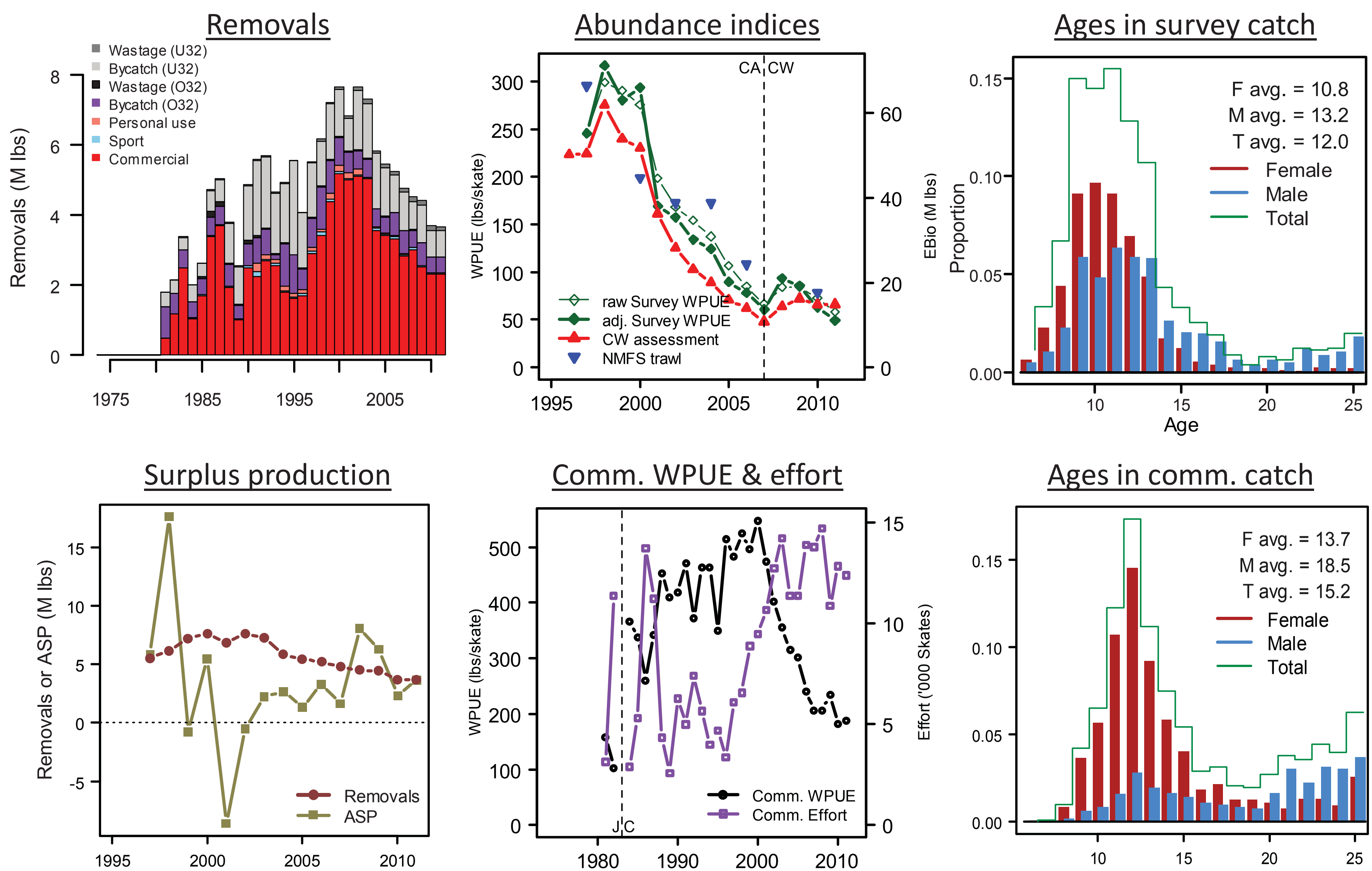


Figure 46. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 4A.

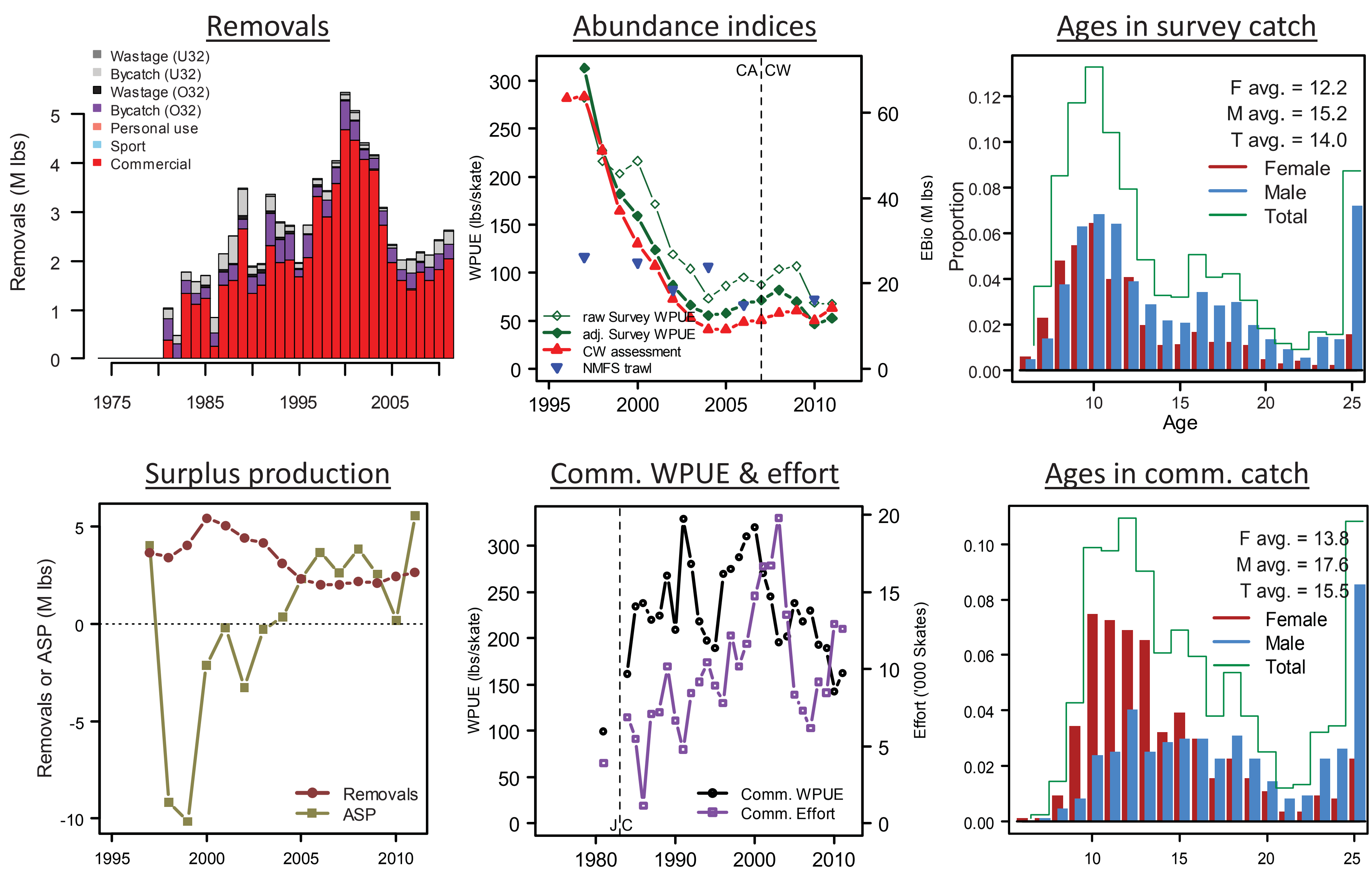


Figure 47. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 4B.

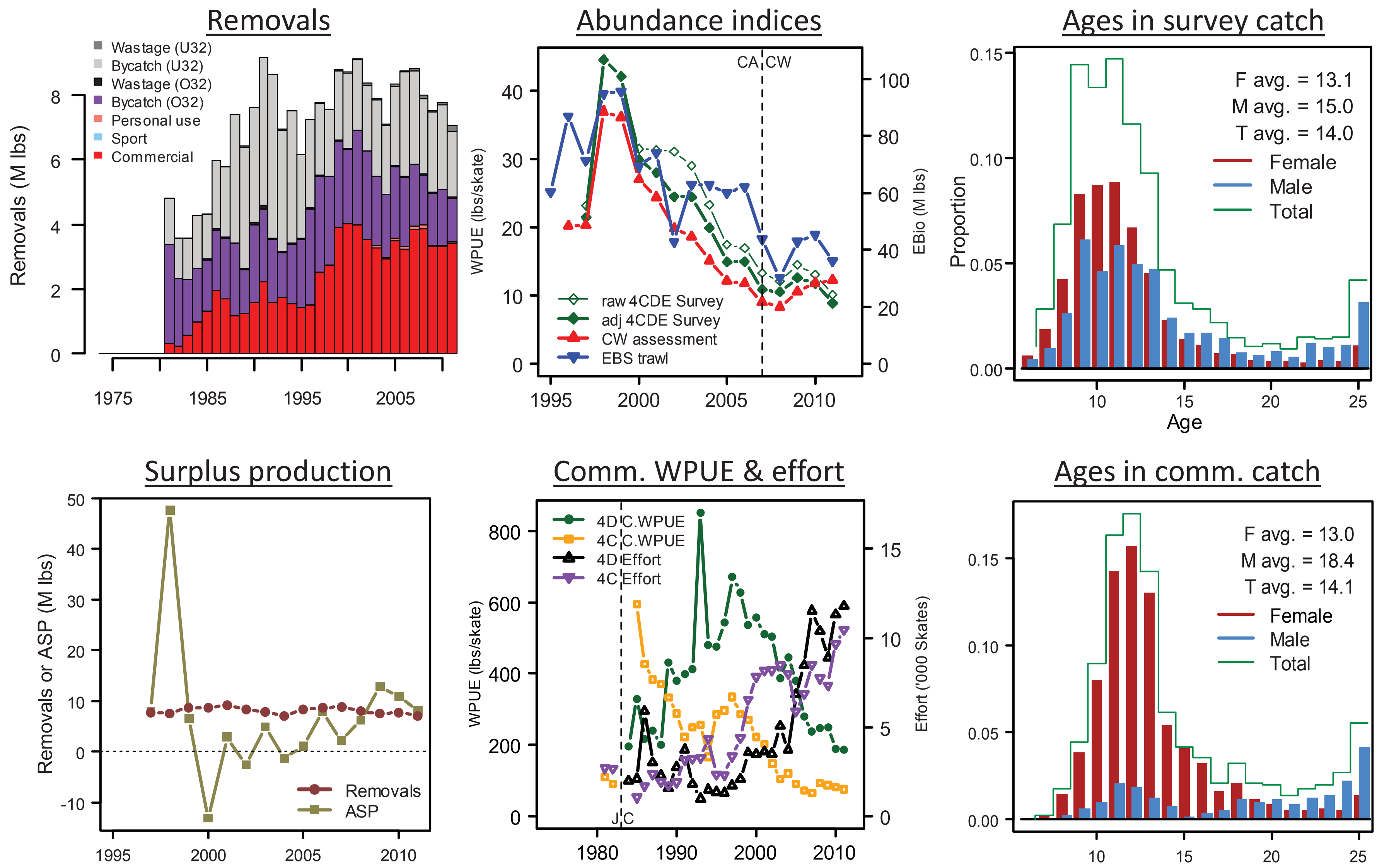


Figure 48. Summary of removals, abundance indices, age structures, surplus production, and commercial effort for Area 4CDE.

Appendix A. Selected fishery and survey data summaries.

Table A1. Total removals (million pounds, net weight). Removals include commercial catch, IPHC survey catches, sport catch, personal use catch, bycatch, and wastage. All sizes (including U32 bycatch and wastage) are included in this table.

	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1974	0.928	6.430	6.174	13.499	5.103	8.331	----	----	----	40.465
1975	0.870	9.181	6.927	13.849	4.654	4.282	----	----	----	39.763
1976	0.648	9.508	6.282	14.643	5.198	5.285	----	----	----	41.564
1977	0.634	7.390	3.868	13.023	5.116	4.138	----	----	----	34.169
1978	0.519	6.198	4.815	13.752	3.174	6.377	----	----	----	34.835
1979	0.473	6.840	5.564	17.616	1.329	6.793	----	----	----	38.615
1980	0.446	7.164	4.121	18.442	1.529	9.948	----	----	----	41.650
1981	0.629	7.010	4.868	19.846	2.020	7.618	----	----	----	41.991
1982	0.669	6.601	4.325	18.161	7.042	6.212	----	----	----	43.010
1983	0.738	6.625	7.302	18.150	9.804	8.723	----	----	----	51.342
1984	0.960	10.553	6.855	23.095	8.300	7.894	----	----	----	57.657
1985	1.100	12.323	10.514	24.174	11.845	8.685	----	----	----	68.641
1986	1.332	13.249	12.212	37.741	9.782	11.540	----	----	----	85.856
1987	1.455	14.830	12.279	37.490	9.112	12.978	----	----	----	88.144
1988	1.148	15.272	13.110	46.548	7.387	13.699	----	----	----	97.164
1989	1.218	12.686	11.730	41.967	9.009	12.417	----	----	----	89.027
1990	0.948	11.061	12.309	38.184	11.132	----	4.851	1.886	7.607	87.978
1991	0.936	9.758	12.284	34.549	14.350	----	5.582	1.936	9.153	88.548
1992	1.154	9.975	13.006	37.007	11.032	----	5.702	3.351	8.628	89.855
1993	1.224	13.228	14.347	33.446	9.236	----	4.646	2.809	6.923	85.859
1994	1.014	12.023	13.435	34.973	5.457	----	4.933	2.737	7.498	82.070
1995	1.166	12.557	10.017	26.289	4.987	----	5.556	1.957	6.152	68.681
1996	1.158	11.245	11.503	27.728	5.734	----	4.085	2.732	7.233	71.418
1997	1.406	14.109	12.661	33.713	10.785	----	5.512	3.673	7.754	89.613
1998	1.939	14.900	13.416	33.786	12.878	----	6.152	3.427	7.541	94.039
1999	1.796	14.373	12.735	33.111	15.976	----	7.211	4.039	8.759	98.000
2000	1.677	12.630	11.441	27.996	17.386	----	7.634	5.442	8.686	92.892
2001	1.987	12.062	11.019	29.822	18.522	----	6.830	5.067	9.117	94.426
2002	1.915	14.200	11.383	30.256	19.832	----	7.645	4.405	8.340	97.976
2003	1.521	13.892	11.829	31.849	19.452	----	7.283	4.170	7.865	97.861
2004	1.687	14.715	14.457	35.470	17.343	----	5.830	3.097	7.089	99.688
2005	1.878	15.253	14.653	36.079	14.940	----	5.441	2.324	8.304	98.872
2006	1.976	14.818	14.261	35.173	12.773	----	5.234	2.029	8.732	94.996
2007	1.735	12.395	12.740	36.898	11.009	----	4.770	2.036	8.796	90.379
2008	1.607	10.095	10.382	34.471	12.837	----	4.527	2.178	7.966	84.063
2009	1.501	8.604	8.412	30.731	12.929	----	4.422	2.121	7.515	76.235
2010	1.170	8.731	7.476	29.071	12.215	----	3.695	2.440	7.760	72.558
2011	1.113	8.679	4.580	23.195	9.343	----	3.674	2.634	7.037	60.255

Table A2. Commercial catch (million pounds, net weight). Figures include IPHC research catches.

