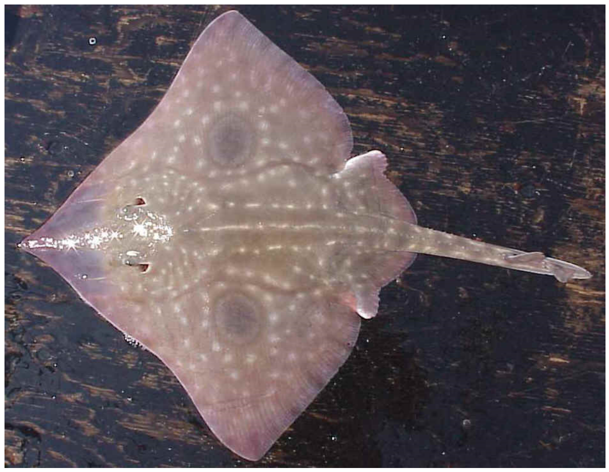
# Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019



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This report may be cited as:

Taylor, I.G., Gertseva, V., Bizzarro, J., and Stephens, A. Status of Big Skate (*Beringraja binoculata*) Off the U.S. West Coast, 2019. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

# Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019

## Contents

# Executive Summary

executive-summary

## Stock

stock

This assessment reports the status of the Big Skate (*Beringraja binoculata*) resource in U.S. waters off the coast of ... using data through 2018.

## Catches

catches

Information on historical landings of Big Skate are available back to xxxx... (Table a). Commercial landings were small during the years of World War II, ranging between 329 to 395 metric tons (mt) per year.

(Figures a-b)
(Figure c)

Since 2000, annual total landings of Big Skate have ranged between 135-412 mt, with landings in 2018 totaling 173 mt.

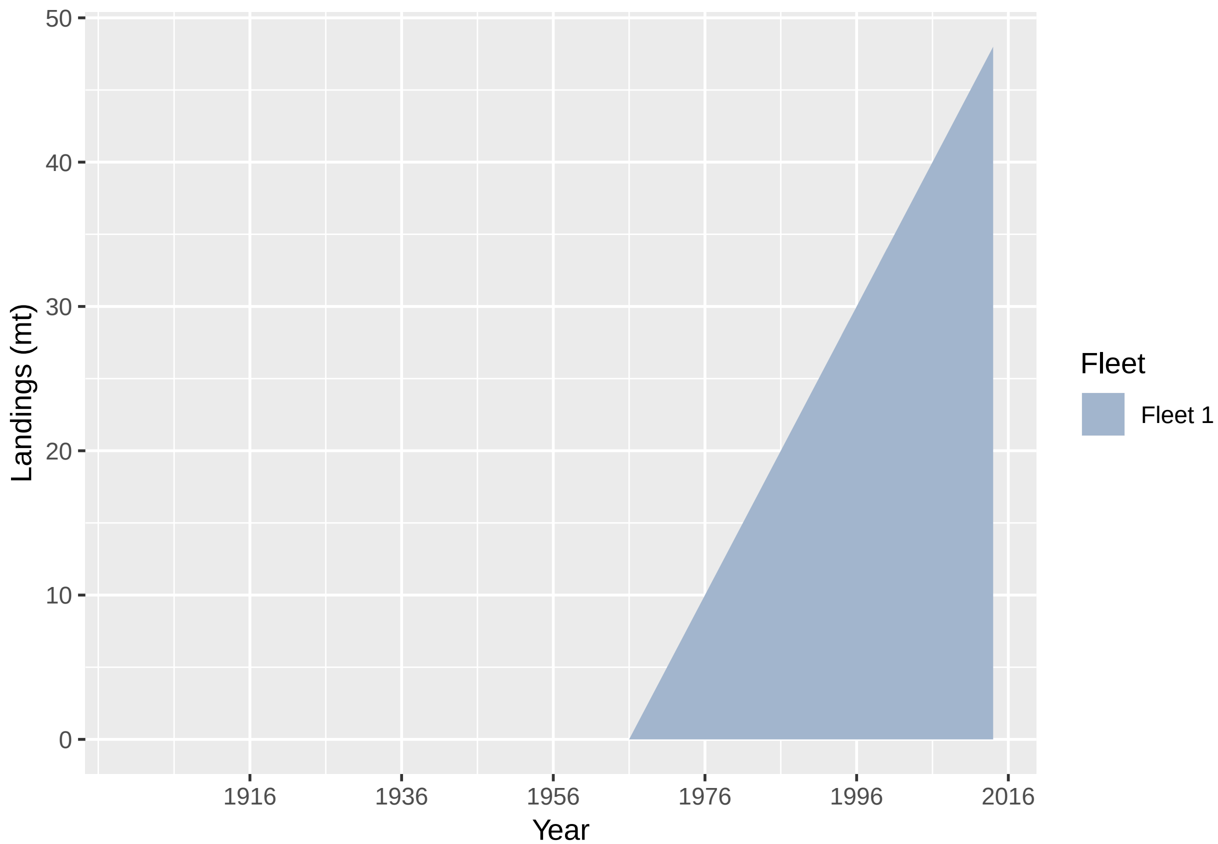



Figure a: Big Skate catch history for the recreational fleets. fig:Exec_catch1

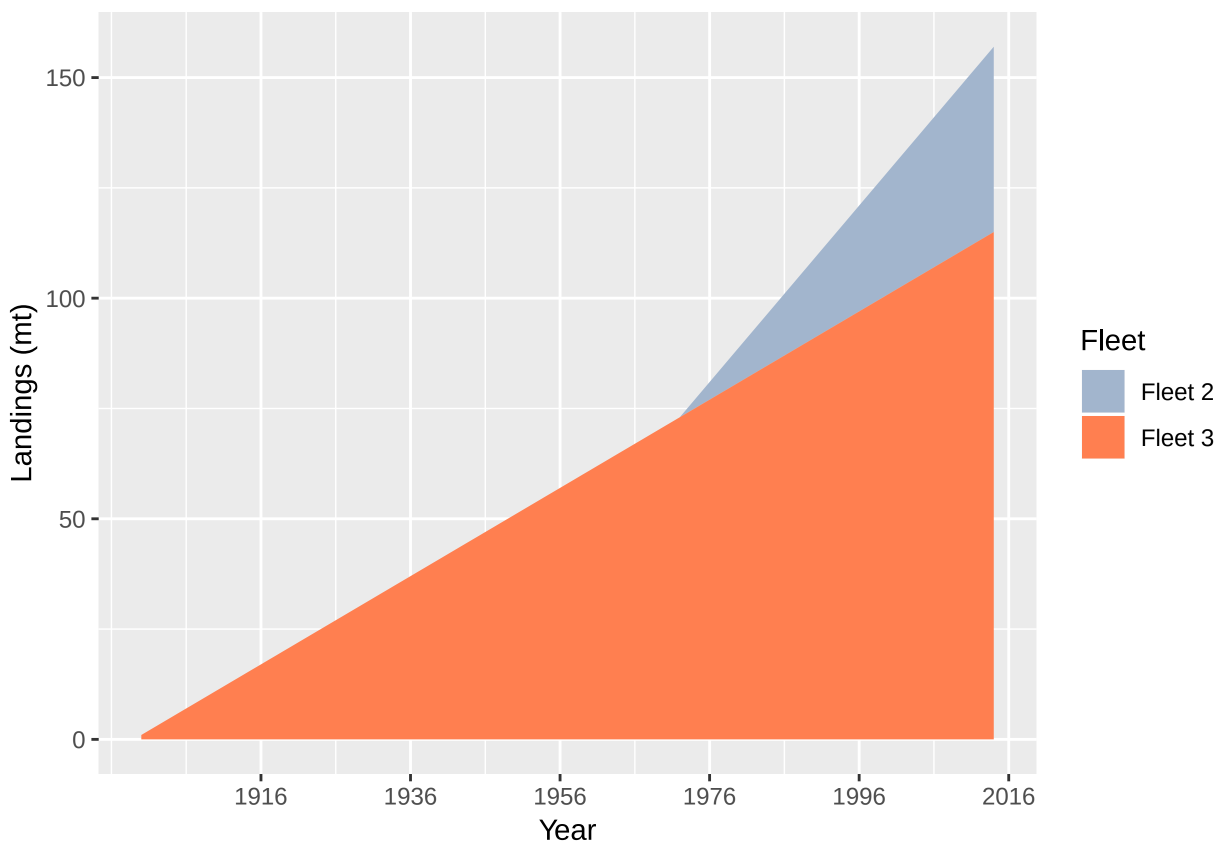



Figure b: Stacked line plot of Big Skate catch history for the commercial fleets. fig:Exec_catch2

Table a: Recent Big Skate landings (mt) by fleet.

tab:Exec_catch

| Year | Landings 1 | Landings 2 | Landings 3 | Landings 4 | Landings 5 | Total |
|---|---|---|---|---|---|---|
| 2005 | - | - | - | - | - | - |
| 2006 | - | - | - | - | - | - |
| 2007 | - | - | - | - | - | - |
| 2008 | - | - | - | - | - | - |
| 2009 | - | - | - | - | - | - |
| 2010 | - | - | - | - | - | - |
| 2011 | - | - | - | - | - | - |
| 2012 | - | - | - | - | - | - |
| 2013 | - | - | - | - | - | - |
| 2014 | - | - | - | - | - | - |

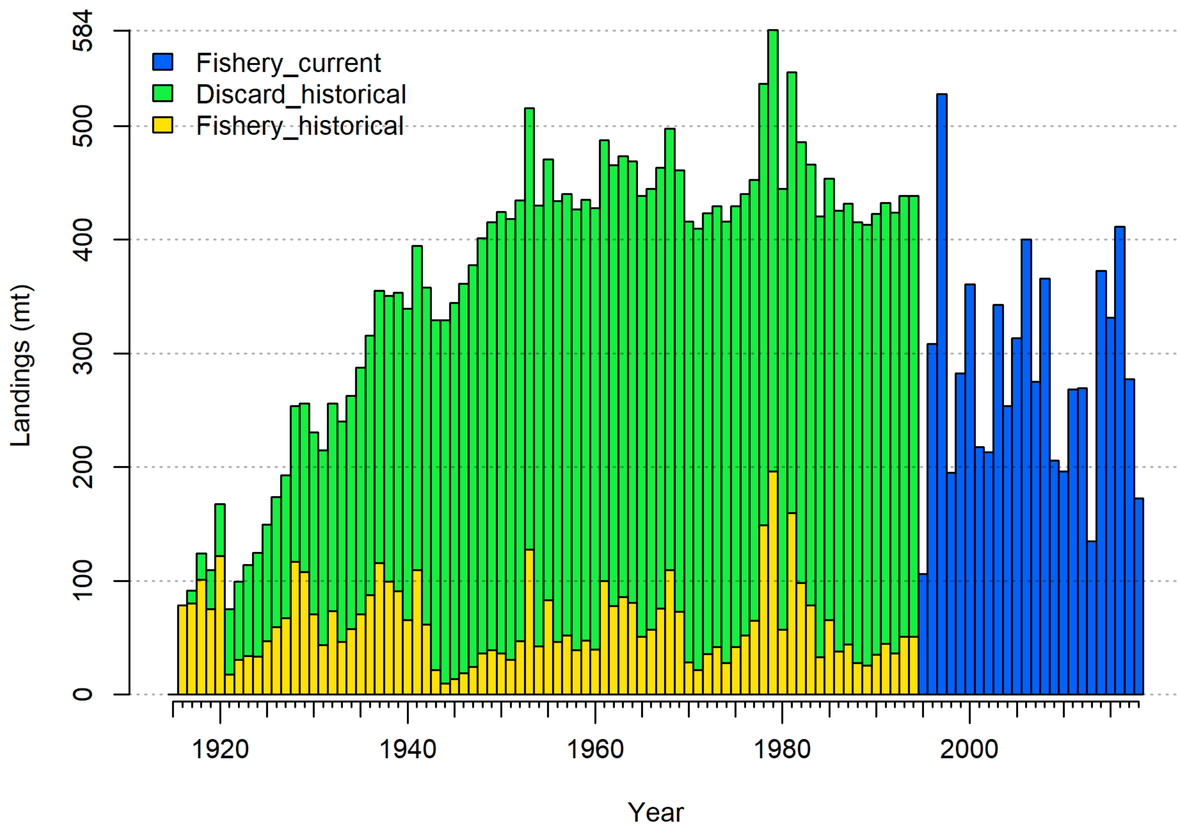



Figure c: Catch history of Big Skate in the model. fig:r4ss_catches

# Data and Assessment

data-and-assessment

This the first full assessment for Big Skate, which was last assessed as part of the "Other species" Complex. This assessment uses the newest version of Stock Synthesis (3.30.xx). The model begins in 1916, and assumes the stock was at an unfished equilibrium that year.

(Figure d).

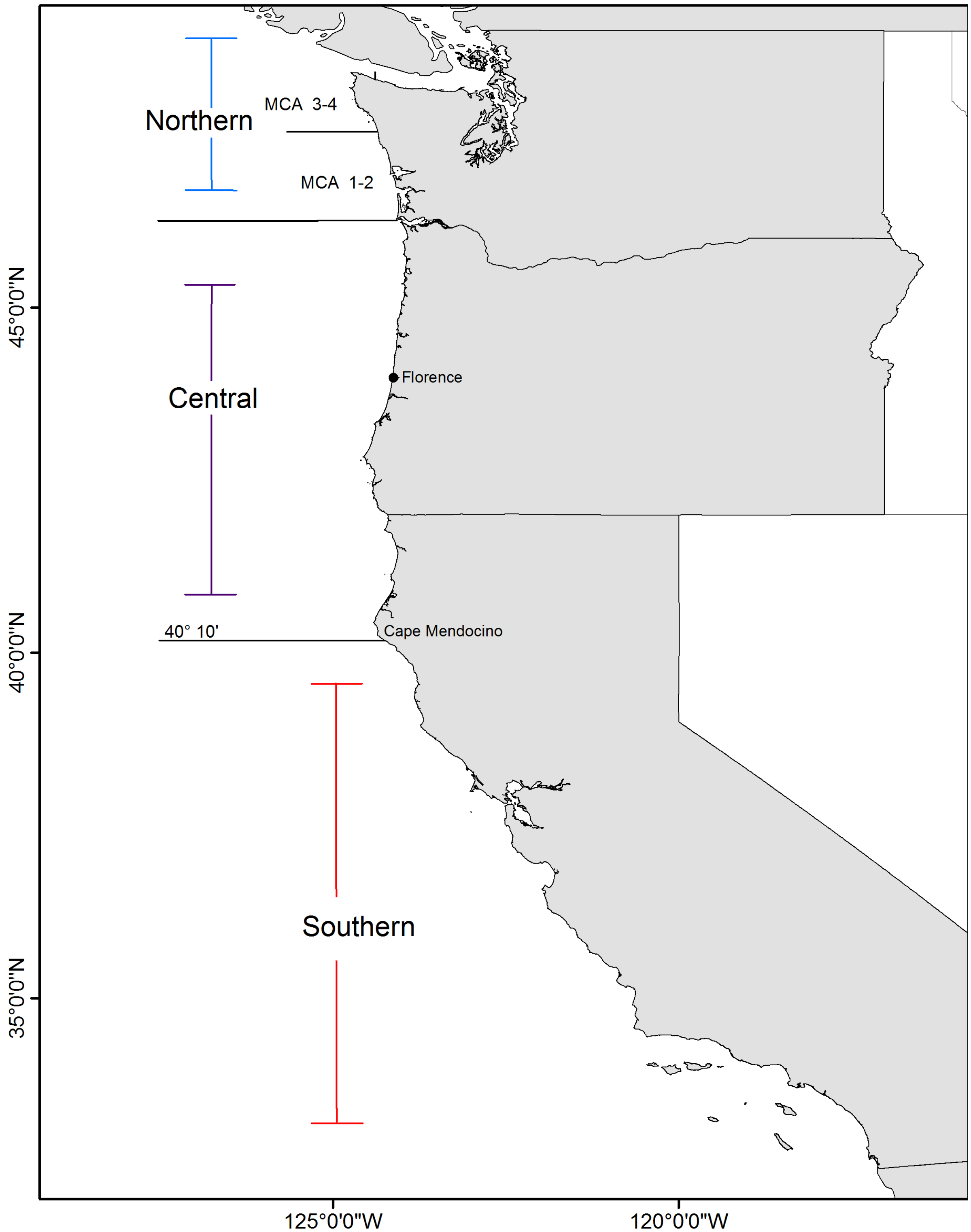



Figure d: Map depicting the distribution of California scorpionfish out to 600 ft. The stock assessment is bounded at Pt. Conception in the north to the U.S./Mexico border in the south. fig:assess_region_map

##Stock Biomass{-} (Figure e and Table b).

