Redtail Surfperch Recreational Fishery in Northern California

Operating Model Report

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Introduction

This report describes the parameters used in the base operating model for an MSE of the recreational Redtail Surfperch (Amphistichus rhodoterus) fishery. While some fishery independent sampling of individuals for length compositions and life history information has occurred for this species, no population estimates or formal assessments have been conducted. Parameter estimates were based on published estimates or CDFW data as reported in the 2019 Enhanced Status Report whenever possible, and expert judgement when no estimates were available. The number of simulations for a final model run (nsim) was set at 300 and fishing was projected 50 years to the future (proyears). The management interval tested was 1 year. The maximum instantaneous fishing mortality rate for an age class (maxF) was set at 0.8, which is the default value in the DLMtool. The number of samples for stochastic MPs (reps) was set at 1, and the percentile of the sample of the management recommendation (pstar) used for each stochastic MP was set at 0.5. Note that all length-based parameters are modeled in terms of Fork Length in mm, and so for consistency the custom MPs testing out size-based approaches convert size limits expressed in Total Lengths in inches to the corresponding Fork Length in mm.

Operating Model

The OM rdata file can be downloaded from here

Download and import into R using `myOM <- readRDS('OM.rdata')`

Species Information

Species: *Amphistichus rhodoterus*

Common Name: *Redtail Surfperch*

Management Agency:

Region:

OM Parameters

OM Name: Name of the operating model: OMName

nsim: The number of simulations: 300

proyears: The number of projected years: 50

interval: The assessment interval - how often would you like to update the management system? 3

pstar: The percentile of the sample of the management recommendation for each method: 0.5

maxF: Maximum instantaneous fishing mortality rate that may be simulated for any given age class: 0.8

reps: Number of samples of the management recommendation for each method. Note that when this is set to 1, the mean value of the data inputs is used. 1

Source: A reference to a website or article from which parameters were taken to define the operating model

Kat Meyer

Stock Parameters

Mortality and age: maxage, R0, M, Msd

maxage: The maximum age of individuals that is simulated. There are maxage+1 (recruitment to age-0) age classes in the storage matrices. maxage is the plus group where all age-classes > maxage are grouped, unless option switched off with OM@cpars$plusgroup=0 . Single value. Positive integer.

Specified Value(s): 16

The maximum observed age for surfperch was 14 years. However, most individuals live around 10 yr (Baltz 1983, Carlisle and others 1960, Bennett and Wydoski 1977). The maximum age in the OM was set to 16 to allow exploration of a range of natural mortality values.

R0: Initial number of unfished recruits to age-0. This number is used to scale the size of the population to match catch or data, but does not affect any of the population dynamics unless the OM has been conditioned with data. As a result, for a data-limited fishery any number can be used for R0 . In data-rich stocks R0 may be estimated as part of a stock assessment, but for data limited stocks users can choose either an arbitrary number (say, 1000) or choose a number that produces simulated catches in recent historical years that are similar to real world catch data. Single value. Positive real number.

Specified Value(s): 1e+05

In the absence of a stock assessment, there is currently no estimate for the unfished number of recruits (R0). It is used as a scaling parameter in the DLMtool, so the starting number of recruits does not affect the results of the model, and it was set arbitrarily at 100,000.

M: The instantaneous rate of natural mortality. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0.29, 0.44

Natural mortality has never been directly estimated for Redtail Surfperch, but several empirical estimators were applied to life history parameters for the species. The distribution of natural mortality rates included in the model reflect the wide range of empirically-derived estimates from multiple methods (Alverson and Carney 1985, Hoenig 1983, Pauly 1980, Then et al 2015). Based on these methods we assumed that natural mortality ranges between 0.29 and 0.44.

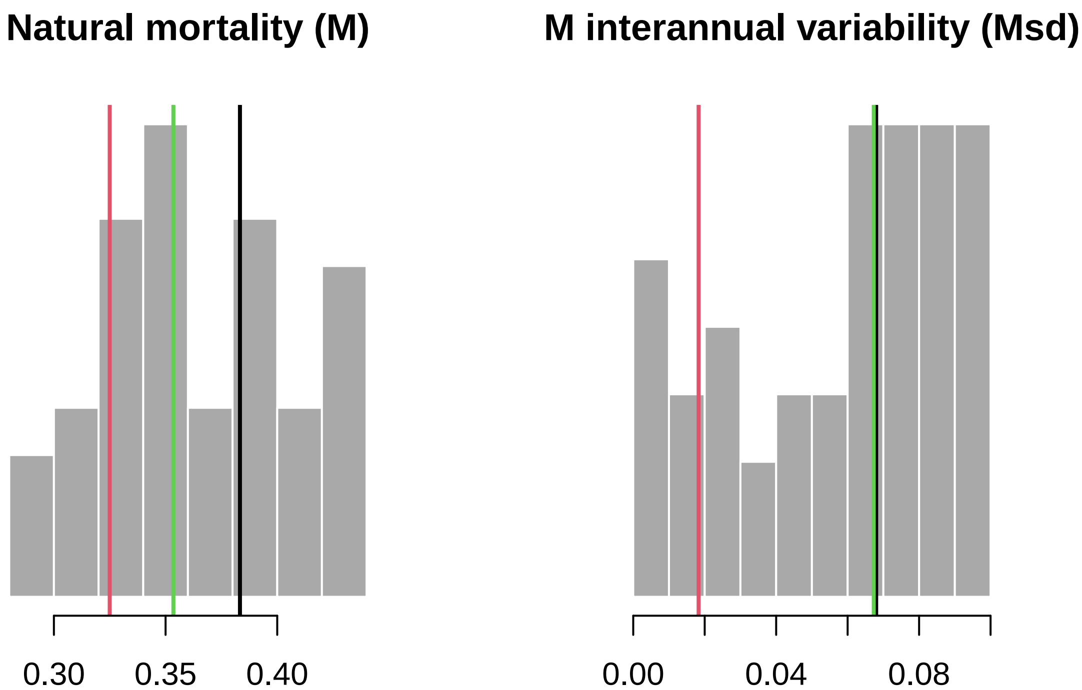
Msd: Inter-annual variation in M expressed as a coefficient of variation of a log-normal distribution. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter is positive, yearly M is drawn from a log-normal distribution with a mean specified by log(M) drawn for that simulation and a standard deviation in log space specified by the value of Msd drawn for that simulation. Uniform distribution lower and upper bounds. Non-negative real numbers

Specified Value(s): 0, 0.1

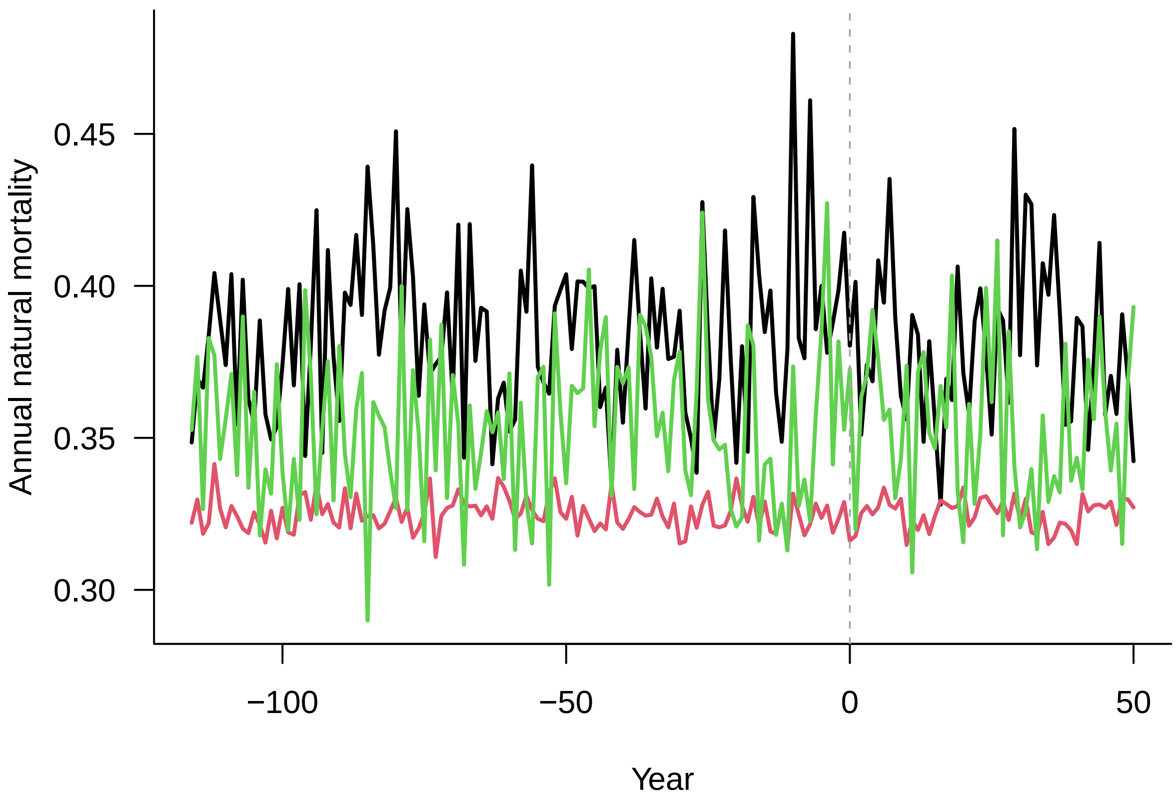
A relatively low inter-annual variability in M was specified in the model.

Natural Mortality Parameters

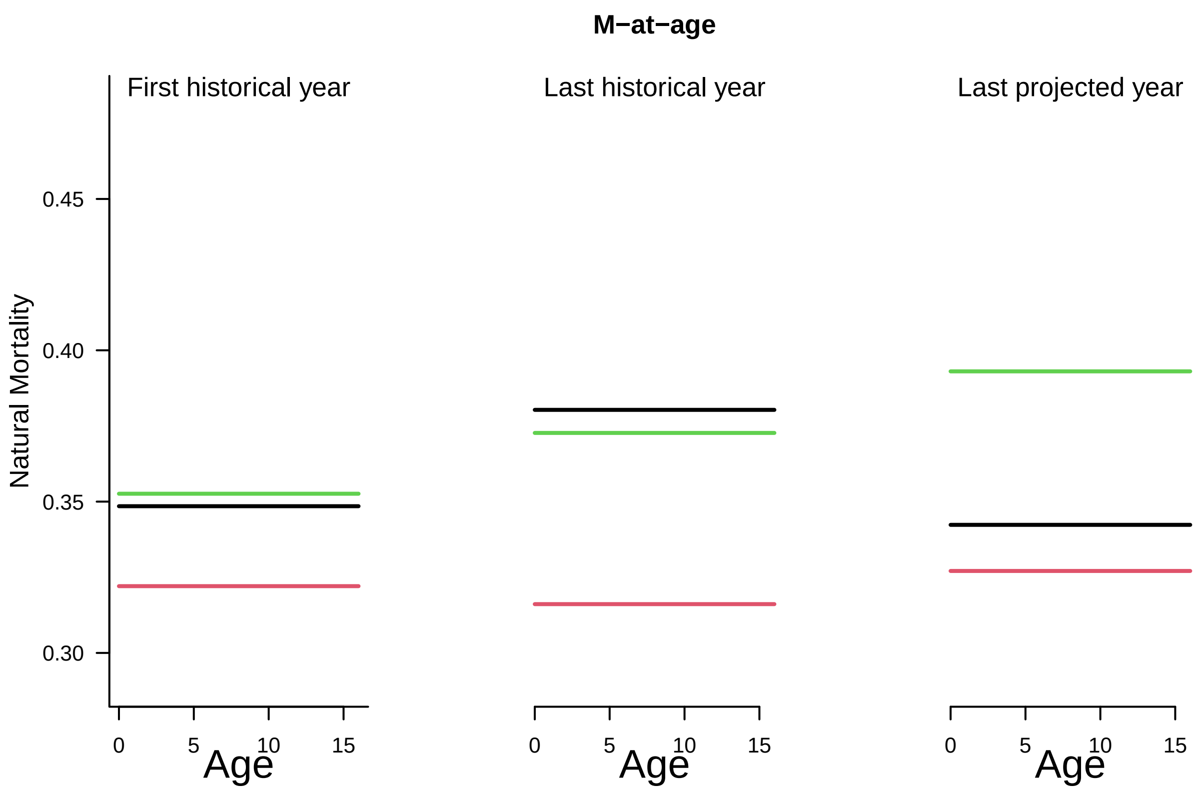
Sampled Parameters Histograms of simulations of `M`, and `Msd` parameters, with vertical colored lines indicating 3 randomly drawn values used in other plots:



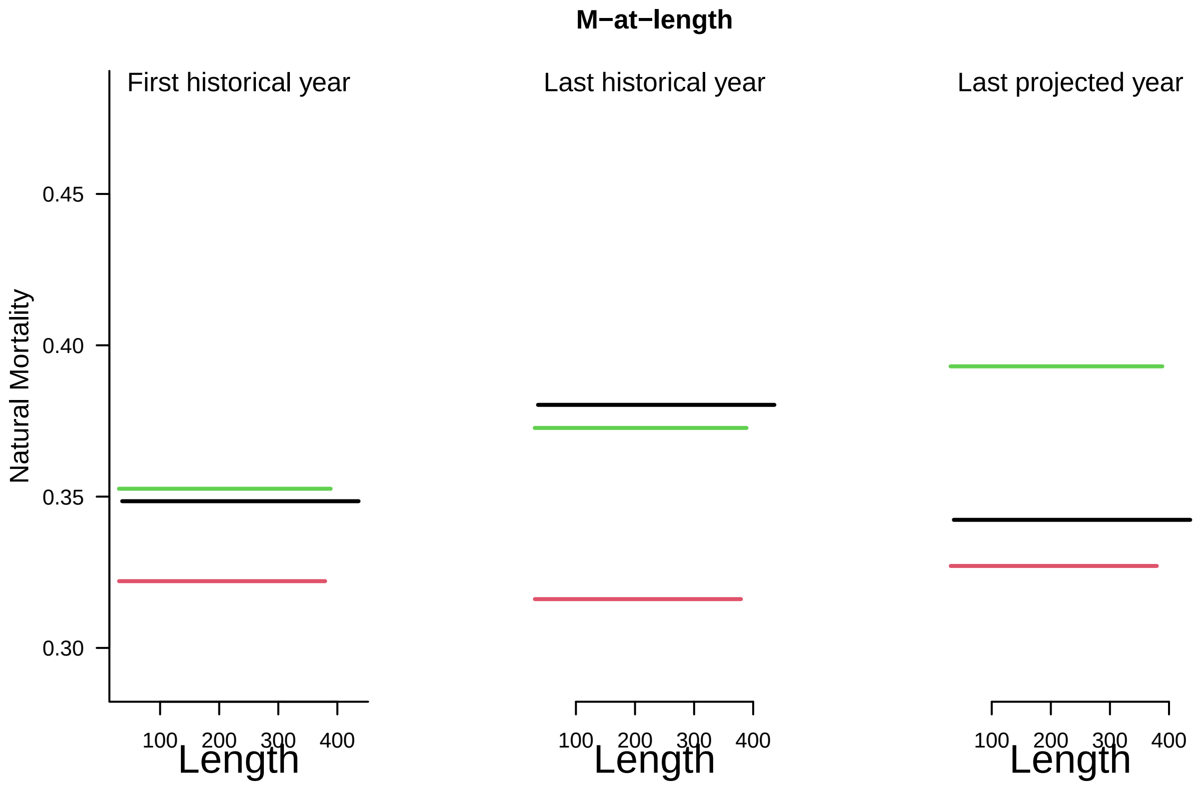
Time-Series The average natural mortality rate by year for adult fish for 3 simulations. The vertical dashed line indicates the end of the historical period:



M-at-Age Natural mortality-at-age for 3 simulations in the first historical year, the last historical year (i.e., current year), and the last projected year:



M-at-Length Natural mortality-at-length for 3 simulations in the first historical year, the last historical year (i.e., current year), and the last projected year:



Recruitment: h, SRrel, Perr, AC

h: Steepness of the stock recruit relationship. Steepness governs the proportion of unfished recruits produced when the stock is at 20% of the unfished population size. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years of a given simulation. Uniform distribution lower and upper bounds. Values from 1/5 to 1.

Specified Value(s): 0.2, 0.5

Like other species in the family Embiotocidae, Redtail Surfperch are viviparous, giving birth to fully developed juveniles during the summer months in nearshore aggregrations. Mating for most species initiates in the fall, and females store the sperm for a few months until the eggs are ready for fertilization (Triplett 1960, Carlisle and others 1960, Bennett and Wydoski 1977, Brookins 1995, Department unpublished data). The number of young produced is approximately proportional to the size of the female, and so we assumed low steepness values for this stock. Redtail Surfperch produce a maximum number of 51 embryos (Baltz 1983, Bennett and Wydoski 1977, Ngoile 1978, Department unpublished data). Surfperch newborns are fully developed and free swimming, ranging in size from 2 to 3 in. (3.8 to 7.6 cm).

SRrel: Type of stock-recruit relationship. Use 1 to select a Beverton Holt relationship, 2 to select a Ricker relationship. Single value. Integer

Specified Value(s): 1

There is no information on Redtail Surfperch stock recruitment relationships. Because surfperch bear a relatively small number of live young, we assumed a Beverton Holt relationship with a low steepness, resulting in a more linear relationship between the adult spawning biomass and the number of young produced.

Perr: Recruitment process error, which is defined as the standard deviation of the recruitment deviations in log space. For each simulation a single value is drawn from a uniform distribution specified by the upper

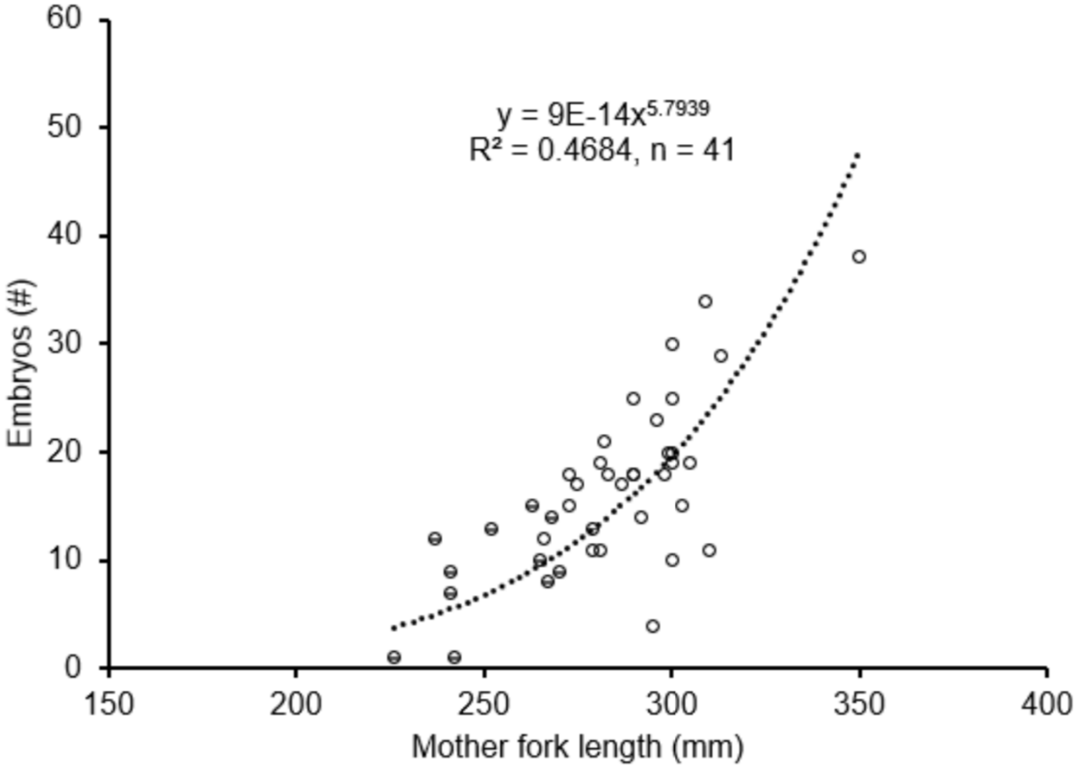


Figure 1: Redtail Surfperch fecundity: number of embryos versus mother fork length (mm) (Reproduced from CDFW 2019)

and lower bounds provided. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0.1, 0.3

There is no information on how recruitment success varies from year to year. However, given the relatively substantial parental investment to bear live young, recruitment may be more stable from year to year than in broadcast spawning species where juvenile survival can be heavily influenced by environmental conditions.