	2A	2B	2C	3A	3B	4	4A	4B	4C	4D	4E	Total
1974	0.520	4.620	5.600	8.190	1.670	0.710	----	----	----	----	----	21.310
1975	0.460	7.130	6.240	10.600	2.560	0.630	----	----	----	----	----	27.620
1976	0.240	7.280	5.530	11.040	2.730	0.720	----	----	----	----	----	27.540
1977	0.210	5.430	3.190	8.640	3.190	1.220	----	----	----	----	----	21.880
1978	0.100	4.610	4.320	10.300	1.320	1.350	----	----	----	----	----	22.000
1979	0.050	4.860	4.530	11.340	0.390	1.370	----	----	----	----	----	22.540
1980	0.020	5.650	3.240	11.970	0.280	0.710	----	----	----	----	----	21.870
1981	0.202	5.658	4.007	14.228	0.451	----	0.494	0.386	0.298	0.008	0.004	25.736
1982	0.211	5.538	3.501	13.524	4.800	----	1.169	0.010	0.243	0.004	0.007	29.007
1983	0.265	5.438	6.381	14.132	7.755	----	2.495	1.343	0.415	0.148	0.014	38.386
1984	0.431	9.054	5.867	19.767	6.688	----	1.053	1.104	0.580	0.392	0.035	44.971
1985	0.493	10.389	9.206	20.840	10.889	----	1.717	1.237	0.620	0.674	0.036	56.101
1986	0.581	11.225	10.611	32.802	8.819	----	3.381	0.261	0.686	1.223	0.043	69.632
1987	0.592	12.246	10.685	31.308	7.758	----	3.692	1.501	0.878	0.703	0.111	69.474
1988	0.486	12.858	11.364	37.906	7.082	----	1.931	1.592	0.707	0.453	0.009	74.388
1989	0.472	10.431	9.532	33.735	7.843	----	1.025	2.651	0.571	0.674	0.013	66.947
1990	0.325	8.574	9.728	28.847	8.694	----	2.503	1.333	0.529	1.005	0.060	61.598
1991	0.355	7.191	8.687	22.926	11.934	----	2.255	1.513	0.678	1.437	0.105	57.081
1992	0.435	7.626	9.819	26.782	8.622	----	2.699	2.317	0.793	0.727	0.071	59.891
1993	0.504	10.627	11.290	22.738	7.855	----	2.561	1.962	0.831	0.836	0.064	59.268
1994	0.370	9.911	10.379	24.844	3.860	----	1.803	2.017	0.715	0.711	0.121	54.731
1995	0.297	9.623	7.766	18.336	3.125	----	1.617	1.680	0.668	0.643	0.127	43.882
1996	0.296	9.546	8.871	19.693	3.663	----	1.700	2.069	0.680	0.706	0.120	47.344
1997	0.413	12.423	9.916	24.637	9.062	----	2.908	3.318	1.117	1.152	0.250	65.196
1998	0.460	13.172	10.196	25.698	11.161	----	3.417	2.901	1.256	1.308	0.188	69.757
1999	0.450	12.705	10.143	25.316	13.835	----	4.369	3.571	1.760	1.893	0.263	74.305
2000	0.483	10.811	8.445	19.273	15.413	----	5.155	4.692	1.736	1.931	0.351	68.290
2001	0.680	10.288	8.403	21.539	16.336	----	5.015	4.468	1.647	1.844	0.479	70.699
2002	0.851	12.073	8.602	23.131	17.313	----	5.091	4.080	1.210	1.753	0.555	74.659
2003	0.819	11.789	8.412	22.754	17.223	----	5.024	3.863	0.886	1.956	0.415	73.141
2004	0.884	12.162	10.234	25.167	15.460	----	3.561	2.719	0.954	1.655	0.314	73.110
2005	0.803	12.331	10.625	26.033	13.171	----	3.404	1.975	0.534	2.578	0.370	71.824
2006	0.830	12.005	10.492	25.714	10.791	----	3.332	1.590	0.493	2.368	0.366	67.981
2007	0.789	9.772	8.473	26.493	9.249	----	2.828	1.416	0.551	2.720	0.578	62.869
2008	0.682	7.755	6.206	24.521	10.748	----	3.015	1.763	0.724	2.552	0.600	58.566
2009	0.490	6.637	4.955	21.755	10.779	----	2.528	1.593	0.644	2.210	0.455	52.046
2010	0.419	6.729	4.486	20.503	10.114	----	2.325	1.829	0.789	2.116	0.410	49.720
2011	0.540	6.560	2.431	14.533	7.351	----	2.313	2.030	0.792	2.179	0.458	39.187

Table A3. Sport catch (million pounds, net weight).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.013	0.008	0.072	0.196	0.000	0.000	0.000	0.000	0.289
1978	0.010	0.004	0.082	0.282	0.000	0.000	0.000	0.000	0.378
1979	0.015	0.009	0.174	0.365	0.000	0.000	0.000	0.000	0.563
1980	0.019	0.006	0.332	0.488	0.000	0.000	0.000	0.000	0.845
1981	0.019	0.012	0.318	0.751	0.000	0.012	0.000	0.000	1.112
1982	0.050	0.033	0.489	0.716	0.000	0.011	0.000	0.000	1.299
1983	0.063	0.052	0.553	0.945	0.000	0.003	0.000	0.000	1.616
1984	0.118	0.062	0.621	1.026	0.000	0.013	0.000	0.000	1.840
1985	0.193	0.262	0.682	1.210	0.000	0.008	0.000	0.000	2.355
1986	0.333	0.186	0.730	1.908	0.000	0.020	0.000	0.000	3.177
1987	0.446	0.264	0.780	1.989	0.000	0.030	0.000	0.000	3.509
1988	0.249	0.252	1.076	3.264	0.000	0.036	0.000	0.000	4.877
1989	0.327	0.318	1.559	3.005	0.000	0.024	0.000	0.000	5.233
1990	0.197	0.381	1.330	3.638	0.000	0.040	0.000	0.000	5.586
1991	0.158	0.292	1.654	4.264	0.014	0.127	0.000	0.000	6.509
1992	0.250	0.290	1.668	3.899	0.029	0.043	0.000	0.000	6.179
1993	0.246	0.328	1.811	5.265	0.018	0.057	0.000	0.000	7.725
1994	0.186	0.328	2.001	4.487	0.021	0.042	0.000	0.000	7.065
1995	0.236	0.887	1.759	4.488	0.022	0.055	0.000	0.000	7.447
1996	0.229	0.887	2.129	4.740	0.021	0.077	0.000	0.000	8.083
1997	0.355	0.887	2.172	5.514	0.028	0.069	0.000	0.000	9.025
1998	0.383	0.887	2.501	4.702	0.017	0.096	0.000	0.000	8.586
1999	0.338	0.859	1.843	4.228	0.017	0.094	0.000	0.000	7.379
2000	0.344	1.021	2.258	5.305	0.015	0.073	0.000	0.000	9.016
2001	0.446	1.015	1.925	4.675	0.016	0.029	0.000	0.000	8.106
2002	0.399	1.260	2.090	4.202	0.013	0.048	0.000	0.000	8.012
2003	0.404	1.218	2.258	5.427	0.009	0.031	0.000	0.000	9.347
2004	0.487	1.613	2.937	5.606	0.007	0.053	0.000	0.000	10.703
2005	0.484	1.841	2.798	5.672	0.014	0.050	0.000	0.000	10.859
2006	0.516	1.773	2.526	5.337	0.014	0.046	0.000	0.000	10.212
2007	0.504	1.556	3.049	6.283	0.025	0.044	0.000	0.000	11.461
2008	0.457	1.520	3.083	5.629	0.018	0.043	0.000	0.000	10.750
2009	0.458	1.098	2.383	4.758	0.030	0.024	0.000	0.000	8.751
2010	0.373	1.156	1.971	4.285	0.024	0.016	0.000	0.000	7.825
2011	0.398	1.220	1.313	4.541	0.025	0.018	0.000	0.000	7.515

Table A4. Personal use (million pounds, net weight).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.010	0.050	0.720	0.960	0.060	0.230	0.000	0.000	2.030
1992	0.014	0.100	0.370	0.490	0.030	0.110	0.000	0.000	1.114
1993	0.016	0.300	0.110	0.330	0.060	0.120	0.000	0.000	0.936
1994	0.011	0.300	0.110	0.330	0.060	0.120	0.000	0.000	0.931
1995	0.014	0.300	0.000	0.097	0.037	0.094	0.000	0.000	0.542
1996	0.015	0.300	0.000	0.097	0.037	0.094	0.000	0.000	0.543
1997	0.015	0.300	0.000	0.097	0.037	0.094	0.000	0.000	0.543
1998	0.011	0.300	0.170	0.097	0.037	0.094	0.000	0.000	0.709
1999	0.011	0.300	0.170	0.074	0.020	0.166	0.000	0.000	0.741
2000	0.018	0.300	0.170	0.074	0.020	0.166	0.000	0.000	0.748
2001	0.016	0.300	0.170	0.074	0.020	0.166	0.000	0.000	0.746
2002	0.016	0.300	0.170	0.074	0.020	0.166	0.000	0.000	0.746
2003	0.027	0.300	0.628	0.280	0.028	0.021	0.003	0.096	1.383
2004	0.019	0.300	0.677	0.404	0.034	0.029	0.001	0.056	1.520
2005	0.036	0.300	0.598	0.429	0.046	0.036	0.001	0.091	1.537
2006	0.036	0.300	0.598	0.429	0.046	0.036	0.001	0.091	1.537
2007	0.036	0.300	0.580	0.380	0.050	0.027	0.003	0.107	1.483
2008	0.030	0.405	0.525	0.372	0.048	0.015	0.002	0.092	1.489
2009	0.029	0.405	0.458	0.334	0.032	0.017	0.001	0.030	1.306
2010	0.025	0.405	0.425	0.313	0.023	0.015	0.001	0.032	1.239
2011	0.025	0.405	0.425	0.313	0.023	0.015	0.001	0.038	1.245

Table A5. O32 Bycatch (million pounds, net weight).

	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1974	0.252	0.899	0.371	4.478	2.816	1.901	----	----	----	10.717
1975	0.252	0.909	0.451	2.612	1.661	1.106	----	----	----	6.991
1976	0.252	0.940	0.503	2.740	1.945	1.180	----	----	----	7.560
1977	0.254	0.720	0.407	3.366	1.546	1.976	----	----	----	8.269
1978	0.253	0.553	0.213	2.443	1.307	3.404	----	----	----	8.173
1979	0.253	0.696	0.638	4.491	0.689	3.451	----	----	----	10.218
1980	0.253	0.516	0.418	4.928	0.870	5.740	----	----	----	12.725
1981	0.252	0.533	0.403	3.990	1.095	4.366	----	----	----	10.639
1982	0.252	0.299	0.199	3.197	1.684	2.952	----	----	----	8.583
1983	0.253	0.292	0.200	2.083	1.219	2.473	----	----	----	6.520
1984	0.252	0.515	0.211	1.512	0.922	2.307	----	----	----	5.719
1985	0.252	0.546	0.201	0.796	0.341	2.245	----	----	----	4.381
1986	0.253	0.557	0.203	0.674	0.198	2.612	----	----	----	4.497
1987	0.253	0.791	0.203	1.587	0.392	2.668	----	----	----	5.894
1988	0.253	0.772	0.203	2.124	0.042	3.202	----	----	----	6.596
1989	0.253	0.719	0.203	1.801	0.438	1.914	----	----	----	5.328
1990	0.253	1.030	0.675	2.640	1.216	----	0.627	0.335	2.380	9.156
1991	0.253	1.223	0.545	3.129	1.036	----	0.731	0.236	2.254	9.407
1992	0.276	1.016	0.574	2.646	1.114	----	0.728	0.656	1.943	8.953
1993	0.276	0.651	0.333	1.911	0.465	----	0.129	0.479	1.407	5.651
1994	0.276	0.572	0.396	2.355	0.848	----	1.200	0.536	1.831	8.014
1995	0.381	0.706	0.219	1.464	0.828	----	1.089	0.149	2.110	6.946
1996	0.474	0.166	0.233	1.404	0.962	----	0.590	0.458	2.979	7.266
1997	0.474	0.109	0.240	1.545	0.728	----	0.845	0.198	2.973	7.112
1998	0.834	0.117	0.238	1.471	0.730	----	1.189	0.327	2.725	7.631
1999	0.761	0.108	0.231	1.283	0.742	----	0.911	0.336	2.644	7.016
2000	0.634	0.128	0.254	1.286	0.645	----	0.806	0.580	2.290	6.623
2001	0.645	0.149	0.184	1.620	0.633	----	0.572	0.387	2.917	7.107
2002	0.204	0.153	0.166	1.074	0.712	----	0.533	0.196	2.733	5.771
2003	0.102	0.133	0.144	1.179	0.499	----	0.519	0.220	2.112	4.908
2004	0.115	0.140	0.149	1.523	0.393	----	0.520	0.294	1.920	5.054
2005	0.139	0.191	0.144	1.322	0.359	----	0.460	0.279	2.212	5.106
2006	0.204	0.151	0.214	1.062	0.508	----	0.649	0.232	2.137	5.157
2007	0.103	0.154	0.215	0.989	0.451	----	0.656	0.325	1.897	4.790
2008	0.172	0.067	0.216	1.058	0.485	----	0.496	0.211	1.553	4.258
2009	0.198	0.109	0.216	0.972	0.469	----	0.645	0.277	1.631	4.517
2010	0.261	0.093	0.215	0.904	0.416	----	0.452	0.311	1.723	4.375
2011	0.106	0.152	0.214	1.035	0.430	----	0.451	0.306	1.350	4.044

Table A6. O32 Commercial wastage (million pounds, net weight).

	2A	2B	2C	3A	3B	4	4A	4B	4C	4D	4E	Total
1974	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1979	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	- - - -	- - - -	- - - -	- - - -	- - - -	0.000
1981	0.000	0.000	0.000	0.000	0.000	- - - -	0.061	0.044	0.022	0.024	0.001	0.000
1982	0.000	0.000	0.000	0.000	0.000	- - - -	0.183	0.014	0.037	0.066	0.002	0.000
1983	0.000	0.000	0.000	0.000	0.000	- - - -	0.138	0.056	0.033	0.026	0.004	0.000
1984	0.000	0.000	0.000	0.000	0.000	- - - -	0.028	0.023	0.010	0.007	0.000	0.000
1985	0.002	0.102	0.216	0.929	0.200	- - - -	0.027	0.070	0.015	0.018	0.000	1.601
1986	0.004	0.203	0.433	1.857	0.401	- - - -	0.110	0.058	0.023	0.044	0.003	3.200
1987	0.003	0.173	0.368	1.580	0.341	- - - -	0.092	0.062	0.028	0.059	0.004	2.722
1988	0.001	0.049	0.206	1.506	0.122	- - - -	0.051	0.044	0.015	0.014	0.001	1.952
1989	0.007	0.046	0.193	1.458	0.194	- - - -	0.046	0.035	0.015	0.015	0.001	2.028
1990	0.015	0.117	0.243	1.110	0.216	- - - -	0.036	0.040	0.014	0.014	0.002	1.939
1991	0.002	0.072	0.347	1.143	0.418	- - - -	0.008	0.009	0.003	0.003	0.001	2.227
1992	0.007	0.053	0.245	0.643	0.181	- - - -	0.024	0.029	0.010	0.010	0.002	1.254
1993	0.009	0.096	0.192	0.341	0.063	- - - -	0.026	0.030	0.010	0.010	0.002	0.813
1994	0.001	0.069	0.228	0.845	0.039	- - - -	0.020	0.017	0.007	0.008	0.001	1.288
1995	0.003	0.039	0.054	0.128	0.009	- - - -	0.034	0.028	0.014	0.015	0.002	0.257
1996	0.001	0.029	0.044	0.177	0.022	- - - -	0.026	0.023	0.009	0.010	0.002	0.348
1997	0.006	0.037	0.040	0.074	0.054	- - - -	0.033	0.029	0.011	0.012	0.003	0.289
1998	0.001	0.053	0.041	0.154	0.056	- - - -	0.020	0.016	0.005	0.007	0.002	0.358
1999	0.007	0.040	0.067	0.117	0.071	- - - -	0.020	0.016	0.004	0.008	0.002	0.395
2000	0.007	0.028	0.038	0.059	0.058	- - - -	0.015	0.012	0.004	0.007	0.001	0.260
2001	0.003	0.046	0.037	0.065	0.032	- - - -	0.012	0.007	0.002	0.009	0.001	0.271
2002	0.005	0.036	0.026	0.139	0.034	- - - -	0.007	0.004	0.001	0.005	0.001	0.290
2003	0.002	0.035	0.025	0.068	0.035	- - - -	0.008	0.004	0.002	0.008	0.002	0.215
2004	0.000	0.036	0.031	0.076	0.015	- - - -	0.011	0.007	0.003	0.010	0.002	0.197
2005	0.005	0.037	0.032	0.156	0.026	- - - -	0.012	0.007	0.003	0.010	0.002	0.287
2006	0.002	0.036	0.021	0.051	0.011	- - - -	0.008	0.007	0.003	0.008	0.001	0.139
2007	0.003	0.029	0.029	0.053	0.018	- - - -	0.010	0.009	0.003	0.010	0.002	0.156
2008	0.001	0.022	0.012	0.061	0.004	- - - -	0.061	0.044	0.022	0.024	0.001	0.133
2009	0.001	0.020	0.010	0.044	0.021	- - - -	0.183	0.014	0.037	0.066	0.002	0.130
2010	0.001	0.027	0.009	0.021	0.020	- - - -	0.138	0.056	0.033	0.026	0.004	0.105
2011	0.004	0.020	0.005	0.029	0.007	- - - -	0.028	0.023	0.010	0.007	0.000	0.099

Table A7-1. U32 Bycatch (million pounds, net weight).