The 2018 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass at 99.8% (95% asymptotic interval: ± 99.8%-99.8%) (Figure f). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is high.

Table b: Recent trend in beginning of the year spawning output and depletion for the model for Big Skate.

tab:SpawningDeplete_mod1

| Year | Spawning Output (million eggs) | ~ 95% confidence interval | Estimated depletion | ~ 95% confidence interval |
|---|---|---|---|---|
| 2010 | 70693.200 | (70693.2-70693.2) | 0.998 | (0.998-0.998) |
| 2011 | 70697.500 | (70697.5-70697.5) | 0.998 | (0.998-0.998) |
| 2012 | 70699.900 | (70699.9-70699.9) | 0.998 | (0.998-0.998) |
| 2013 | 70702.400 | (70702.4-70702.4) | 0.998 | (0.998-0.998) |
| 2014 | 70709.200 | (70709.2-70709.2) | 0.998 | (0.998-0.998) |
| 2015 | 70708.700 | (70708.7-70708.7) | 0.998 | (0.998-0.998) |
| 2016 | 70708.900 | (70708.9-70708.9) | 0.998 | (0.998-0.998) |
| 2017 | 70706.000 | (70706-70706) | 0.998 | (0.998-0.998) |
| 2018 | 70706.500 | (70706.5-70706.5) | 0.998 | (0.998-0.998) |
| 2019 | 70709.900 | (70709.9-70709.9) | 0.998 | (0.998-0.998) |

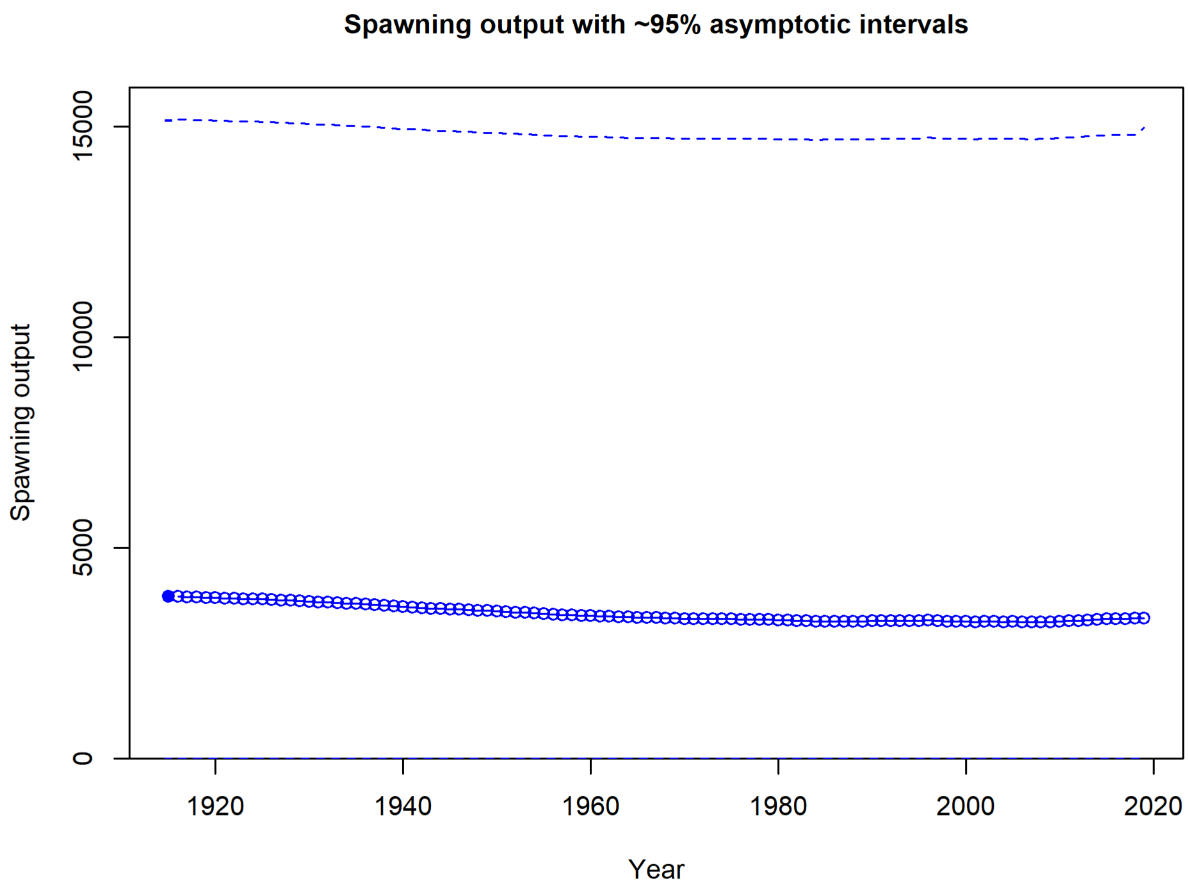



Figure e: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

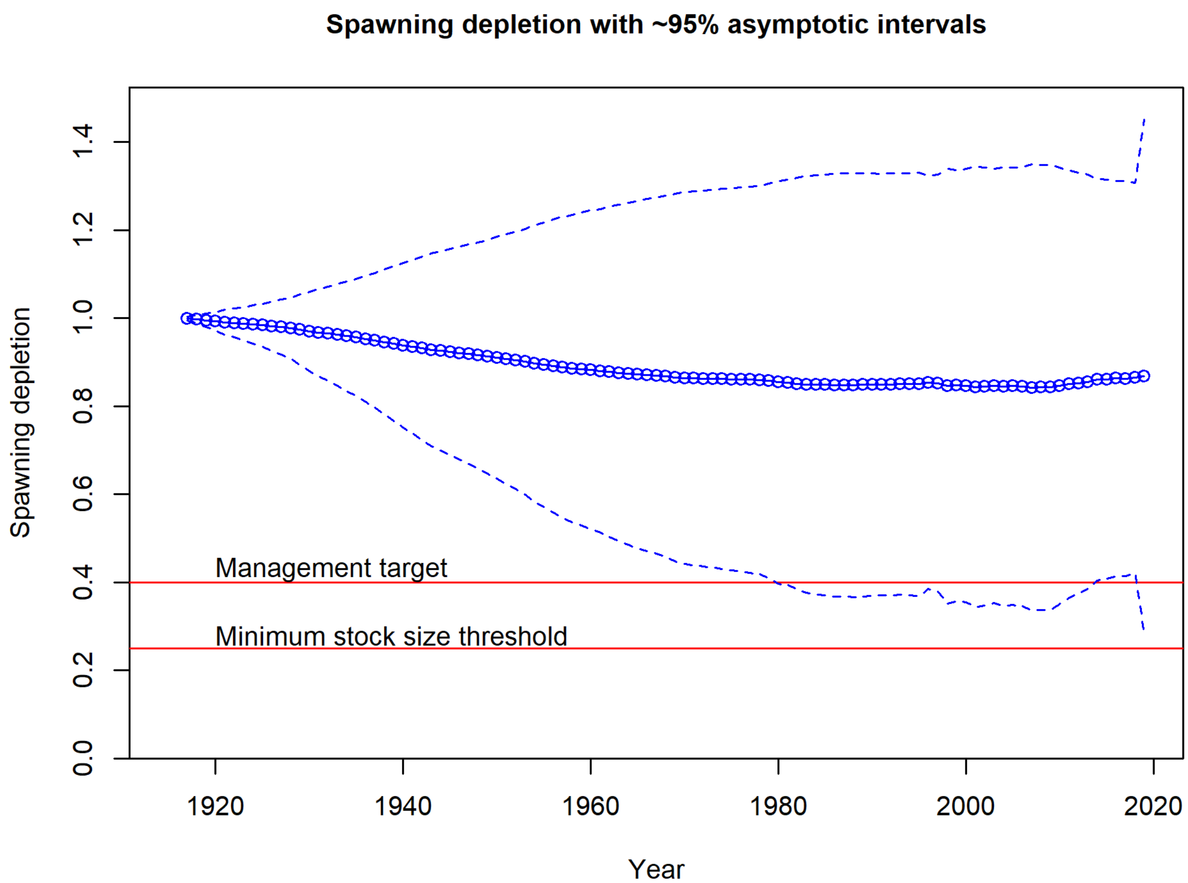



Figure f: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

# Recruitment

recruitment

Recruitment deviations were estimated from xxxx-xxxx (Figure g and Table c).

Table c: Recent recruitment for the model.

tab:Recruit_mod1

| Year | Estimated Recruitment (millions) | ˜ 95% confidence interval |
|---|---|---|
| 2010 | 749.57 | (749.57 - 749.57) |
| 2011 | 749.59 | (749.59 - 749.59) |
| 2012 | 749.60 | (749.6 - 749.6) |
| 2013 | 749.61 | (749.61 - 749.61) |
| 2014 | 749.64 | (749.64 - 749.64) |
| 2015 | 749.63 | (749.63 - 749.63) |
| 2016 | 749.63 | (749.63 - 749.63) |
| 2017 | 749.62 | (749.62 - 749.62) |
| 2018 | 749.62 | (749.63 - 749.63) |
| 2019 | 749.64 | (749.64 - 749.64) |

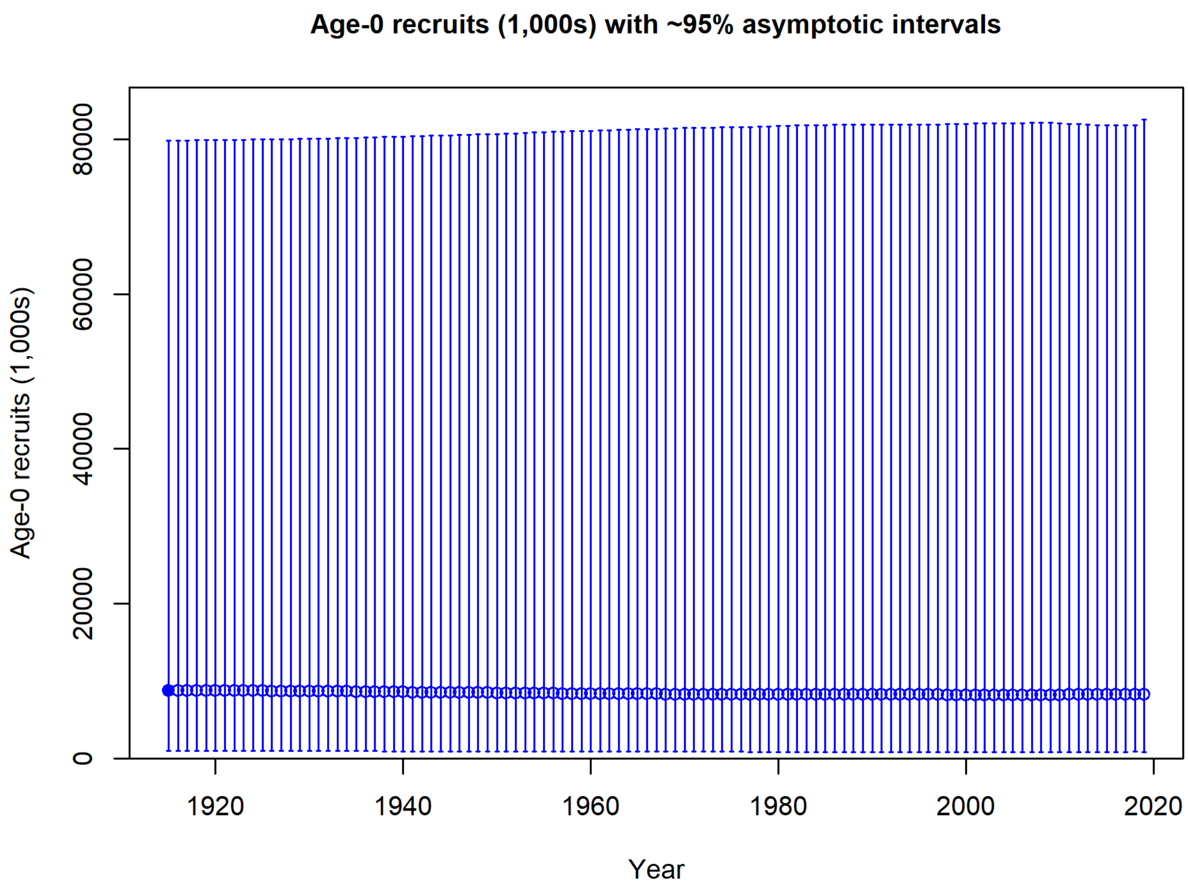



Figure g: Time series of estimated Big Skate recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruits_all

## Exploitation status

exploitation-status

Harvest rates estimated by the base model ..... management target levels (Table d and Figure h).