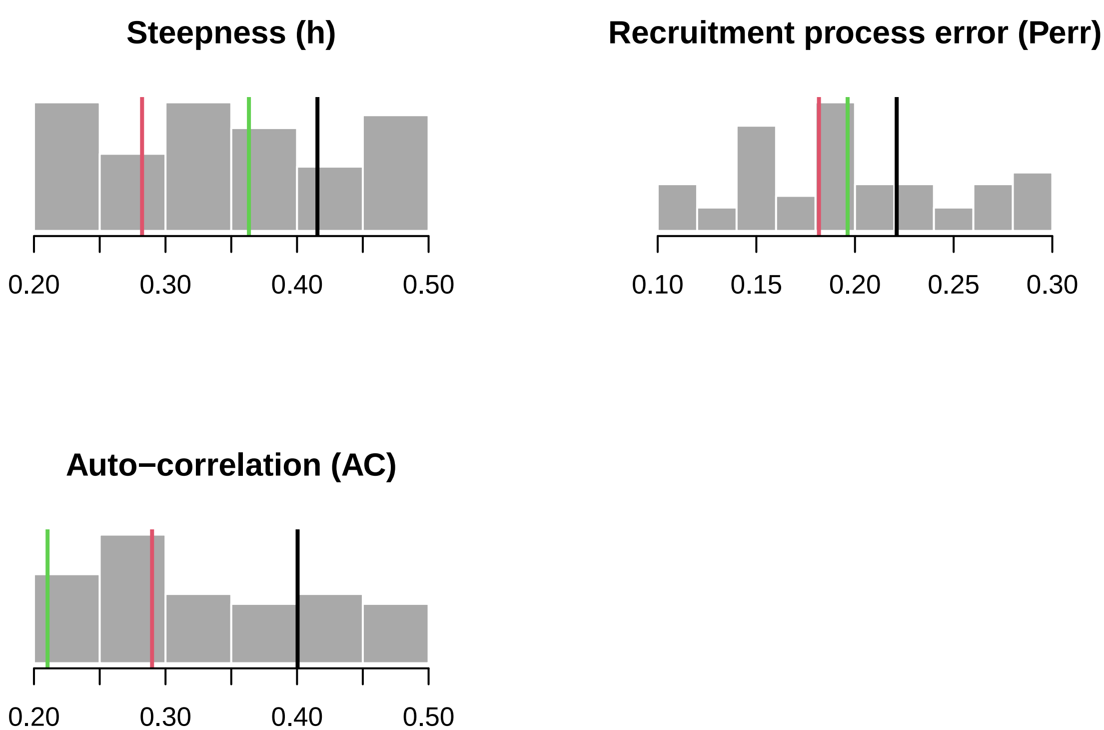
AC: Autocorrelation in the recruitment deviations in log space. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided, and used to add lag-1 auto-correlation to the log recruitment deviations. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0.2, 0.5

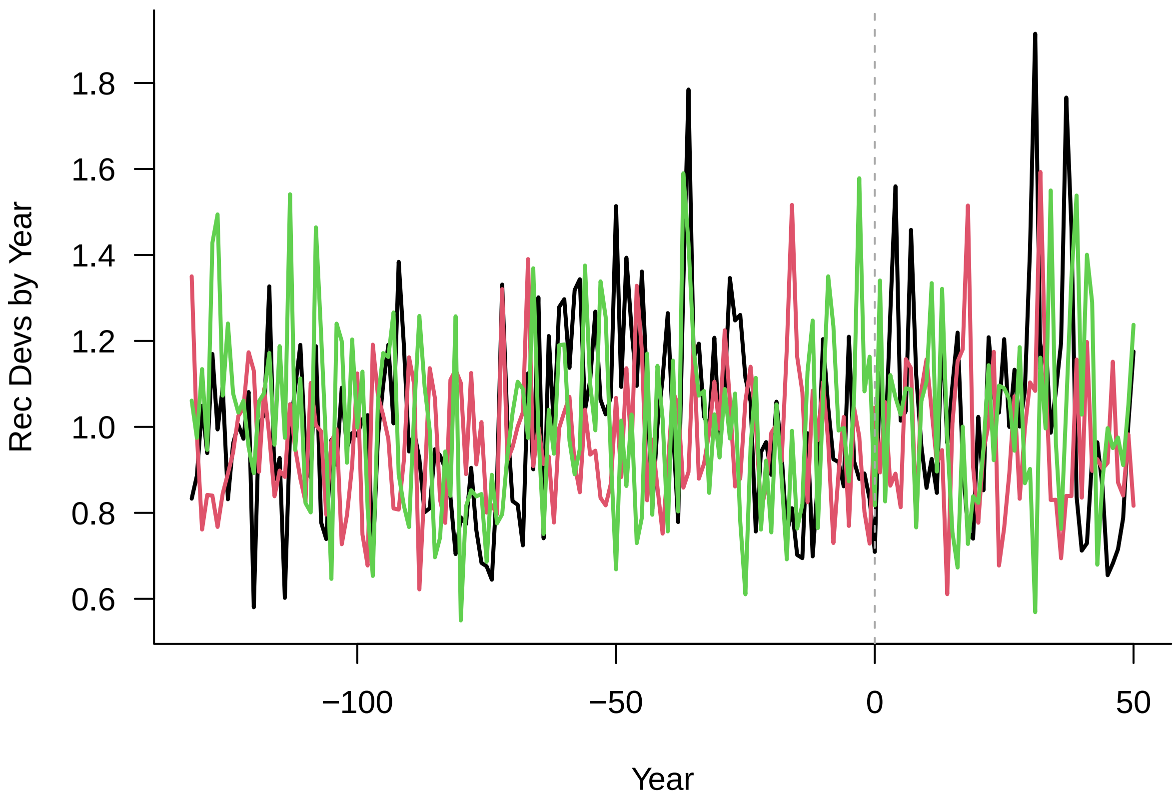
There is no information on autocorrelation in recruitment. However, given the fact that young are born live, stock sizes may be more influenced by the number of adults in the population than by environmental conditions.

Recruitment Parameters

Sampled Parameters Histograms of 48 simulations of steepness (`h`), recruitment process error (`Perr`) and auto-correlation (`AC`) for the Beverton-Holt stock-recruitment relationship, with vertical colored lines indicating 3 randomly drawn values used in other plots:



Time-Series Time-series plot showing 3 samples of recruitment deviations for historical and projection years:



Growth: Linf, K, t0, LenCV, Ksd, Linfsd

Linf: The von Bertalanffy growth parameter Linf, which specifies the average maximum size that would reached by adult fish if they lived indefinitely. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless Linfsd is a positive number. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 396.9, 485.1

There is a slight difference between male and female growth rates, with females reaching slightly larger maximum sizes. However, these differences are fairly minimal, and a sex-specific model is not necessary. The von Bertalanffy growth parameters were estimated by fitting to age-length data collected by CDFW during fishery independent sampling, and the Linf was estimated to be 441.9 mm Fork Length, k was estimated to be 0.18, and t0 was estimated to be -0.44.

K: The von Bertalanffy growth parameter k, which specifies the average rate of growth. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless Ksd is a positive number. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 0.16, 0.2

No justification provided.

t0: The von Bertalanffy growth parameter t0, which specifies the theoretical age at a size 0. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Uniform distribution lower and upper bounds. Non-positive real numbers.

Specified Value(s): -0.48, -0.4

No justification provided.

LenCV: The coefficient of variation (defined as the standard deviation divided by mean) of the length-at-age. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided to specify the distribution of observed length-at-age, and the CV of this distribution is constant for all age classes (i.e, standard deviation increases proportionally with the mean). Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 0.08, 0.15

Based on the observed variability in the length at age we modeled a CV between 8 and 15%.

Ksd: Inter-annual variation in K. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter has a positive value, yearly K is drawn from a log-normal distribution with a mean specified by the value of K drawn for that simulation and a standard deviation (in log space) specified by the value of Ksd drawn for that simulation. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0, 0

Not used

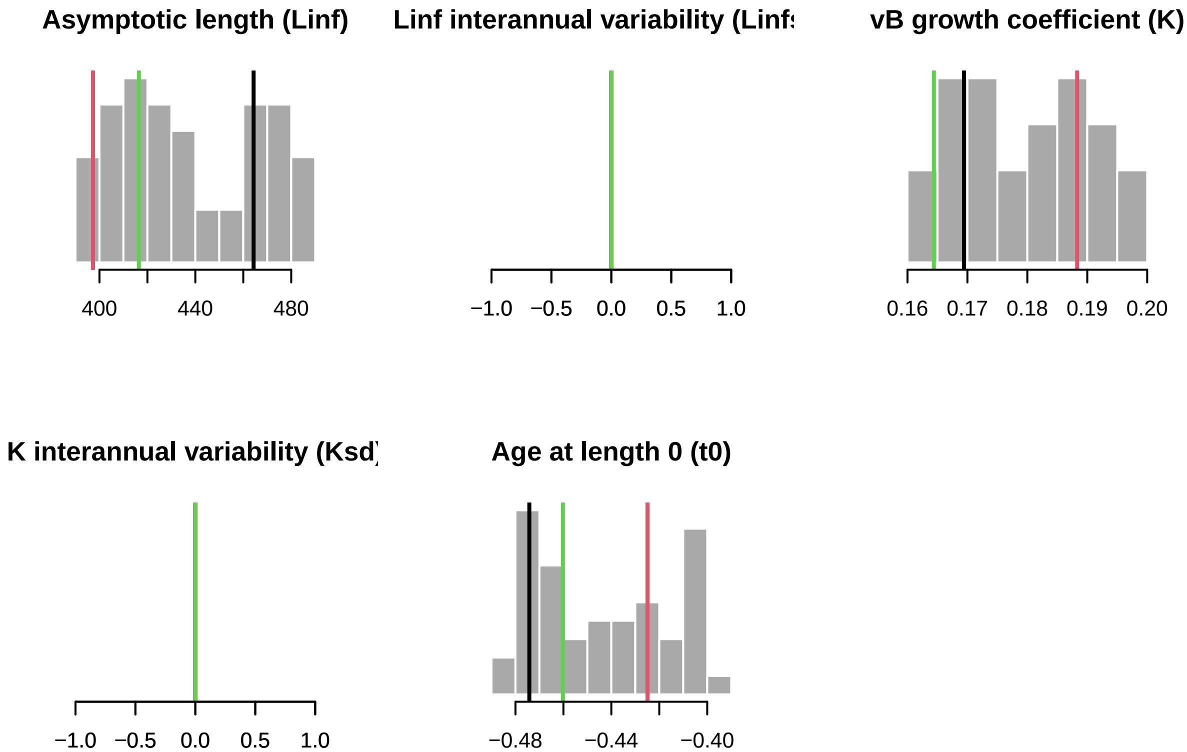
Linfsd: Inter-annual variation in Linf. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter has a positive value, yearly Linf is drawn from a log-normal distribution with a mean specified by the value of Linf drawn for that simulation and a standard deviation (in log space) specified by the value of Linfsd drawn for that simulation. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0, 0

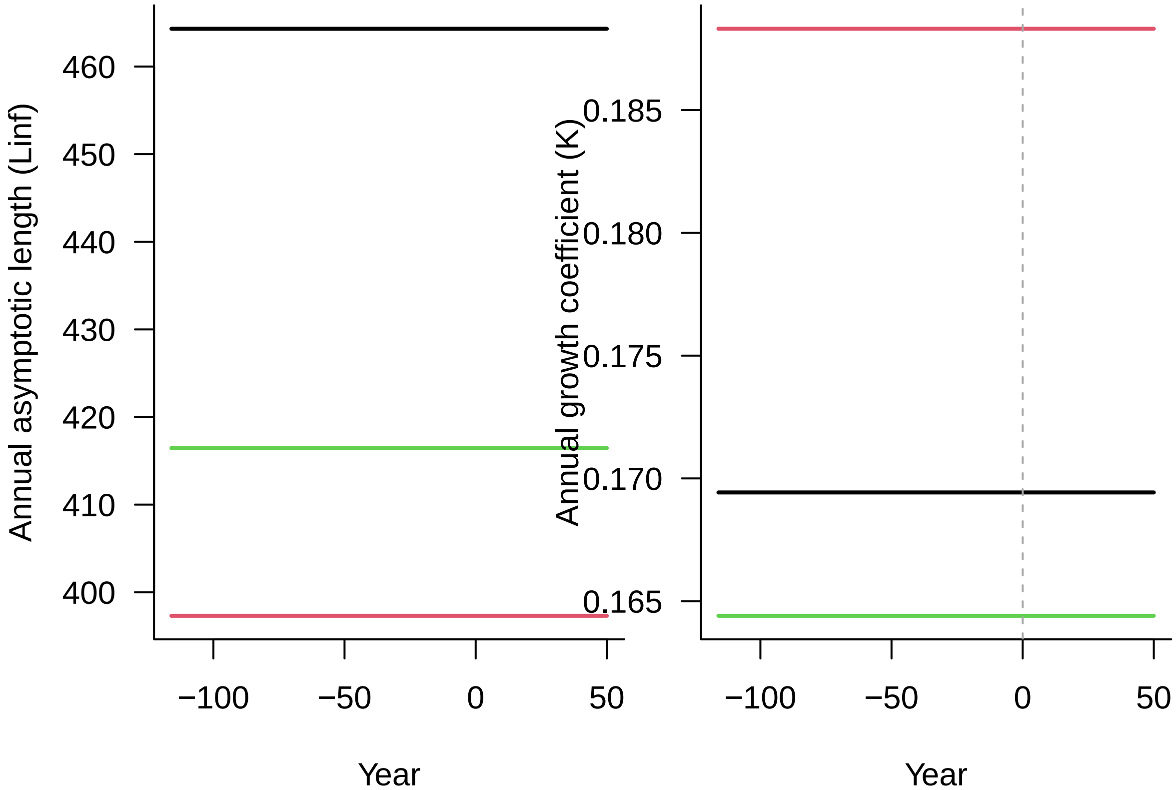
Not used.

Growth Parameters

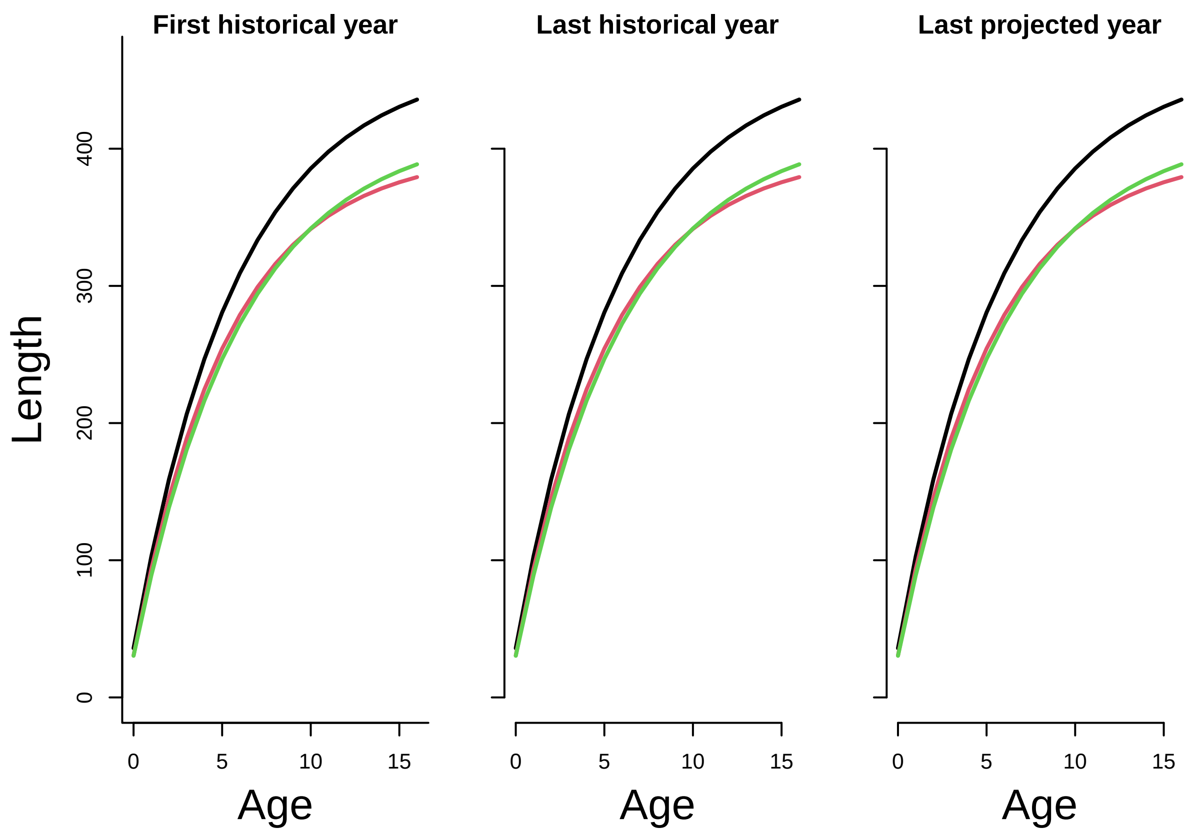
Sampled Parameters Histograms of simulations of von Bertalanffy growth parameters `Linf`, `K`, and `t0`, and inter-annual variability in Linf and K (`Linfsd` and `Ksd`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



Time-Series The Linf and K parameters in each year for 3 simulations. The vertical dashed line indicates the end of the historical period:



Growth Curves Sampled length-at-age curves for 3 simulations in the first historical year, the last historical year, and the last projection year.