	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1974	0.154	0.830	0.161	0.770	0.604	5.718	----	----	----	8.236
1975	0.154	0.999	0.188	0.546	0.412	2.544	----	----	----	4.843
1976	0.154	1.124	0.205	0.756	0.498	3.383	----	----	----	6.120
1977	0.155	1.097	0.173	0.728	0.348	0.938	----	----	----	3.439
1978	0.155	0.918	0.164	0.612	0.533	1.619	----	----	----	4.001
1979	0.154	1.156	0.183	1.290	0.246	1.968	----	----	----	4.997
1980	0.154	0.856	0.102	0.924	0.376	3.496	----	----	----	5.908
1981	0.154	0.655	0.104	0.730	0.468	2.042	----	----	----	4.153
1982	0.154	0.568	0.103	0.600	0.491	1.804	----	----	----	3.720
1983	0.154	0.651	0.104	0.873	0.716	1.796	----	----	----	4.294
1984	0.154	0.559	0.091	0.628	0.586	2.385	----	----	----	4.402
1985	0.154	0.593	0.100	0.205	0.236	1.962	----	----	----	3.249
1986	0.154	0.604	0.101	0.162	0.212	2.964	----	----	----	4.197
1987	0.154	0.858	0.101	0.653	0.481	3.071	----	----	----	5.317
1988	0.154	0.837	0.101	1.241	0.008	5.655	----	----	----	7.996
1989	0.155	0.779	0.101	1.465	0.380	5.368	----	----	----	8.248
1990	0.155	0.649	0.181	1.473	0.829	----	1.540	0.147	3.552	8.525
1991	0.155	0.770	0.189	1.714	0.635	----	2.118	0.109	4.574	10.262
1992	0.168	0.728	0.161	2.022	0.866	----	2.035	0.308	5.050	11.339
1993	0.168	1.010	0.409	2.381	0.596	----	1.698	0.310	3.740	10.313
1994	0.168	0.647	0.127	1.553	0.538	----	1.706	0.120	4.076	8.934
1995	0.233	0.816	0.122	1.494	0.917	----	2.678	0.106	2.589	8.956
1996	0.141	0.133	0.111	1.294	0.970	----	1.584	0.159	2.717	7.109
1997	0.141	0.105	0.157	1.420	0.715	----	1.541	0.098	2.224	6.402
1998	0.248	0.096	0.123	1.191	0.659	----	1.297	0.157	2.029	5.800
1999	0.226	0.085	0.127	1.602	0.995	----	1.582	0.073	2.139	6.830
2000	0.188	0.102	0.141	1.606	0.865	----	1.336	0.106	2.324	6.667
2001	0.192	0.028	0.157	1.390	1.042	----	0.935	0.145	2.164	6.052
2002	0.431	0.092	0.174	1.120	1.212	----	1.695	0.081	2.035	6.784
2003	0.158	0.115	0.197	1.611	1.065	----	1.564	0.039	2.348	7.275
2004	0.171	0.121	0.204	2.082	0.837	----	1.567	0.053	2.135	7.300
2005	0.398	0.165	0.196	1.808	0.766	----	1.386	0.050	2.460	7.043
2006	0.374	0.143	0.127	1.913	0.892	----	1.063	0.193	3.219	7.793
2007	0.284	0.146	0.127	1.782	0.793	----	1.075	0.270	2.857	7.325
2008	0.250	0.064	0.128	1.906	0.853	----	0.814	0.176	2.339	6.455
2009	0.310	0.104	0.128	1.750	0.825	----	1.057	0.231	2.456	6.861
2010	0.084	0.088	0.128	1.628	0.731	----	0.741	0.260	2.596	6.343
2011	0.034	0.145	0.127	1.863	0.755	----	0.740	0.255	2.033	6.343

Table A7-2. Break down of U32 Bycatch (million pounds, net weight) into U26 and U32/O26 components.

U26	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1996	0.006	0.024	0.030	0.578	0.437	0.752	0.035	1.155	3.015
1997	0.006	0.017	0.042	0.621	0.343	0.878	0.023	0.893	2.823
1998	0.011	0.019	0.032	0.425	0.244	0.592	0.045	1.032	2.400
1999	0.010	0.013	0.039	0.526	0.300	1.053	0.030	1.456	3.427
2000	0.008	0.016	0.044	0.528	0.261	0.814	0.038	1.504	3.213
2001	0.008	0.003	0.080	0.709	0.531	0.413	0.038	1.146	2.929
2002	0.096	0.020	0.097	0.629	0.656	1.169	0.017	1.251	3.936
2003	0.035	0.025	0.100	0.815	0.532	1.004	0.011	1.560	4.081
2004	0.038	0.026	0.103	1.053	0.418	1.006	0.014	1.418	4.077
2005	0.120	0.036	0.099	0.914	0.382	0.890	0.014	1.634	4.090
2006	0.126	0.022	0.039	1.045	0.417	0.735	0.125	2.081	4.590
2007	0.074	0.023	0.039	0.973	0.370	0.743	0.175	1.847	4.245
2008	0.031	0.010	0.039	1.041	0.398	0.563	0.114	1.512	3.708
2009	0.041	0.016	0.039	0.956	0.385	0.731	0.149	1.588	3.905
2010	0.004	0.014	0.039	0.889	0.342	0.512	0.168	1.678	3.646
2011	0.003	0.023	0.039	1.017	0.353	0.511	0.165	1.314	3.425

O26/U32	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1996	0.135	0.109	0.081	0.717	0.533	0.833	0.125	1.562	4.094
1997	0.135	0.088	0.115	0.798	0.372	0.663	0.075	1.332	3.578
1998	0.237	0.077	0.091	0.765	0.415	0.705	0.112	0.997	3.400
1999	0.216	0.072	0.088	1.076	0.695	0.529	0.043	0.684	3.403
2000	0.180	0.086	0.097	1.079	0.604	0.522	0.068	0.820	3.455
2001	0.184	0.025	0.077	0.680	0.511	0.522	0.106	1.019	3.123
2002	0.335	0.072	0.076	0.491	0.557	0.525	0.064	0.784	2.903
2003	0.123	0.090	0.097	0.796	0.533	0.559	0.029	0.788	3.016
2004	0.134	0.095	0.101	1.029	0.419	0.560	0.038	0.717	3.093
2005	0.278	0.129	0.097	0.893	0.383	0.496	0.036	0.826	3.139
2006	0.247	0.121	0.088	0.868	0.475	0.328	0.068	1.138	3.334
2007	0.210	0.123	0.088	0.809	0.422	0.332	0.095	1.010	3.090
2008	0.219	0.054	0.089	0.865	0.454	0.251	0.062	0.827	2.821
2009	0.269	0.087	0.089	0.794	0.439	0.326	0.081	0.868	2.955
2010	0.080	0.074	0.089	0.739	0.389	0.229	0.092	0.918	2.609
2011	0.031	0.122	0.088	0.846	0.402	0.228	0.090	0.719	2.526

Table A8. U32 Commercial wastage (million pounds, net weight).

	2A	2B	2C	3A	3B	4	4A	4B	4C	4D	4E	Total
1974	0.002	0.081	0.042	0.061	0.013	0.002	----	----	----	----	----	0.201
1975	0.004	0.143	0.048	0.091	0.021	0.002	----	----	----	----	----	0.309
1976	0.002	0.164	0.044	0.107	0.025	0.002	----	----	----	----	----	0.344
1977	0.002	0.135	0.026	0.093	0.032	0.004	----	----	----	----	----	0.292
1978	0.001	0.113	0.036	0.115	0.014	0.004	----	----	----	----	----	0.283
1979	0.001	0.119	0.039	0.130	0.004	0.004	----	----	----	----	----	0.297
1980	0.000	0.136	0.029	0.132	0.003	0.002	----	----	----	----	----	0.302
1981	0.002	0.152	0.036	0.147	0.006	----	0.004	0.002	0.002	0.000	0.000	0.351
1982	0.002	0.163	0.033	0.124	0.067	----	0.010	0.000	0.002	0.000	0.000	0.401
1983	0.003	0.192	0.064	0.117	0.114	----	0.023	0.009	0.004	0.000	0.000	0.526
1984	0.005	0.363	0.065	0.162	0.104	----	0.010	0.008	0.006	0.001	0.000	0.724
1985	0.006	0.431	0.109	0.194	0.179	----	0.017	0.010	0.006	0.001	0.000	0.953
1986	0.007	0.474	0.134	0.338	0.152	----	0.036	0.002	0.007	0.003	0.000	1.153
1987	0.007	0.498	0.142	0.373	0.140	----	0.041	0.013	0.010	0.002	0.001	1.227
1988	0.005	0.504	0.160	0.507	0.133	----	0.022	0.015	0.008	0.001	0.000	1.355
1989	0.004	0.393	0.142	0.503	0.154	----	0.012	0.026	0.007	0.002	0.000	1.243
1990	0.003	0.310	0.152	0.476	0.177	----	0.031	0.013	0.007	0.003	0.001	1.173
1991	0.003	0.160	0.142	0.413	0.253	----	0.029	0.016	0.009	0.004	0.001	1.030
1992	0.004	0.162	0.169	0.525	0.190	----	0.036	0.026	0.011	0.002	0.001	1.126
1993	0.005	0.216	0.202	0.480	0.179	----	0.035	0.023	0.011	0.002	0.001	1.154
1994	0.002	0.196	0.194	0.559	0.091	----	0.026	0.024	0.010	0.002	0.002	1.106
1995	0.002	0.186	0.097	0.282	0.049	----	0.015	0.013	0.006	0.001	0.001	0.652
1996	0.002	0.184	0.115	0.323	0.059	----	0.016	0.017	0.007	0.001	0.001	0.725
1997	0.002	0.248	0.136	0.426	0.161	----	0.029	0.029	0.011	0.002	0.003	1.047
1998	0.002	0.275	0.147	0.473	0.218	----	0.039	0.025	0.014	0.003	0.002	1.198
1999	0.003	0.276	0.154	0.491	0.296	----	0.055	0.031	0.022	0.004	0.003	1.335
2000	0.003	0.240	0.135	0.393	0.370	----	0.072	0.041	0.024	0.004	0.005	1.287
2001	0.005	0.236	0.143	0.459	0.443	----	0.080	0.038	0.026	0.006	0.008	1.444
2002	0.009	0.286	0.155	0.516	0.528	----	0.092	0.032	0.022	0.008	0.010	1.658
2003	0.009	0.302	0.165	0.530	0.593	----	0.104	0.029	0.018	0.011	0.009	1.770
2004	0.011	0.343	0.225	0.612	0.597	----	0.085	0.018	0.023	0.012	0.008	1.934
2005	0.013	0.388	0.260	0.659	0.558	----	0.093	0.012	0.015	0.022	0.010	2.030
2006	0.014	0.410	0.283	0.667	0.511	----	0.101	0.009	0.015	0.025	0.011	2.046
2007	0.016	0.438	0.267	0.918	0.423	----	0.132	0.018	0.032	0.032	0.010	2.286
2008	0.015	0.262	0.212	0.924	0.681	----	0.133	0.019	0.017	0.060	0.014	2.337
2009	0.015	0.231	0.262	1.118	0.773	----	0.139	0.012	0.014	0.050	0.010	2.624
2010	0.007	0.233	0.242	1.417	0.887	----	0.138	0.032	0.020	0.052	0.010	3.038
2011	0.006	0.177	0.065	0.881	0.752	----	0.127	0.033	0.040	0.109	0.023	2.213

Table A8-2. Break down of U32 Wastage (million pounds, net weight) into U26 and U32/O26 components.

U26	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1996	0.000	0.004	0.007	0.009	0.003	0.001	0.001	0.000	0.025
1997	0.000	0.006	0.004	0.011	0.006	0.001	0.001	0.001	0.029
1998	0.000	0.003	0.004	0.009	0.007	0.001	0.001	0.001	0.026
1999	0.000	0.004	0.004	0.013	0.011	0.002	0.002	0.001	0.037
2000	0.000	0.003	0.006	0.009	0.014	0.003	0.003	0.001	0.039
2001	0.000	0.003	0.006	0.014	0.016	0.005	0.002	0.003	0.048
2002	0.000	0.006	0.005	0.016	0.025	0.010	0.001	0.002	0.065
2003	0.000	0.008	0.004	0.016	0.032	0.008	0.002	0.001	0.071
2004	0.000	0.017	0.010	0.017	0.038	0.010	0.001	0.001	0.095
2005	0.000	0.016	0.015	0.025	0.038	0.008	0.001	0.004	0.107
2006	0.000	0.017	0.022	0.033	0.043	0.014	0.001	0.005	0.136
2007	0.000	0.017	0.012	0.039	0.042	0.018	0.002	0.005	0.134
2008	0.000	0.007	0.011	0.033	0.074	0.020	0.001	0.005	0.151
2009	0.000	0.005	0.012	0.046	0.067	0.019	0.001	0.006	0.155
2010	0.000	0.004	0.009	0.048	0.080	0.020	0.002	0.006	0.169
2011	0.000	0.004	0.004	0.041	0.074	0.018	0.004	0.017	0.161

O26/U32	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1996	0.002	0.180	0.108	0.314	0.056	0.015	0.016	0.009	0.700
1997	0.002	0.242	0.132	0.415	0.155	0.028	0.028	0.015	1.018
1998	0.002	0.272	0.143	0.464	0.211	0.038	0.024	0.018	1.172
1999	0.003	0.272	0.150	0.478	0.285	0.053	0.029	0.028	1.298
2000	0.003	0.237	0.129	0.384	0.356	0.069	0.038	0.032	1.248
2001	0.005	0.233	0.137	0.445	0.427	0.075	0.036	0.037	1.396
2002	0.009	0.280	0.150	0.500	0.503	0.082	0.031	0.038	1.593
2003	0.009	0.294	0.161	0.514	0.561	0.096	0.027	0.037	1.699
2004	0.011	0.326	0.215	0.595	0.559	0.075	0.017	0.042	1.839
2005	0.013	0.372	0.245	0.634	0.520	0.085	0.011	0.043	1.923
2006	0.014	0.393	0.261	0.634	0.468	0.087	0.008	0.046	1.910
2007	0.016	0.421	0.255	0.879	0.381	0.114	0.016	0.069	2.152
2008	0.015	0.255	0.201	0.891	0.607	0.113	0.018	0.086	2.186
2009	0.015	0.226	0.250	1.072	0.706	0.120	0.011	0.068	2.469
2010	0.007	0.229	0.233	1.369	0.807	0.118	0.030	0.076	2.869
2011	0.006	0.173	0.061	0.840	0.678	0.109	0.029	0.155	2.052

Table A9a. IPHC setline survey WPUE of O32 sh in weight (net pounds per skate).

Figures refer to entire areas. For cases where only part of an area was fished (e.g., northern 2B, western 3A), the WPUE shown is an adjusted value. J-hook values are raw J-hook catch rates. Area 4CDE is constructed from five subareas: Area 4D Edge, Area 4IC (Pribilofs), 4ID (St. Matthew); Area 4S (southern Bering Sea shelf), and 4N (northern Bering Sea shelf. The 4N and 4S time series are constructed using trawl survey data (see text for full details). The bottom area (0-400fm) in thousands of nmi^2 is also listed for each area.