Table d: Recent trend in spawning potential ratio and exploitation for Big Skate in the model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is F divided by $F_{SPR}$.

tab:SPR_Exploit_mod1

| Year | Fishing intensity | ~ 95% confidence interval | Exploitation rate | ~ 95% confidence interval |
|---|---|---|---|---|
| 2009 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2010 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2011 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2012 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2013 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2014 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2015 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2016 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2017 | 0.00 | (0-0) | 0.00 | (0-0) |
| 2018 | 0.00 | (0-0) | 0.00 | (0-0) |

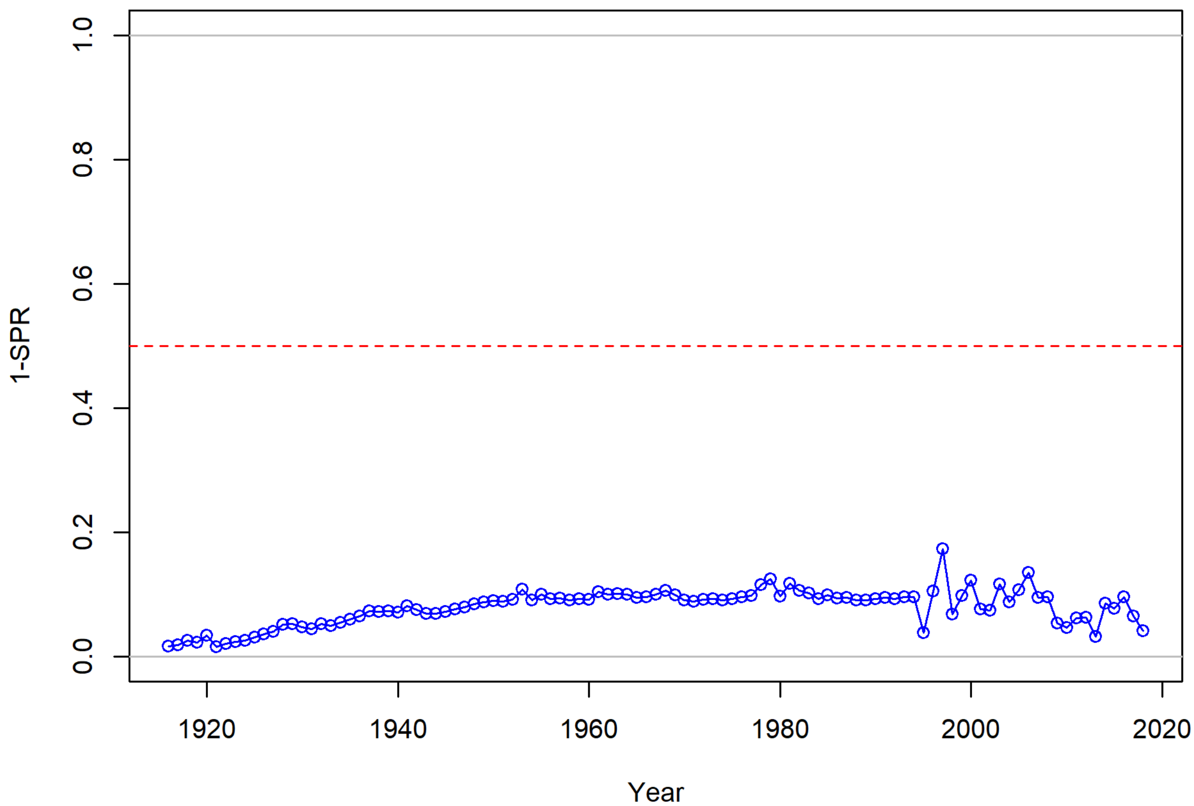



Figure h: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018. fig:SPR_all

# Ecosystem Considerations

ecosystem-considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

# Reference Points

reference-points

This stock assessment estimates that Big Skate in the model is above the biomass target ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{25\%}$). The estimated relative depletion level for the base model in 2019 is 99.8% (95% asymptotic interval: ± 99.8%-99.8%, corresponding to an unfished spawning biomass of 70709.9 million eggs (95% asymptotic interval: 70709.9-70709.9 million eggs) of spawning biomass in the base model (Table e). Unfished age 1+ biomass was estimated to be 2,814 mt in the base case model. The target spawning biomass ($SB_{40\%}$) is 2,834 million eggs, which corresponds with an equilibrium yield of 5,906 mt. Equilibrium yield at the proxy $F_{MSY}$ harvest rate corresponding to $SPR_{50\%}$ is 5,070 mt (Figure i).

Table e: Summary of reference points and management quantities for the base case model. tab:Ref_pts_mod1

| **Quantity** | **Estimate** | **Low 2.5% limit** | **High 2.5% limit** |
|---|---|---|---|
| Unfished spawning output (million eggs) | 7,086 | 7,086 | 7,086 |
| Unfished age 1+ biomass (mt) | 2,814 | 2,814 | 2,814 |
| Unfished recruitment ($R_0$) | 7,502 | 7,502 | 7,502 |
| Spawning output(2018 million eggs) | 7,071 | 7,071 | 7,071 |
| Depletion (2018) | 0.998 | 0.998 | 0.998 |
| **Reference points based on $\mathbf{SB_{40\%}}$** | | | |
| Proxy spawning output ($B_{40\%}$) | 2,834 | 2,834 | 2,834 |
| SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$) | 0.625 | 0.625 | 0.625 |
| Exploitation rate resulting in $B_{40\%}$ | 0.04 | 0.04 | 0.04 |
| Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt) | 5,906 | 5,906 | 5,906 |
| ***Reference points based on SPR proxy for MSY*** | | | |
| Spawning output | 1,417 | 1,417 | 1,417 |
| $SPR_{proxy}$ | 0.5 | | |
| Exploitation rate corresponding to $SPR_{proxy}$ | 0.058 | 0.058 | 0.058 |
| Yield with $SPR_{proxy}$ at $SB_{SPR}$ (mt) | 5,070 | 5,070 | 5,070 |
| ***Reference points based on estimated MSY values*** | | | |
| Spawning output at $MSY$ ($SB_{MSY}$) | 2,578 | 2,578 | 2,578 |
| $SPR_{MSY}$ | 0.602 | 0.602 | 0.602 |
| Exploitation rate at $MSY$ | 0.043 | 0.043 | 0.043 |
| Dead Catch $MSY$ (mt) | 5,939 | 5,939 | 5,939 |
| Retained Catch $MSY$ (mt) | 5,939 | 5,939 | 5,939 |

# Management Performance

management-performance

Table f

# Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

Table f: Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflect the commercial landings plus the model estimated discarded biomass.

tab:mnmgt_perform

| Year | OFL (mt; ABC prior to 2011) | ABC (mt) | ACL (mt; OY prior to 2011) | Estimated total catch (mt) |
|---|---|---|---|---|
| **2007** | - | - | - | - |
| **2008** | - | - | - | - |
| **2009** | - | - | - | - |
| **2010** | - | - | - | - |
| **2011** | - | - | - | - |
| **2012** | - | - | - | - |
| **2013** | - | - | - | - |
| **2014** | - | - | - | - |
| **2015** | - | - | - | - |
| **2016** | - | - | - | - |
| **2017** | - | - | - | - |
| **2018** | - | - | - | - |

94 # Decision Table

decision-table

Table g: Projections of potential OFL (mt) for each model, using the base model forecast.

tab:OFL_projection

| Year | OFL |
|---|---|
| 2019 | 158932.00 |
| 2020 | 149035.00 |
| 2021 | 141655.00 |
| 2022 | 136395.00 |
| 2023 | 132529.00 |
| 2024 | 129293.00 |
| 2025 | 126187.00 |
| 2026 | 122991.00 |
| 2027 | 119650.00 |
| 2028 | 116197.00 |
| 2029 | 112719.00 |
| 2030 | 109333.00 |

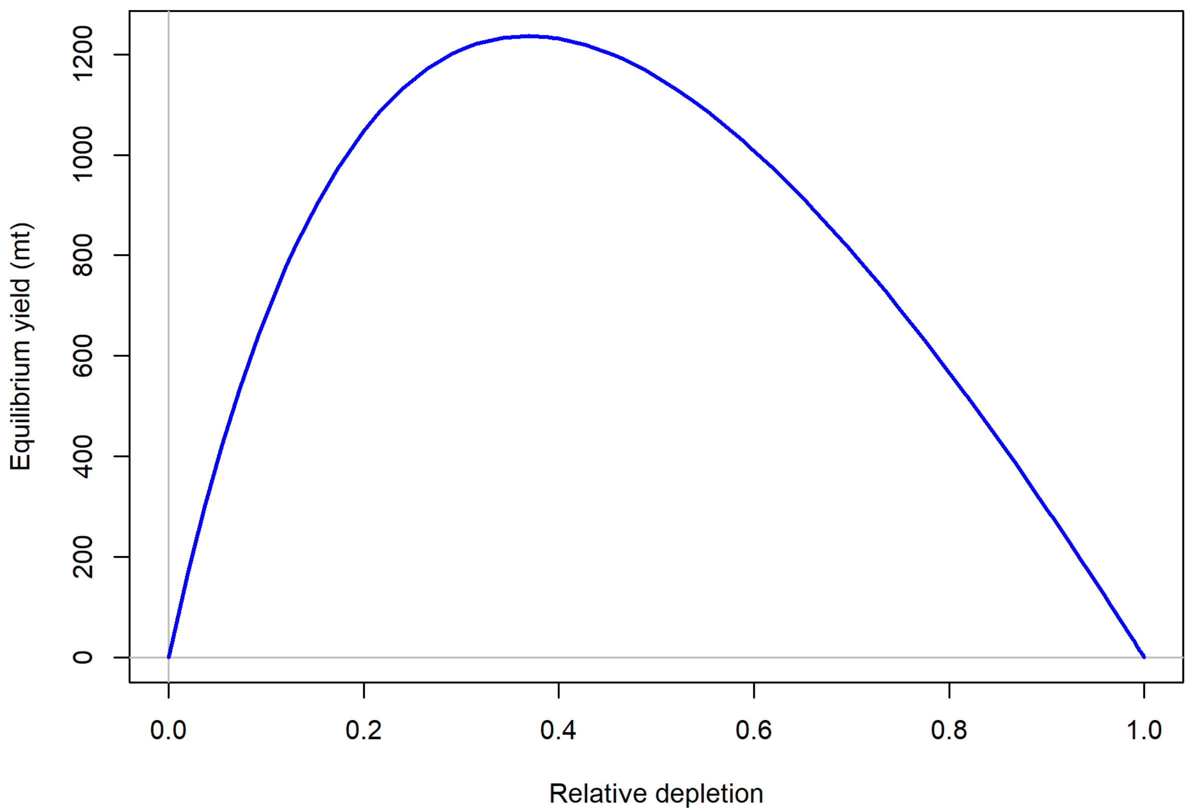



Figure i: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. fig:Yield_all

Table h: Summary of 10-year projections beginning in 2020 for alternate states of nature based on an axis of uncertainty for the model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. An entry of "–" indicates that the stock is driven to very low abundance under the particular scenario.

tab:Decision_table_mod1

| | | | States of nature | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Low M 0.05 | | Base M 0.07 | | High M 0.09 | |
| | Year | Catch | Spawning Output | Depletion | Spawning Output | Depletion | Spawning Output | Depletion |
| 40-10 Rule, Low M | 2019 | - | - | - | - | - | - | - |
| | 2020 | - | - | - | - | - | - | - |
| | 2021 | - | - | - | - | - | - | - |
| | 2022 | - | - | - | - | - | - | - |
| | 2023 | - | - | - | - | - | - | - |
| | 2024 | - | - | - | - | - | - | - |
| | 2025 | - | - | - | - | - | - | - |
| | 2026 | - | - | - | - | - | - | - |
| | 2027 | - | - | - | - | - | - | - |
| | 2028 | - | - | - | - | - | - | - |
| 40-10 Rule | 2019 | - | - | - | - | - | - | - |
| | 2020 | - | - | - | - | - | - | - |
| | 2021 | - | - | - | - | - | - | - |
| | 2022 | - | - | - | - | - | - | - |
| | 2023 | - | - | - | - | - | - | - |
| | 2024 | - | - | - | - | - | - | - |
| | 2025 | - | - | - | - | - | - | - |
| | 2026 | - | - | - | - | - | - | - |
| | 2027 | - | - | - | - | - | - | - |
| | 2028 | - | - | - | - | - | - | - |
| 40-10 Rule, High M | 2019 | - | - | - | - | - | - | - |
| | 2020 | - | - | - | - | - | - | - |
| | 2021 | - | - | - | - | - | - | - |
| | 2022 | - | - | - | - | - | - | - |
| | 2023 | - | - | - | - | - | - | - |
| | 2024 | - | - | - | - | - | - | - |
| | 2025 | - | - | - | - | - | - | - |
| | 2026 | - | - | - | - | - | - | - |
| | 2027 | - | - | - | - | - | - | - |
| | 2028 | - | - | - | - | - | - | - |
| Average Catch | 2019 | - | - | - | - | - | - | - |
| | 2020 | - | - | - | - | - | - | - |
| | 2021 | - | - | - | - | - | - | - |
| | 2022 | - | - | - | - | - | - | - |
| | 2023 | - | - | - | - | - | - | - |
| | 2024 | - | - | - | - | - | - | - |
| | 2025 | - | - | - | - | - | - | - |
| | 2026 | - | - | - | - | - | - | - |
| | 2027 | - | - | - | - | - | - | - |
| | 2028 | - | - | - | - | - | - | - |

Table i: Base case results summary.

tab:base_summary

| Quantity | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Landings (mt) | | | | | | | | | | |
| Total Est. Catch (mt) | | | | | | | | | | |
| OFL (mt) | | | | | | | | | | |
| ACL (mt) | | | | | | | | | | |
| (1-$SPR$)(1-$SPR_{50\%}$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Exploitation rate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Age 1+ biomass (mt) | 2654110 | 2654240 | 2654360 | 2654400 | 2654430 | 2654570 | 2654490 | 2654470 | 2654390 | 2654450 |
| Spawning Output | 70693.2 | 70697.5 | 70699.9 | 70702.4 | 70709.2 | 70708.7 | 70708.9 | 70706.0 | 70706.5 | 70709.9 |
| 95% CI | (70693.2-70693.2) | (70697.5-70697.5) | (70699.9-70699.9) | (70702.4-70702.4) | (70709.2-70709.2) | (70708.7-70708.7) | (70708.9-70708.9) | (70706-70706) | (70706.5-70706.5) | (70709.9-70709.9) |
| Depletion | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 95% CI | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) | (0.998-0.998) |
| Recruits | 749.57 | 749.59 | 749.60 | 749.61 | 749.64 | 749.63 | 749.63 | 749.62 | 749.62 | 749.64 |
| 95% CI | (749.57 - 749.57) | (749.59 - 749.59) | (749.6 - 749.6) | (749.61 - 749.61) | (749.64 - 749.64) | (749.63 - 749.63) | (749.63 - 749.63) | (749.62 - 749.62) | (749.63 - 749.63) | (749.64 - 749.64) |

## Research and Data Needs

research-and-data-needs

We recommend the following research be conducted before the next assessment:

1. **xxxx**:
2. **xxxx**:
3. **xxxx**:
4. **xxxx**:
5. **xxxx**:

# 1 Introduction

introduction

## 1.1 Distribution and Life History

distribution-and-life-history

Big Skate (*Raja binoculata*) is the largest of the skate species in North America with a documented maximum length of 244 cm total length and a maximum weight of 91 kg (Eschmeyer and Herald 1983). The species name "binoculata" (two-eyed) refers to the prominent ocellus at the base of each pectoral fin. Big skate range from the Bering Sea to Cedros Island in Baja California, but are uncommon south of Pt. Conception. Big skate have a shallow depth distribution of 3-800 m, but are most common in the 3-110 m depth zone. Big Skate are observed in progressively shallower water in the northern parts of its range. They occur in coastal bays, estuaries, and over the continental shelf, usually on sandy or muddy bottoms, but occasionally on low strands of kelp.