Maturity: L50, L50_95

L50: Length at 50% maturity. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. The L50 and L50_95 parameters are converted to ages using the growth parameters provided and used to construct a logistic curve to determine the proportion of the population that is mature in each age class. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 217.55, 240.45

Bennett and Wydoski (1977) determined that 70% of 2-yr old male Redtail Surfperch were mature. Ngoile (1978) determined that approximately 17% of 3-yr-old females and 88% of 4-yr-old females were mature. These estimates correspond to a size at 50% maturity of 229 mm and a size at 95% maturity of 241 mm. Length at maturity was recently assessed using CDFW data for Redtail Surfperch by replicating the methods presented in Bennett and Wydoski (1977). Department staff estimated larger sizes at first maturity, with a size at 50% maturity of 259 mm and a size at 95% maturity of 293 mm. This is attributed to latitudinal differences between this study and the Bennett and Wydoski (1977) study, but introduces a major source of uncertainty for this analysis. We decided to use the published estimates in the base model but included the CDFW estimates as a robustness scenario.

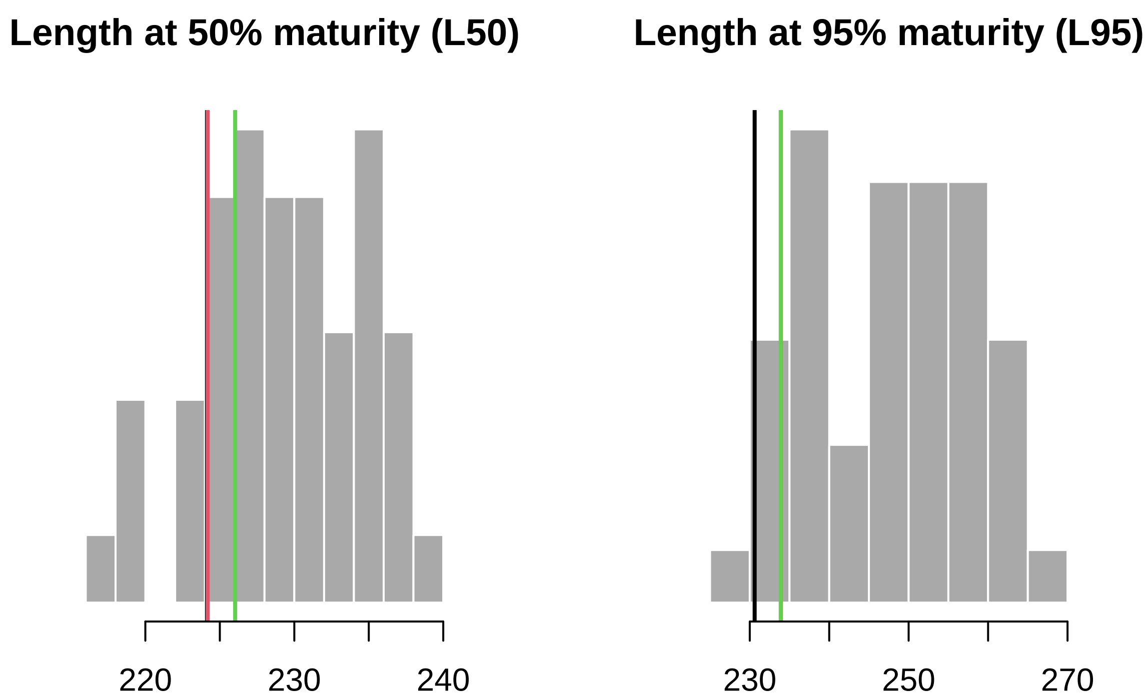
L50_95: Difference in lengths between 50% and 95% maturity. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. The value drawn is then added to the length at 50% maturity to determine the length at 95% maturity. This parameterization is used instead of specifying the size at 95 percent maturity to avoid situations where the value drawn for the size at 95% maturity is smaller than that at 50% maturity. The L50 and L50_95 parameters are converted to ages using the growth parameters provided and used to construct a logistic curve to determine the proportion of the population that is mature in each age class. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 5, 30

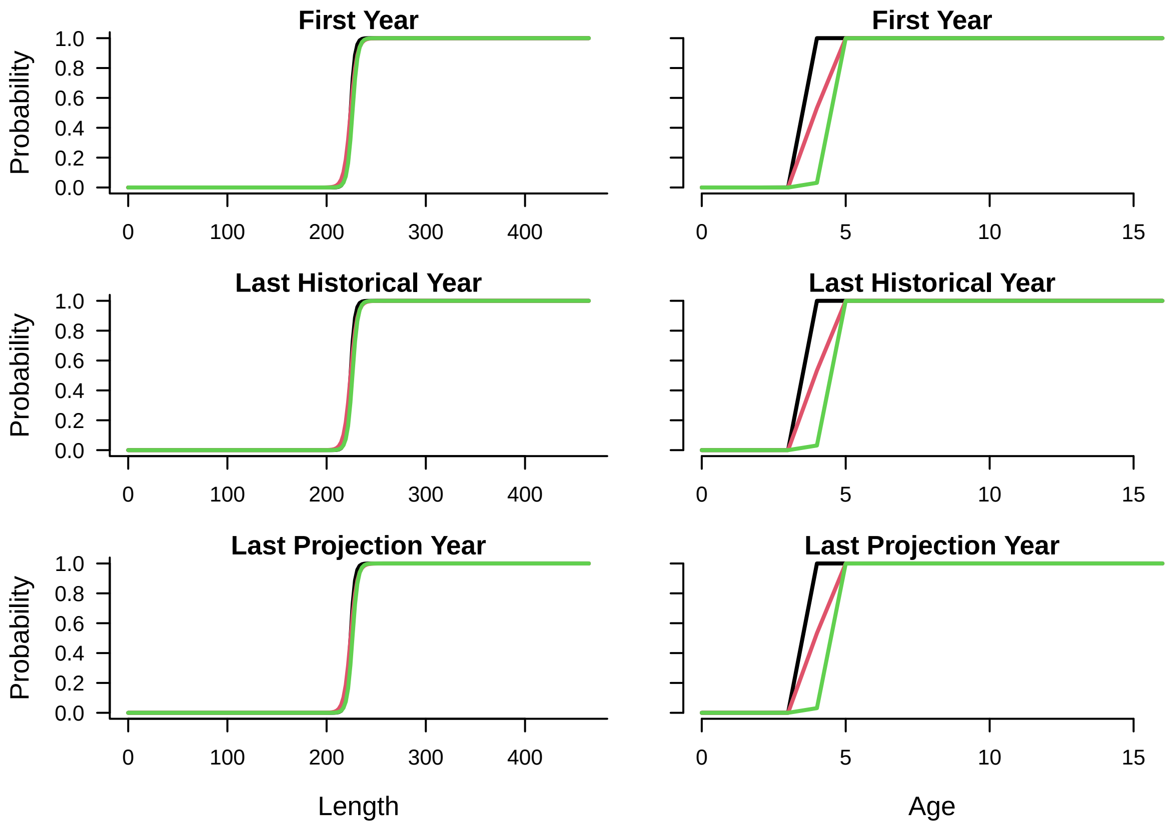
No justification provided.

Maturity Parameters

Sampled Parameters Histograms of simulations of `L50` (length at 50% maturity), and `L95` (length at 95% maturity), with vertical colored lines indicating 3 randomly drawn values used in other plots:



Maturity at Age and Length Maturity-at-age and -length for 3 simulations in the first historical year, the last historical year (i.e., current year), and the last projected year:



Stock depletion and Discard Mortality: D, Fdisc

D: Estimated current level of stock depletion, which is defined as the current spawning stock biomass divided by the unfished spawning stock biomass. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This parameter is used during model initialization to select a series of yearly historical recruitment values and fishing mortality rates that, based on the information provided, could have resulted in the specified depletion level in the simulated last historical year. Uniform distribution lower and upper bounds. Positive real numbers (typically < 1)

Specified Value(s): 0.3, 0.4

Depletion is also unknown for this stock, and there have been no formal assessments of the status of the stock. As a proxy for current depletion we fit the Length-Based Spawning Potential Ratio (LBSPR) model (Hordyk et al. 2015) to length frequency data collected by the California Recreational Fisheries Sampling (CRFS) Program and found that the SPR has hovered between 30 and 40% of unfished SPR over the last 5 years.

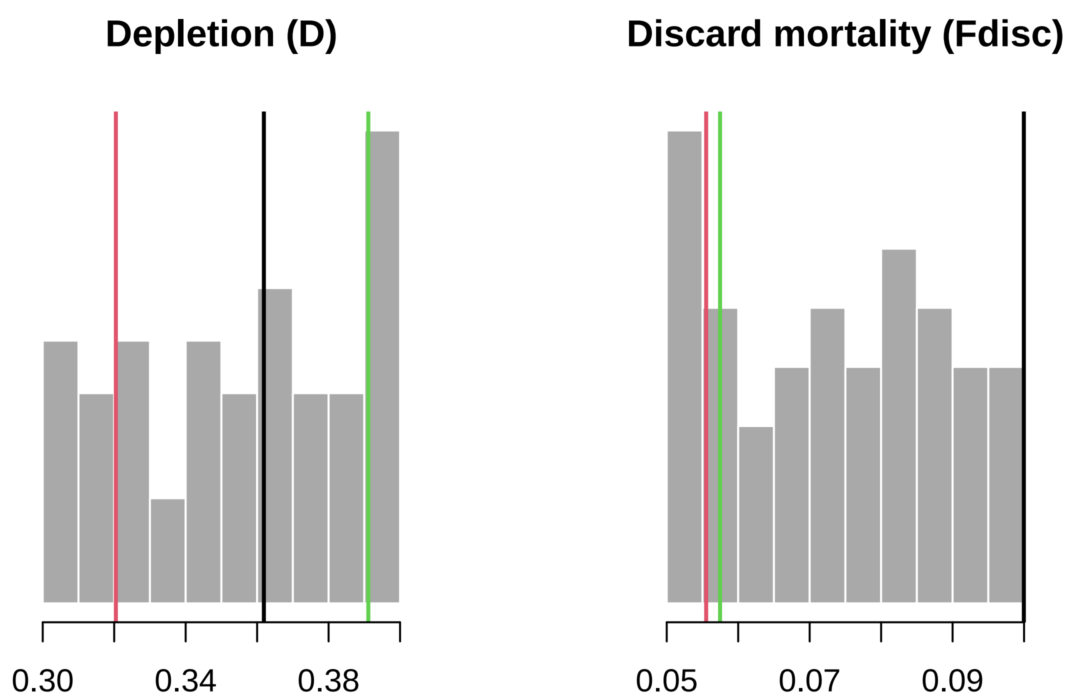
Fdisc: The instantaneous discard mortality rate the stock experiences when fished using the gear type specified in the corresponding fleet object and discarded. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Uniform distribution lower and upper bounds. Non-negative real numbers.

Specified Value(s): 0.05, 0.1

We assumed that discard mortality rates are similar to other hook and line fisheries.

Depletion and Discard Mortality

Sampled Parameters Histograms of simulations of depletion (spawning biomass in the last historical year over average unfished spawning biomass; `D`) and the fraction of discarded fish that are killed by fishing mortality (`Fdisc`), with vertical colored lines indicating 3 randomly drawn values.



Length-weight conversion parameters: a, b

a: The alpha parameter in allometric length-weight relationship. Single value. Weight parameters are used to determine catch-at-age and population-at-age from the number of individuals in each age class and the length of each individual, which is drawn from a normal distribution determined by the Linf , K , t0 , and LenCV parameters. As a result, they function as a way to scale between numbers at age and biomass, and are not stochastic parameters. Single value. Positive real number.

Specified Value(s): 0

An exponential model was fit to length and weight data from fish samples collected during CDFW fishery-independent surveys, and these parameters were used to model the length-weight relationship.

b: The beta parameter in allometric length-weight relationship. Single value. Weight parameters are used to determine catch-at-age and population-at-age from the number of individuals in each age class and the length of each individual, which is drawn from a normal distribution determine by the Linf , K , t0 , and LenCV parameters. As a result, they function as a way to scale between numbers at age and biomass, and are not stochastic parameters. Single value. Positive real number.

Specified Value(s): 3.02

No justification provided.

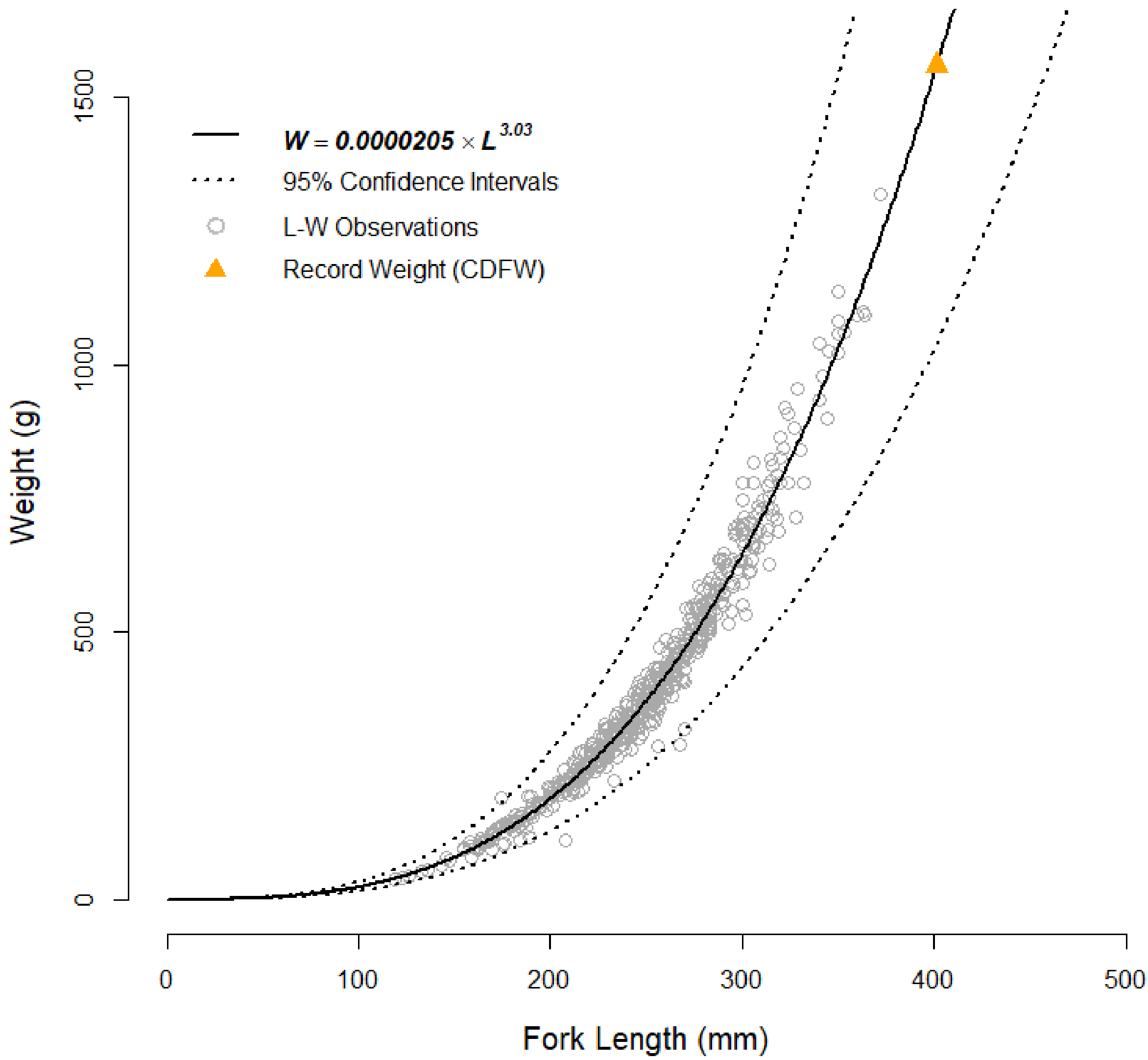


Figure 2: Estimated weight-length relationship for Redtail Surfperch

Spatial distribution and movement: Size_area_1, Frac_area_1, Prob_staying

Size_area_1: The size of area 1 relative to area 2. The fraction of the unfished biomass in area 1. Please specify numbers between 0 and 1. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. For example, if Size_area_1 is 0.2, then 20% of the total area is allocated to area 1. Fishing can occur in both areas, or can be turned off in one area to simulate the effects of a no take marine reserve. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 0.25, 0.35

Redtail Surfperch are a very nearshore species that inhabit the sandy surf zone between roughly central California and southern British Columbia. Management changes in the last 20 years have likely resulted in the protection of substantial nearshore sandy habitats where Redtail Surfperch live. A Marine Protected Area (MPA) network was implemented along the north coast of California in 2012. Between Cape Mendocino and the California-Oregon border, three State Marine Conservation Areas (SMCA's) were established which prohibit recreational and commercial take of Redtail Surfperch along stretches of sandy beach habitat that were historically productive areas for this fishery. In addition, long stretches of sandy beach habitat fall within the jurisdiction of the jointly managed Redwood National and State Park (RNSP). In 1999 the RNSP general plan prohibited off road vehicle use through the park, which greatly reduced commercial fishery access in this area. Since then, there are large areas with minimal to no fishing in this region. Based on this information we assumed that between 25-35% of surfperch habitat was protected in 2012.

Frac_area_1: The fraction of the unfished biomass in area 1. Please specify numbers between 0 and 1. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. For example, if Frac_area_1 is 0.5, then 50% of the unfished biomass is allocated to area 1, regardless of the size of area 1 (i.e, size and fraction in each area determine the density of fish, which may impact fishing spatial targeting). In each time step recruits are allocated to each area based on the proportion specified in Frac_area_1. Uniform distribution lower and upper bounds. Positive real numbers.

Specified Value(s): 0.25, 0.35

We assumed that the fraction of the population in each area was proportional to the size of that area.

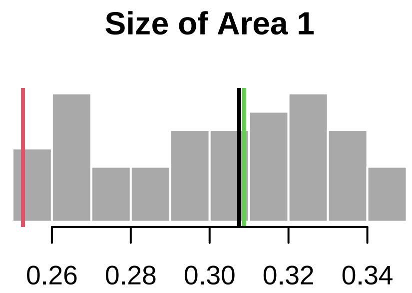
Prob_staying: The probability of individuals in area 1 remaining in area 1 over the course of one year. Please specify numbers between 0 and 1. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. For example, in an area with a Prob_staying value of 0.95 each fish has a 95% probability of staying in that area in each time step, and a 5% probability of moving to the other area. Uniform distribution lower and upper bounds. Positive fraction.