Bottom	2A	2B	2C	3A	3B	4A	4B	4D	4IC	4ID	4S	4N	4CDE	Total
0-400	14.132	29.601	14.580	49.178	29.584	19.888	19.711	15.313	2.094	1.925	141.103	59.499	219.934	396.608
20-275	10.725	23.770	11.915	41.998	25.581	16.989	11.865	14.318	1.951	1.693	109.163	23.323	150.448	293.291
	J-Hook WPUE:													
1974	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1975	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1976	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1977	---	13	---	58	---	---	---	---	---	---	---	---	---	---
1978	---	19	---	27	---	---	---	---	---	---	---	---	---	---
1979	---	---	---	41	---	---	---	---	---	---	---	---	---	---
1980	---	25	---	76	---	---	---	---	---	---	---	---	---	---
1981	---	16	---	131	---	---	---	---	---	---	---	---	---	---
1982	---	21	114	130	---	---	---	---	---	---	6	0	---	---
1983	---	18	142	119	---	---	---	---	---	---	4	0	---	---
	C-Hook WPUE:													
1984	---	57	260	361	---	---	---	---	---	---	6	1	---	---
1985	---	42	261	378	---	---	---	---	---	---	6	1	---	---
1986	---	38	283	305	---	---	---	---	---	---	7	0	---	---
1987	---	---	---	---	---	---	---	---	---	---	8	0	---	---
1988	---	---	---	---	---	---	---	---	---	---	17	0	---	---
1989	---	---	---	---	---	---	---	---	---	---	11	0	---	---
1990	---	---	---	---	---	---	---	---	---	---	12	1	---	---
1991	---	---	---	---	---	---	---	---	---	---	11	2	---	---
1992	---	---	---	---	---	---	---	---	---	---	9	1	---	---
1993	---	96	---	261	---	---	---	---	---	---	19	5	---	---
1994	---	---	---	254	---	---	---	---	---	---	15	4	---	---
1995	29	159	---	300	---	---	---	---	---	---	16	4	---	---
1996	32	166	306	317	352	---	---	---	---	---	24	18	---	---
1997	35	144	411	331	414	245	282	111	111	111	19	4	23	138
1998	36	83	232	281	435	299	216	299	299	299	26	7	45	134
1999	37	88	205	241	438	290	203	290	290	290	26	0	42	126
2000	39	91	233	272	373	276	216	213	213	213	19	3	32	121
2001	41	101	237	256	357	199	171	197	197	197	20	5	31	112
2002	33	92	261	299	297	168	119	263	263	263	12	2	31	109
2003	22	73	223	229	262	154	104	195	195	195	17	4	29	92
2004	27	86	173	270	236	137	73	132	132	132	17	3	23	88
2005	28	72	171	276	211	107	86	69	69	69	16	3	18	82
2006	16	59	144	233	181	85	96	54	82	65	17	3	17	71
2007	19	57	140	212	191	67	87	59	41	60	12	3	13	66
2008	19	90	108	189	126	84	103	78	31	94	8	3	13	60
2009	8	86	115	149	113	84	107	78	34	59	12	3	15	55
2010	17	89	110	117	91	73	68	48	59	51	12	3	13	47
2011	27	80	136	121	80	58	68	33	51	14	10	3	10	45

Table A9b. Standard errors of IPHC setline survey WPUE of O32 sh in weight (net pounds per skate).

Same as Table A9, but showing the standard errors of WPUE for each regulatory area.

Bottom	2A	2B	2C	3A	3B	4A	4B	4D	4IC	4ID	4S	4N	4CDE	Total
0-400	14.132	29.601	14.580	49.178	29.584	19.888	19.711	15.313	2.094	1.925	141.103	59.499	219.934	396.608
20-275	10.725	23.770	11.915	41.998	25.581	16.989	11.865	14.318	1.951	1.693	109.163	23.323	150.448	293.291
	J-Hook WPUE:													
1974	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1975	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1976	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1977	---	1.7	---	4.6	---	---	---	---	---	---	---	---	---	---
1978	---	2.5	---	2.3	---	---	---	---	---	---	---	---	---	---
1979	---	---	---	3.2	---	---	---	---	---	---	---	---	---	---
1980	---	2.4	---	5.4	---	---	---	---	---	---	---	---	---	---
1981	---	2.2	---	8.9	---	---	---	---	---	---	---	---	---	---
1982	---	2.6	11.3	10.7	---	---	---	---	---	---	1.1	0	---	---
1983	---	2.4	8.5	7.9	---	---	---	---	---	---	0.9	0	---	---
	C-Hook WPUE:													
1984	---	5.6	18.5	22.8	---	---	---	---	---	---	1.3	0.1	---	---
1985	---	4.6	17.0	19.6	---	---	---	---	---	---	1.2	0.1	---	---
1986	---	3.4	18.4	20.4	---	---	---	---	---	---	1.5	0.0	---	---
1987	---	---	---	---	---	---	---	---	---	---	1.7	0.1	---	---
1988	---	---	---	---	---	---	---	---	---	---	3.6	0.0	---	---
1989	---	---	---	---	---	---	---	---	---	---	2.2	0.0	---	---
1990	---	---	---	---	---	---	---	---	---	---	2.6	0.1	---	---
1991	---	---	---	---	---	---	---	---	---	---	2.3	0.4	---	---
1992	---	---	---	---	---	---	---	---	---	---	1.8	0.2	---	---
1993	---	11.4	---	19.9	---	---	---	---	---	---	4.0	1.0	---	---
1994	---	---	---	17.9	---	---	---	---	---	---	3.0	0.8	---	---
1995	9.5	13.1	---	21.8	---	---	---	---	---	---	3.4	0.7	---	---
1996	8.2	15.9	25.3	17.6	19.7	---	---	---	---	---	4.9	3.8	---	---
1997	6.8	10.9	37.0	17.1	22.4	25.4	30.6	18.2	18.2	18.2	4.0	0.8	4.0	2.9
1998	7.5	7.0	14.3	11.5	19.2	31.7	19.1	31.7	31.7	31.7	5.3	1.4	3.6	4.1
1999	8.2	7.4	15.8	10.2	18.8	35.8	16.2	35.8	35.8	35.8	5.4	0.0	3.7	4.3
2000	10.8	7.4	16.5	12.2	14.5	29.6	15.9	34.3	34.3	34.3	3.9	0.6	3.3	3.5
2001	13.5	7.5	18.4	12.6	16.0	20.5	18.2	32.2	32.2	32.2	4.2	0.9	3.3	3.5
2002	13.1	6.9	18.9	13.6	12.1	20.2	10.8	46.3	46.3	46.3	2.4	0.4	3.2	3.6
2003	6.1	5.7	16.8	11.4	9.6	18.0	9.9	30.0	30.0	30.0	3.5	0.7	2.7	3.1
2004	8.0	7.5	12.8	11.2	9.8	16.9	7.1	29.8	29.8	29.8	3.5	0.6	2.6	3.1
2005	9.7	6.0	11.5	13.0	10.1	11.5	7.6	13.2	13.2	13.2	3.4	0.7	2.4	2.4
2006	5.2	4.9	10.6	10.9	7.6	12.0	10.2	12.3	15.3	35.4	3.5	0.7	2.2	2.4
2007	7.6	4.6	11.1	10.1	7.9	8.8	10.7	10.5	11.3	15.7	2.5	0.6	1.9	1.8
2008	6.0	7.4	6.8	8.6	5.3	10.8	13.4	10.4	11.9	8.5	1.7	0.5	1.7	1.3
2009	2.3	5.6	7.2	6.5	4.9	11.0	11.9	13.5	6.8	5.7	2.4	0.7	1.6	1.8
2010	4.0	7.0	7.0	5.3	3.9	10.1	7.2	7.1	12.6	13.4	2.5	0.7	1.5	1.7
2011	4.0	6.7	9.5	5.4	4.0	6.5	7.3	4.8	6.9	10.7	2.0	0.7	1.3	1.4

Table A10. Commercial WPUE (net pounds per skate).

Values before 1984 are raw J-hook catch rates, with no hook correction. 1983 is excluded because it consists of a mixture of J- and C-hook data. No value is shown for area/years after 1980 with fewer than 500 skates of reported catch/effort data. Total column recomputed in 2007 with new bottom area numbers.

	2A	2B	2C	3A	3B	4A	4B	4C	4D	4E	Total
J-hook CPUE:											
1974	59	64	57	65	57	---	---	---	---	---	---
1975	59	68	53	66	68	---	---	---	---	---	---
1976	33	53	42	60	65	---	---	---	---	---	---
1977	83	61	45	61	73	---	---	---	---	---	---
1978	39	63	56	78	53	---	---	---	---	---	---
1979	50	48	80	86	37	---	---	---	---	---	---
1980	37	65	79	118	113	---	---	---	---	---	---
1981	33	67	145	142	160	158	99	110	---	---	---
1982	22	68	167	170	217	103	---	91	---	---	---
1983	---	---	---	---	---	---	---	---	---	---	---
C-hook CPUE:											
1984	63	148	314	524	475	366	161	NA	197	---	350
1985	62	147	370	537	602	333	234	594	330	---	395
1986	60	120	302	522	515	265	238	427	239	---	351
1987	57	131	260	504	476	341	220	384	241	---	345
1988	134	137	281	503	655	453	224	371	201	---	387
1989	124	134	258	455	590	409	268	331	384	---	376
1990	168	175	269	353	484	434	209	288	381	---	334
1991	158	148	233	319	466	471	329	223	398	---	333
1992	115	171	230	397	440	372	278	249	412	---	338
1993	147	208	256	393	514	463	218	257	851	---	399
1994	93	215	207	353	377	463	198	167	480	---	328
1995	116	219	234	416	476	349	189	286	475	---	351
1996	159	226	238	473	556	515	269	297	543	---	415
1997	226	241	246	458	562	483	275	335	671	---	423
1998	194	232	236	451	611	525	287	287	627	---	429
1999	342	213	199	437	538	497	310	271	535	---	398
2000	263	229	186	443	577	547	318	223	556	---	416
2001	169	226	196	469	431	474	270	203	511	---	382
2002	181	222	244	507	399	402	245	148	503	---	379
2003	173	221	233	487	364	355	196	105	389	---	346
2004	143	203	240	485	328	315	202	120	444	---	338
2005	137	195	203	446	293	301	238	91	379	---	314
2006	155	201	170	403	292	241	218	72	280	---	283
2007	96	198	160	398	257	206	230	65	237	---	268
2008	69	174	161	370	234	206	193	94	247	---	249
2009	98	199	155	318	211	234	189	88	249	---	236
2010	149	222	158	285	173	182	142	82	188	---	210
2011	94	240	182	283	142	188	162	76	187	---	212

IPHC Staff regulatory proposals: 2012

Bruce M. Leaman and Heather L. Gilroy

Introduction

In making catch limit recommendations for 2012, staff has considered the results of the 2011 stock assessment, changes in the commercial and survey indices used to monitor the stock, a harvest policy that reflects coastwide policy goals, and concerns about individual regulatory areas. The staff recommendations are also made in the context of the uncertainty in the stock assessment process and future estimates of exploitable biomass. Detailed results of these and other additional investigations are reported in the 2011 Report of Assessment and Research Activities (http://www.iphc.int/library/raras.html).

Coastwide commercial fishery weight per unit effort (WPUE) was relatively stable (+1%) for the first time since 2000 and following a decade-long decrease. The primary contributors to the change were increases in parts of Areas 2 and 4 and a halt to the decline in Area 3A. However, commercial WPUE in Area 3B continued to decline and the index for Area 2A (which remains an open-access fishery with short openings) retreated from the large upward excursion seen in 2010 and returned to a value similar to those of the past several years. The 2011 unadjusted IPHC stock assessment survey WPUE showed a coastwide decrease of -5% but did show notable increases in Areas 2A (+59%) and 2C (+24%), a modest increase in Area 3A (+3%) but large decreases in Areas 3B (-13%), 4A (-20%), and 4CDE (-23%).

Late season data from 2010, which were unavailable for the 2010 assessment, revised the estimate of 2011 biomass estimated by the selected assessment model downward by approximately 9%. This adjustment is large in comparison with recent years, where the adjustments due to late-season data have been in the 2-3% range. This year's stock assessment further revises last year's estimate of 2011 exploitable biomass (Ebio) downwards by an additional 16%. The estimate of Ebio for the beginning of 2012, based on the WobbleSQ assessment model variant is 260 Mlb, compared with the 2010 estimate based on the Trendless assessment model variant of 318 Mlb for the beginning of 2011. This reduction is the primary factor in the staff's recommended catch limits for 2012.

Biomass apportionment among regulatory areas

Staff recommendations continue with the same basis for apportionment of the coastwide Ebio estimate into regulatory area Ebio estimates as was used in 2011. That is, the coastwide estimate is apportioned using survey WPUE for each regulatory area, adjusted for catchability and survey timing differences (Webster and Hare 2011), averaged using a three-year, reverse weighting formula (Webster 2011), and multiplied by the 0-400 fm bottom area for each regulatory area.

An estimate of bottom area is required for the apportionment process but all the options of bottom-area definition have been noted by the staff as a source of potential bias in the apportionment process if all bottom areas included in the apportionment process do not have corresponding survey WPUE data (Hare et al. 2011). The current procedure of using the 0-400 fm range as the appropriate range of halibut distribution during the survey period results from examination of detailed commercial fishery catch records, indicating that fishing (hence biomass distribution) occurs in this range. However, the survey covers only the 20-275 fm range and uses WPUE values for this range applied to the 0-400 fm range. Therefore, there are potential biases to using either only the 20-275 fm range (biomass is distributed across greater depth ranges), or the 0-400 fm range (no survey data for some of this range). Staff has proposed an expansion of the existing survey to cover the 0-400 fm range, at least experimentally, but that expansion is dependent on additional funding. Webster et al. (2012) examined the potential biases in a pilot-scale survey expansion in Area 2A during 2011 and found substantial differences in survey WPUE in both shallower (10-25 fm) and deeper (275-400 fm) stations for this area. The relationship of these differences to those which might be found in other regulatory areas is unknown. However, the differences seen in Area 2A heighten the concerns about potential biases arising from the relative magnitude of currently-unsurveyed bottom areas among the regulatory areas (Hare et al. 2011).

The combination of hook competition and survey timing adjustments, together with the reverse-weighting of the three most recent index values, results in adjusted survey WPUE values that differ, sometimes appreciably, from the unadjusted values. This distinction is important because the apportionment formula that is used to estimate exploitable biomass distribution among regulatory areas uses the adjusted survey WPUE index (weighted by bottom area). The areas at the extreme ends of the halibut range (Areas 2A, 4B, and 4CDE) are the most susceptible to differences between raw and adjusted WPUE values (Hare 2012).

Harvest rate and uncertainty in the assessment process

The Commission has requested that staff present measures of uncertainty in the assessment and apportionment process in order to consider such uncertainty when it adopts catch limits. In fisheries science, the term uncertainty is used to describe potential errors, variation, and bias in underlying data, environmental conditions, biophysical influences on stock dynamics, and the technical process of modeling the stock. The staff presented a conceptual paper on sources of uncertainty in estimating CEY in 2004 (Clark et al. 2004). The major sources of uncertainty identified were the structural framework of the assessment model, variation associated with alternative parameter estimates, hypotheses about recruitment and growth dynamics, and effects of ecosystem changes. The assessment process is one of estimation, rather than measurement, and uncertainty occurs at almost every stage of it. For the 2011 assessment process, staff presented some quantitative examples of these types of uncertainty, as well as examining the impacts of biomass projection errors (affecting beginning year Ebio from the end of the previous year) and a broader examination of the retrospective revisions of Ebio estimates for a given year when subsequent years of data are added. These issues are common to all stock assessments around the world and vary in relative magnitude depending on species, area, and fishing history. Indeed, many stock assessments do not report these types of uncertainty, although they exist in virtually all such catch-at-age assessments.

Following initial presentation of this information at the Commission's Interim Meeting webcast, some stakeholders have expressed concern that the halibut assessment is flawed and that the harvest policy followed by the Commission is likewise in error. We continue to evaluate alternative formulations to address the retrospective issue but the fundamental approach of the harvest policy (constant exploitation yield, or CEY) is scientifically appropriate for governing removals. The stock assessment results in annual re-estimation of previous Ebios in response to more recent data, along with new estimates of current Ebio, hence CEY. In recent years this has meant progressively lower CEY values as new data has led to revised (lower) year class strength estimates, although real declines in the strength of recruiting year classes from 1989-1998 also contribute. Staff will continue to conduct research to solve this problem including consideration of different assessment approaches but it is possible that annual declines in CEY will continue to be observed, due at least in part to the retrospective problem, until a solution is found or until a different assessment approach may be developed.