Skates are the largest and most widely distributed group of batoid fish with approximately 245 species ascribed to two families (Ebert and Compagno 2007)(**???**). Skates are benthic fish that are found in all coastal waters but are most common in cold temperatures and polar waters (Ebert and Compagno 2007).

There are about eleven species of skates from either of three genera (Amblyraja, Bathyraja, and Raja) present in the Northeast Pacific Ocean off California, Oregon and Washington (Ebert 2003). Of that number, just three species (Longnose Skate, *Raja rhina*; Big Skate, *Raja binoculata*; and Sandpaper Skate, *Bathyraja interrupta*) make up over 95 percent of West Coast Groundfish Bottom Trawl Survey (WCGBTS) catches in terms of biomass and numbers, with the Longnose Skate leading in both categories (with 62 percent of biomass and 56 percent of numbers).

Mating has been observed with distinct pairing with embrace. Big Skate are oviparous and lay horned egg cases up to a foot in length with up to seven embryos per egg case (Eschmeyer and Herald 1983). The female deposits her eggs in pairs on sandy or muddy flats; there is no discrete breedingseason and egg-laying occurs year-round (Ebert 2003). Females may use discrete spawning beds, as large numbers of egg cases have been found in certain localized areas (IUCN/SSC Shark Specialist Group 2005). The young emerge after 9 months and measure 18–23 cm (7–9 in).

Female Big Skates mature at 1.3–1.4 m (4 ft 3 in–4 ft 7 in) long and 12–13 years old, while males mature at 0.9–1.1 m (2 ft 11 in–3 ft 7 in) long and seven to eight years old (Bester 2009). The growth rate of Big Skates in the Gulf of Alaska are comparable to those off California, but differ from those off British Columbia. The lifespans of big skates off Alaska are up to 15 years, while those off British Columbia are up to 26 years.

Big Skates are usually seen buried in sediment with only their eyes showing. They feed on polychaete worms, mollusks, crustaceans, and small benthic fishes. Polychaetes and mollusks comprise a slightly greater percentage of the diet of younger individuals. The eyespots on the skates' wings are believed to serve as decoys to confuse predators. A known predator of big skates is the Broadnose Sevengill Shark (*Notorhynchus cepedianus*). Juvenile Northern Elephant Seals (*Mirounga angustirostris*) are known to consume the egg cases of the Big Skate. Known parasites include the copepod *Lepeophtheirus cuneifer*.

## 1.2 Early Life History

`early-life-history`

Bizzarro.

## 1.3 Map

`map`

A map showing the scope of the assessment and depicting boundaries for fisheries or data collection strata is provided in Figure 1.

## 1.4 Ecosystem Considerations

`ecosystem-considerations-1`

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

## 1.5 Fishery Information

`fishery-information`

Big Skate are caught in commercial and recreational fisheries on the West Coast using line and trawl gears. There is a limited market for pectoral fins (skate wings).

The history of Big Skate (*Raja binoculata*) is not well documented. They were used as a food source by the native Coastal and Salish Tribes (Batdorf, C n.d.) long before Europeans settled in the Pacific Northwest and then as fertilizer by the settlers (Bowers, G. M. n.d.). No directed fishery for Big Skate has been documented; rather, they were taken along with other skates and rays as "scrap fish" and used for fertilizer, fish meal and oil.

Skates have been regarded as a predator on desirable market species such as Dungeness crab, and were thought of as nuisance fish with no appeal as a food item save for small local markets. They had been discarded or harvested at a minimal level until their livers became valued along with those of other shark family members for the extraction of vitamin A in the 1940s. Chapman (Chapman, W.M. n.d.) recorded that "At present they are being fished heavily, in common with the other elasmobranchs of the coast, forthe vitamins in their livers. The carcasses are either thrown away at sea or made into fish meal. Little use is made of the excellent meat of the wings".

Little information is available about the historic fishery for Big Skate. In records before 2000, they are lumped together with other skates or in market categories; this necessitates considerable attention to reconstructing the fishery by observing the composition of catches in the modern fishery and applying those to historical records.

## 1.6 Stock Status and Management History

`stock-status-and-management-history`

Big Skate were managed in the Other Fish complex until 2015 when they were designated an Ecosystem Component (EC) species. Catches of Big Skate are estimated to have averaged 95 mt from 2007–2011, along with large landings of "Unspecified Skate". Analysis of Oregon port-sampling data indicates that about 98 percent of the recent Unspecified Skate landings in Oregon were comprised of Big Skate. Such large landings indicates targeting of Big Skate has occurred and an EC designation was not warranted. Based on this evidence, Big Skate was redesignated as an actively-managed species in the fishery. Big skate have been managed with stock-specific harvest specifications since 2017.

The recent OFL of 541 mt was calculated by applying approximate MSY harvest rates toestimates of stock biomass from the Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl Survey. This survey-based biomass estimate is likely underestimated since Big Skate are distributed all the way to the shoreline and no West Coast trawl surveys have been conducted in water shallower than 55 meters. This introduces an extra source of uncertainty to management and suggests that increased precaution is needed to reduce the risk of overfishing the stock.

There has been consideration for managing Big Skate in a complex with Longnose Skate, the other actively-managed West Coast skate species, but the two species have disparate distributions and fishery interactions (Longnose Skate is much more deeply distributed than Big Skate) and that option was not endorsed. The Pacific Fishery Management Council has chosen to set the Annual Catch Limit (ACL) equal to the Allowable Biological Catch (ABC) with a buffer for management uncertainty (P*) of 0.45.

## 1.7 Management Performance

`management-performance-1`

Table f

## 1.8 Fisheries Off Mexico or Canada

`fisheries-off-mexico-or-canada`

#Assessment

##Data Data used in the Big Skate assessment are summarized in Figure 2. Descriptions of the data sources are in the following sections.

###Commercial Fishery Landings

Catch reconstructions for WA, OR, and CA Tribal catch in WA

###Commercial Discards

Estimated discards

###Commercial Fishery Length and Age Data

The input sample sizes were calculated via the Stewart Method (Ian Stewart, personal communication, IPHC):

$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} < 44$$

$$\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} \geq 44$$

###Sport Fishery Removals and Discards

Biological samples from the recreational fleets are described in the sections below.

###Fishery-Dependent Indices of Abundance

**Data Source 1**

*Data Source 1 Index Standardization*

*Data Source 1 Length Composition*

**Data Source 2**

**Data Source 3**

###Fishery-Independent Data Sources

**Alaska Fisheries Science Center (AFSC) Triennial Shelf Survey**
Research surveys have been used since the 1970s to provide fishery-independent information about the abundance, distribution, and biological characteristics of Big Skate. A coast-wide survey was conducted in 1977 (Gunderson, Donald Raymond and Sample, Terrance M. n.d.) by the Alaska Fisheries Science Center, and repeated every three years through 2001.

The final year of this survey, 2004, was conducted by the NWFSC according to the AFSC protocol. We refer to this as the **Triennial Survey**.

The survey design used equally-spaced transects from which searches for tows in a specific depth range were initiated. The depth range and latitudinal range was not consistent across years, but all years in the period 1980-2004 included the area from 40° 10'N north to the Canadian border and a depth range that included 55-366 meters, which spans the range where the vast majority of Big Skate encountered in all trawl surveys. Therefore the index was based on this depth range. The survey as conducted in 1977 had incomplete coverage and is not believe to be comparable to the later years, and is not used in the index.

An index of abundance was estimated based on the VAST delta-GLMM model as described for the NWFSC Combo Index above. In this case as well, Q-Q plots indicated slightly better performance of the gamma over lognormal models for positive tows (Figure **??**).

### Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey

In 2003, the NWFSC took over an ongoing slope survey the AFSC had been conducting, and expanded it spatially to include the continental shelf. This survey, referred to in this document as the **NWFSC Combo Survey**, has been conducted annually since. It uses a random-grid design covering the coastal waters from a depth of 55 m to 1,280 m from late-May to early-October (Bradburn, M.J. and Keller, A.A and Horness, B.H. n.d. , Keller, A.A. and Wallace, J.R. and Methot, R.D. n.d.). Four chartered industry vessels are used each year (with the exception of 2013 when the U.S. federal-government shutdown curtailed the survey). Yellowtail catches in the NWFSC Combo Survey are shown in **??**.

The data from the NWFSC Combo survey was analyzed using a spatio-temporal delta-model (Thorson, J. T. and Shelton, A. O. and Ward, E. J. and Skaug, H. J. n.d.), implemented as an R package VAST (**???**) and publicly available online (https://github.com/James-Thorson/VAST). Spatial and spatio-temporal variation is specifically included in both encounter probability and positive catch rates, a logit-link for encounter probability, and a log-link for positive catch rates. Vessel-year effects were included for each unique combination of vessel and year in the database.

*Data Source 1 Index Standardization* VAST

*Data Source 1 Length Composition*

**Triennial Survey** *Data Source 2 Index Standardization* VAST

###Biological Parameters and Data

### Measurement Details and Conversion Factors

Disc width to total length (estimated by Ian on Apr 15, similar to Ebert 2008 estimates for Alaska) L = 1.3399 * W estimated from 95 samples from WCGBTS where both measurements collected (R-squared = 0.9983). Little sex difference observed, so using single relationship for both sexes. Inter-spiracle width to total length from Downs & Cheng (2013): L = 12.111 + 9.761*ISW (females) L = 3.824 + 10.927*ISW (males)

Love et al. (n.d.)

### Length and Age Compositions

Length comps (some based on widths)

WCGBTS Lengths from all years except 2006 and 2007 Widths in 2006 and 2007

Triennial Survey Sample sizes: 3 in 1998 (all widths), 84 in 2001 (3 widths, 81 lengths), 100 in 2004 (all lengths) Triennial survey About 90+ samples in each of 2001 and 2004 Only 3 unsexed fish from 1998

Commercial fisheries In process Discard comps from 2010-2015

Length compositions were provided from the following sources:

- Source 1 (*type, e.g., commercial dead fish, research, recreational*, yyyy-yyyy)
- Source 2 (*type*, yyyy-yyyy)
- Source 3 (*research*, yyyy, yyyy, yyyy, yyyy)

The length composition of all fisheries aggregated across time by fleet is in Figure 3. Descriptions and details of the length composition data are in the above section for each fleet or survey.

### Age Structures

von Bertalanffy growth curve (**???**), $L_i = L_\infty e^{(-k[t-t_0])}$, where $L_i$ is the length (cm) at age $i$, $t$ is age in years, $k$ is rate of increase in growth, $t_0$ is the intercept, and $L_\infty$ is the asymptotic length.

Ages WCGBTS Currently only 333 ages from 2010 present in data warehouse as of Apr 15 Patrick submitting an 300 additional ages from 2016 and 2017 to Beth on Apr 2 and promised further additions during the week of Apr 15.

Triennial Survey No ages

Commercial fisheries 2009 samples from WA were stratified by length, so should be treated as conditionals

## Aging Precision and Bias

## Weight-Length

Estimated by Ian based on WCGBT samples (n = 1159) using code in /R/growth_plots.R Weight = 7.4924e-06 * Length ^ 2.9925

## Sex Ratio, Maturity, and Fecundity

Estimated by Melissa Head from port samplers samples (n = 278, of which 241 were from OR and 37 from WA). 24 were mature.

Code is in /maturity/Longnose_BigSkate_maturity.r

Parameter estimates: L50% = 149.5858, Slope parameter for SS = -0.13358

Adding 55 additional samples from the WCGBTS (of which only 4 were mature) changes the parameter estimate to L50% = 148.2453, Slope = -0.13155

## Natural Mortality

The Hamel prior for M is lognormal(ln(5.4/max age),.438), which based on 1 age-15 fish out of 1034 observed in the WCGBTS results in lognormal( -1.021651, 0.438)

If it needs to be fixed, it should be set to M = 5.4/max age = 5.4/15 = 0.36

###Environmental or Ecosystem Data Included in the Assessment In this assessment, neither environmental nor ecosystem considerations were explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

##Previous Assessments

###History of Modeling Approaches Used for this Stock

Deriving estimates of OFL for species in the “Other Fish” complex or potential alternative complexes

The current “Other Fish” complex and proposed alternatives include a number of species for which estimates of OFL contributions are not available from stock assessments or data-poor methods. Four of the species had OFL contributions for the 2013–2014 management cycle calculated by applying approximate MSY harvest rates to estimates of stock biomass from the NWFSC West Coast Bottom Trawl Survey (Bradburn et al., 2012). This approach is described in detail in Cope et al. (2012).

###yyyy Assessment Recommendations

**Recommendation 1:**

STAT response: xxxxx

**Recommendation 2:**

STAT response: xxxxx

**Recommendation 3:**

STAT response: xxxx

##Model Description

###Transition to the Current Stock Assessment

###Summary of Data for Fleets and Areas There are xxx fleets in the base model. They include:

*Commercial*: The commercial fleets include ...

*Recreational*: The recreational fleets include ...

*Research*: There are xx sources of fishery-independent data available ...

###Other Specifications

###Modeling Software The STAT team used Stock Synthesis 3 version 3.30.05.03 by Dr. Richard Methot at the NWFSC. This most recent version was used, since it included improvements and corrections to older versions. The r4SS package (GitHub release number v1.27.0) was used to post-processing output data from Stock Synthesis.

###Data Weighting

###Priors The log-normal prior for female natural mortality were based on a meta-analysis completed by Hamel (n.d.), as described under "Natural Mortality." Female natural mortality was fixed at the median of the prior, 0.xxx for an assumed maximum age of xx. An uninformative prior was used for the male offset natural mortality, which was estimated.

The prior for steepness ($h$) assumes a beta distribution with parameters based on an update for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was endorsed by the Science and Statistical Committee in 2018. The prior is a beta distribution with $mu$=0.xxx and $sigma$=0.xxx. Steepness is fixed in the base model at the mean of the prior. The priors were applied in sensitivity analyses where these parameters were estimated.

###Estimated and Fixed Parameters A full list of all estimated and fixed parameters is provided in Tables **??**.