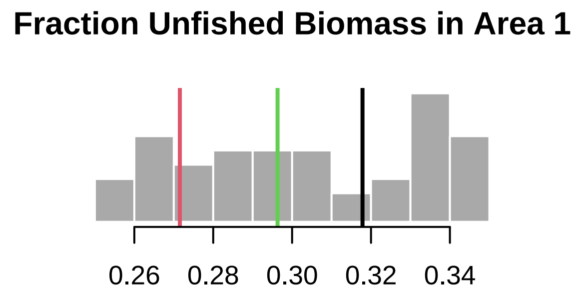
Specified Value(s): 0.9, 0.99

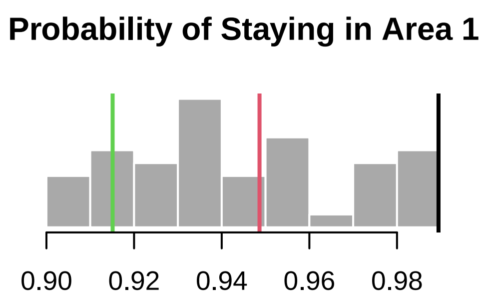
Movement studies have shown that the majority of fish did not venture significant distances from the original tagging locations, suggesting a high degree of site fidelity. The majority of tagged fish moved less than 3 miles per year (Pruden 2000). Based on this, we assumed a high probability of staying in a particular area from year to year. However, some fish exhibited movements of up to 70 miles per year (Pruden 2000), and surfperch may also exhibit some degree of annual migration southward in the spring and northward during late summer and fall (Pruden 2000). Based on this information we explored lower probabilities of staying in robustness testing.

Spatial & Movement

Sampled Parameters Histograms of 48 simulations of size of area 1 (`Size_area_1`), fraction of unfished biomass in area 1 (`Frac_area_1`), and the probability of staying in area 1 in a year (`Frac_area_1`), with vertical colored lines indicating 3 randomly drawn values used in other plots:







Fleet Parameters

The species has been exploited to some extent for centuries by coastal indigenous communities, and it is thought that commercial exploitation began in the late 1800s, although records of catch were not documented until 1928. Catch and participation in the commercial fishery has declined since the 1990s, and the number of fishermen landing fish 10 or more times per year declined from a high of 100 in 1992 to less than 10 in 2008. As a result the largest amount of take is currently in the recreational sector. For this reason, the MPs tested focus on the recreational sector, but we wanted to model the historical fishing effort in both sectors. This is described more fully below.

Historical years of fishing, spatial targeting: nyears, Spat_targ

nyears: The number of years for the historical simulation. Single value. For example, if the simulated population is assumed to be unfished in 1975 and this is the year you want to start your historical simulations, and the most recent year for which there is data available is 2019, then nyears equals 45.

Specified Value(s): 117

We assumed the first year of exploitation was 1900 and that the most recent historical year was 2017.

Spat_targ: Distribution of fishing in relation to vulnerable biomass (VB) across areas. The distribution of fishing effort is proportional to VB^Spat_targ. Upper and lower bounds of a uniform distribution. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This parameter allows the user to model either avoidance or spatial targeting behavior by the fleet. If the parameter value is 1, fishing effort is allocated across areas in proportion to the population density of that area. Values below 1 simulate an avoidance behavior and values above 1 simulate a targeting behavior.

Specified Value(s): 1, 1

Spatial targeting was set to 1 to represent a stock that is actively targeted by the fishers.

Trend in historical fishing effort (exploitation rate), interannual variability in fishing effort: EffYears, EffLower, EffUpper, Esd

EffYears: Vector indicating the historical years where there is information available to infer the relative fishing effort expended.This vector is specified in terms of the position of the year in the vector rather than the calendar year. For example, say our simulation starts with an unfished stock in 1975,and the current year (the last year for which there is data available) is 2019. Then there are 45 historical years simulated, and EffYears should include numbers between 1 and 45. Note that there may not be information available for every historical year, especially for data poor fisheries. In these situations, the EffYears vector should include only the positions of the years for which there is information, and the vector may be shorter than the total number of simulated historical years (nyears).

There are limited data available with which to estimate the relative extent of fishing effort, especially prior to 1980 in the recreational sector. In addition, it was challenging to estimate the combined fishing effort from each fleet. Prior to 1980 we assumed that the commercial sector dominated landings, and EffUpper and EffLower reflect the available information on commercial landings, which peaked in the 1950s.

In the recreational sector estimates are available from 2005 to 2017 for the total number of fishing trips in the "Beach and Bank" mode via the CRFS sampling program, which is the primary fishing mode for anglers targeting surfperch, both statewide and in northern California. While not all trips in this mode targeted Redtail Surfperch, this is the best available metric of fishing effort. Statewide the Beach and Bank mode averaged 643,570 trips per year, which was similar to the estimated average number of Beach and Bank trips from 1980-1986 (Karpov et al. 1995). Based on this we concluded that recreational effort has stayed approximately stable since 1980, but may have dipped between 2000 and 2010, and then increased since 2010.

While catch can sometimes be indicative of fishing effort, recreational catch was estimated using a different method as part of the Marine Recreational Fishery Statistics Survey (MRFSS) program, and are not directly comparable with catch rates since 2004. However catch estimates indicate a decline in overall recreational surfperch take between 1981 and 2003. Estimates from CRFS indicate a generally stable level of catch from 2004 to 2011, and then an increase in catch since that time. It is unknown whether this increase in catch is due to increased availability of surfperch due environmental conditions or as a result of spatial protections, or whether this represents an increase in fishing effort.

We chose to model historical fishing effort that tracked the changes in commercial catch, which peaked in the 1950s, and then assumed that, due to the decrease in the commercial sector and assumption of stable effort in the recreational sector, fishing effort declined until the mid 2000s and then has increased in recent years following the recent increase in recreational catch.

EffLower: Lower bound on relative fishing effort corresponding to EffYears. EffLower must be a vector that is the same length as EffYears describing how fishing effort has changed over time. Information on relative fishing effort can be entered in any units provided they are consistent across the entire vector because the data provided will be scaled to 1 (divided by the maximum number provided).

EffUpper: Upper bound on relative fishing effort corresponding to EffYears. EffUpper must be a vector that is the same length as EffYears describing how fishing effort has changed over time. Information on relative fishing effort can be entered in any units provided they are consistent across the entire vector because the data provided will be scaled to 1 (divided by the maximum number provided).

EffYears	EffLower	EffUpper
1901	0.00000	0.00000
1936	0.05080	0.07610
1937	0.00000	0.00000

EffYears	EffLower	EffUpper
1938	0.03390	0.05080
1939	0.01850	0.02780
1940	0.00809	0.01210
1941	0.00589	0.00884
1942	0.08980	0.13500
1943	0.09350	0.14000
1944	0.12800	0.19200
1945	0.16800	0.25300
1946	0.30700	0.46000
1947	0.32600	0.49000
1948	0.38800	0.58200
1949	0.44700	0.67100
1950	0.27000	0.40400
1951	0.32700	0.49000
1952	0.30000	0.44900
1953	0.39900	0.59900
1954	0.35000	0.52500
1955	0.29500	0.44200
1956	0.50300	0.75400
1957	0.80000	1.20000
1958	0.64100	0.96100
1959	0.64300	0.96500
1960	0.62800	0.94200
1961	0.38400	0.57600
1962	0.48300	0.72500
1963	0.47500	0.71200
1964	0.32200	0.48200
1965	0.33900	0.50900
1966	0.32700	0.49100
1967	0.40000	0.60000
1968	0.38500	0.57800
1969	0.30300	0.45500
1970	0.40300	0.60400
1971	0.43000	0.64400
1972	0.40700	0.61100
1973	0.26400	0.39500
1974	0.28500	0.42800
1975	0.24900	0.37300
1976	0.35400	0.53000
1977	0.25300	0.38000
1978	0.33700	0.50500
1979	0.43600	0.65500
1980	0.30800	0.46200
1981	0.37200	0.55800
1982	0.40100	0.60100
1983	0.74600	1.12000
1984	0.36400	0.54700
1985	0.44600	0.66900
1986	0.38300	0.57400
1987	0.25300	0.38000
1988	0.23300	0.34900
1989	0.45700	0.68500

EffYears	EffLower	EffUpper
1990	0.18900	0.28300
1991	0.25300	0.38000
1992	0.28900	0.43300
1993	0.33900	0.50800
1994	0.28700	0.43000
1995	0.34100	0.51100
1996	0.24900	0.37400
1997	0.27700	0.41500
1998	0.25300	0.38000
1999	0.15000	0.22500
2000	0.25800	0.38800
2001	0.21400	0.32100
2002	0.12100	0.18200
2003	0.11900	0.17800
2004	0.17500	0.26200
2005	0.15700	0.23500
2006	0.13500	0.20300
2007	0.13500	0.20200
2008	0.12400	0.18600
2009	0.10500	0.15800
2010	0.03290	0.04940
2011	0.14000	0.21000
2012	0.14000	0.21000
2013	0.10800	0.16200
2014	0.11600	0.17500
2017	0.18100	0.27100

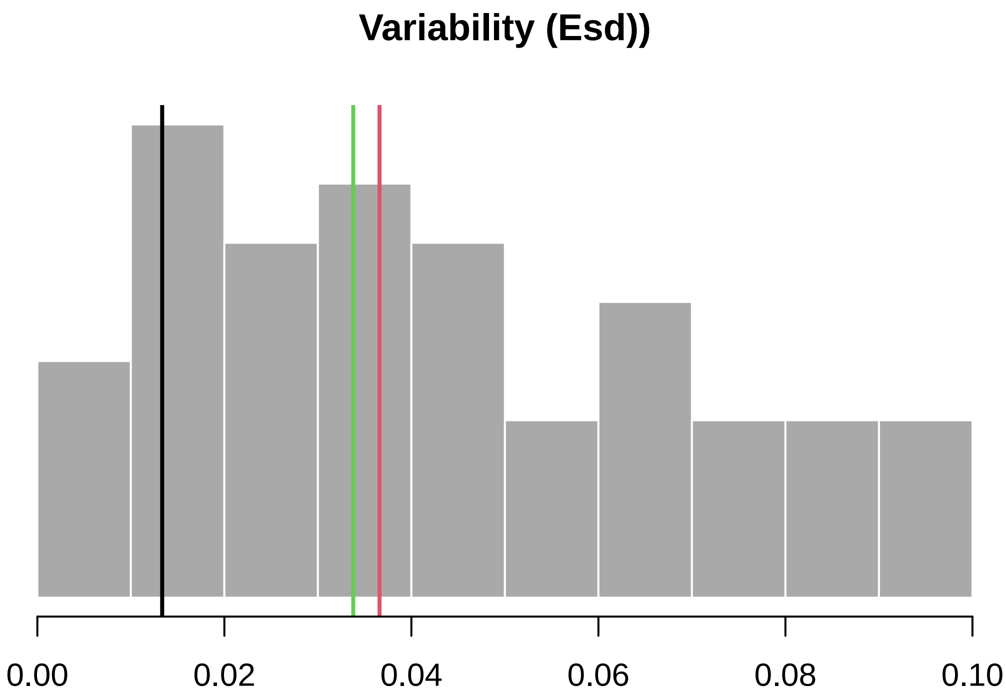
Esd: Additional inter-annual variability in fishing mortality rate. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter has a positive (non-zero) value, the yearly fishing mortality rate is drawn from a log-normal distribution with a standard deviation (in log space) specified by the value of Esd drawn for that simulation. This parameter applies only to historical projections.

Specified Value(s): 0, 0.1

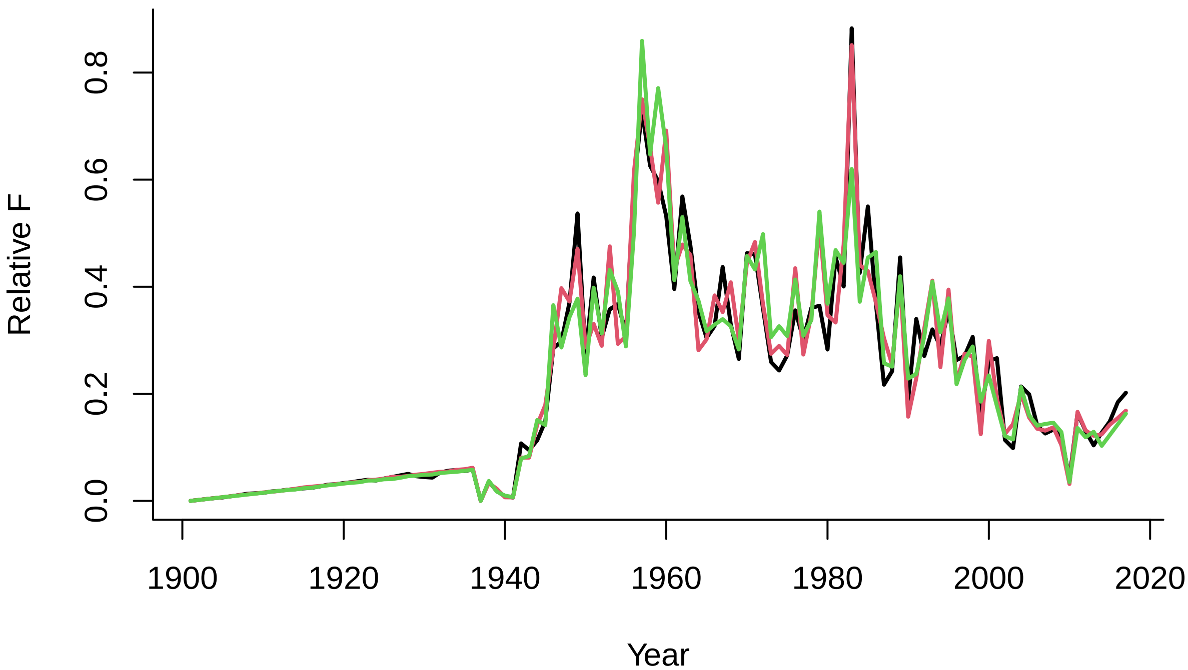
A low interannual variability in effort of 0-10% was assumed.

Historical Effort

Sampled Parameters Histograms of 48 simulations of inter-annual variability in historical fishing mortality (`Esd`), with vertical colored lines indicating 3 randomly drawn values used in the time-series plot:



Time-Series Time-series plot showing 3 trends in historical fishing mortality (`OM@EffUpper` and `OM@EffLower` or `OM@cpars$Find`):



Annual increase in catchability, interannual variability in catchability: qinc, qcv

qinc: Mean temporal trend in catchability (also though of as the efficiency of fishing gear) parameter, expressed as a percentage change in catchability (q) per year. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Positive numbers indicate an increase and negative numbers indicate a decrease. q then changes by this amount for in each year of the simulation This parameter applies only to forward projections.

Specified Value(s): -0.1, 0.1

In the base model we examined future changes in fishing effort that ranged between -0.1% to 0.1% per year, representing a lack of information on how future effort is likely to change. However, there is a possibility that recreational fishing effort could increase substantially in the future as the population of Northern California grows. Therefore, we explored how susbstantial long-term increases in fishing effort might impact the stock as part of the robustness testing process.

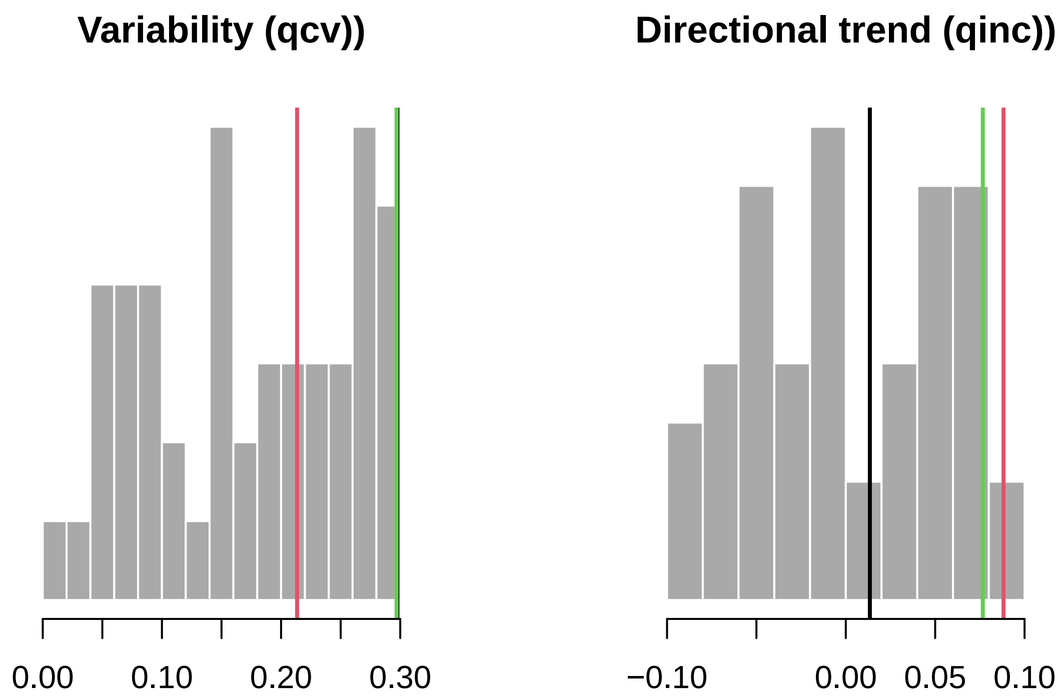
qcv: Inter-annual variability in catchability expressed as a coefficient of variation. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This parameter applies only to forward projections.

Specified Value(s): 0, 0.3

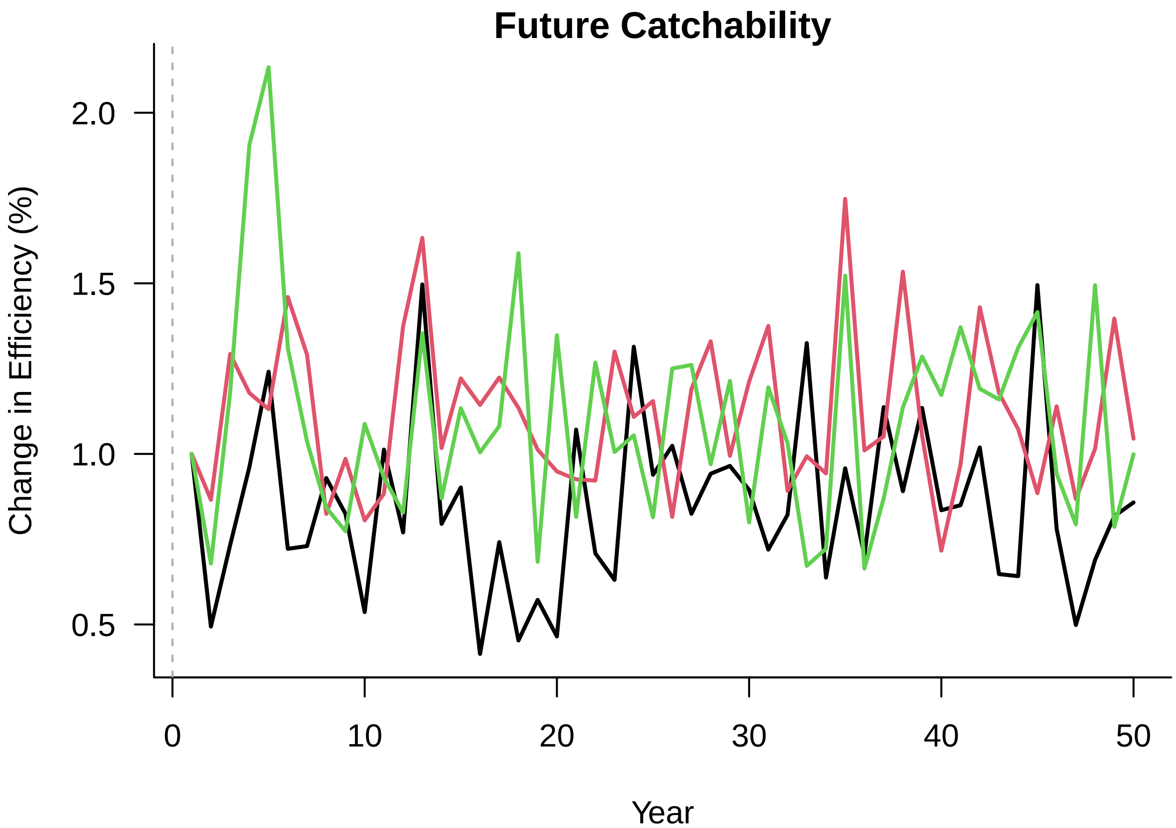
There is no information available to estimate how catchability is likely to vary. We used the default parameter values in the DLMtool.