Some of our staff reports from 2011 (Hare 2012, Valero 2012) present an ad hoc 'fix' for the retrospective re-estimation, which assumes that the projected cumulative reduction in this year's Ebio estimate resulting from the re-estimation will at least match the maximum observed historically and should lead to a reduction in the harvest rate to match this cumulative biomass re-estimation. This approach would reduce the status quo harvest rate to achieve this cumulative reduction in one year, which would essentially reduce the current yield from the fishery by over 50%. The positive aspect of this approach is that it would attempt to have the realized harvest rate match the target harvest rate. An effect of the retrospective problem is that the realized historical harvest rates are progressively increased as the underlying biomass upon which they are based is reduced. We have not followed that approach in our recommendations for 2012, nor has this ad hoc approach been taken for those other north Pacific stocks where retrospective issues have been identified. Staff will address the retrospective issue as a primary assessment focus in 2012.

We continue to recommend a Slow Up – Full Down (SUFullD) harvest control rule as being more responsive to stock decreases and precautionary for estimates of increases. This means that 100% of any identified decreases in yield (i.e., when the current FCEY is lower than the previous year's catch limit) are recommended compared with only 50% of identified decreases under the previous SUFastD policy. Only one-third of the difference between current catch limits and any increase in Fishery CEY (the Slow Up component) will be recommended, as in all years since the introduction of this harvest control rule.

We also recommend continuation of the standardized treatment of fish above 26 in (O26) for removals by all directed fisheries. That is, including direct deductions for U32/O26 bycatch and wastage mortality (BAWM) as well as directed removals of this size class, when calculating FCEY.

Catch limit recommendations

The staff recommendations total 33.135 million pounds for 2012, a decrease of approximately 19% from 2011 (Table 1). The Area 2A recommendation includes all removals (commercial, treaty Tribes, and sport) allocated by the Pacific Fishery Management Council's Catch Sharing Plan. Area 4CDE is treated as a single regulatory unit by the Commission, although the North Pacific Fishery Management Council's (NPFMC) Catch Sharing Plan allocates the Commission catch limit into limits for the individual regulatory areas. The Area 2B catch limit recommendation includes totals for the commercial and sport fisheries. The Canadian Department of Fisheries and Oceans (DFO) will allocate the adopted catch limit between the sport and commercial fisheries. For Areas 2C and 3A the catch limit recommendation includes the use of the NPFMC and National Marine Fisheries Service (NMFS) authorized Guideline Harvest Levels (GHL) for the halibut recreational charter fisheries of 0.931 Mlb and 3.103 Mlb, respectively, as the projected removals by that sector for 2012. The catch limit recommendations are made with the expectation that both Canada and the U.S. will manage to their domestic targets for sport fish catch in order that the Commission's management targets for 2012 will be achieved.

The staff recommends a slow rate of increase in catch limits when estimated Fishery CEY is higher than the previous year's catch limit and a complete reduction of catch limits when FCEY is lower than the previous year's catch limit (a Slow Up – Full Down policy). For Areas 2A and 2C the staff recommends an increase over the 2011 catch limit equivalent to one-third of the difference between the 2011 catch limit and the estimated 2012 fishery CEY. For all other areas, the staff recommends catch limits at the FCEY level for 2012.

Fishing seasons

As in the past years, the staff recommends March 15 to November 15 opening and closing dates for the quota share fishing season. This recommendation is a compromise between minimizing interceptions of migrating fish and providing opportunity for market presence of fish wild halibut. All Area 2A commercial fisheries should also occur within this period.

For the Area 2A directed commercial fishery, the staff recommends an opening pattern similar to 2011, starting the last week of June with a series of 10-hour periods, with fishing period limits. Therefore we recommend the following series for 2012: June 27, July 11, July 25, August 8, August 22, September 5, and September 19. The size of the fishing period limits will be determined when more information is available on fleet participation.

Catch sharing plans: Areas 2A, 2B, and 4CDE

The Commission does not make allocative decisions within regulatory areas or among different user groups. However, for Areas 2A and 4CDE the staff recommends that the Commission endorse the catch sharing plans developed by the Pacific and North Pacific Fishery Management Councils for these areas, respectively. Similarly, the staff recommends that the catch sharing allocation of 88% commercial and 12% recreational, developed by DFO for Area 2B, be endorsed.

Proposed changes to the IPHC regulations

Canadian commercial logbook regulations

The IPHC staff recommends changing the IPHC logbook regulations for the Canadian fishery to match the British Columbia Integrated Groundfish Fishing Log. The recommended change would be to delete the options of recording the location as defined as a direction and distance from a point of land and of catch weights recorded by day. Therefore, location would be recorded as latitude and longitude and catch weights would be recorded by set.

Area 2A logbook options

The IPHC staff recommends adding an option to allow fishers to use the ODFW Oregon Fixed Gear Logbook for the Area 2A commercial fishery. The IPHC and ODFW staffs worked together to ensure that this logbook meets the needs of IPHC as well as ODFW.

Area 2C sport shing regulations for the charter vessels

The IPHC has received a request from the North Pacific Fishery Management Council (Appendix 1) concerning management measures to restrict the charter halibut harvest in Area 2C, in order to stay within the Council's Guideline Harvest Level (GHL). This request would change the existing regulation of a one-fish, maximum size limit of 37 inches for halibut retained in the charter sport fishery in Area 2C. The requested regulation change is to implement a "reverse slot limit" allowing retention of one fish, ≤45 inches or ≥ 68 inches in length, with head on. In addition, as in the past, if the halibut was filleted the entire carcass, must be retained on board the vessel until all fillets were offloaded.

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Table 1. Staff recommended catch limits for 2012 by IPHC regulatory area (million lbs, net weight). Recommendations based on coastwide assessment of exploitable biomass with survey apportionment to Regulatory Area exploitable biomass using hook competition and survey timing adjustment factors, with reverse-weighted averaging. Also includes direct deductions for U32/O26 bycatch and wastage mortality. Removal data are preliminary. Also shown are the 2011 catch limits for comparison.

Reg Area	Exploitable biomass	Harvest Rate	Total CEY	2011 Other Removals	2011 Catch Limit	2012 Fishery CEY	Slow Up-Full Down Adjustment	2012 Catch Limit Recomm.	
2A	6.15	21.5%	1.32	0.17	0.91	**1.15**	-0.16	**0.99**	1,3
2B	34.90	21.5%	7.50	0.87	7.65	**6.63**	0.00	**6.63**	2,4
2C	27.28	21.5%	5.86	2.65	2.33	**3.21**	-0.59	**2.62**	3
3A	92.00	21.5%	19.78	7.86	14.36	**11.92**	0.00	**11.92**	4
3B	41.17	16.1%	6.64	1.57	7.51	**5.07**	0.00	**5.07**	4
4A	14.86	16.1%	2.40	0.83	2.41	**1.57**	0.00	**1.57**	4
4B	14.25	16.1%	2.30	0.43	2.18	**1.87**	0.00	**1.87**	4
4CDE	29.40	16.1%	4.74	2.28	3.72	**2.47**	0.00	**2.47**	4
Total	260.00	19.4%	50.54	16.66	41.07	**33.88**	-0.95	**33.135**	

Note:Exploitable biomass is coastwide assessment, survey partitioning; Hook & Timing Afs; Kalman wts

[1] Catch limits and Fishery CEY for 2A includes commercial, sport, and treaty subsistence catches

[2] Catch limits and Fishery CEY for 2B includes commercial and sport catch

[3] Calculated as 2010 catch limit plus 1/3 of the difference between 2011 Fishery CEY and 2010 Catch Limit

[4] Calculated as 2011 Fishery CEY

Assumes GHL of 0.931 Mlb in Area 2C, 3.103 Mlb in Area 3A under Other Removals

Other removals for 2C and 3A are adding projected unguided harvest to the applicable GHL

Includes direct accounting for U32/O26 BAWM

Table 2. Estimated shery CEY, staff recommended catch limits, and catch limits of Paci c halibut by IPHC regulatory area (in thousands of pounds, net weight), 2002-2011.

Regulatory Area	2002	2003	2004[1]	2005	2006	2007[2]	2008	2009	2010	2011
	Estimated Fishery CEY									
2A[3]	1,310	1,290	1,810	1,170	1,490	660	650	500	570	1,120
2B	11,750	11,320	15,780[4]	12,700[4]	13,200[4]	6,220[4]	4,650[4]	4,920[4]	5,550[4]	7,940[4]
2C	8,500	9,110	17,030	11,800	10,330	4,980	3,920	2,860	2,390	2,330
3A	24,140	34,220	29,980	26,300	24,940	27,630	22,250	20,840	18,280	14,360
3B	28,560	29,190	15,600	10,700	8,570	16,770	14,270	13,200	8,910	7,510
4A	11,960	11,220	3,470	3,400	3,250	5,230	3,510	2,200	2,120	2,570
4B	7,510	7,760	2,810	1,700	1,070	2,560	2,700	2,090	2,750	2,210
4CDE	11,810	13,820	3,390	4,400	3,110	3,850	3,680	1,970	3,820	3,990
Total	105,540	117,930	89,870	72,170	65,960	67,900	55,630	48,580	44,390	42,030
	Staff Recommendations									
Regulatory Area	2002	2003	2004	2005	2006	2007[2]	2008	2009	2010	2011
2A[3]	1,310	1,310	1,480	1,330	1,380	1,020	1,000	860	760	910
2B	11,750	11,750	13,800[4]	13,250[4]	13,220[4]	9,720[4]	8,060[4]	6,960[4]	6,590[4]	7,650[4]
2C	8,500	8,500	11,310	10,930	10,630	7,810	6,210	4,540	3,710	2,330
3A	22,630	22,630	25,060	25,470	25,200	26,010	24,220	22,530	19,990	14,360
3B	17,130	17,130	15,600	13,150	10,860	12,830	10,900	11,670	9,900	7,510
4A	4,970	4.970	3,470	3,440	3,350	3,980	3,100	2,650	2,330	2,410
4B	3,440	4,180	2,810	2,260	1,670	1,970	1,860	1,940	2,160	2,180
4CDE	4,450	4,450	3,390	3,990	3,550	3,650	3,890	2,930	3,580	3,720
Total	74,180	74,920	76,920	73,820	69,860	66,990	59,240	54,080	49,020	41,070
	Catch Limits									
Regulatory Area	2002	2003	2004	2005	2006	2007[2]	2008	2009	2010	2011
2A[3]	1,310	1,310	1,480	1,330	1,380	1,340	1,220	950	810	910
2B	11,750	11,750	13,800[4]	13,25[4]	13,220[4]	11,470[4]	9,000[4]	7,630[4]	7,500[4]	7,650[4]
2C	8,500	8,500	10,500	10,930	10,630	8,510	6,210	5,020	4,400	2,330
3A	22,630	22,630	25,060	25,470	25,200	26,200	24,220	21,700	19,990	14,360
3B	17,130	17,130	15,600	13,150	10,860	9,220	10,900	10,900	9,900	7,510
4A	4,970	4.970	3,470	3,440	3,350	2,890	3,100	2,550	2,330	2,410
4B	4,180	4,180	2,810	2,260	1,670	1,440	1,860	1,870	2,160	2,180
4CDE	4,450	4,450	3,785	3,989	3,550	4,100	3,890	3,460	3,580	3,720
Total	74,920	74,920	76,505	73,819	69,860	65,170	60,400	54,080	50,670	41,070

[1] Staff catch limit recommendations revised after Bluebook based on CEY harvest policy

[2] Estimated fishery CEY and staff recommendations from coastwide stock assessment with survey partitioning to area as presented in the 2007 Annual Meeting Handout. The closed area stock assessment produced staff recommendations by area in millions of pounds of: Area 2A = 1.34; Area 2B = 11.47; Area 2C = 8.51; Area 3A = 26.20; Area 3B = 9.22; Area 4A = 2.89; and 4B = 1.44 and Area 4CDE = 4.10. The Commission determined the 2007 catch limits using recommendations based on the closed area stock assessment.

[3] Area 2A includes sport catch and treaty Indian catch

[4] Area 2B includes sport catch

Appendix 1. Letter from the North Pacific Fishery Management Council concerning management of charter harvest in Area 2C in 2012.

North Pacific Fishery Management Council

Eric A. Olson, Chairman
Chris Oliver, Executive Director

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December 27, 2011

Dr. Bruce Leaman, Executive Director
International Pacific Halibut Commission
2320 West Commodore Way, Suite 300
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RE: Council Recommendation for 2012 Charter Halibut Management

Dear Bruce:

In December 2011 the Council recommended management measures to keep the charter halibut sector to its respective guideline harvest levels (GHLs) in Area 2C and Area 3A for 2012. For Area 2C the Council recommended that the Commission consider replacing its regulation of one fish of 37 inches or less with a "reverse slot limit" of one fish ≤ 45 inches or ≥ 68 inches ("U45/068") based on an increased GHL from 788,000 lb in 2011 to 931,000 lb in 2012. For Area 3A the Council recommended no change to the 2-fish limit (of any size) despite the decreased GHL from 3.651 Mlb in 2011 to 3.103 Mlb in 2012. Note that Alaska Department of Fish and Game (ADF&G) estimates placed charter halibut harvests in both areas well under their respective GHLs in 2011.

The Council had requested that its October 2008 recommendation to replace the GHL program with a Halibut Catch Sharing Plan for the charter and commercial fishery sectors in Area 2C and Area 3A be implemented first in 2011, and after that deadline was missed, in 2012. Instead in September 2011 NMFS staff recommended that the Council provide policy guidance to the Commission on management measures for 2012. Citing policy and technical issues raised by more than 4,000 public comments on a proposed rule to implement the CSP NMFS Alaska Region staff advised the Council that it would not proceed with publishing a final rule until it received policy clarifications from the Council and assistance with responding to public comments and additional economic analyses from Council staff. The Council provided the requested policy guidance during its December meeting and directed staff to complete the response to comments and additional analyses for Council review in April 2012; a status report will be provided to the Council in February 2012.

The Council recommendations were based on an IPHC staff report of anticipated 2012 GHLs for Area 2C and Area 3A; ADF&G staff reports on 2011 charter halibut harvests; ADF&G analyses of preliminary committee recommendations for potential 2012 measures; final committee recommendations; and public testimony at both committee and Council meetings.

The Council strongly urges the Commission to consider replacing its regulation of one fish ≤ 37 inches with a one fish U45/068 inch limit for Area 2C and to take no action for Area 3A for 2012. Jane DiCosimo will represent the Council at the 2012 IPHC Annual Meeting to provide additional details, as requested.

Sincerely,

Chris Oliver

Chris Oliver
Executive Director

Appendix
IPHC Research Program: Review of 2011 research and proposals for 2012

IPHC Staff

Introduction

This report reviews research conducted by the IPHC staff in the past year as well as research proposed for the upcoming year. The report is divided into two sections, with the first section briefly reviewing the status of research conducted this past year. The second section presents the preliminary staff research proposals for 2012. Information is provided on when each project was initiated, the anticipated completion date, the annual cost, a description of the costs, and the purpose of the project. This report does not include ongoing staff tasks such as data collection and processing that are necessary for the management of the fishery.

Research projects are organized into three funding categories that reflect availability and source of research funds. Limited research requiring direct financial support from the Commission is possible under the basic $4.1 million (as of FY2011) government appropriations, although a number of programs can be conducted using only the staff resources that are supported by the appropriations. The three funding categories are:

1) **Funded Research:** Necessary research projects of high priority that can only be conducted with appropriations funding or carryover from 2011;

2) **Contracts and Grants:** Agreements with other parties to conduct specific research. In this case, contracts and grants are shown for projects where the IPHC staff is the principle investigator; and

3) **Research conducted without direct funding:** Necessary research projects of high priority that can be conducted through staff time alone or if sufficient funds are available within the IPHC budget.

Nearly all of the research done by the staff is directed toward one of three continuing objectives of the Commission:

i) Improving the annual stock assessment and quota recommendations;

ii) Developing information on current management issues; and

iii) Adding to knowledge of the biology and life history of halibut.

In each of these areas our routine work program applies the best information and methods available, and our research program aims to improve the information and methods by answering the most important outstanding questions.