The base model has a total of xxx estimated parameters in the following categories:

- xxx,
- xxx
- xxx, and
- xxx selectivity parameters

The estimated parameters are described in greater detail below and a full list of all estimated and parameters is provided in Table **??**.

*Growth.*

*Natural Mortality.*

*Selectivity.*

*Other Estimated Parameters.*

*Other Fixed Parameters.*

##Model Selection and Evaluation ###Key Assumptions and Structural Choices

###Alternate Models Considered

###Convergence

##Response to the Current STAR Panel Requests

**Request No. 1:**

**Rationale:** xxx

**STAT Response:** xxx

**Request No. 2:**

**Rationale:** xxx

**STAT Response:** xxx

**Request No. 3:**

**Rationale:** x.

**STAT Response:** xxx

**Request No. 4:**

**Rationale:** xxx

**STAT Response:** xxx

**Request No. 5:**

**Rationale:** xxx

**STAT Response:** xxx

##Base Case Model Results The following description of the model results reflects a base model that incorporates all of the changes made during the STAR panel (see previous section). The base model parameter estimates and their approximate asymptotic standard errors are shown in Table **??** and the likelihood components are in Table **??**. Estimates of derived reference points and approximate 95% asymptotic confidence intervals are shown in Table e. Time-series of estimated stock size over time are shown in Table **??**.

###Parameter Estimates

The additional survey variability (process error added directly to each year's input variability) for all surveys was estimated within the model.

(Figure 5 ).

The stock-recruit curve … Figure 6 with estimated recruitments also shown.

###Fits to the Data Model fits to the indices of abundance, fishery length composition, survey length composition, and conditional age-at-length observations are all discussed below.

###Uncertainty and Sensitivity Analyses A number of sensitivity analyses were conducted, including:

1. Sensitivity 1
2. Sensitivity 2
3. Sensitivity 3
4. Sensitivity 4
5. Sensitivity 5, etc/

###Retrospective Analysis

###Likelihood Profiles

###Reference Points Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model, (2017). Sustainable total yield (landings plus discards) were 5,070 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95% confidence interval of 5,070 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished level ($SB_{40\%}$) was 2,834 mt.

(Figure 10

The 2018 spawning biomass relative to unfished equilibrium spawning biomass is above/below the target of 40% of unfished levels (Figure 11). The relative fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, has been xxx the management target for the entire time series of the model.

Table e shows the full suite of estimated reference points for the base model and Figure 12 shows the equilibrium curve based on a steepness value xxx.

#Harvest Projections and Decision Tables The forecasts of stock abundance and yield were developed using the final base model, with the forecasted projections of the OFL presented in Table g.

The forecasted projections of the OFL for each model are presented in Table h.

#Regional Management Considerations

#Research Needs There are a number of areas of research that could improve the stock assessment for Big Skate. Below are issues identified by the STAT team and the STAR panel:

1. **xxxx**:
2. **xxxx**:
3. **xxxx**:
4. **xxxx**:
5. **xxxx**:

#Acknowledgments

#Figures

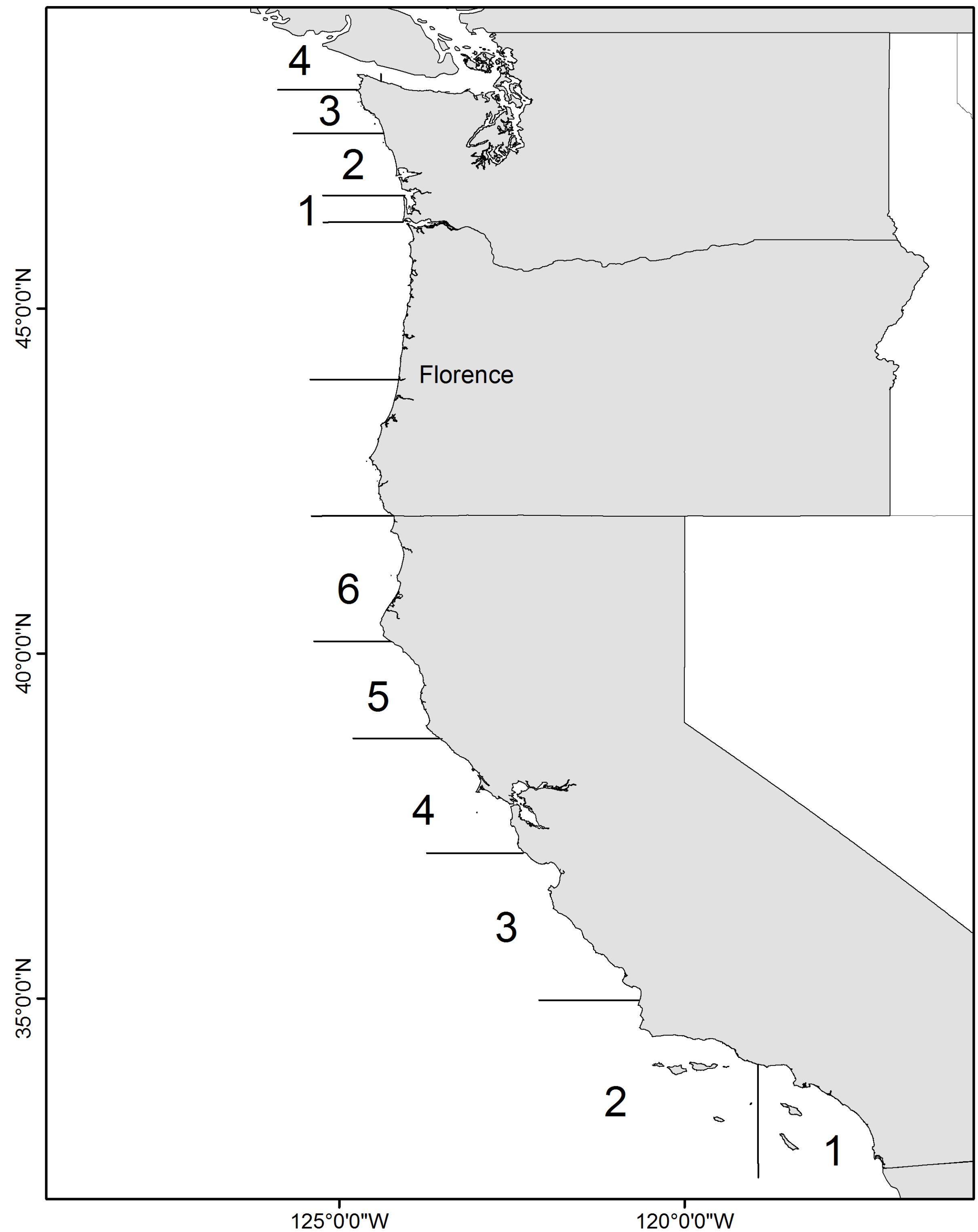



Figure 1: Map showing the state boundary lines for management of the recreational fishing fleets fig:boundary_map

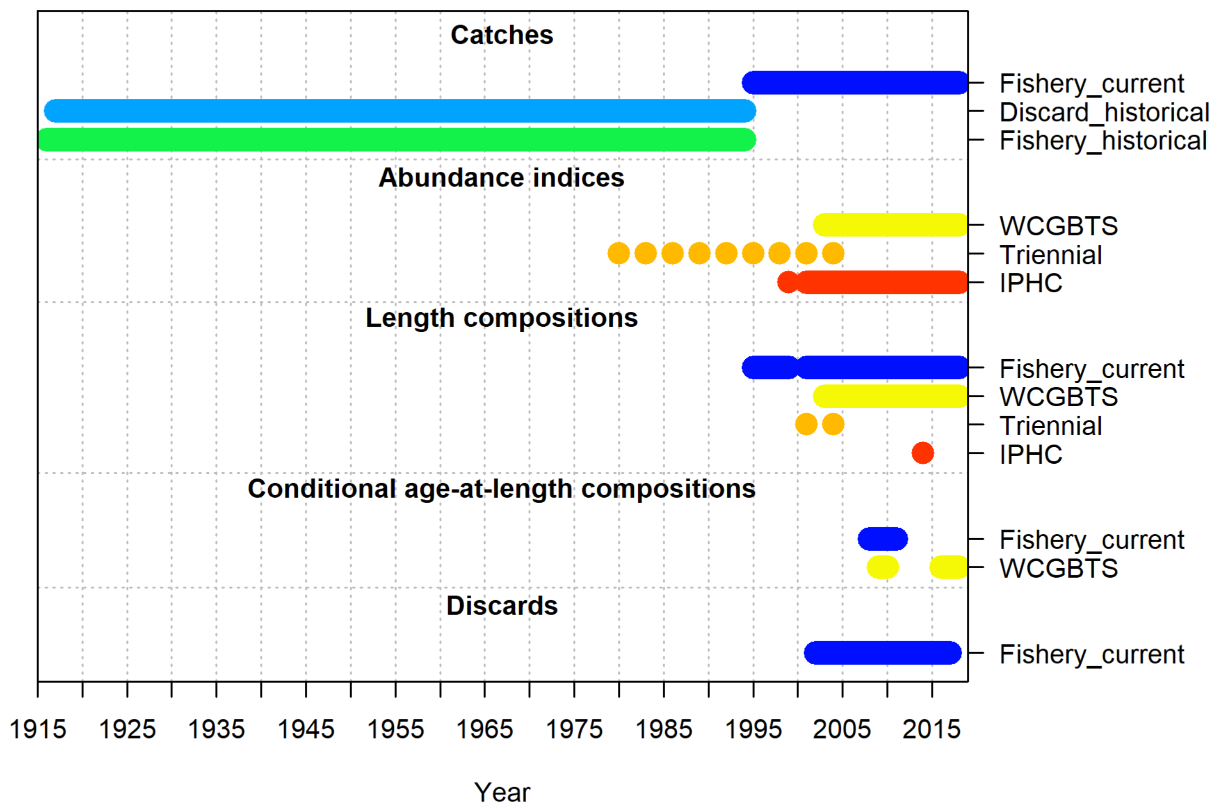



Figure 2: Summary of data sources used in the model. fig:data_plot

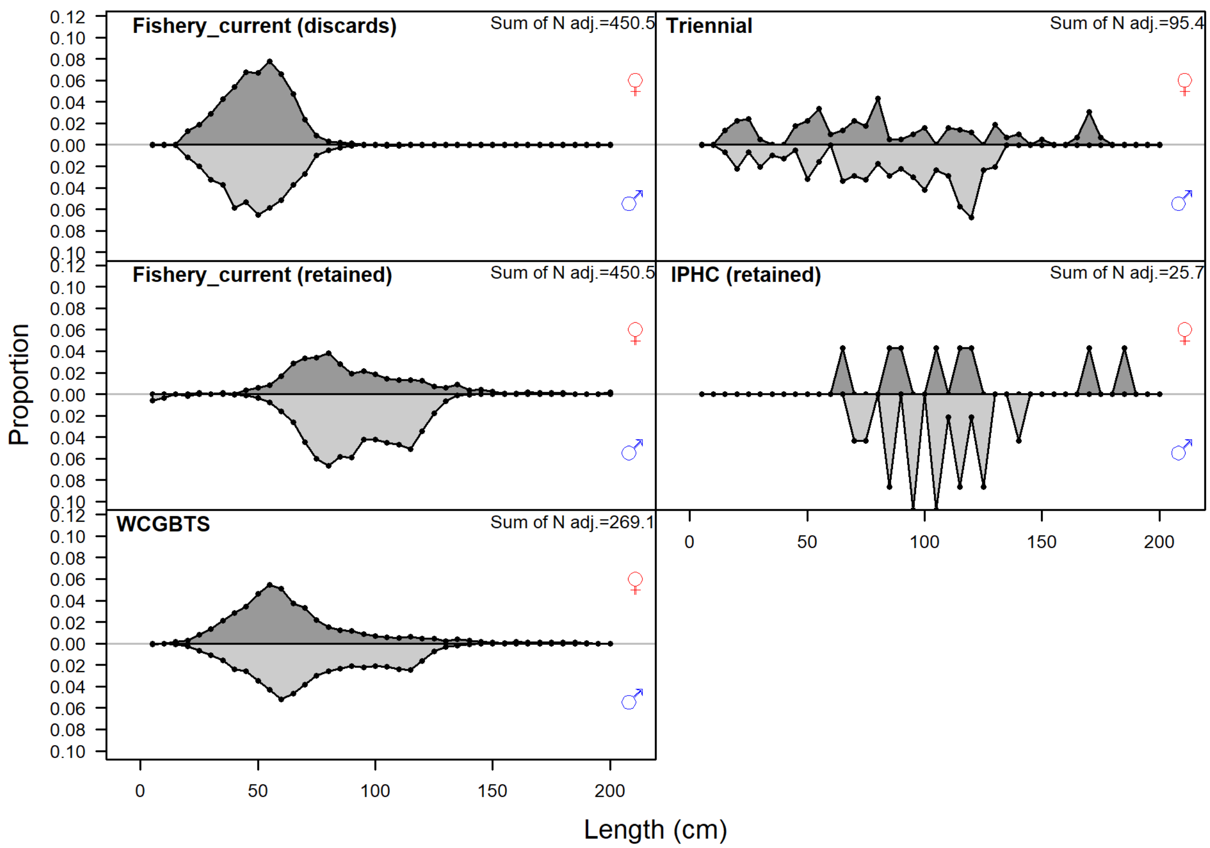



Figure 3: Length comp data, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:comp_lendat_aggregated_across_time