Future Catchability

Sampled Parameters Histograms of 48 simulations of inter-annual variability in fishing efficiency (`qcv`) and average annual change in fishing efficiency (`qinc`), with vertical colored lines indicating 3 randomly drawn values used in the time-series plot:



Time-Series Time-series plot showing 3 trends in future fishing efficiency (catchability):



Fishery gear length selectivity: L5, LFS, Vmaxlen, isRel

L5: Shortest length at which 5% of the population is vulnerable to selection by the gear used in this fleet. Values can either be specified as lengths (in the same units used for the maturity and growth parameters in the stock object) or as a percentage of the size of maturity (see the parameter isRel for more information). For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless cpars is used to provide time-varying selection.

Specified Value(s): 145.35, 160.65

The selectivity of the recreational fishery was estimated by fitting a logistic model to a fishery-independent data set collected by CDFW scientists using hook and line gear similar to that used by fishery participants. Because this data is fishery-independent it includes sub-legal fish that would not show up in a fishery-dependent data set, and thus allowed us to estimate the selectivity of the gear. We estimated a 5% probability of selection at 153 mm FL and full selectivity at 289 mm FL, and used a +/-5% range around these values in the model.

LFS: Shortest length at which 100% of the population is vulnerable to selection by the gear used by this fleet. Values can either be specified as lengths (in the same units used for the maturity and growth parameters in the stock object) or as a percentage of the size of maturity (see the parameter isRel for more information). For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless cpars is used to provide time-varying selection.

Specified Value(s): 274.55, 303.45

No justification provided.

Vmaxlen: Proportion of fish selected by the gear at the asymptotic length ('Stock@Linf'). Upper and Lower bounds between 0 and 1. A value of 1 indicates that 100% of fish are selected at the asymptotic length, and the selection curve is logistic. If Vmaxlen is less than 1 the selection curve is dome shaped. For example, if Vmaxlen is 0.4, then only 40% of fish are vulnerable to the fishing gear at the asymptotic length.

Specified Value(s): 1, 1

We assumed a logistic selectivity curve, and so vunerability at the maximum size is set to 1.

isRel: Specify whether selection and retention parameters use absolute lengths or relative to the size of maturity. Single logical value (TRUE or FALSE).

Specified Value(s): FALSE

Parameter values are provided in absolute rather than proportional values.

Fishery length retention: LR5, LFR, Rmaxlen, DR

LR5: Shortest length at which 5% of the population is vulnerable to retention by the fleet. Values can either be specified as lengths (in the same units used for the maturity and growth parameters in the stock object) or as a percentage of the size of maturity (see the parameter isRel for more information). For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless cpars is used to provide time-varying selection.

Specified Value(s): 183.06, 202.34

Rather than assume knife-edged retention at the size limit, we fit a logistic model to length data sampled by the California Recreational Fisheries Sampling (CRFS) Program. All of these fish are retained, but there are sub-legal fish present in the data set, indicating imperfect compliance with the size limit. We estimated a 5% probability of retention at 192.7 mm FL and full selectivity at 303.1 mm FL, and used a +/-5% range around these values in the model.

LFR: Shortest length where 100% of the population is vulnerable to retention by the fleet. Values can either be specified as lengths (in the same units used for the maturity and growth parameters in the stock object) or as a percentage of the size of maturity (see the parameter isRel for more information). For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the same in all years unless cpars is used to provide time-varying selection.

Specified Value(s): 287.94, 318.26

No justification provided.

Rmaxlen: Proportion of fish retained at the asymptotic length ('Stock@Linf'). Upper and Lower bounds between 0 and 1. A value of 1 indicates that 100% of fish are retained at the asymptotic length, and the selection curve is logistic. If Rmaxlen is less than 1 the retention curve is dome shaped. For example, if Rmaxlen is 0.4, then only 40% of fish at the asymptotic length are retained.

Specified Value(s): 1, 1

No justification provided.

DR: Discard rate, defined as the proportion of fully selected fish that are discarded by the fleet. Upper and Lower bounds between 0 and 1, with a value of 1 indicates that 100% of selected fish are discarded. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided.

Specified Value(s): 0, 0.1

No justification provided.

Current Year: CurrentYr

CurrentYr: The last historical year simulated before projections begin. Single value. Note that this should match the last historical year specified in the Data object, which is usually the last historical year for which data is available.

Specified Value(s): 2017

No justification provided.

Existing Spatial Closures: MPA

MPA: Logical argument (TRUE or FALSE). Creates an MPA in Area 1 for all years if true is selected. Defaults to FALSE.

Specified Value(s): FALSE

The MPAs implemented along the north coast in 2012 provide protection to Redtail Surfperch habitat. Between Cape Mendocino and the California-Oregon border, three State Marine Conservation Areas (SMCA's) were established which prohibit recreational and commercial take of Redtail Surfperch along stretches of sandy beach habitat that were historically productive areas for this fishery. Additionally, long stretches of sandy beach habitat fall within the jurisdiction of the jointly managed Redwood National and State Park (RNSP). In 1999 the RNSP general plan was updated, resulting in a prohibition on off-road vehicle use which greatly impacted the commercial fishery in this area. Commercial fishermen in the area generally require trucks to drive down beaches following schools of Surfperch, and fill the bed of the trucks with fish. Although it is legal to commercially fish from the beach, the prohibition on vehicle use essentially made it economically infeasible. This change in management, along with MPA implementation, is thought to protect between 25 and 35% of surfperch habitat. Because fishermen who had previously held commercial licenses before the change were able to retain beach access, we assumed that these spatial protections took effect in 2012, when the north coast MPAs were created.

Obs Parameters

This section describes the parameters that are used to generate the simulated fishery data within the MSE model. The only data routinely collected for this fishery are 1) fishery-dependent length samples (between 50-300 per year historically), 2) estimates of total catch. All other parameters used for the observation model were based on the values presented in Carruthers et al. (2014) and are found in the 'Generic_obs' observation object in the DLMtool.

Catch statistics: Cobs, Cbiascv, CAA_nsamp, CAA_ESS, CAL_nsamp, CAL_ESS

Cobs: Observation error around the total catch. Observation error in the total catch is expressed as a coefficient of variation (CV). Cobs requires upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly observation error values for the catch data are then drawn from this distribution. For each time step the simulation model records the true catch, but the observed catch is generated by applying this yearly error term (plus any bias, if specified) to the true catch.

Specified Value(s): 0.1, 0.3

We assume that year to year catch estimates are variable but have no known sources of directional bias from year to year.

Cbiascv: Log-normally distributed coefficient of variation controlling the sampling bias in observed catch for each simulation. Bias occurs when catches are systematically skewed away from the true catch level (for example, due to underreporting of catch or undetected illegal catches). Cbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years.

Specified Value(s): 0.1

CAA_nsamp: Number of catch-at-age observations collected per time step. For each time step a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Positive integers.

Specified Value(s): 0, 0

No age samples are collected.

CAA_ESS: Effective sample size of catch-at-age observations collected per time step. For each time step a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. CAA_ESS should not exceed CAA_nsamp. Positive integers.

Specified Value(s): 0, 0

No age samples are collected.

CAL_nsamp: Number of catch-at-length observations collected per time step. For each time step a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Positive integers.

Specified Value(s): 50, 300

The number of length samples are based on historical sampling rates for this fishery.

CAL_ESS: Effective sample size. For each time step a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. CAL_ESS should not exceed CAL_nsamp. Positive integers.

Specified Value(s): 50, 300

We assume that samples are collected from fishing events that happen at different locations on different dates, and thus the effective sample size is the same as the actual sample size.

Index imprecision, bias and hyperstability: Iobs, Btobs, Btbiascv, beta

Iobs: Observation error in the relative abundance index expressed as a coefficient of variation (CV). Iobs requires upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly observation error values for the index of abundance data are then drawn from this distribution. For each time step the simulation model records the true change in abundance, but the observed index is generated by applying this yearly error term (plus any bias, if specified) to the true relative change in abundance. Positive real numbers.

Specified Value(s): 0.1, 0.4

Btobs: Observation error in the absolute abundance expressed as a coefficient of variation (CV). Btobs requires upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly observation error values for the absolute abundance data are then drawn from this distribution. For each time step the simulation model records the true abundance, but the observed abundance is generated by applying this yearly error term (plus any bias, if specified) to the true abundance. Positive real numbers.

Specified Value(s): 0.2, 0.5

Btbiascv: Log-normally distributed coefficient (CV) controlling error in observations of the current stock biomass. Bias occurs when the observed index of abundance is is systematically higher or lower than the true relative abundance. Btbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.3

beta: A parameter controlling hyperstability/hyperdepletion in the measurement of abundance. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Values below 1 lead to hyperstability (the observed index decreases more slowly than the true abundance) and values above 1 lead to hyperdepletion (the observed index decreases more rapidly than true abundance). Positive real numbers.

Specified Value(s): 0.5, 2

Bias in maturity, natural mortality rate and growth parameters: LenMbiascv, Mbiascv, Kbiascv,t0biascv, Linfbiascv

LenMbiascv: Log-normal coefficient of variation for sampling bias in observed length at 50 percent maturity. LenMbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.1

Mbiascv: Log-normal coefficient of variation for sampling bias in observed natural mortality rate. Uniform distribution lower and upper bounds. Mbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

Kbiascv: Log-normal coefficient of variation for sampling bias in observed growth parameter K. Kbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.1

t0biascv: Log-normal coefficient of variation for sampling bias in observed t0. t0biascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.1

Linfbiascv: Log-normal coefficient of variation for sampling bias in observed maximum length. Linfbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.05

Bias in length at first capture, length at full selection: LFCbiascv, LFSbiascv

LFCbiascv: Log-normal coefficient of variation for sampling bias in observed length at first capture. LFCbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.05

LFSbiascv: Log-normal coefficient of variation for sampling bias in length-at-full selection. LFSbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.05

Bias in fishery reference points, unfished biomass, FMSY, FMSY/M ratio, biomass at MSY relative to unfished: FMSY_Mbiascv, BMSY_B0biascv

FMSY_Mbiascv: Log-normal coefficient of variation for sampling bias in estimates of the ratio of the fishing mortality rate that gives the maximum sustainable yield relative to the assumed instantaneous natural mortality rate. FMSY/M. FMSY_Mbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

BMSY_B0biascv: Log-normal coefficient of variation for sampling bias in estimates of the BMSY relative to unfished biomass (BMSY/B0). BMSY_B0biascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

Management targets in terms of the index (i.e., model free), the total annual catches and absolute biomass levels: Irefbiascv, Crefbiascv, Brefbiascv

Irefbiascv: Log-normal coefficient of variation for sampling bias in the observed relative index of abundance (Iref). Irefbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

Crefbiascv: Log-normal coefficient of variation for sampling bias in the observed reference catch (Cref). Crefbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

Brefbiascv: Log-normal coefficient of variation for sampling bias in the observed reference biomass (Bref). Brefbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.5

Depletion bias and imprecision: Dbiascv, Dobs

Dbiascv: Log-normal coefficient of variation for sampling bias in the observed depletion level. Dbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.5

Dobs: Log-normal coefficient of variation controlling error in observations of stock depletion among years. Observation error in the depletion expressed as a coefficient of variation (CV). Dobs requires the upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly observation error values for the depletion data are then drawn from this distribution. For each time step the simulation model records the true depletion, but the observed depletion is generated by applying this yearly error term (plus any bias, if specified) to the true depletion.

Specified Value(s): 0.05, 0.1

Recruitment compensation and trend: hbiascv, Recbiascv, sigmaRbiascv

hbiascv: Log-normal coefficient of variation for sampling persistent bias in steepness. hbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.2

Recbiascv: Log-normal coefficient of variation for sampling persistent bias in recent recruitment strength. Recbiascv requires the upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly bias values for the depletion data are then drawn from this distribution. Positive real numbers.

Specified Value(s): 0.1, 0.3

sigmaRbiascv: Log-normal coefficient of variation for sampling persistent bias in recruitment variability. sigmaRbiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years. Positive real numbers.

Specified Value(s): 0.1

No justification provided.

Effort: Eobs, Ebiascv

Eobs: Observation error around the total effort. Observation error in the total effort is expressed as a coefficient of variation (CV). Eobs requires upper and lower bounds of a uniform distribution, and for each simulation a CV is sampled from this distribution. Each CV is used to specify a log-normal error distribution with a mean of 1 and a standard deviation equal to the sampled CV. The yearly observation error values for the effort data are then drawn from this distribution. For each time step the simulation model records the true effort, but the observed effort is generated by applying this yearly error term (plus any bias, if specified) to the true effort.

Specified Value(s): 0, 0

No justification provided.

Ebiascv: Log-normally distributed coefficient of variation controlling the sampling bias in observed effort for each simulation. Bias occurs when effort is systematically skewed away from the true effort level. Ebiascv is a single value specifying the standard deviation of a log-normal distribution with a mean of 1 and a standard deviation equal to the sampled CV. For each simulation a bias value is drawn from this distribution, and that bias is applied across all years.

Specified Value(s): 0

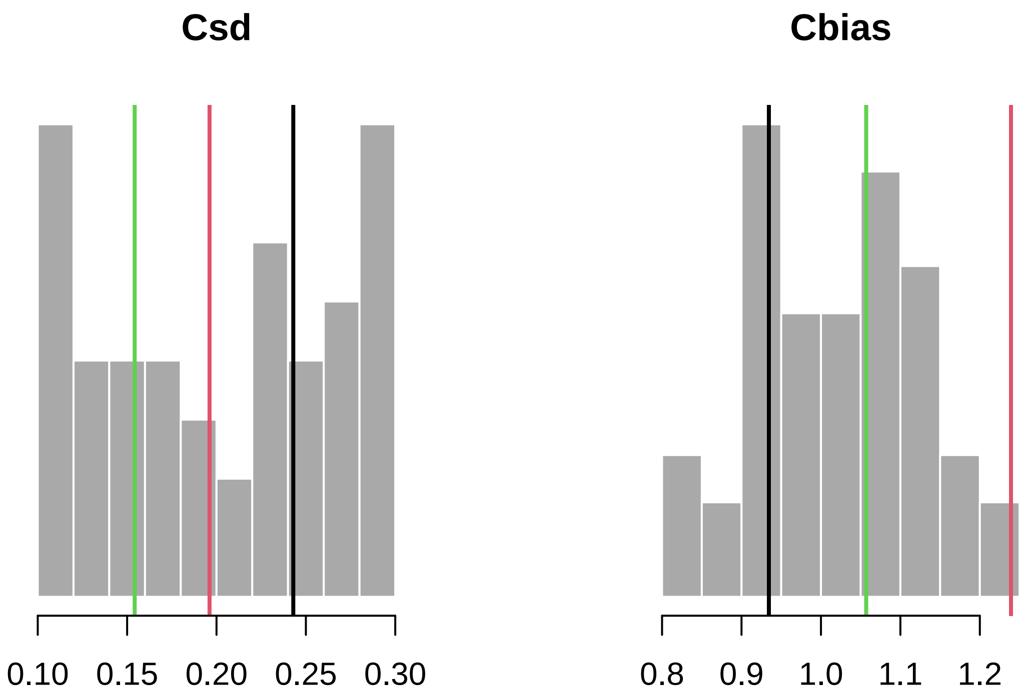
No justification provided.