SECTION I:
REVIEW OF RESEARCH CONDUCTED IN 2011

Biological research conducted by the IPHC staff continued in three basic areas: life history, fish movements, and stock composition. Other work addressed fishery management issues, while the assessment group focused on a variety of analyses examining the commercial fishery minimum size limit, effects of bycatch on stock yield, assessment survey design, and harvest policy performance. Most of this was conducted as part of the normal staff duties. Funding for projects outside of staff salaries came from supplemental funding; these and other studies from 2011 are outlined below.

Overview of 2011

Genetic research continued in 2011, focusing primarily on use of genetic analyses for sex identification and also working to complete the population genetics studies begun in 2002. With respect to the former, a manuscript was published in January detailing sex-linkage in three microsatellite markers, suggesting the possibility that genetic techniques might be used to partition commercial catch via the IPHC's port sampling program. During the 2011 commercial fishing season, samplers were placed aboard commercial vessels to collect samples that will be used in a formal analysis of the accuracy of genetic methods relative to the numerical sex partitioning technique presently used in the IPHC stock assessment (see following paragraph). These samples, and others collected by the 2010 undergraduate intern, will be analyzed at the University of Washington's Marine Molecular Biology Laboratory (MMBL) under the supervision of Dr. Lorenz Hauser. In addition, laboratory analyses were conducted in 2011 to add western Aleutian Island and Sea of Okhotsk samples to existing microsatellite- and mitochondrial DNA-based analyses of population structure. Significant genetic population structure has not been detected using samples that span from the Queen Charlotte Islands through the southeast Bering Sea and eastern Aleutian Islands. This is in contrast to a recent publication in which significant Pacific halibut stock structure was reported using samples collected in the western Aleutians, however that analysis did not account for the sex-specific microsatellite marker presence in the samples. Formal statistical analysis and publication of the full results is anticipated in 2012.

The current sex-specific assessment requires information on the sex composition of the population, which is proxied by data from the surveys. We've recently been interested in the potential for sampling the commercial landings for obtaining direct observations of the sex composition of the catch to confirm or correct the current statistical estimation of the sex composition of commercial landings. A pilot study was undertaken in 2010 for this purpose, collecting tissue samples which would be analyzed for genetic sex markers. The results showed it was possible to obtain the necessary samples, but a sufficient number were collected only from Areas 2B and 3A. Additional collections were undertaken in 2011 in additional areas (2B, 3B, 4A, and 4B) to further investigate the potential of this approach. Sample analysis is being conducted under the supervision of Dr. Hauser (MMBL), with results expected later this winter.

IPHC has been engaged for several years in projects examining halibut migrations via tagging. Past studies have used PAT tags to obtain general movement patterns but these have been insufficient in providing data to estimate migration rates and daily movements. Since 2006, IPHC has been testing the suitability of archival tags for halibut, specifically examining different tag types, attachment configurations and tag designs. This work has included small releases of test tags in Areas 2B (2008) and 3A (2009). In addition, since 2009 IPHC has had a long term holding study at the Oregon Coast Aquarium (OCA) of ~30 animals to test different attachment protocols. In 2011, we began looking at the applicability of geomagnetic tags for tracking halibut movements. Geomag tags hold promise for providing much greater movement detail over a greater time horizon but there are as-yet unresolved issues regarding effects on location data by variations in the magnetic field in the north Pacific. Work conducted in 2011 focused on assessing the accuracy of the data recorded by geomag tags by setting out geomag tags at preselected stationary locations in Area 3A.

The collaborative study between the IPHC and the NMFS Alaska Fisheries Science Center (NMFS/AFSC) has concluded that eastern Bering Sea (BS) bomb radiocarbon concentrations during the years of 1944 to 1981 were different from those of the Gulf of Alaska (GOA) during the same time. Based on analysis of otoliths from the BS and GOA, the results suggest the onset of atmospheric ^{14}C in the BS indeed preceded the GOA in both time and signal strength. The BS curve displays an earlier and more rapid increase in ^{14}C, a substantially higher ^{14}C peak, and an exponential post-peak decay that is much less pronounced in the GOA. It is hypothesized that, because of its unique oceanographic conditions, the BS responded differently than the GOA during the peak times of nuclear atmospheric testing in regard to the uptake of atmospheric ^{14}C. The rate at which ^{14}C moves through a body of water may be attributed to factors such as current, wind, ^{14}C reservoirs, and water depth. It is further hypothesized that the atmospheric ^{14}C signature may have traveled through the BS at a faster rate than it did through the GOA, resulting in an earlier ^{14}C pulse which was incorporated into all BS species alive at that time.

Water column profilers were deployed in 2011 on all IPHC survey vessels. This effort is the result of the grant from NOAA for the purchase of profilers in 2008. The profilers collect data on salinity, temperature, dissolved oxygen, ocean acidity (pH), and fluorescence (chlorophyll) throughout the water column, which provide a unique and valuable annual snapshot of oceanic conditions above the continental shelf over most of the northeast Pacific Ocean. Over 1,200 casts were made this year. Data from the first two years of this project, 2009 and 2010, are posted for public use and 2011 data processing is in progress.

A pilot study comparing the IPHC standard survey bait of chum salmon with three alternative bait species was conducted in Area 3A in 2011. The goals were to select one of two competing experimental designs, and to provide information on variance for use in designing a large scale experiment to be carried out in 2012. Alternative baits fished included herring, pollock, and pink salmon. Data analyses showed evidence that the setline weight per unit effort (WPUE) was different among baits, that U32 catch is affected by bait type, and that catch of common species of bycatch was higher using chum salmon than the alternative baits. There is also some concern that the alternative bait types, e.g., herring, are more likely to fall off the hook than chum salmon. A positive result was that the experimental design using a mixed-bait set could be used in the primary experiment, which will greatly improve efficiency and statistical power.

Cooperative data collection continued on the assessment surveys in 2011. Activities took place in almost all surveys regions:

- On the Area 2A surveys, cooperative studies continued with Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) to collect rockfish (*Sebastes* spp.) bycatch data. In addition, this year we worked with WDFW to conduct 100% hook counts for all stations in the Salish Sea.

- On the Area 2B survey vessels, a third biologist collected hook-by-hook occupancy information for all species, and otoliths, maturities, and lengths for rockfish (except thornyheads) and data were provided to the Canadian Department of Fisheries and Oceans (DFO).
- Cooperative work with the Alaska Department of Fish and Game (ADF&G) resulted in the collection of whole-haul catch data for yelloweye rockfish from survey vessels operating in the Fairweather survey region of Area 3A and in the Sitka, Ommaney, and Ketchikan charter regions of Area 2C.
- In 2011 we began a two-year effort to length and sex the first five spiny dogfish at stations coastwide, exceptions being first three dogfish in B.C. and all dogfish in the Bering Sea). This project began as a request from NMFS/AFSC and was expanded coastwide to enhance the project.
- Pacific cod subsampling on Bering Sea stations was resumed in 2011 at the request of NMFS/AFSC. Additional information was also collected on lamprey scarring on the cod being sampled.

Also on the assessment surveys, data collection continued in 2011 to increase our understanding of the scope and impact of whale interactions with longline gear, and in particular the impact on setline surveys. Gear damage occurrence was assessed on every set, and additional data were collected when marine mammals were in the area. The protocols for this data collection were developed in concert with other agencies, in particular the NMFS Auke Bay sablefish survey team, who are attempting to quantify the impact of sperm whale depredation on their surveys.

For several years, IPHC has been contracted by NMFS Auke Bay Lab (ABL) to assist with their sablefish data collection program (Project 617.00). In 2003/2004, the program was reviewed and modified to meet the IPHC confidentiality policy and to encompass all vessels, rather than just vessels greater than 60 feet in length. Under a Statement of Work (SOW), NMFS contracts IPHC to collect and review information on sablefish catches during the IPHC port sampler's logbook interview. Sablefish data are entered by IPHC staff, edited, and an electronic summary provided to the ABL scientists. Vessels are assigned a unique code in the summarized data to preserve confidentiality. In 2011, the Auke Bay scientists came to Seattle to attend a portion of port sampler training to meet the samplers and provided direct training. The SOW was renewed for 2012.

IPHC also received several grants in 2011. NMFS provided a grant for the incremental increase in port sampling costs due to the IFQ program (Project 300.00-81).

For the 2011 undergraduate internship, a study was undertaken to evaluate the need to re-examine the length/weight relationship used by IPHC. Ms. Danielle Courcelles, an Environmental Science major from Simon Fraser University (Burnaby, B.C.), joined the staff for the summer to design, carry out, and report on her analysis of length/weight data she collected in Area 3A. Her sampling of 193 fish of all sizes from Portlock-Seward Gully grounds of Area 3A showed a significant difference in length/weight for fish caught on those grounds, similar to a small study conducted in 1989 by the IPHC staff. The full results will be included in this year's RARA.

Other field activities in 2011 included (1) placing staff aboard the NMFS/AFSC trawl surveys in the Gulf of Alaska to collect otoliths and data on the relative abundance of juveniles, (2) continued collection of halibut tissue samples on the surveys for studies on mercury and other contaminants by the Alaska Department of Environmental Conservation, and (3) collection of seabird occurrence data on the surveys.

On the quantitative side, the staff of the Assessment Program annually produces the stock assessment, which forms the basis for staff Catch Limit Recommendations. The data that go into the assessment, the assessment itself, and the harvest policy used to determine sustainable catch levels are all continually reviewed and refined. A few of this year's more influential and substantive analyses are summarized to highlight the nature of analytical work in the Assessment Program.

a. The current commercial minimum size limit (MSL) of 32 inches (81.3 cm) has been in place since 1974 when it was increased from 26 inches (66 cm), which had been the MSL since 1940. The change in 1974 was implemented during a time when halibut size-at-age was much greater than is presently the case. The topic of changing (i.e., lowering) the MSL in response to reduced size-at-age arises annually. An analysis was conducted to estimate the biological and fishery impacts of lowering the size limit anywhere from 1 to 16 cm.

b. The North Pacific Fishery Management Council is considering reducing the Pacific halibut Prohibited Species Catch (PSC) limits for the Gulf of Alaska groundfish fisheries. Staff conducted an analysis to estimate the potential directed yield and female spawning biomass impacts from reducing the PSC limits for both trawl and longline fisheries.

c. Data from commercial landings have demonstrated that halibut can occur at depths outside of the 20-275 fathom range of the current setline survey. In addition, within the current depth range there exist areas which for various reasons have no survey stations. In 2011, the IPHC conducted an expanded survey in Area 2A, which included stations from 10-400 fathoms, and for the first time fished stations within the inland waters of the Salish Sea in WA. This study was a test of survey fishing in deep and shallow waters, but the expansion of stations within the existing 20-275 fathoms grid also examined means to improve the precision of the survey's WPUE index in Area 2A, by increasing sample size

d. Following a request from Canadian commissioners, staff reviewed the data from the 1995-97 setline surveys in Area 2B, which yielded much higher WPUE values than in subsequent or previous years. The survey design was slightly different in those years, although the range of the survey was similar. We found no evidence that the design was a factor in the higher WPUE values; rather, it was the recruitment of two strong year classes into the fishery. In fact, the design in those years included several stations located outside of the current survey depth range on Dogfish Bank, stations which had very little halibut catch, and these are now excluded from WPUE calculation for reasons of consistency. In addition, examination of adjacent regulatory areas found similar features of the WPUE time series as seen in Area 2B.

e. Work on the harvest policy included updates, potential changes and considerations of its performance in the context of current stock trends and status. Ongoing work on the Management Strategy Evaluation (MSE) included setting up of the general evaluation framework and development of simulation, observation, and estimation components.

f. In previous years, projections of exploitable biomass assumed no changes in population processes and revisions of past population estimates. Alternative assumptions and methods were included in alternative projections that account for potential future changes in size-at-age and ongoing downward revisions of past recruitment estimates and the initial numbers of the projections.

g. An analysis of recent and historical changes in size-at-age was conducted, along with potential mechanisms and implications for the harvest policy.

h. A comprehensive review of the history of IPHC tagging programs was conducted with a focus on halibut migration. The most important finding was the consistency among results of historical and modern tagging programs regarding extensive halibut migratory patterns through their life. Implications for harvest policy, bycatch impacts, and stock assessment are discussed in the report.

i. A draft journal paper on the analysis of data from the PIT tag study was also prepared. Model results show that ontogenetic migration in a broadly eastward and southward direction continues for larger fish, when in the recent history of the IPHC, the assumption had been that only smaller, younger fish migrated. Differences in fishing mortality and exploitation rates among areas support the view that exploitation was much heavier in eastern areas than western areas prior to the introduction of a coastwide stock assessment in 2007.

j. An analysis was prepared on criteria and a potential framework for evaluation, along with pros and cons, of a proposed alternative apportionment method.

Budget Summary for 2011 Projects

Project No.	Project Title	FY11 Budget	FY11 Actual
Field Experiments			
416.00	PIT tagging study: Double tag expt.	$ 400	$ 21
604.00	NMFS trawl survey: At-sea data collection	50,758	61,478
	Total Field Experiments	***$ 51,158***	***$ 61,499***
Other Research			
610.11	Water column profiler (general survey)	$ 1,500	1,050
610.12	Water column profiler (Oregon)	2,500	1,795
610.13	Water Column profiler (coastwide)	87,171	30,762
618.00	Undergraduate internships	13,717	13,678
621.00	Genetic population structure – lab work by UW	7,382	68,638
621.14	Genetic techniques for partitioning commercial catch by gender	9,320	32,429
622.12	PAT Tags: Summer 2008 releases (Area 4)	0	1,281
636.00	Analysis of gonad staging on IPHC setline surveys	23,000	0
642.00	Assessment of mercury and contaminants in Pacific halibut	3,200	377
646.12	PAT Tags: Summer 2006 releases (Area 2B)	0	500
650.12	Archival tags: pilot releases (2008 releases in Area 2B)	5,000	477
650.13	Archival tags: mounting protocols (OCA)	14,800	2,486
650.14	Archival tags: pilot releases (2009 releases in Area 3A)	3,000	3,855
650.15	Archival tags: Preparation for coastwide release	150,000	110,000
650.16	Archival tags: Site selection in Area 4B	12,000	2,400
650.17	Archival tags: Geomag tag performance in the Gulf of AK	63,990	65,600
659.11	Area 2A assessment survey pilot expansion	126,258	93,013
660.11	Comparison of alternative baits for assessment survey	104,511	119,973
	Total Other Research	***$ 627,376***	***$ 548,315***
	GRAND TOTAL	***$ 678,534***	***$ 609,814***

Notes: Values shown do not include any revenues generated from the sale of fish or other cost offsets.

Other 2011 Research – Contracts and Grants

Granting agency shown in parentheses

Project No.	Project Title	FY11 Income
300.00-81	AK port sampling grant (NMFS)	$ 373,641
420.00	Area 2B rockfish data collection (DFO)	9,624
610.13-81	Water column profiler grant (NOAA)	31,635
617.00	AK catcher vessel logbook and sablefish data collection (NMFS)	61,500
	GRAND TOTAL	***$ 476,400***

2011 Research publications

IPHC staff noted in **Bold** type.

Erikson, L. M. and **Kong, T. M.** Changes in commercial catch sampling for Pacific halibut 1994 to 2009. Int. Pac. Halibut Comm. Tech. Rep. 54.

Galindo, H. M., **Loher, T.**, and Hauser, L. 2011. Genetic sex identification and the potential evolution of sex determination in Pacific halibut (*Hippoglossus stenolepis*). Mar. Biotechnol. 13:1027–1037.

Gilroy, H. L., **Kong, T. M.**, and **MacTavish, K. A.** 2011. Regulations and management decisions of the Pacific halibut fisheries, 1993-2009. Int. Pac. Halibut Comm. Tech. Rep. 55.

Kaimmer, S. M. 2011. Special setline experiments 1985-1994 objectives, data formats, and collections. Int. Pac. Halibut Comm. Tech. Rep. 53.

Loher, T. 2011. Analysis of match–mismatch between commercial fishing periods and spawning ecology of Pacific halibut (*Hippoglossus stenolepis*), based on winter surveys and behavioural data from electronic archival tags. ICES J. Mar. Sci. 68(10):2240-2251.

Loher, T. and Rensmeyer, R. 2011. Physiological responses of Pacific halibut, *Hippoglossus stenolepis*, to intracoelomic implantation of electronic archival tags, with a review of tag implantation techniques employed in flatfishes. Rev. Fish Biol. Fish. 21(1):97-115.