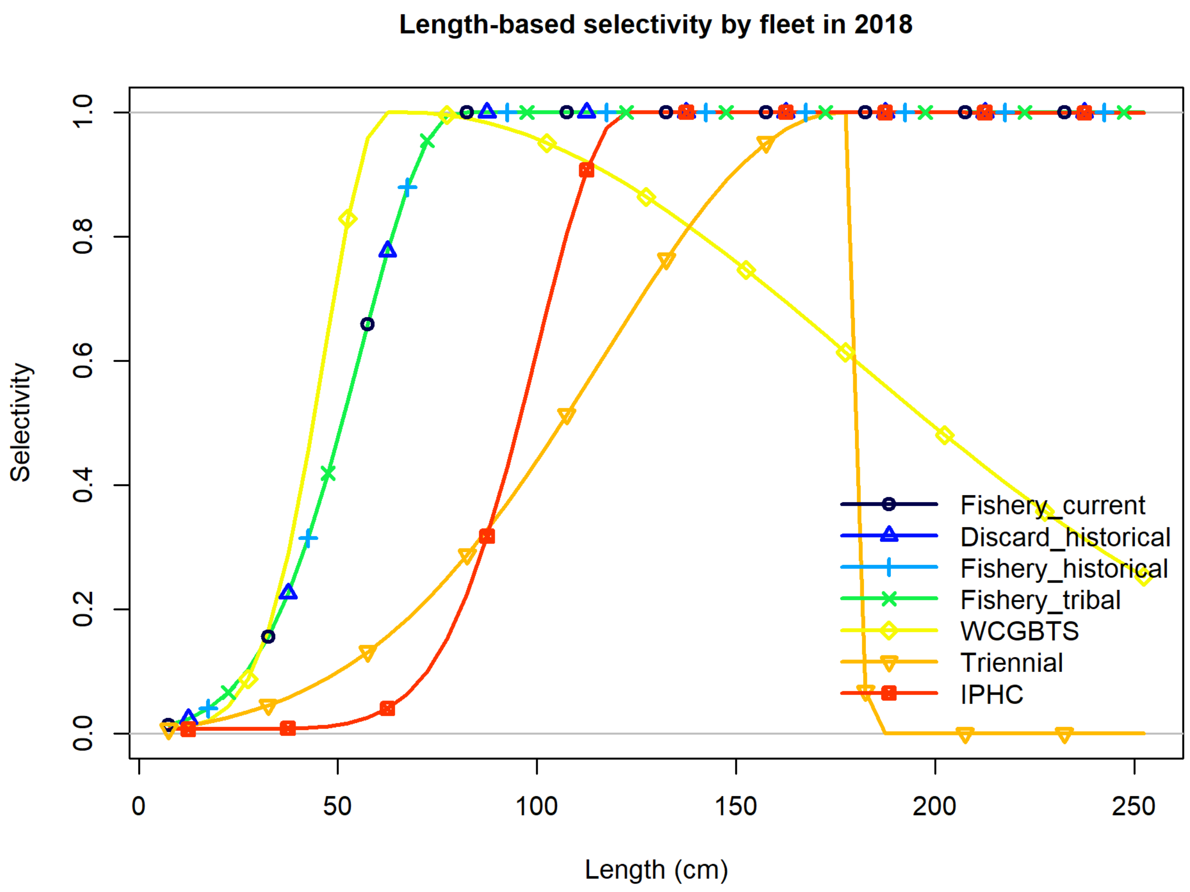



Figure 4: Selectivity at length for all of the fleets in the base model. fig:sel01_multiple_flee

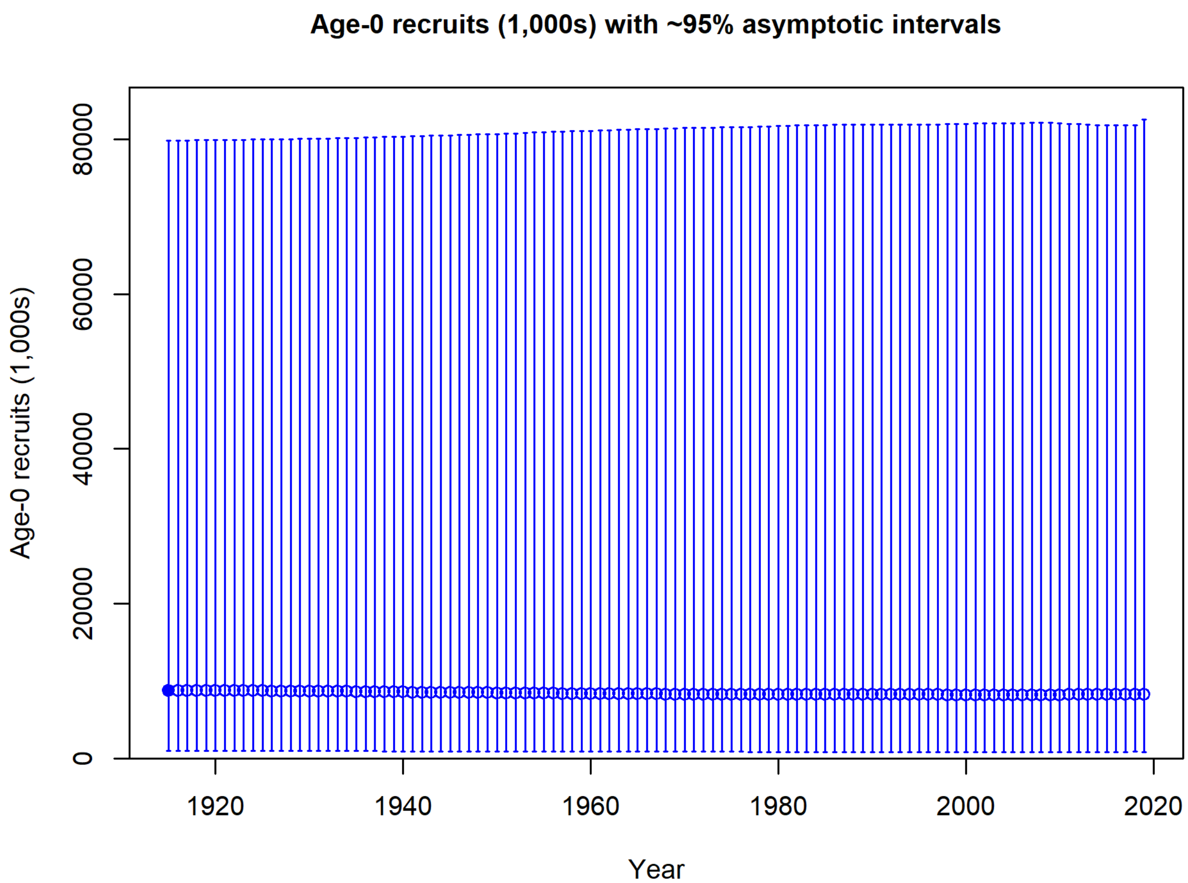



Figure 5: Estimated time-series of recruitment for Big Skate. fig:ts11_Age-0_recruits_(1

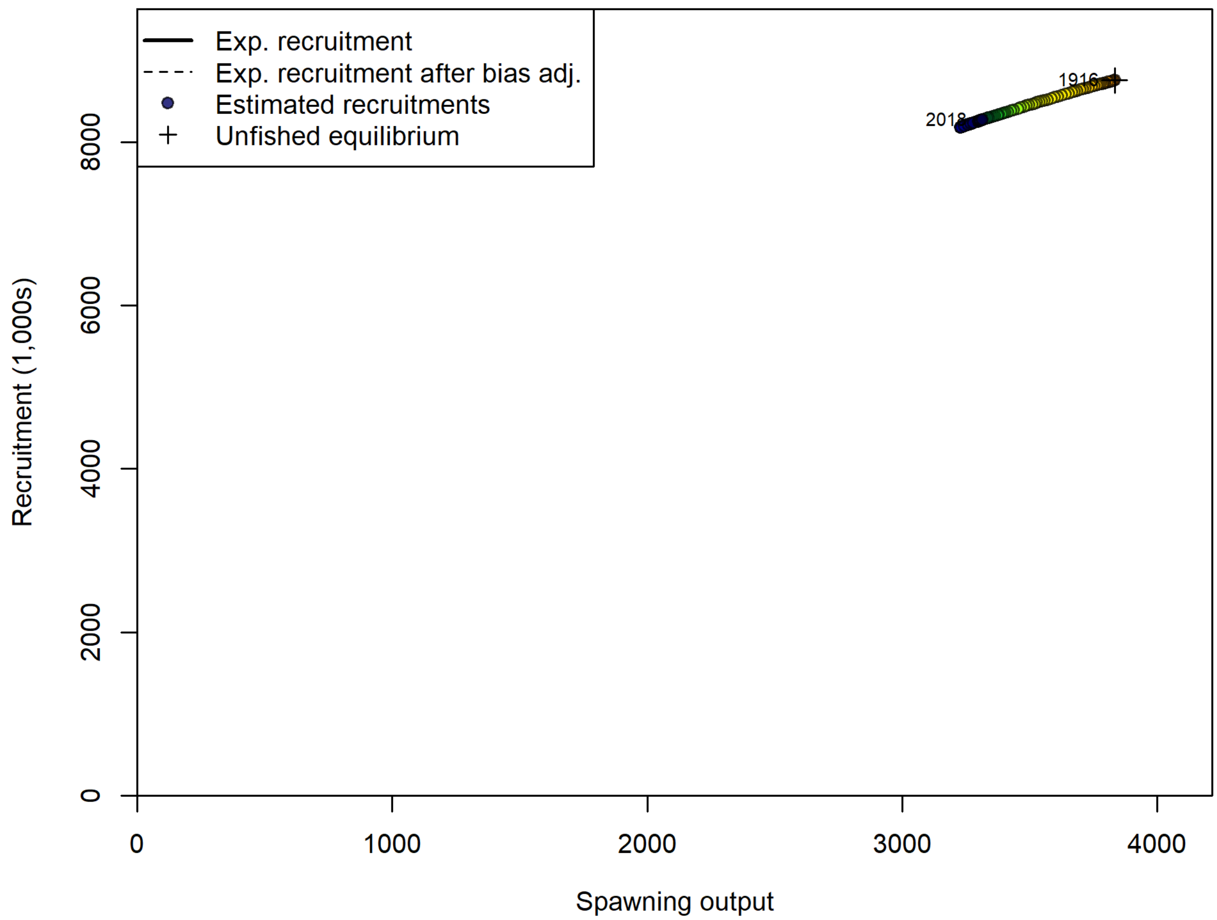



Figure 6: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for Big Skate. The green line shows the effect of the bias correction for the lognormal distribution. fig:SR_curve2

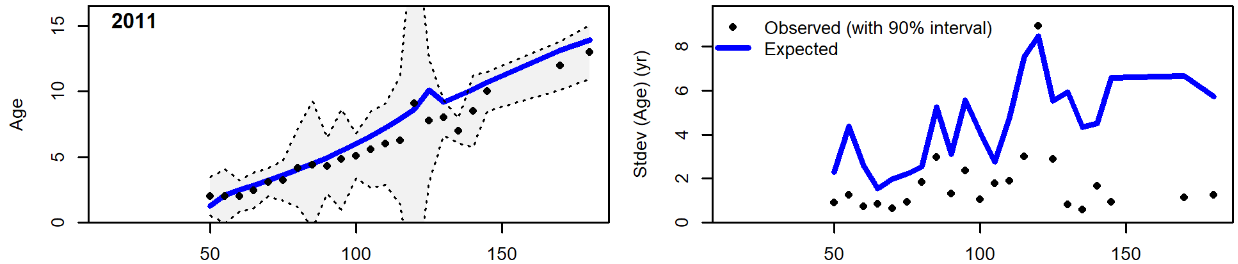



Figure continued from previous page

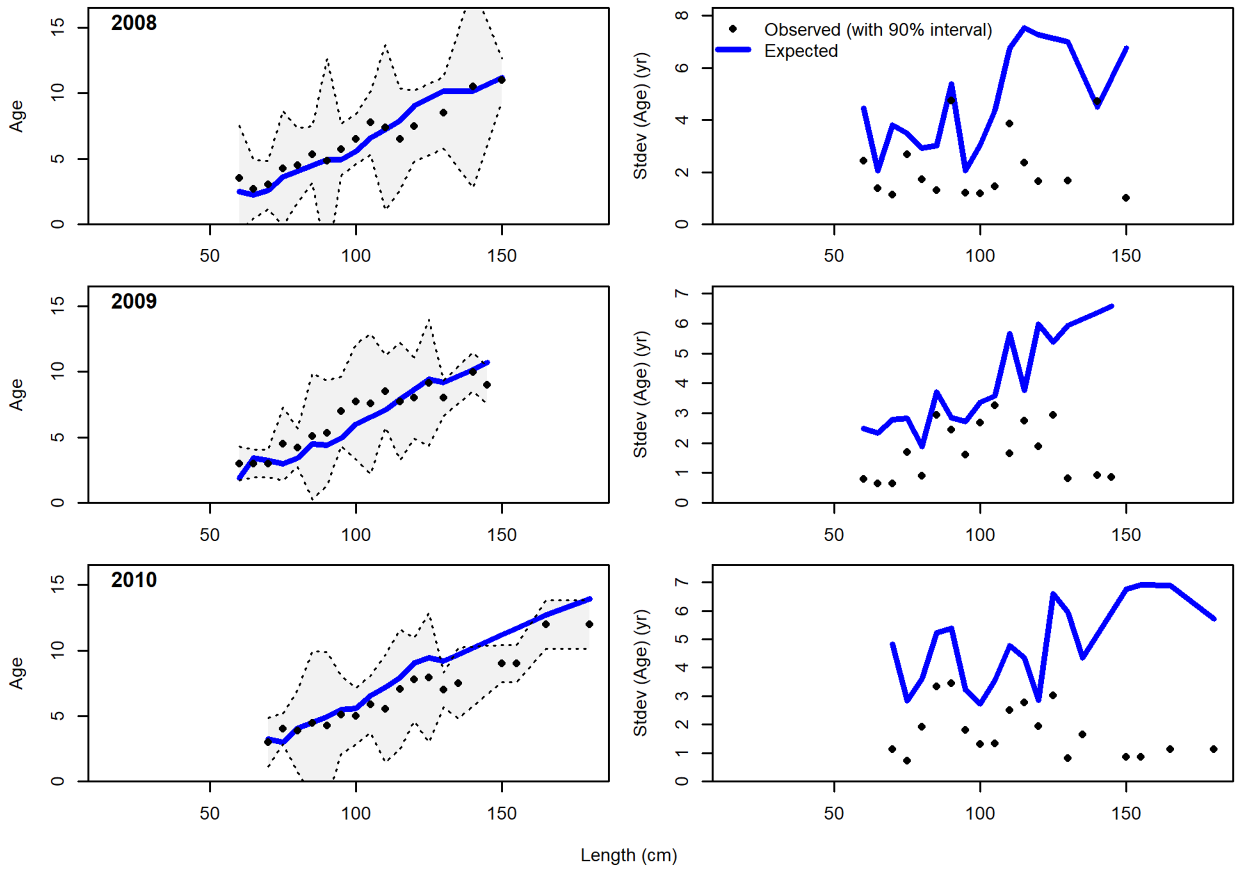



Figure 7: Conditional AAL plot, retained, Fishery_current (plot 1 of 2) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. fig:mod1_4_co