Obs Plots

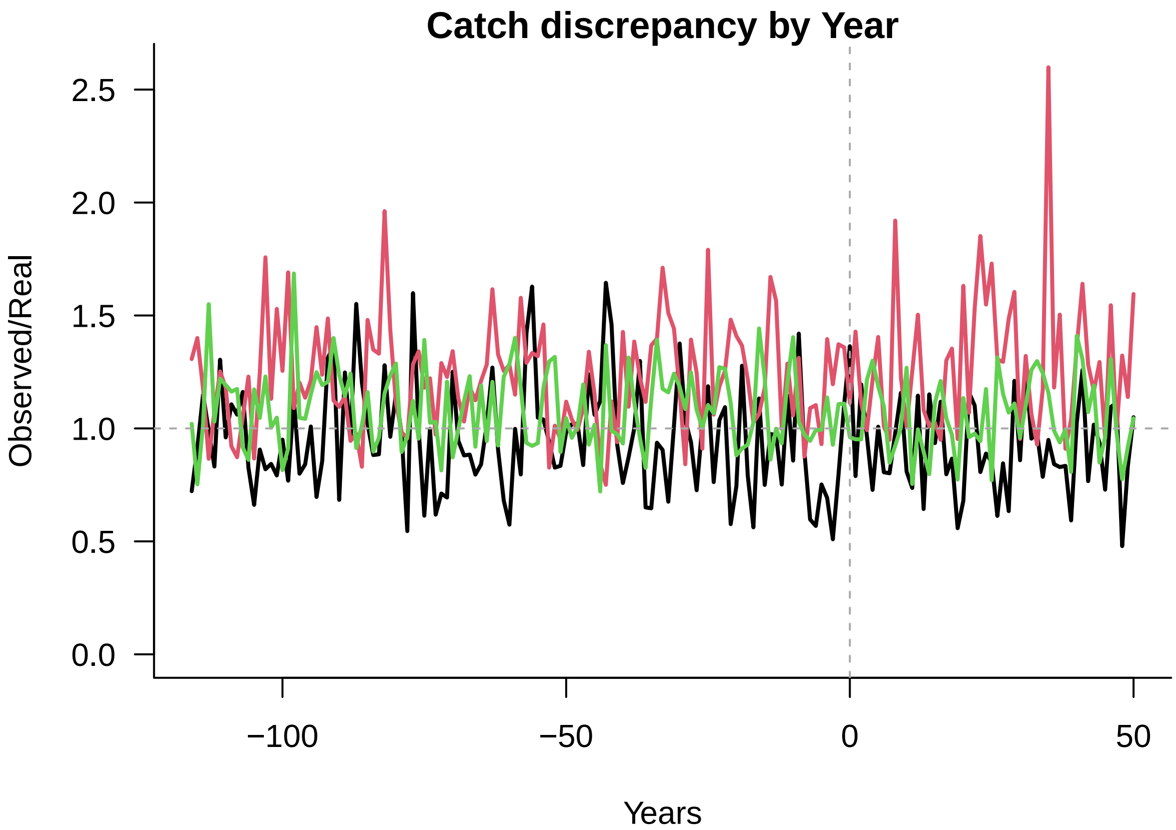
Observation Parameters

Catch Observations

Sampled Parameters Histograms of 48 simulations of inter-annual variability in catch observations (`Csd`) and persistent bias in observed catch (`Cbias`), with vertical colored lines indicating 3 randomly drawn values used in other plots:

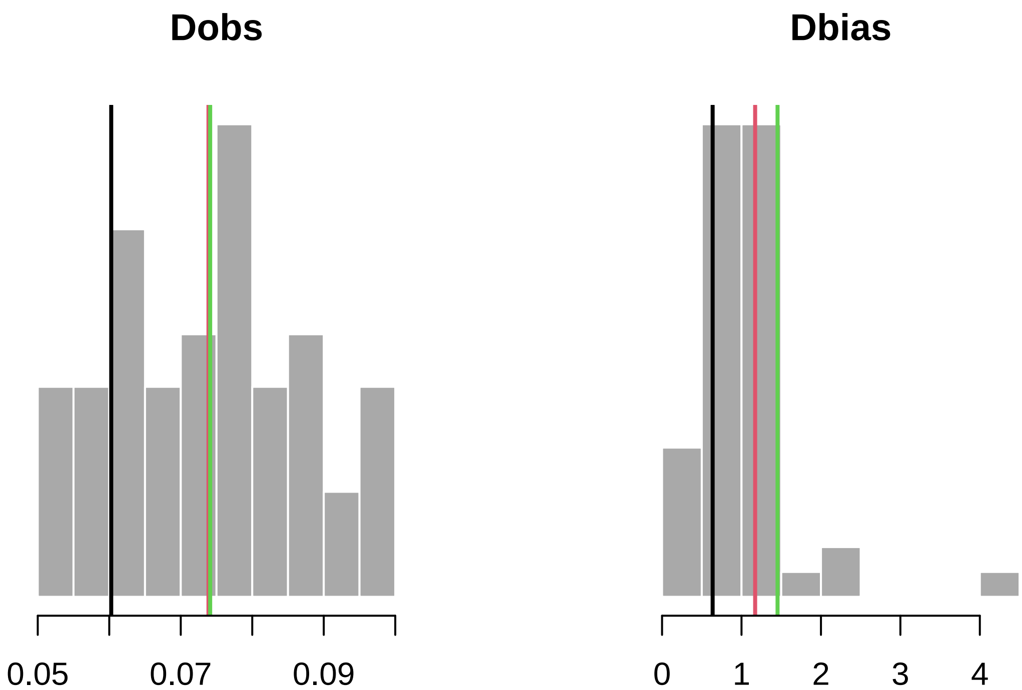


Time-Series Time-series plots of catch observation error for historical and projection years:

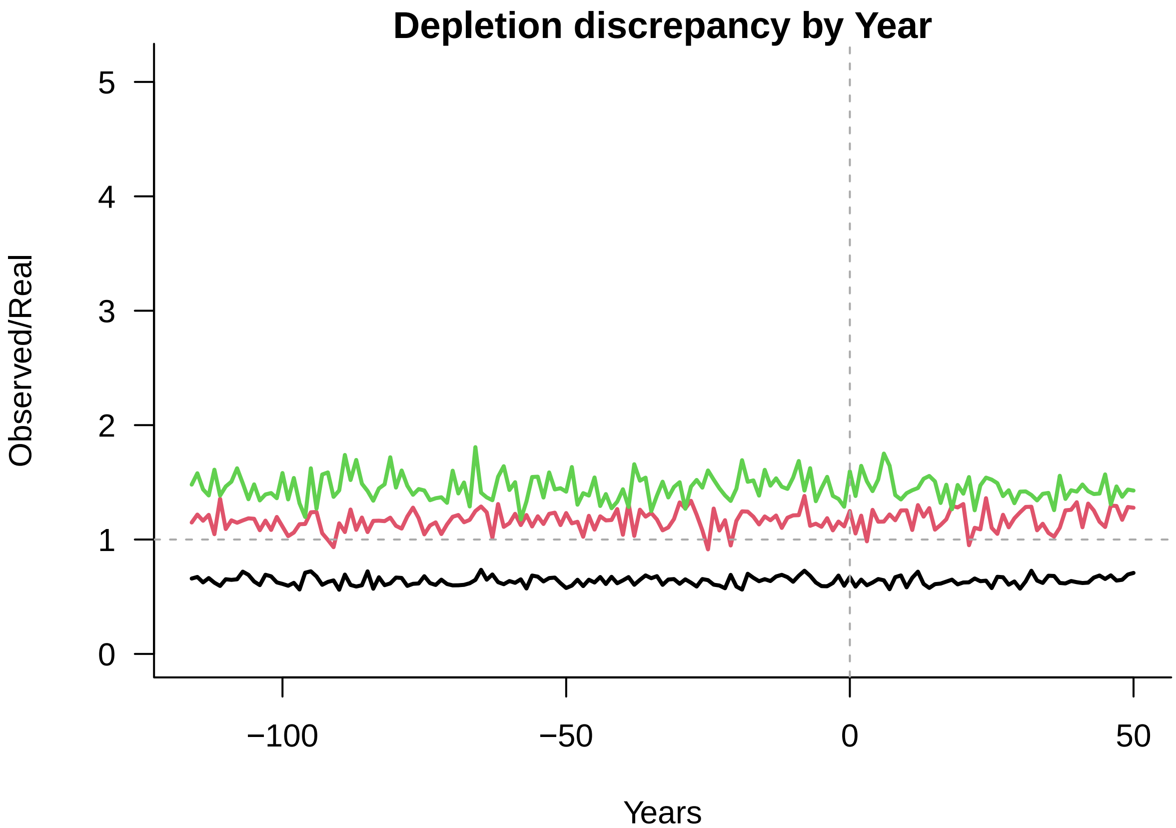


Depletion Observations

Sampled Parameters Histograms of 48 simulations of inter-annual variability in depletion observations (`Dobs`) and persistent bias in observed depletion (`Dbias`), with vertical colored lines indicating 3 randomly drawn values used in other plots:

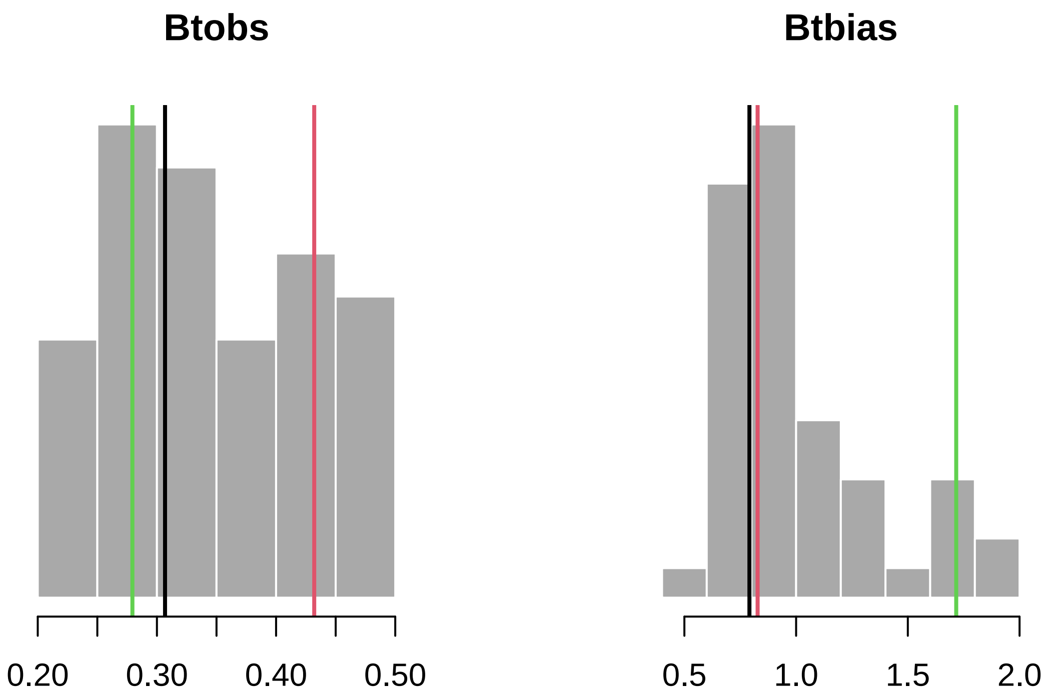


Time-Series Time-series plots of depletion observation error for historical and projection years:

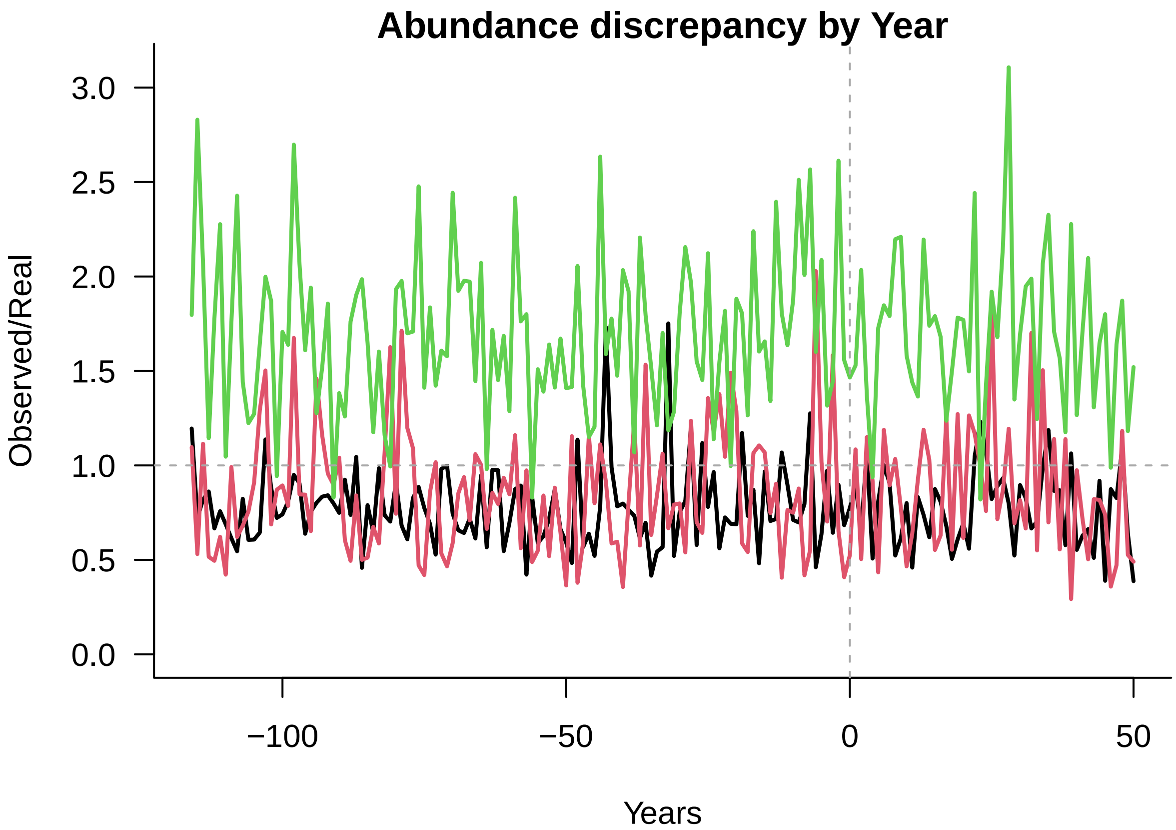


Abundance Observations

Sampled Parameters Histograms of 48 simulations of inter-annual variability in abundance observations (`Btobs`) and persistent bias in observed abundance (`Btbias`), with vertical colored lines indicating 3 randomly drawn values used in other plots:

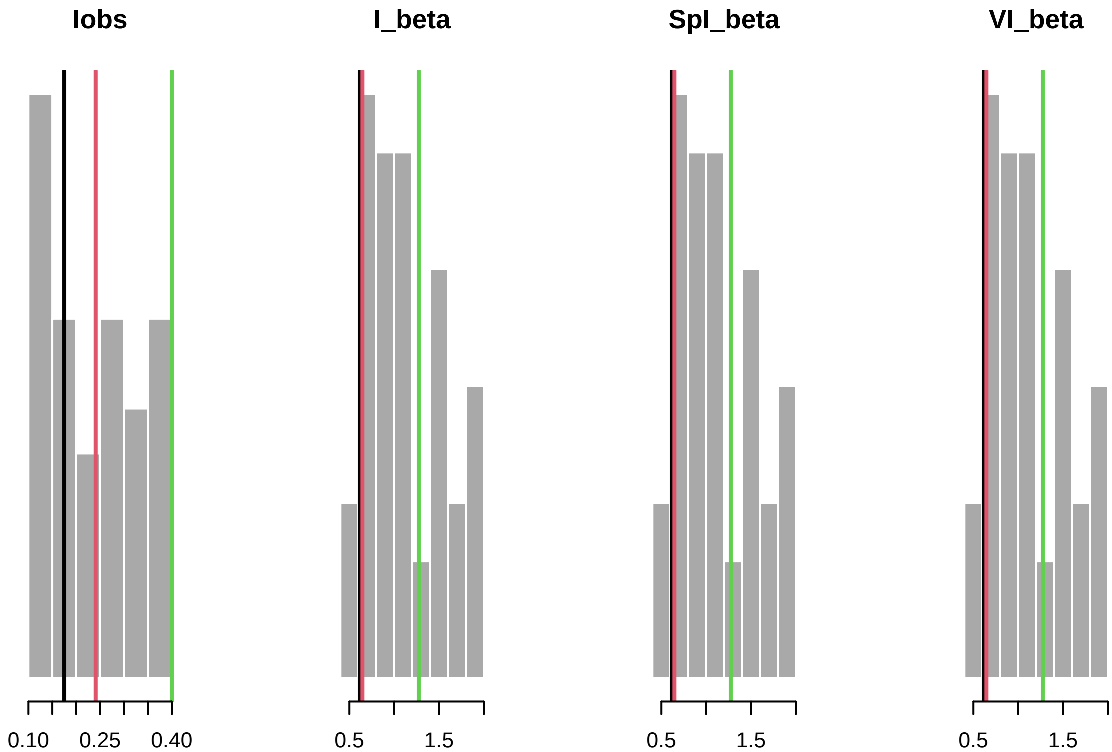


Time-Series Time-series plots of abundance observation error for historical and projection years:

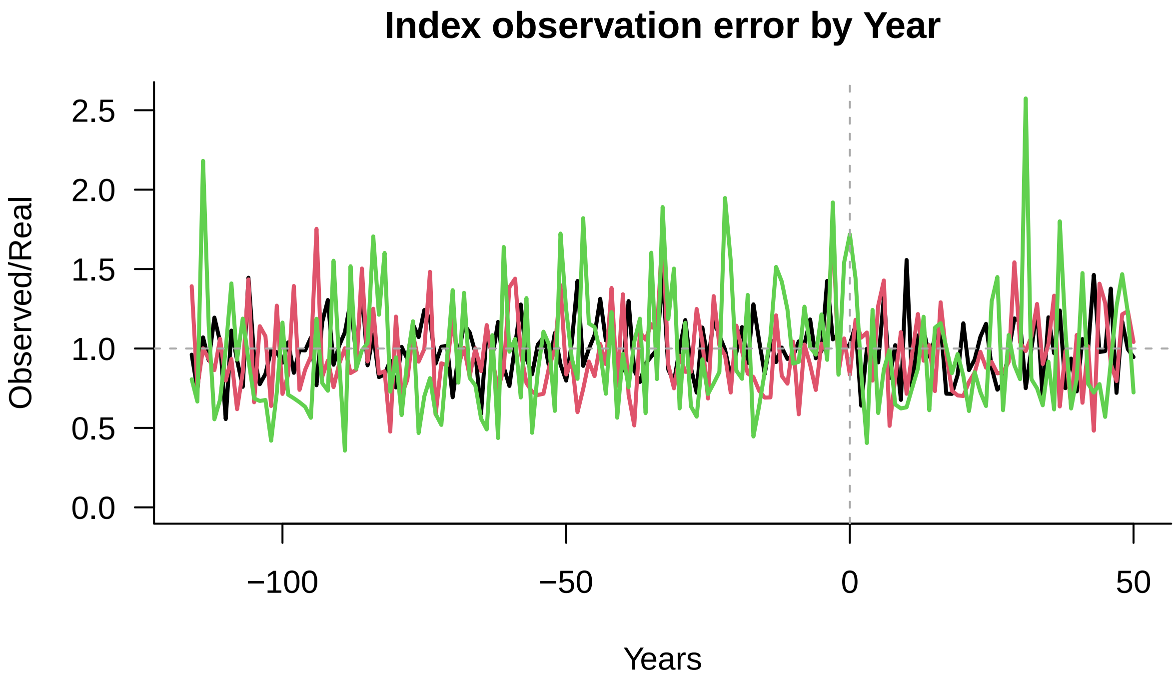


Index Observations

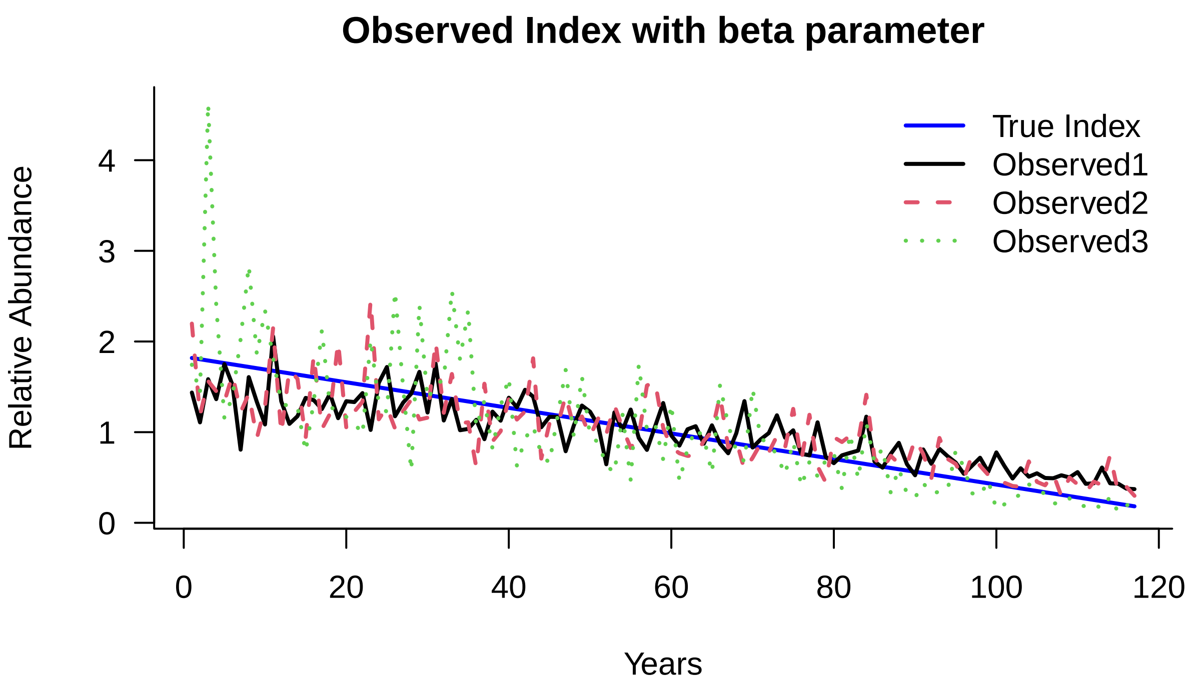
Sampled Parameters Histograms of 48 simulations of inter-annual variability in index observations (`Iobs`) and hyper-stability/depletion in observed index (`beta`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