Loher, T., and **Hobden, J.C.** 2012. Small-scale spatial structure in longline catches of Pacific halibut (*Hippoglossus stenolepis*): influence of fish length and sex. Fishery Bulletin 110(1):46-51.

Loher, T., and **Stephens, S. M.** 2011. Use of veterinary ultrasound to identify sex and assess female maturity of Pacific Halibut in nonspawning condition. N. Amer. J. Fish. Mgmt. 31:6, 1034-1042.

Seitz, A. C., **Loher, T.**, Norcross, B. L., Nielsen, J. L. 2011. Dispersal and behavior of Pacific halibut *Hippoglossus stenolepis* in the Bering Sea and Aleutian Islands region. Aquat. Biol. 12: 225–239.

West, Catherine F., **Wischniowski, S.** and C. Johnston. 2011. Little Ice Age Climate: *Gadus macrocephalus* otoliths as a measure of local variability. *In* The Archaeology of North Pacific Fisheries, edited by Madonna Moss and Aubrey Cannon. University of Alaska Press, Fairbanks.

2011 Conference presentations and Ppsters

IPHC staff noted in **Bold** type.

Carlile, D., **Loher, T., Vatter, A.**, Eiler, J., Nielsen, J., Tribuzio, C. and Lunsford, C. Detection range of acoustic transmitters and receivers in deep waters of southeast Alaska. American Fisheries Society Annual Meeting. Seattle, WA. September 6-9, 2011. (oral)

Dykstra, C. L. Fish population census and sampling in the Strait of Juan de Fuca and Puget Sound. 2011 Salish Sea Ecosystem Conference. Vancouver, B.C. October 25-27, 2011. (poster)

Leaman, B. M., Kaimmer, S. K. and Webster, R. A. Hook size and spacing effects on the catch of Pacific halibut. International Symposium on Circle Hooks. Miami, FL. May 4-6, 2011. (oral)

Loher, T. and Seitz, A.C. Reconciling contradictory tagging results to develop a coherent model of large-scale mixing and segregation in Pacific halibut: a lesson in biases. Eighth International Flatfish Symposium, IJmuiden, Netherlands, November 5-10, 2011. (oral)

Sohn, D., Ciannelli, L. Duffy-Anderson, J. T., and **Loher, T.** Phenology, geography, and size of Pacific halibut (*Hippoglossus stenolepis*) early life history stages associated with abiotic and biotic variables in the Gulf of Alaska. Eighth International Flatfish Symposium, IJmuiden, Netherlands, November 5-10, 2011. (oral)

Valero, J. L. Tagging programs at the IPHC: What we have learned about Pacific halibut migration and how we have applied it to stock assessment and management from 1925 to 2011. IATTC workshop on integrating movement information from tagging data into fisheries stock assessments. La Jolla, CA. October 4-7, 2011. (oral)

Valero, J. L. Workable paradigms for modeling movement within a stock assessment model. IATTC workshop on integrating movement information from tagging data into fisheries stock assessments. La Jolla, CA. October 4-7, 2011. (oral)

Williams, G. H. The introduction of circle hooks in the North Pacific: Impact on the Pacific halibut fishery and management. International Symposium on Circle Hooks. Miami, FL. May 4-6, 2011. (oral)

SECTION II.
RESEARCH PROPOSED FOR 2012 - OVERVIEW

Projects to be carried out in 2012 consist of a continuation of several projects currently underway. Selected continuing projects include:

1. **Water column pro lers (Projects 610. 13)** – The first profiler was deployed on an IPHC survey vessel in 2003, and a second went out in 2007. Coastwide deployment began in 2009. The profilers measure temperature, salinity, dissolved oxygen, pH, and florescence. For 2012, a depth recorder will be added to each profiler. Plans also call for a profiler to be deployed at each station during the 2012 summer assessment survey.

2. **Archival tagging (Project 650.13)** – Staff proposes to continue its research into archival and geomagnetic tags, with the holding experiment at the Oregon Coast Aquarium (OCA) in Newport, OR. The ~30 fish housed in tanks at OCA are being used to examine the suitability of different archival mounting configurations. The results will support the anticipated future use of this type of technology.

3. **Comparison of alternative baits for the assessment survey (Project 660.11)** – Rising bait prices and potentially unstable supplies has prompted the staff to consider alternative baits for the assessment survey. A pilot study in 2011 provided a design for a broader study proposed for 2012 to more fully examine catch rate differences between our standard #2 semi-bright chum salmon and other bait types.

Staff will also continue with other long-standing projects in 2012. These include the collaborative work on contaminants in halibut with ADEC (#642.00), placement of IPHC staff on the NMFS summer trawl surveys (#604.00), and the undergraduate internship program (#618.00). Cooperative projects with WDFW and ODFW to provide data on bycatch species on the setline surveys in Area 2A will continue, as will efforts with DFO in Area 2B, in Areas 2C/3A with ADF&G, and in Area 4 with NMFS/AFSC.

In addition, projects conducted under contract to other agencies or through research grants will be continued in 2012. IPHC port sampling activities in Alaska will continue being supported by a grant from NMFS (Project 300.00-81), and IPHC port samplers in Alaska will collect sablefish logbook data for the NMFS Auke Bay lab (Project 617.00).

Three new studies are proposed for 2012:

1. **Prevalence of Ichthyophonus in halibut** – Ichthyophonus In 2011 the IPHC and USGS Marrowstone Marine Field Station conducted a pilot survey to determine prevalence of the parasite Ichthyophonus in Pacific halibut sourced from three geographically disparate areas. Ichthyophonus was detected in 26.6, 33.8, and 76.7% of halibut sampled from the northern Bering Sea, Oregon coast, and Prince William Sound respectively. Prevalence in Prince William Sound is the highest reported for any Northeast Pacific marine fish species, and is indicative of an epizootic. It is not clear if these infection patterns are unusual, or what effect if any Ichthyophonus may be having on Pacific halibut population (mortality) or growth dynamics.

The staff proposes to conduct more extensive occurrence sampling during the 2012 stock assessment survey. Discussions are also underway regarding future lab studies.

2. **Whisker hooks –** Modified circle hooks, with a wire appendage sticking out the back of the hook, are finding success in pelagic longlines to reduce turtle bycatch. “Weedless” hooks have been around for some time. The staff proposes to look at the potential for these types of hooks to reduce the hooking success of rockfish while having little to no effect on halibut catch rates.

3. **Otolith growth increment study –** IPHC’s extensive otolith archive holds a wealth of information about otolith growth. Changes in the annual growth increments over time would be measured and compiled, going back as far as possible into the archives (1920). While not necessarily linked to changes in fish growth, changes in otolith growth may provide insights into processes which affect the growth of halibut.

2012 Proposed Projects - Budget Summary

Project No.	Project Title	FY12 Budget
Field Experiments		
416.00	PIT tagging study: Double tag expt.	$ 400
604.00	NMFS trawl survey: At-sea data collection	55,661
660.11	Comparison of alternative baits for assessment survey	400,000
	Field Experiments Total	***$ 456,061***
Other Research – Continuing		
610.13	Water column profiler (General survey)	$ 4,000
610.13-87	Water column profiler (Coastwide)	73,893
618.00	Undergraduate internship	13,989
621.00	Genetic techniques for partitioning commercial catch by gender	41,566
636.00	Histology: Analysis of gonad staging	16,800
642.00	Assessment of mercury and contaminants in Pacific halibut	4,000
650.13	Archival tags: Mounting protocols (OCA)	14,800
650.14	Archival tags: 2009 releases (Area 3A)	4,000
650.15	Archival tags: Preparation for coastwide release	130,000
650.16	Archival tags: Site selection in Area 4B	2,600
650.17	Archival tags: Geomag tag performance in the Gulf of AK	6,000
	Subtotal	***$ 311,648***
Other Research – New		
2012-01.11	Prevalence of *Ichthyophonus* in halibut	$ 50,739
2012-02.11	Rockfish bycatch reduction with whisker hooks	29,676
2012-03.11	Growth increment studies on halibut otoliths	16,100
	Subtotal	***$ 96,515***
	Other Research Total	***$ 408,163***
	GRAND TOTAL	***$ 864,224***

Note: Values shown do not include any revenues generated from the sale of fish or other cost offsets.

Other 2012 Research – Contracts and Grants

Granting agency shown in parentheses

Project No.	Project Title	FY12 Income
300.00-81	AK port sampling grant (NMFS)	405,863
420.00	Area 2B rockfish data collection (DFO)	20,000
610.13	Water column profilers – coastwide (NOAA)	73,893
617.00	AK catcher vessel logbook and sablefish data collection (NMFS)	69,000
	GRAND TOTAL	***$ 568,756***

Continuing Research in 2012

Project 416.00: PIT tagging study: Double tag experiment

Budget: $ 400
Start Date: 2003
Anticipated ending: Continuing
Personnel: J. Forsberg, G. Williams, S. Hare, A. Ranta

In September 2003, over 2,600 halibut were double tagged with PIT and external wire tags to provide data for estimating PIT tag shedding. Double-tagged fish continue to be recovered, and this section accounts for the premium rewards paid for the recovered tags. Three rewards were paid in 2011, and a similar number are anticipated in 2012.

Project 604.00: NMFS trawl survey: At-sea data collection

Budget: $ 55,661
Start Date: 1996
Anticipated ending: Continuing
Personnel: L. Sadorus, A. Ranta, S. Hare

The series of NMFS trawl survey data on halibut, parallel to our assessment survey data, is extremely valuable as a second fishery-independent data source for stock assessment. Trawl data are particularly useful because they include large numbers of juveniles (ages 3-7 yr) that do not appear in large numbers in the setline survey. Otoliths have been collected on the NMFS surveys since 1996 and provide relevant age information. These data are incorporated into IPHC's database of the NMFS haul data, expanded to estimates of relative abundance and age/size composition by IPHC area (NMFS calculates estimates by INPFC area), and stored in a database at IPHC. Project cost is comprised of personnel and travel. In 2011, samplers were deployed on the NMFS Gulf of Alaska and Bering Sea surveys. For 2012, samplers will be deployed in the Bering Sea and Aleutian Island surveys.

Project 610.13: Water column profiler project (General survey)

Budget: $ 4,000

Project 610.13-87: Water column profiler project (Coastwide)

Budget: $ 73,893
Grant: $ 73,893 (NOAA)
Start date: 2009
Anticipated ending: Continuing
Personnel: L. Sadorus, S. Hare, P. Stabeno (NMFS PMEL)

The IPHC maintains one of the most extensive sampling platforms in the north Pacific. This platform provides enormous potential for collection of valuable oceanographic data. In particular, understanding the dynamics of the structure of the mixed layer depth – a major GLOBEC goal - requires *in situ* vertical profiling. Since 2001, IPHC has successfully deployed a SeaBird SBE-19 water column profiler during the annual stock assessment survey. A second profiler was added to the program in 2007. In 2009, a NOAA grant provided for the complete outfitting of all chartered survey vessels, resulting in a complete coastwide deployment. Annual costs are directed towards maintenance and calibration of the profilers, and data preparation necessary for submission to the National Ocean Data Center.

Project 618.00: Undergraduate Internship
Budget: $ 13,989 (One intern)
Start Date: 2002
Anticipated duration: Continuing
Personnel: L. Sadorus, T. Loher, other staff support as needed

One undergraduate will be selected through the intern/co-op programs at regional universities and colleges to do a combination of office and at-sea work based out of the Commission offices during the summer months. The program includes various pre-determined office tasks as well as being assigned a research project then designing and executing said project. A final report and presentation are given at the conclusion of the employment term. The report is usually included in the RARA.

Project 621.14: Genetic techniques for partitioning commercial catch by gender
Budget: $ 41,566
Start: 2002
Anticipated Ending: Continuing
Personnel: T. Loher, L. Hauser (UW MMBL), other staff as needed

For 2011, samples of commercially-caught fish were collected for the purposes of comparing genetic sex identification to the survey length-at-age method presently employed in the stock assessment. In 2010, sufficient samples were collected only from Areas 2B and 3A. In 2011, additional samples were collected from Areas 2B, 3B, 4A, and 4D to further investigate the potential of this approach. In 2012, sample analysis will occur under the supervision of Dr. Lorenz Hauser, of the University of Washington's Marine Molecular Biology Laboratory (MMBL).

Project 636.00: Histology: Analysis of gonad staging
Budget: $ 16,800
Start: 2004
Anticipated Ending: Continuing
Personnel: K. MacTavish, other staff as needed

The staff believes it is necessary to re-evaluate our classification criteria for female gonad maturity stage. The method currently used on the assessment surveys is based on visual criteria established in the early 1990s and modified in 1995. These survey data combined with the age data are important components in the stock assessment model. Four maturity stages are presently assigned to female halibut; immature (F1), maturing (F2), spawning (F3) and resting (F4). Once a female halibut has spawned, the gonad transitions to a resting phase, back to maturing, and then to spawning again. Our criteria for classification also assume that the immature (F1) stage is only seen with immature fish but we are seeing anomalies during the survey that question this assumption. Gonad samples were collected in 2004 from which to base this study. In 2012, proposed work entails looking for a size gradient for oocytes dependent on their location within the gonad, determine the maximum precision for oocyte diameter measurements by oocyte maturation stage, determine a sampling protocol for measurement of oocyte diameters, and contract slide preparation for gonads. We will also begin assessment of archived gonads from a set of previously-prepared slides.

Project 642.00: Assessment of mercury and contaminants in Pacific halibut
Budget: $ 4,000
Start Date: 2002
Anticipated ending: Continuing
Personnel: C. Dykstra, Alaska Department of Environmental Conservation (ADEC)

The staff plans on continuing our collaboration with the Alaska Department of Environmental Conservation (ADEC) in 2012, collecting halibut tissue samples for analysis of heavy metal and organic pollutant loading. This work has been ongoing since 2002. Results from a 2002 collection of halibut samples led the Alaska Division of Public Health in 2003 to conclude that the concentrations of heavy metals in Alaskan Pacific halibut were not a public health concern. In 2004 the first results regarding organic pollutants (PCB's, pesticides) were released demonstrating that halibut had the lowest concentrations of the five species (including salmon and sablefish) examined. The Alaska Division of Public Health updated their advice on fish consumption in 2007 with some restrictions on the number of meals of halibut for women of child bearing age and young children. Since 2002 the IPHC has submitted 1,293 samples for testing by ADEC. The IPHC and ADEC are continuing to qualify the data with physical parameters (age, size, and weight) and additional analyses will be done on the samples. ADEC and EPA planned on going ahead with this study regardless of IPHC input. Our involvement in the project has allowed us to provide input on study design, sampling protocols in the field, etc., which will make the resultant information much more robust. In 2011, samples were acquired from the Yakutat/Fairweather inshore, northern Portlock and St. Matthew regions. In 2012, data analysis and writing will be the primary focus, although the staff is looking into obtaining collections from outside Alaska. We expect to consult with appropriate state/provincial agencies responsible for fish health monitoring.

Project 650.13: Archival tags: Holding tank experiments examining mounting protocols
Budget: $ 14,800
Start Date: 2009
Anticipated ending: 2011
Personnel: T. Loher

For 2012, the staff intends to continue holding halibut in tanks at the Oregon Coast Aquarium (OCA) in Newport, OR to investigate alternate mounting protocols for the externally-mounted archival tags. The 2008 releases in Area 2B were our first experience with using an external mount, and that process suggested some revisions and improvements could be possible which would reduce any effect the tags may have on the fish's behavior. Additional improvements to tag design may also be helpful in creating a different mounting device. A total of 30 halibut were captured via hook-and-line and transported live to the OCA. The fish are treated for parasites, examined regularly to assess healing and/or relative infection rates among mounting types, and behavior monitored. At the end of the holding period, fish will be measured to assess relative growth among treatment groups, and tags will be removed to examine the effects of the tag mounts on the tissue and musculature at the attachment site, or internal interactions in the case of an internal-external-streamer modification. The results will support the anticipated use of this type of technology in subsequent years. Expenses for 2012 involve the care and feeding of the fish at OCA.