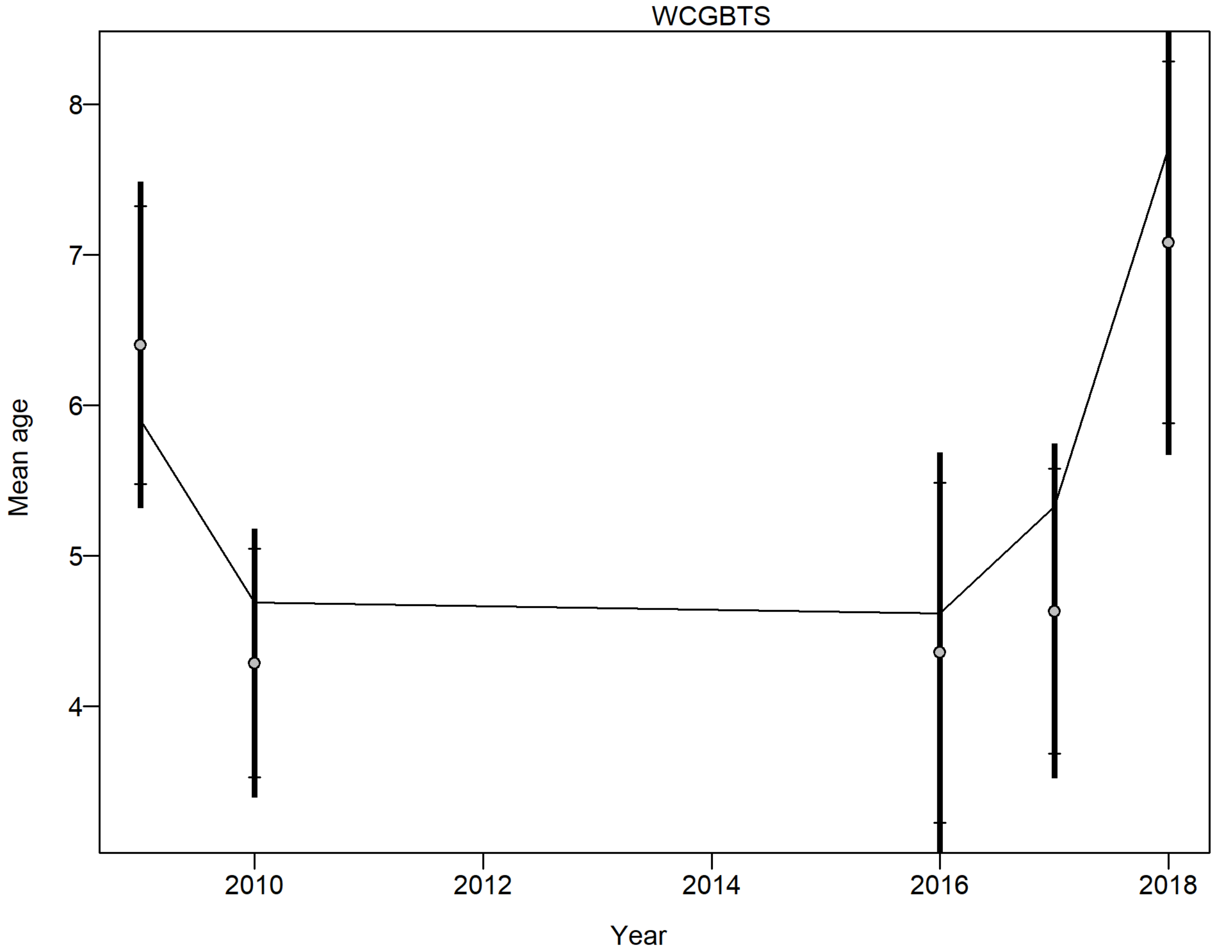



Figure 8: Mean age from conditional data (aggregated across length bins) for WCGBTS with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age_at_length data from WCGBTS: 1.3806 (0.8289_39.92) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_6_com

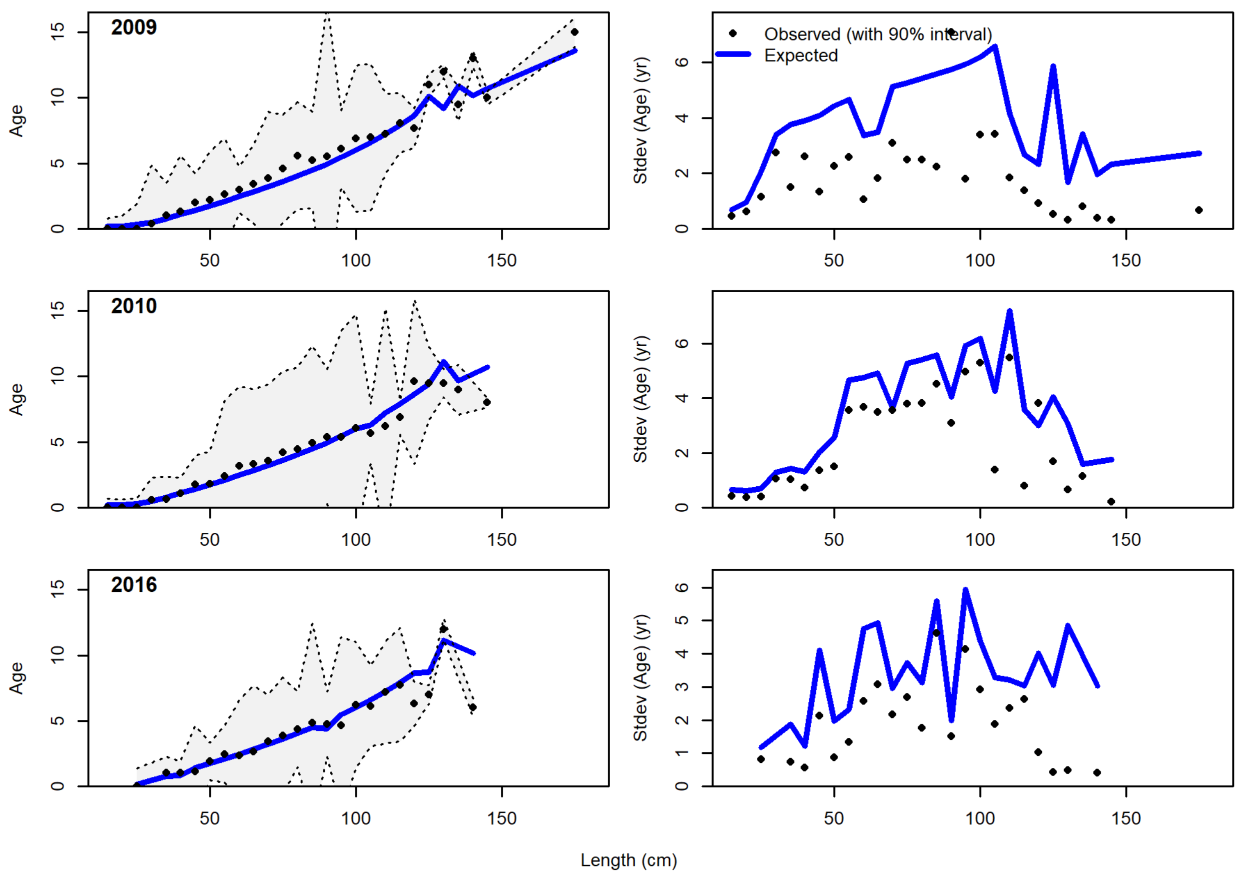
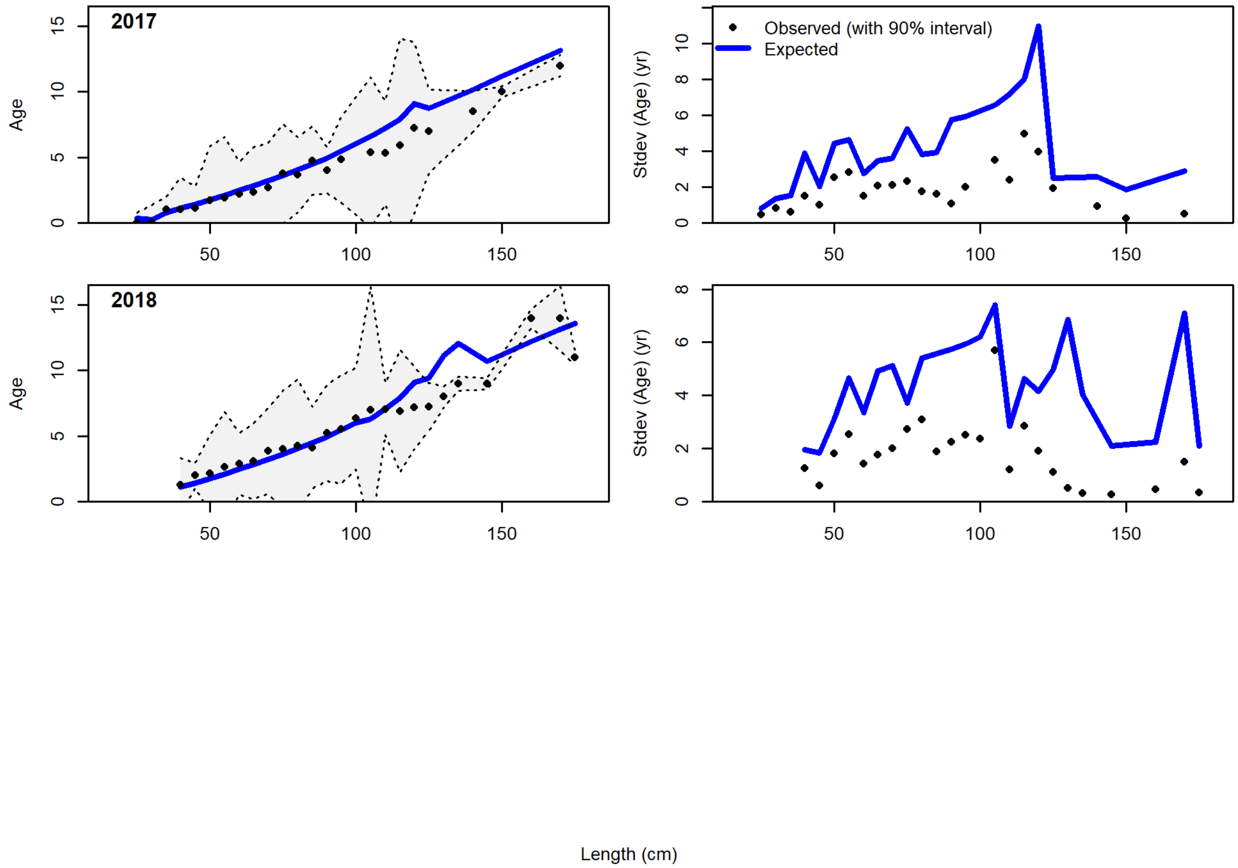



Figure 9: Conditional AAL plot, whole catch, WCGBTS (plot 1 of 2) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. fig:mod1_7_co

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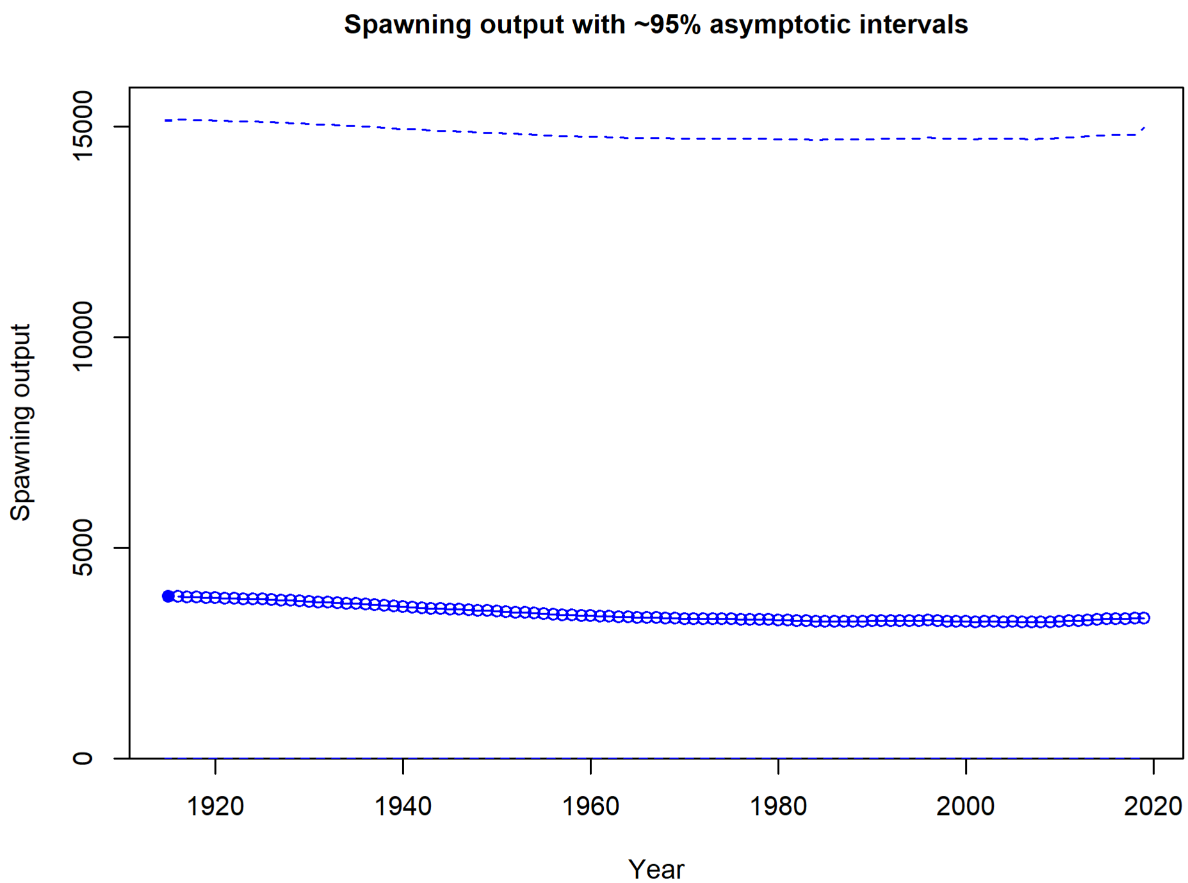


Figure 10: Estimated spawning biomass (mt) with approximate 95% asymptotic intervals. fig:ts7_Spawn