Time-Series Time-series plot of 3 samples of index observation error:

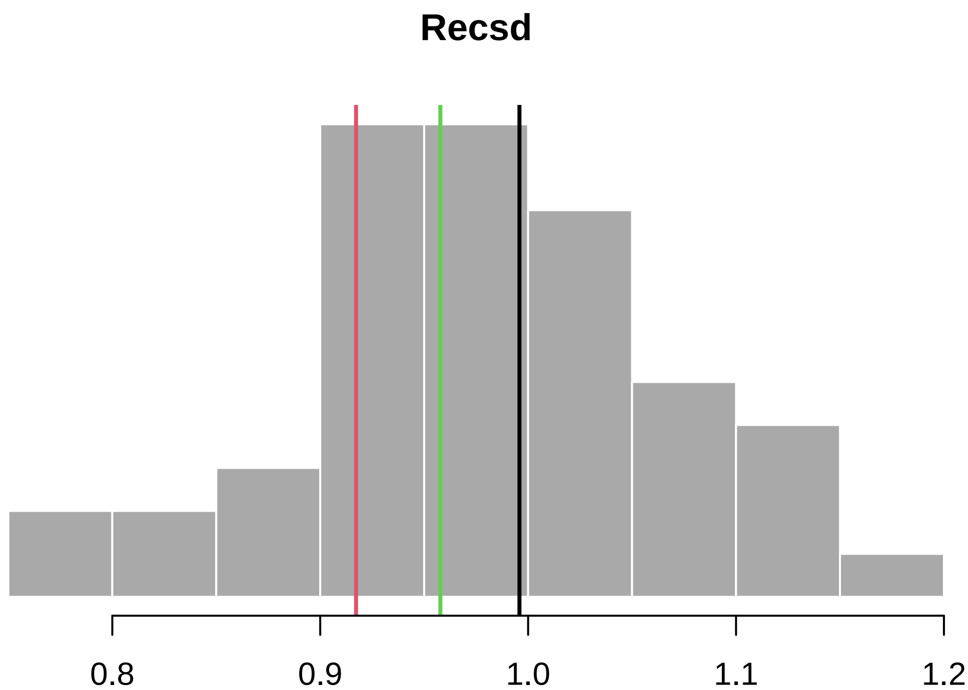


Plot showing an example true abundance index (blue) with 3 samples of index observation error and the hyper-stability/depletion parameter (`beta`):

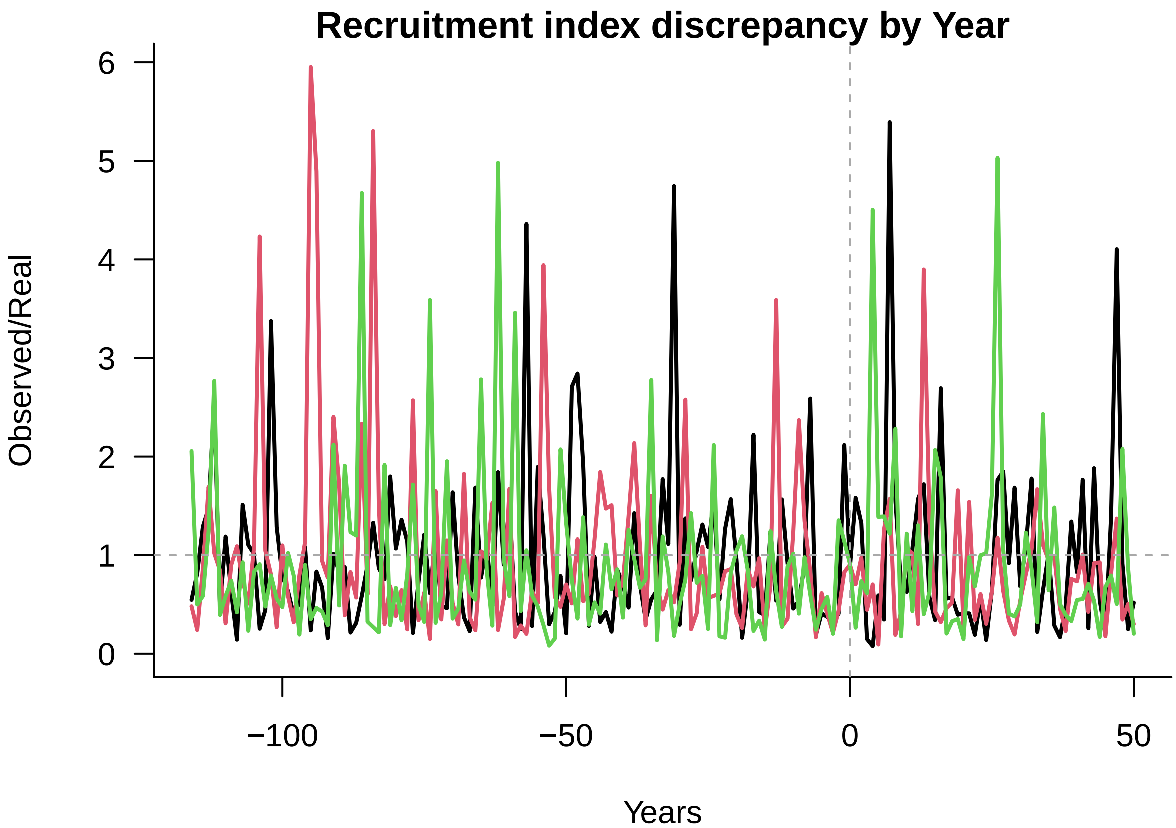


Recruitment Observations

Sampled Parameters Histograms of 48 simulations of inter-annual variability in index observations (`Recsd`) , with vertical colored lines indicating 3 randomly drawn values used in other plots:

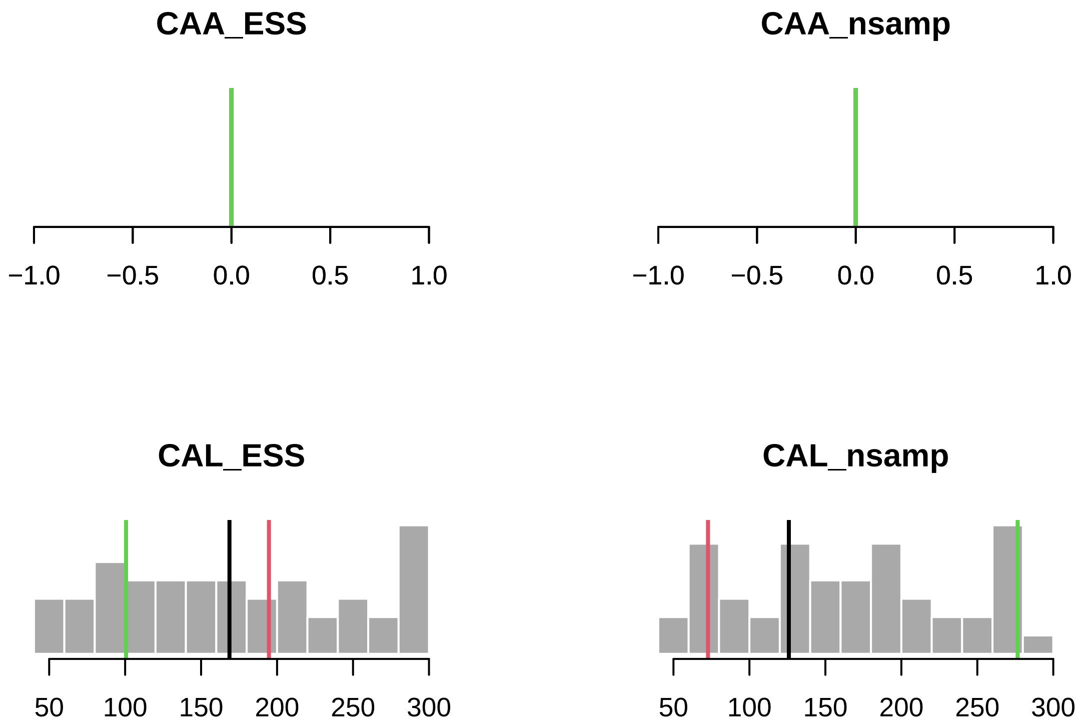


Time-Series Timeseries plots of observeration error for recruitment:



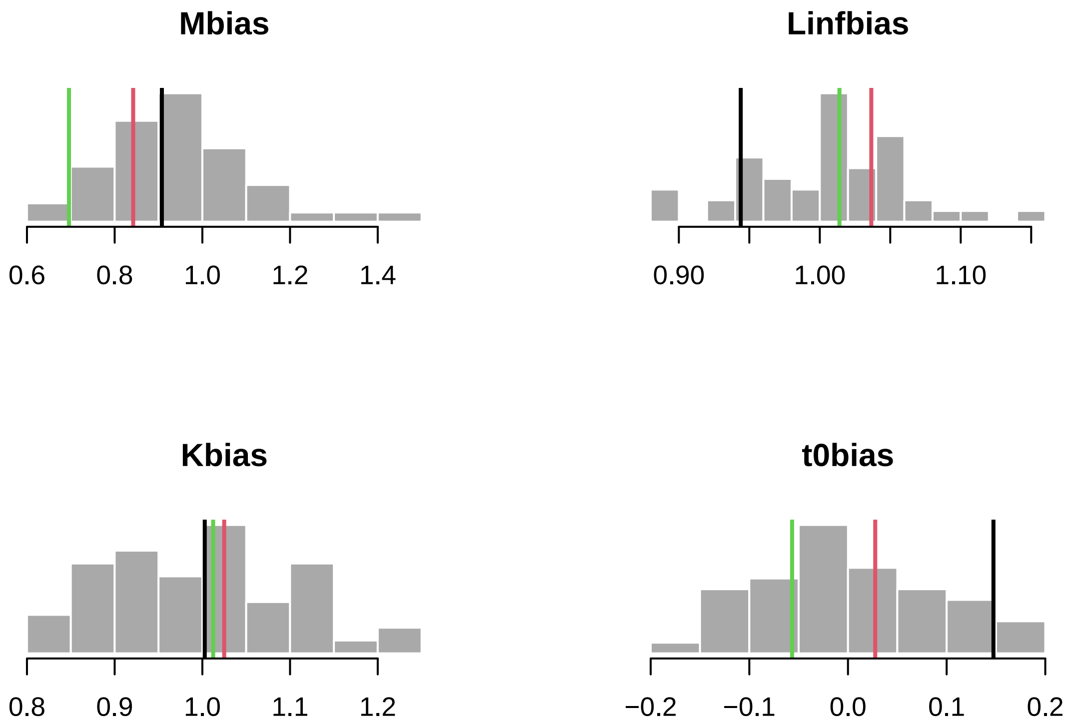
Composition Observations

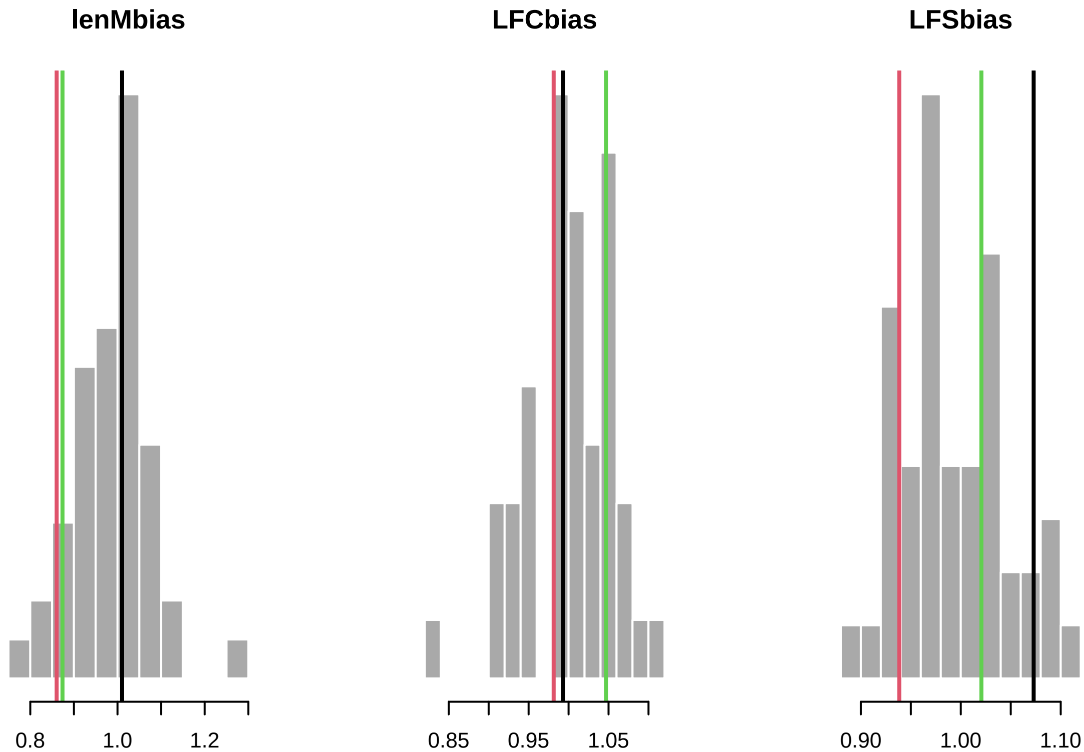
Sampled Parameters Histograms of 48 simulations of catch-at-age effective sample size (`CAA_ESS`) and sample size (`CAA_nsamp`) and catch-at-length effective (`CAL_ESS`) and actual sample size (`CAL_nsamp`) with vertical colored lines indicating 3 randomly drawn values:



Parameter Observations

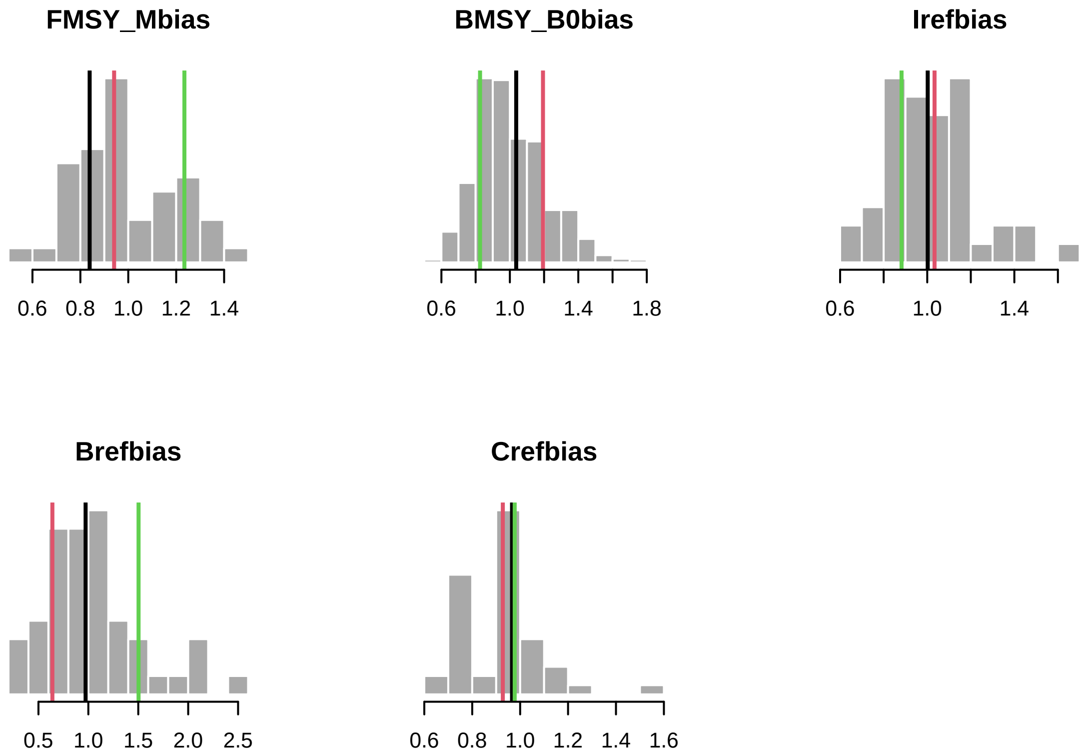
Sampled Parameters Histograms of 48 simulations of bias in observed natural mortality (`Mbias`), von Bertalanffy growth function parameters (`Linfbias`, `Kbias`, and `t0bias`), length-at-maturity (`lenMbias`), and bias in observed length at first capture (`LFCbias`) and first length at full capture (`LFSbias`) with vertical colored lines indicating 3 randomly drawn values:


Mbias
0.6
0.8
1.0
1.2
1.4
Linfbias
0.90
1.00
1.10
Kbias
0.8
0.9
1.0
1.1
1.2
t0bias
−0.2
−0.1
0.0
0.1
0.2



Reference Point Observations

Sampled Parameters Histograms of 48 simulations of bias in observed FMSY/M (`FMSY_Mbias`), BMSY/B0 (`BMSY_B0bias`), reference index (`Irefbias`), reference abundance (`Brefbias`) and reference catch (`Crefbias`), with vertical colored lines indicating 3 randomly drawn values:



Imp Parameters

It is not currently possible to set TACs or TAEs in this recreational fishery at this time, so the default values were used for those implementation parameters. We did assume implementation error in size limits.

Output Control Implementation Error: TACFrac, TACSD

TACFrac: Mean fraction of recommended TAC that is actually taken. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the mean TAC fraction obtained across all years of that simulation, and a yearly TAC frac is drawn from a log-normal distribution with the simulation mean and a coefficient of variation specified by the value of TACSD drawn for that simulation. If the value drawn is greater than 1 the amount of catch taken is greater than that recommended by the TAC, and if it is less than 1 the amount of catch taken is less than that recommended by the TAC. Positive real numbers.