Project 650.14: Archival tags: 2009 releases of dummy test tags
Budget: $ 4,000
Start Date: 2009
Anticipated ending: 2014
Personnel: T. Loher

External and internal tag recovery rates are being tested in the field release of archival test tags. In August-September 2009, 200 fish were tagged off southern Kodiak Island (in Areas 3A and 3B), half with external tags and half with internal implants. Fish were also tagged with a bright pink cheek tag, and rewards of $100 will be given for all tags recovered. Nine fish were recovered in 2011. Expenses in 2012 consist of tag rewards.

Project 650.15: Archival tags: Preparation for coastwide release
Budget: $ 130,000
Start Date: 2013
Anticipated ending: Continuing
Personnel: T. Loher, B. Leaman, R. Webster, J. Forsberg

In preparation for a coastwide release of archival tags in 2013, the staff has been working with Lotek Wireless (St. John's, NL) on a specific tag design and configuration for IPHC use. Although no field activity is planned for 2012, Lotek is continuing their work on our requirements and construction. Results from the 2009 release of dummy archival tags in Area 3A and the examination of several mounting protocols on fish being held at the Oregon Coast Aquarium will feed into the design of the tag and its attachment to the fish.

Project 650.16: Archival tags: Site selection in Area 4B
Budget: $ 2,600
Start date: 2010
Anticipated ending: 2013
Personnel: T. Loher, J. Forsberg, survey team

In 2009, we tagged 773 fish in Area 4B to evaluate tag recovery rates in preparation of a future release of archival tags in the area. Recovery rates of PIT tags released in the Aleutians were quite low, without evidence of recovery hotspots. This suggests that if archival tags were deployed in the Aleutians, we would likely recover relatively few of those tags. This would result in either too few data to draw any conclusions or require that a very large number of tags be initially deployed. Given that archival tags cost $500-1200 each, resorting to a very large deployment would be financially prohibitive and problematic. Our goal is to locate at least two release sites which will yield a sufficient number of recoveries. Eleven tags were recovered in 2011. In 2012, additional recoveries are expected and the budget is to pay for the necessary rewards.

Project 650.17: Pilot study to test geomagnetic tag performance in the Gulf of Alaska

Budget: $ 6,000
Start Date: 2011
Anticipated ending: 2012
Personnel: T. Loher, J. Nielsen (UAF Juneau)

In 2011 we deployed both Desert Star and Lotek geomagnetic tags on 30 halibut in two regions of the Gulf of Alaska: in Area 2C, just offshore of southern Prince of Wales Island; and in Area 3A, offshore of southern Kodiak Island. Tagging was restricted to large fish (110-150 cm FL), most likely to be mature females and likely to conduct a spawning migration shortly after tagging, and was divided into two deployment locations because the coastline and bathymetry of the areas are largely perpendicular to one another with respect to the magnetic environment. In Area 2C, total magnetic field gradients run largely parallel to shore, whereas in Area 3A around Kodiak that gradient runs perpendicular to shore. As such, we hypothesized that geomagnetic positioning based on total field strength would more accurately detect onshore-offshore movement in 2C and alongshore migration around Kodiak. Recoveries are expected in 2012 to enable testing of the hypothesis; project expenses are for the rewards.

Project 660.11: Comparison of alternative baits for assessment survey

Budget: $ 400,000
Start Date: 2011
Anticipated ending: 2012
Personnel: R. Webster, C. Dykstra, T. Geernaert, E. Soderlund, E. White, sea samplers

Rising bait prices and potentially unstable supplies has prompted the staff to consider alternative baits for the assessment survey. The 2011 pilot study conducted in Area 3A provided a design for a broader study proposed for 2012 to more fully examine catch rate differences between our standard #2 semi-bright chum salmon and other bait types. A study design is still being prepared but results from the pilot study showed that a mixed-bait set could be used in the experiment, which will greatly improve efficiency and statistical power. Initial plans call for this to be conducted at all stations in the coastwide assessment survey.

Proposed Research for 2012

Project 2012-01: Prevalence of *Ichthyophonus* in halibut

Budget: $ 50,739
Start Date: 2012
Anticipated ending: 2012
Personnel: C. Dykstra, G. Williams, J. Gregg (USGS)

This study will further characterize *Ichthyophonus* prevalence across the Pacific halibut's range, to determine overall prevalence rates and to see if the Prince William Sound results are repeatable. Twelve sites will be targeted, spread out over the assessment survey ranging from Oregon to the northern Bering Sea. As there is knowledge regarding herring infection rates in Prince William Sound, Sitka Sound area, and Lynn Canal, these areas are likely to be included in the primary target areas for sample collection. The study may be modified to do a more intensive sampling (stratified by age or size) in the Bering Sea and/or Aleutian Islands where we may be able to source samples from smaller fish from the NMFS trawl survey. IPHC will collect the samples, and the USGS lab in Marrowstone will conduct the culture and testing component. The study will provide a bigger sample size to further understand any differences in prevalence rates based on halibut size, age, and sex.

Project 2012-02: Rockfish bycatch reduction with whisker hooks

Budget: $ 29,676
Start Date: 2012
Anticipated ending: 2013
Personnel: S. Kaimmer

Rockfish bycatch is a limiting factor in many areas for the directed halibut fishery. Modified hooks, with a wire appendage sticking out the back of the hook, are finding success in pelagic longlines to reduce turtle bycatch. "Weedless" hooks have been around for some time. The wire is strong enough to reduce light forces (weeds) but light enough to bend out of the way during a forceful hook attack. Applying this technology, spring wires rigged across the hook gap of the typical halibut 16/0 circle hook might reduce the hooking success of rockfish. By varying the spring tension on the wires (using differing wire diameters), we theorize that rockfish catches could be reduced without changing the hooking success for halibut. For this initial work, observations on hooking success would be gathered with a video camera using single hooks deployed probably in southeast Alaska.

Project 2012-03: Growth increment studies on halibut otoliths

Budget: $ 16,100
Start Date: 2012
Anticipated ending: 2012
Personnel: S. Wischniowski, G. Williams, other staff as needed

IPHC's extensive otolith archive holds a wealth of information about otolith growth. Changes in the annual growth increments over time would be measured and compiled, going back as far as possible into the archives (1920). Otoliths covering a broad set of ages and time periods will be selected, and photographed under high magnification, enabling measurements of annual incremental growth. The measurements will be complied and analyzed to identify if any patterns or trends exit. While not necessarily linked to changes in fish growth, changes in otolith growth may provide insights into processes which affect the growth of halibut.

Other 2012 Research – Contracts and Grants

Project 300.00-81: Alaska port sampling

Budget: Staff salaries
Revenue: $ 405,863
Granting agency: NMFS
Start Date: 2002
Anticipated ending: Continuing
Personnel: H. Gilroy, M. Larsen, L. Erikson

The commercial fishery port sampling program hires samplers to collect otoliths, halibut lengths, fishing logbook information and landed weight data. The U.S. program includes staffing eight Alaskan ports and Bellingham, Washington. The samplers act as the liaison between the fishing industry and the Commission staff in Seattle. The Commission is responsible for the overall assessment and management of the halibut fishery and the data collected are necessary for stock assessment. The U.S. government adopted the Individual Fishing Quota (IFQ) allocation program in 1995. This grant provides funds to the IPHC for the incremental cost increase to the Commission sampling program due to the IFQ program. The grant is generated from the NMFS IFQ Fee Collection Program.

Project 610.13: Water column profiler project (Coastwide)

Budget: $ 73,893
Grant: $ 73,893 (NOAA)
Start date: 2009
Anticipated ending: Continuing
Personnel: L. Sadorus, S. Hare, P. Stabeno (NMFS PMEL)

The IPHC maintains one of the most extensive sampling platforms in the north Pacific. This platform provides enormous potential for collection of valuable oceanographic data. In particular, understanding the dynamics of the structure of the mixed layer depth – a major GLOBEC goal - requires *in situ* vertical profiling. Since 2001, IPHC has successfully deployed a SeaBird SBE-19 water column profiler during the annual stock assessment survey (#610.11). A second profiler was added to the program in 2007 (#610.12). In 2009, a NOAA grant provided for the complete outfitting of all chartered survey vessels, resulting in a complete coastwide deployment through

Sept. 2011. Annual costs are directed towards maintenance and calibration of the profilers, and data preparation necessary for submission to the National Ocean Data Center. The IPHC received a no-cost extension to the grant for 2012.

Project 617.00: Alaska catcher vessel logbook and sablefish data collection

Budget: Staff salaries
Revenue: $ 69,000
Contracting agency: NMFS
Start Date: 1999
Anticipated ending: Continuing
Personnel: L. Erikson, H. Gilroy, A. Taheri, port samplers

IPHC and NMFS Auke Bay Lab (ABL) have a sablefish data collection program. The program was reviewed and modified in 2003/2004 to meet the IPHC confidentiality policy and to encompass all vessels rather than just vessels greater than 60 feet. Under a Statement of Work, NMFS contracted IPHC staff to interview the IFQ fishers to review and collect the sablefish information in addition to the halibut information. Logbook data are entered by IPHC staff, matched with landings records, and provided electronically with a summary to the ABL scientists. In the summarized data, the vessels are assigned a unique code to preserve confidentiality.

Assessment and Harvest Policy Studies

1. The stock assessment

Budget: Staff salaries
Personnel: S. Hare, J. Valero, R. Webster

The annual stock assessment process comprises a large amount of work including preparation of IPHC data, estimation of bycatch by length in other fisheries, model development and validation, model fitting, examination of residuals, comparison of alternative model specifications, sensitivity tests, evaluation of harvest strategy, incidental analyses, and reporting.

2. Development of IPHC harvest policy

Budget: Staff salaries
Personnel: J. Valero, S. Hare

Since 2004, the IPHC harvest policy has been based on maintaining coastwide spawning biomass above a reference level, with options in place to reduce the harvest rate should that level be crossed. Work is continuous, with refinements to calculation of the optimum harvest rate itself in light of our present understanding of stock dynamics, fish movement, new information on commercial length-specific selectivity coming from the PIT tag experiment, and impacts of bycatch mortality when accounting for migration. In a broader sense, our harvest policy should also be robust to the many uncertainties inherent in the assessment and management of a broadly distributed and continually migrating stock, particularly one with individual regulatory area catch limits. A formal approach to evaluate such harvest policy is through Management Strategy Evaluation (MSE). An explicit aim of our MSE project is to develop a procedure for deriving catch limit recommendations that would achieve the desired harvest policy, potentially relying on much simpler calculations and at the same time effective across a range of uncertainties about stock, fishery and management behavior. Such procedures have been developed for other fisheries and it is appropriate to investigate their application to halibut management. In addition, we will examine potential effects of fishing on life history traits.

3. Ongoing analytical and statistical studies in support of halibut management

Budget: Staff salaries
Personnel: S. Hare, J. Valero, R. Webster

Every year, the analytical staff engages in a broad range of studies, many unanticipated at the onset of each year, to support halibut management. Examples of recent work include spatio-temporal modeling of setline WPUE, estimation of bycatch impacts on lost yield, surplus production trends, participation and preparation of materials for workshops (apportionment, bycatch, commissioner retreats, etc.), improvements to port sampling programs, among many others. We fully anticipate these side projects to continue to increase in number and scope.

Other Research

1. Seabird occurrence project

Budget: Staff salaries
Start Date: 2002
Anticipated ending: Continuing
Personnel: T. Geernaert, Washington State Sea Grant

During the stock assessment surveys, sea samplers count the number of seabirds in the vicinity of the vessels following gear retrieval. Sampling after the haul addresses the question of where and when certain seabird species occur. These data have been used to identify appropriate seabird deterrent requirements in certain geographic locations. Data have also been collected, using the same protocol, on the NMFS and ADF&G sablefish surveys. IPHC has developed a database to store IPHC seabird occurrence data and the collection project is ongoing.

2. Species identification of amphipods frequenting Pacific halibut (Project 653.00)

Budget: Staff salaries
Start Date: 2006
Anticipated ending: Continuing
Personnel: B. Leaman, E. Soderlund

The project intends to document the occurrence and virulence of attacks by predatory amphipods on halibut caught on IPHC surveys and, by inference, the commercial fishery. The commercial industry suffers annual losses of product due to amphipod predation and must adjust its fishing locations and practices in response to predation. Harvester discussions indicate that predation sites are both known and ephemeral, and the virulence may vary interannually at a given site. The specific identity of the amphipods has not been established and it is probable that more than one species is involved. Harvesters are interested in both documentation of predation areas for avoidance, as well as gaining an understanding of the dynamics of the species at given sites, i.e., whether there are cycles of abundance that respond to other factors. Data were collected on all stations during the 2004, 2005, and 2006 stock assessment surveys as part of standard protocol, recording incidence of sand flea predation, and the extent and virulence of the predation. The last year of data collection for this stage of the project was 2006. The 2007 summer intern performed initial analysis of interannual occurrence and virulence. Additional work will be directed at correlated variables.

3. Bycatch sampling on the assessment surveys

Budget: Staff Salaries
Revenue: To be determined
Start Date: 2003
Anticipated ending: Continuing
Personnel: C. Dykstra, T. Geernaert, E. Soderlund, E. White, sea samplers, agency staff

Area 2A

Since 2002, the IPHC has worked cooperatively with both the Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) to collect rockfish bycatch data. All rockfish caught on operations in 2A are retained and marked externally with a Floy T-bar anchor tag and the tag number is recorded with the set and skate of capture (since 2006) information. All marked fish are retained so state biologists can collect additional data shore-side. Marketable fish are sold. The IPHC then provides each agency with the effort information collected as part of the normal survey data collection.

Area 2B

In 2012, IPHC will continue to work with the Department of Fisheries and Oceans Canada (DFO) to provide a third biologist on IPHC survey vessels to collect hook-by-hook occupancy information for all species. Otoliths, maturities, round weights, and lengths were collected for all rockfish except thornyheads. This is the ninth year of this cooperative program and continued collaboration is anticipated.

Area 2C and eastern 3A

Collection of whole-haul catch data for yelloweye rockfish capture is expected to continue in 2012, at the request of the Alaska Department of Fish and Game (ADFG), for survey vessels operating in the Fairweather, Sitka, Ommaney, and Ketchikan charter regions. This project built upon cooperative work started with ADFG in 2007 and future collaboration is anticipated.

Area 4
Length frequency data on incidentally-caught Pacific cod were collected in 2011 in the 4A Edge and 4D Edge charter regions. This project was initiated at the request of NMFS/AFSC Pacific cod assessment team and is part of a developing effort to collect bycatch information on Pacific cod in the western regions of our survey, where it makes up the largest component of our survey bycatch. The work was discontinued in 2010 at NMFS' request but resumed in 2011 and is anticipated to continue in 2012.

All Areas
This coming year will be the second of a two year (2011-2012) effort to collect size and gender data from spiny dogfish bycatch on the assessment survey. This project began as a request from NMFS/AFSC and has been expanded coastwide to enhance the project. Sampling entails obtaining length and sex data on the first five spiny dogfish at all survey stations coastwide, with the exception of B.C., where the first three dogfish are sampled, and in the Bering Sea survey regions, where all dogfish are sampled.

4. Electronic reporting project for commercial landings in Alaska

Budget: $ 27,000 (covered under Catch Statistics budget: A30-7131-30)
Start Date: 2002
Anticipated ending: Continuing
Personnel: H. Gilroy, L. Erikson, T. Kong, A. Tesfatsion, H. Tran

IPHC, ADF&G, and NMFS staffs have continued to refine the web-based Interagency Electronic Reporting System (IERS). For halibut, the system reduces duplicative reporting resulting from the current requirements of completing ADF&G fish tickets and NMFS/RAM quota share reports, and has been operational since May 2006. The application (eLandings) records data elements required by regulations, prints fish tickets, and connects with the NMFS quota share database. The appropriate data from IERS is being sent to the agencies for their internal databases. The application is continuously being modified, including the incorporation of additional fisheries and tender landings. Agency staffs attend annual workshops and provide training to processors. Costs represent system maintenance costs, software purchase and development, steering committee meetings, and travel costs.

5. Electronic logbooks

Budget: $ 50,000 (Covered under Catch Statistics budget: A10-7131-30)
Start: 2010 (postponed from 2008)
End Date: Pilot project
Personnel: H. Gilroy, L. Erikson, K. MacTavish

In 2011, no funds were spent but the staff provided feedback to NMFS on the electronic logbook program under development for Alaska. The current NMFS logbook program is for a small portion of the fleet and is expected to be available in 2012/2013. The staff will continue to explore options and collaborate with other agencies to determine the feasibility of an electronic logbook in other areas.