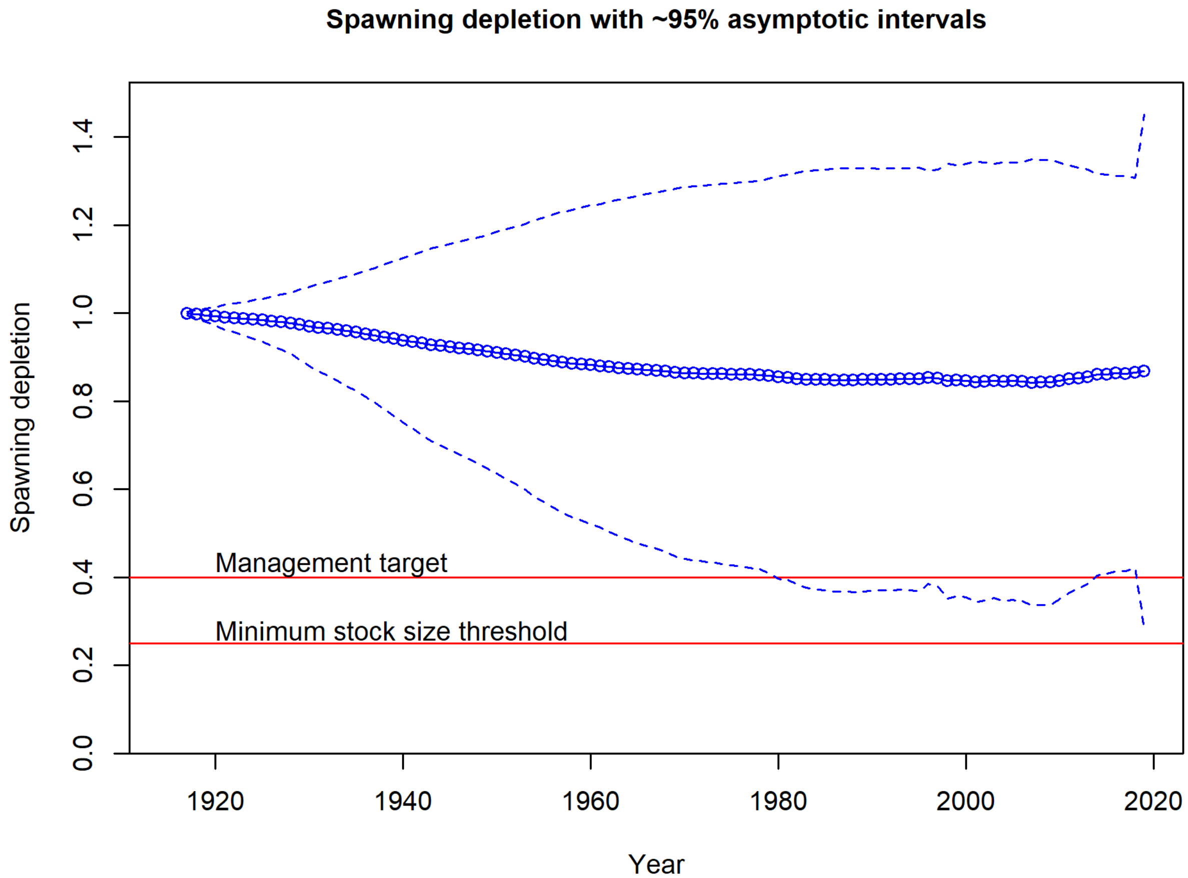


Figure 11: Estimated spawning depletion with approximate 95% asymptotic intervals. fig:ts9_Spawnin

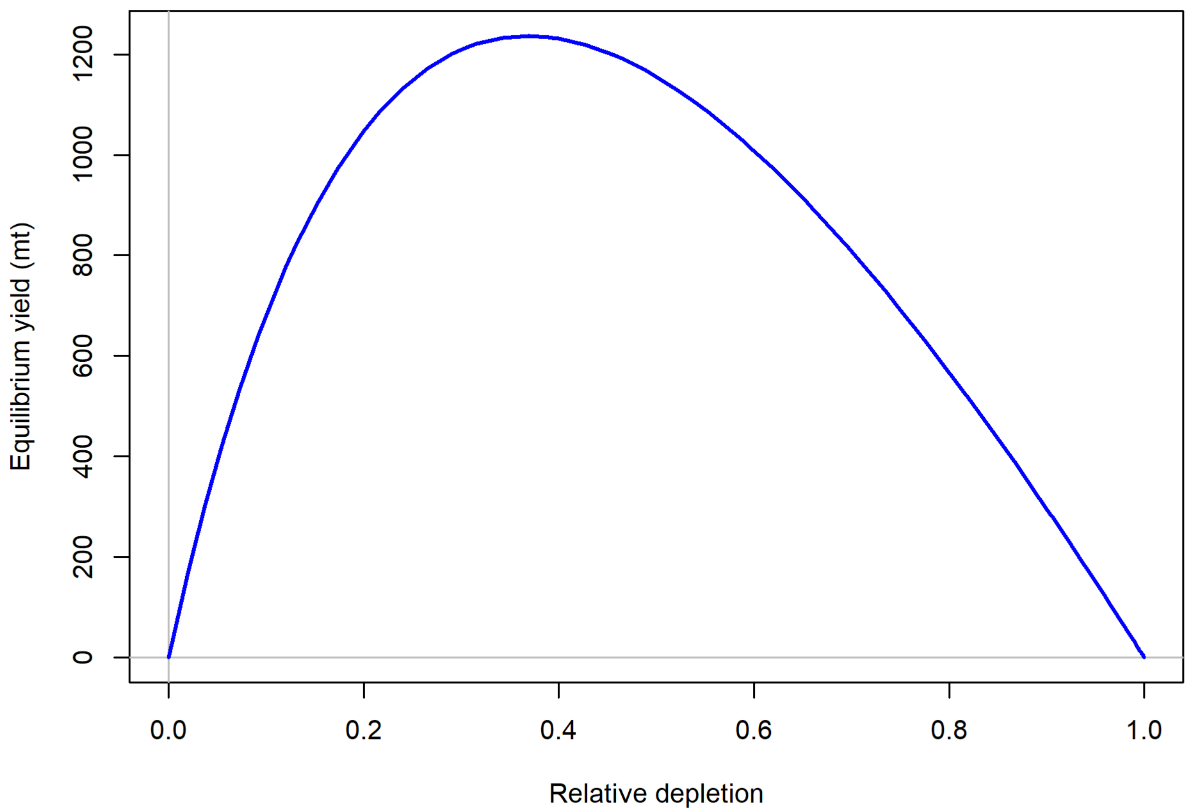


Figure 12: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. fig:yield1_yield_curve

#Appendix A. Detailed fits to length composition data {-}

#References{-}


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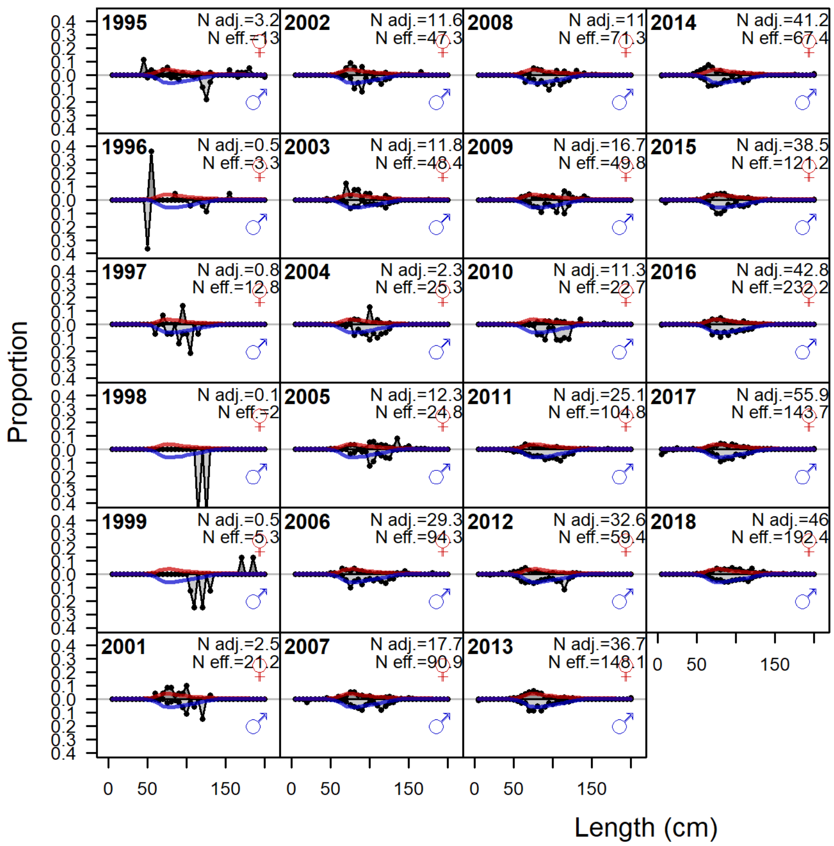

Figure A13: Length comps, retained, Fishery_current. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_1_comp_lenfit_flt1mkt2

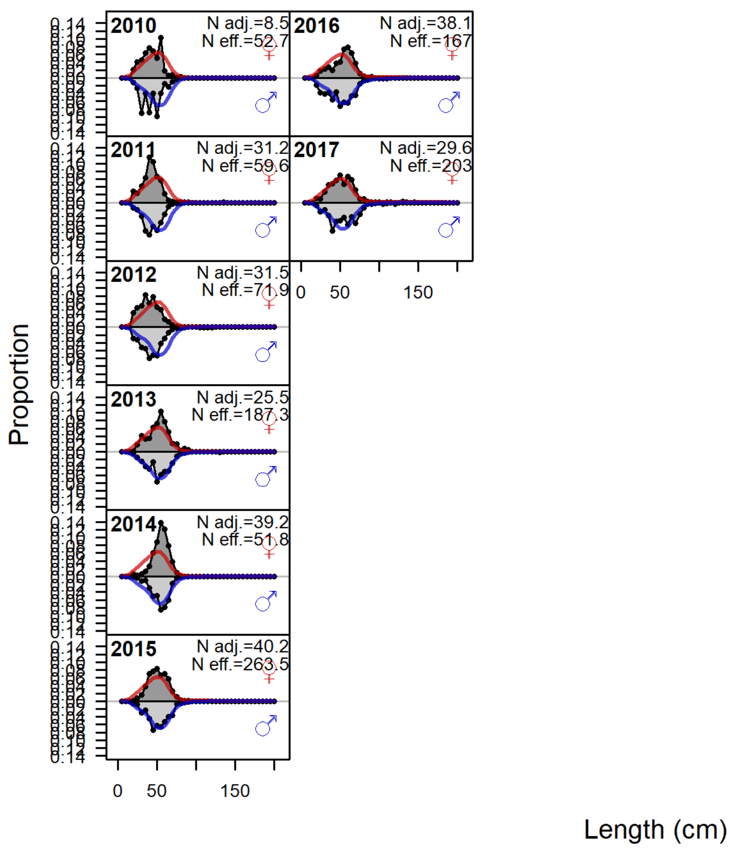


Figure A14: Length comps, discard, Fishery_current. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_2_comp_lenfit_flt1mkt1

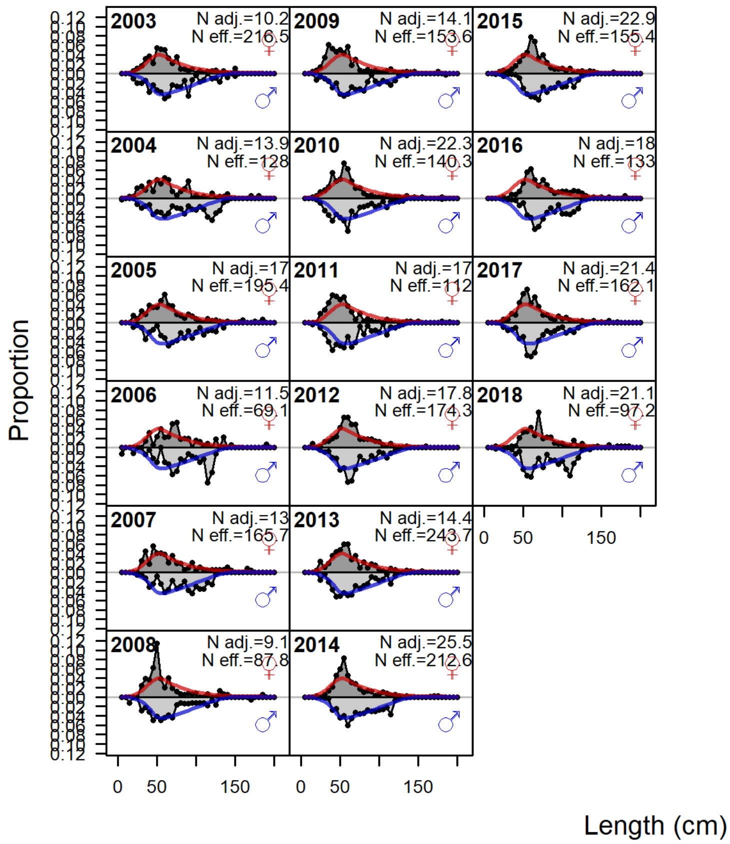


Figure A15: Length comps, whole catch, WCGBTS. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_3_comp_lenfit_flt5mkt0

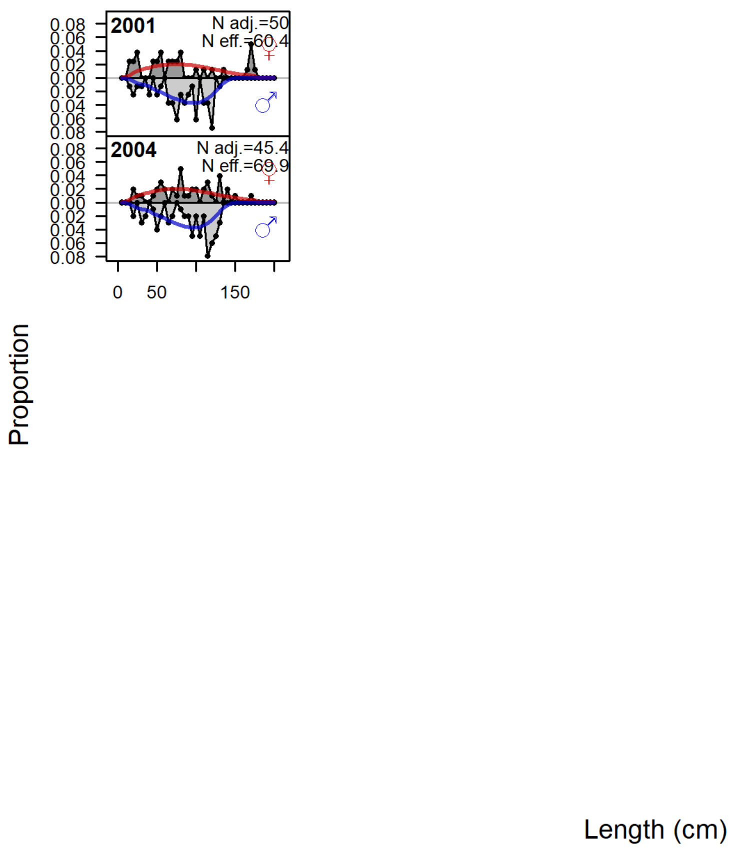


Figure A16: Length comps, whole catch, Triennial. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_4_comp_lenfit_flt6mkt0

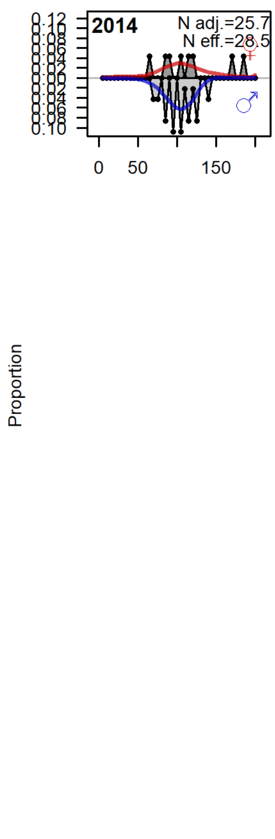


Figure A17: Length comps, retained, IPHC. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_5_comp_lenfit_flt7mkt2