Specified Value(s): 1, 1

TACSD: Log-normal coefficient of variation in the fraction of recommended TAC that is actually taken. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is used, along with the TACFrac drawn for that simulation, to create a log-normal distribution that yearly values specifying the actual amount of catch taken are drawn from. Positive real numbers.

Specified Value(s): 0, 0

Effort Control Implementation Error: TAEFrac, TAESD

TAEFrac: Mean fraction of recommended TAE that is actually taken. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the mean TAE fraction obtained across all years of that simulation, and a yearly TAE frac is drawn from a log-normal distribution with the simulation mean and a coefficient of variation specified by the value of TAESD drawn for that simulation. If the value drawn is greater than 1 the amount of effort employed is greater than that recommended by the TAE, and if it is less than 1 the amount of effort employed is less than that recommended by the TAE. Positive real numbers.

Specified Value(s): 1, 1

TAESD: Log-normal coefficient of variation in the fraction of recommended TAE that is actually taken. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is used, along with the TAEFrac drawn for that simulation, to create a log-normal distribution that yearly values speciying the actual amount of efort employed are drawn from. Positive real numbers.

Specified Value(s): 0, 0

Size Limit Control Implementation Error: SizeLimFrac, SizeLimSD

SizeLimFrac: Mean fraction of recommended size limit that is actually retained. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is the mean size limit fraction obtained across all years of that simulation, and a yearly size limit fraction is drawn from a log-normal distribution with the simulation mean and a coefficient of variation specified by the value of SizeLimSD drawn for that simulation. If the value drawn is greater than 1 the size of fish retained is greater than that recommended by the size limit, and if it is less than 1 the amount of size of fish retained is less than that recommended by the size limit. Positive real numbers.

Specified Value(s): 0.85, 1

Based on the large number of sublegal fish retained in recent years, it was assumed that the size of retained fish would be within 85-100% of the desired size limit.

SizeLimSD: Log-normal coefficient of variation in the fraction of recommended size limit that is actually retained. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This value is used, along with the SizeLimFrac drawn for that simulation, to create a log-normal distribution that yearly values speciying the actual fraction of the size limit retained are drawn from. Positive real numbers.

Specified Value(s): 0, 0

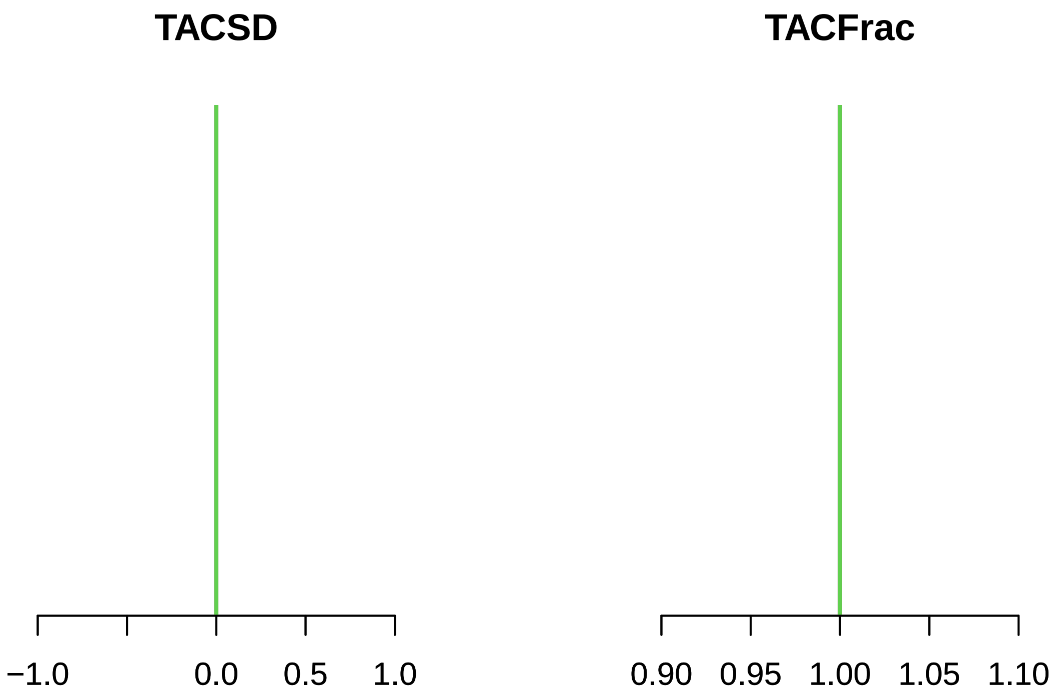
It was assumed that the implementation of the size limit would not change from year to year, and so this parameter was set to 0.

Imp Plots

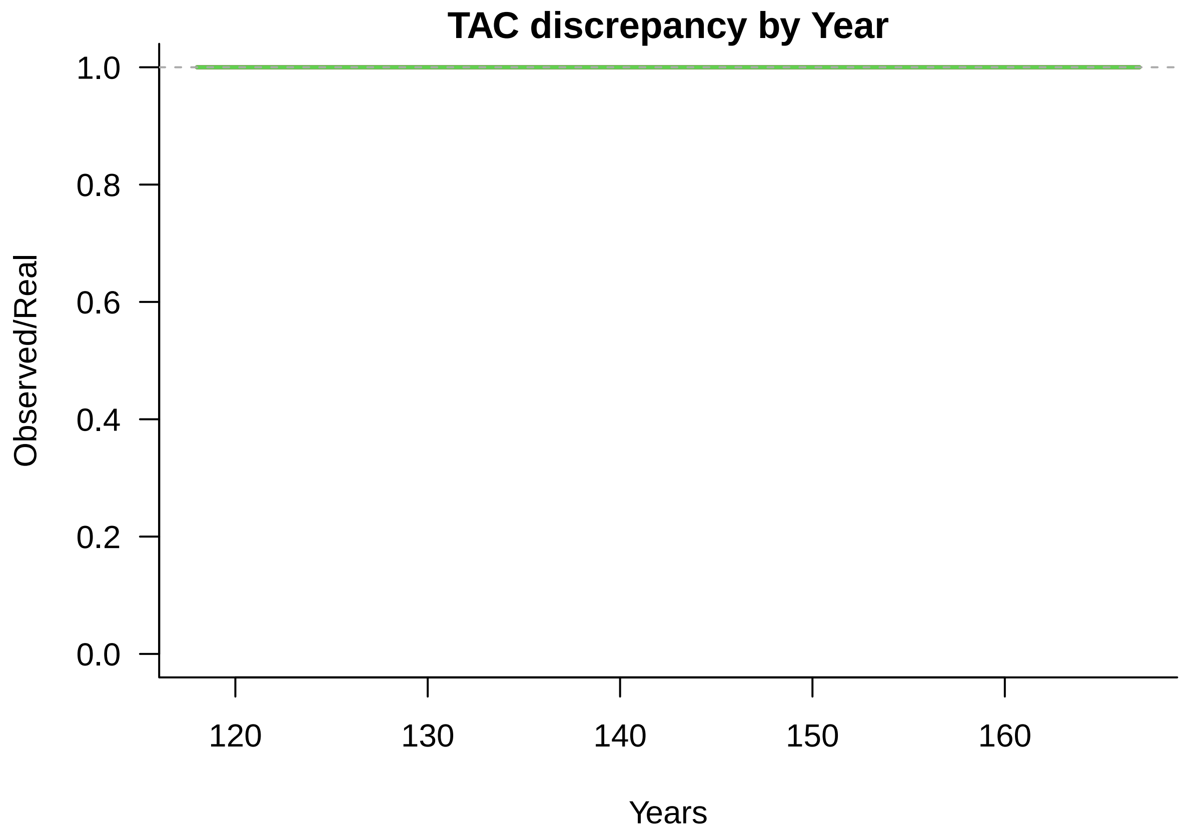
Implementation Parameters

TAC Implementation

Sampled Parameters Histograms of 0 simulations of inter-annual variability in TAC implementation error (`TACSD`) and persistent bias in TAC implementation (`TACFrac`), with vertical colored lines indicating 3 randomly drawn values used in other plots:

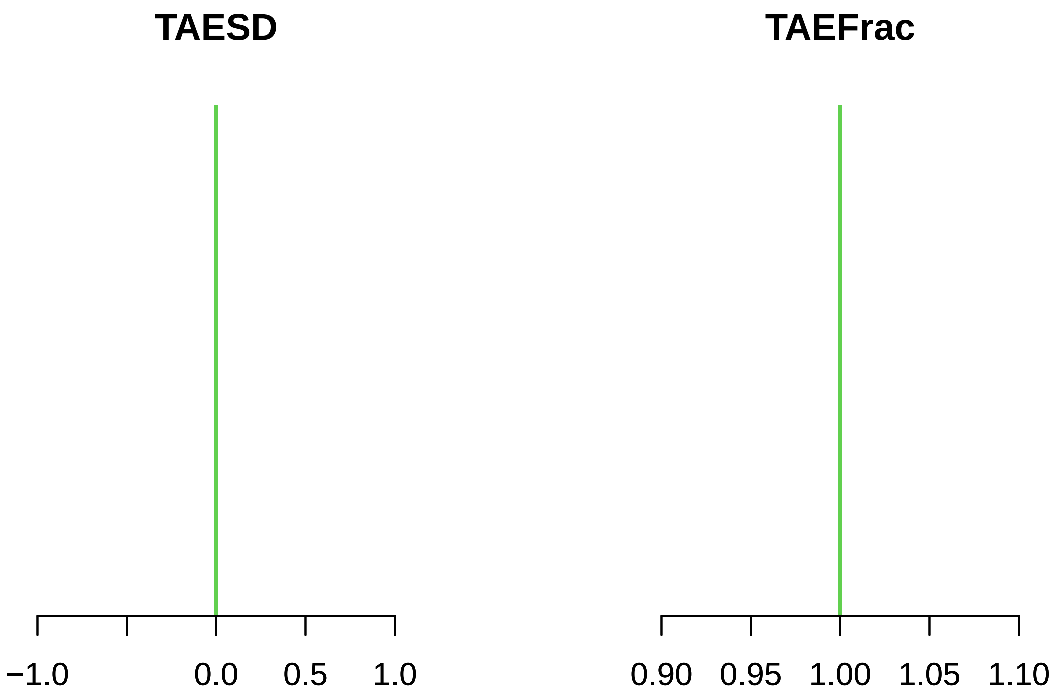


Time-Series Time-series plots of 0 samples of TAC implementation error by year:

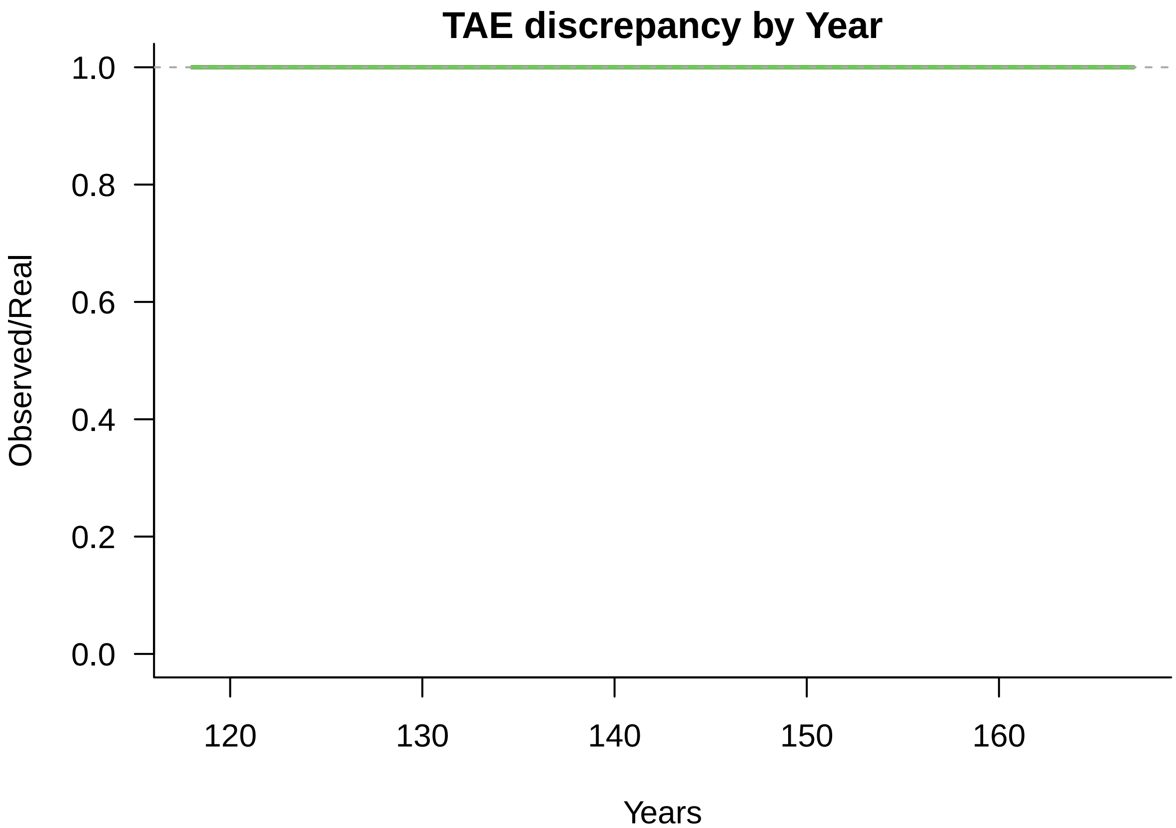


TAE Implementation

Sampled Parameters Histograms of 0 simulations of inter-annual variability in TAE implementation error (`TAESD`) and persistent bias in TAC implementation (`TAEFrac`), with vertical colored lines indicating 3 randomly drawn values used in other plots:

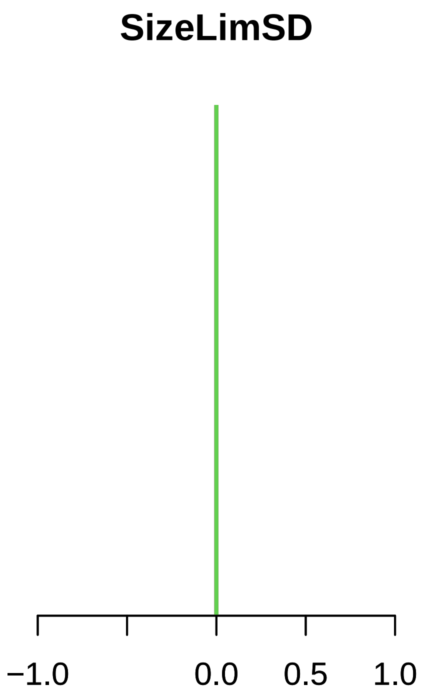


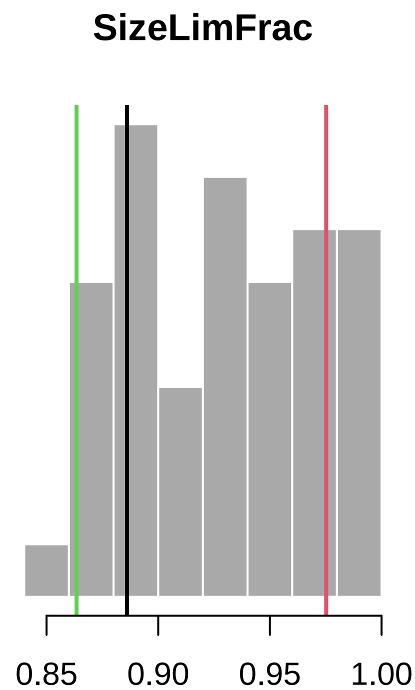
Time-Series Time-series plots of 0 samples of TAE implementation error by year:



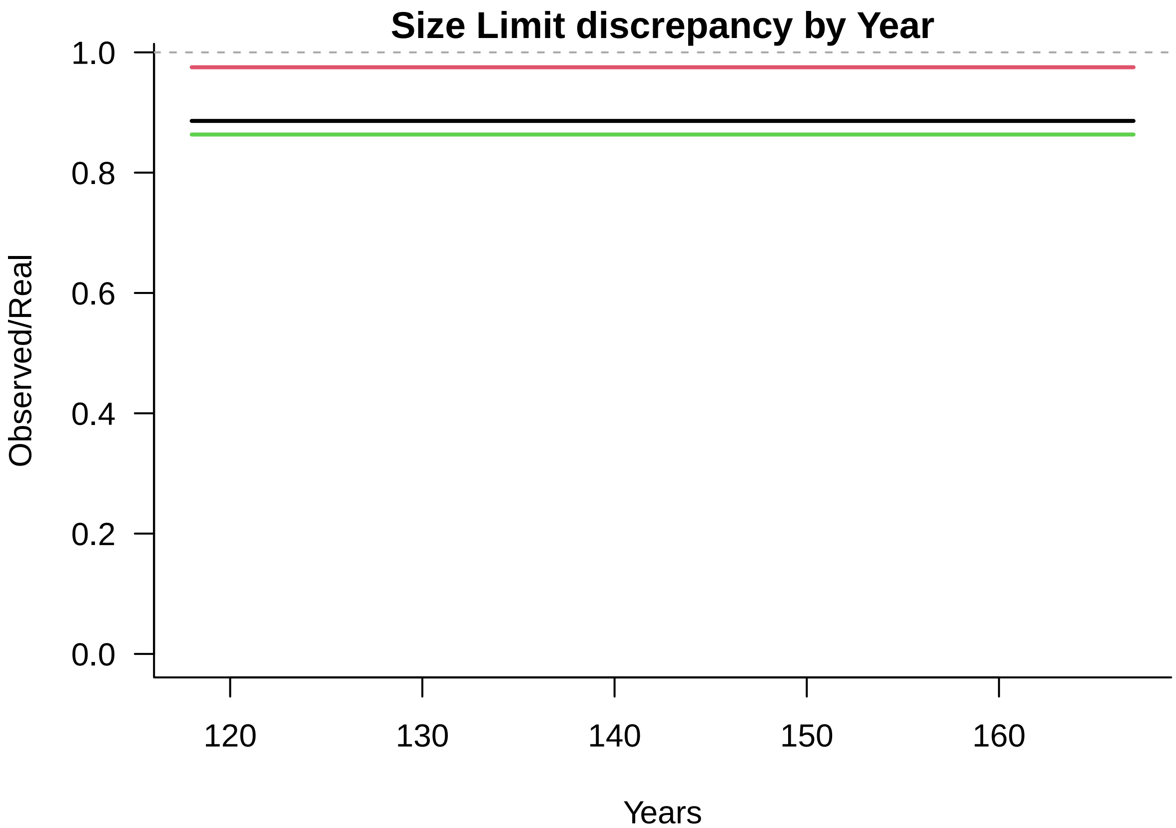
Size Limit Implementation

Sampled Parameters Histograms of 0 simulations of inter-annual variability in size limit implementation error (`SizeLimSD`) and persistent bias in size limit implementation (`SizeLimFrac`), with vertical colored lines indicating 3 randomly drawn values used in other plots:





Time-Series Time-series plots of 0 samples of Size Limit implementation error by year:

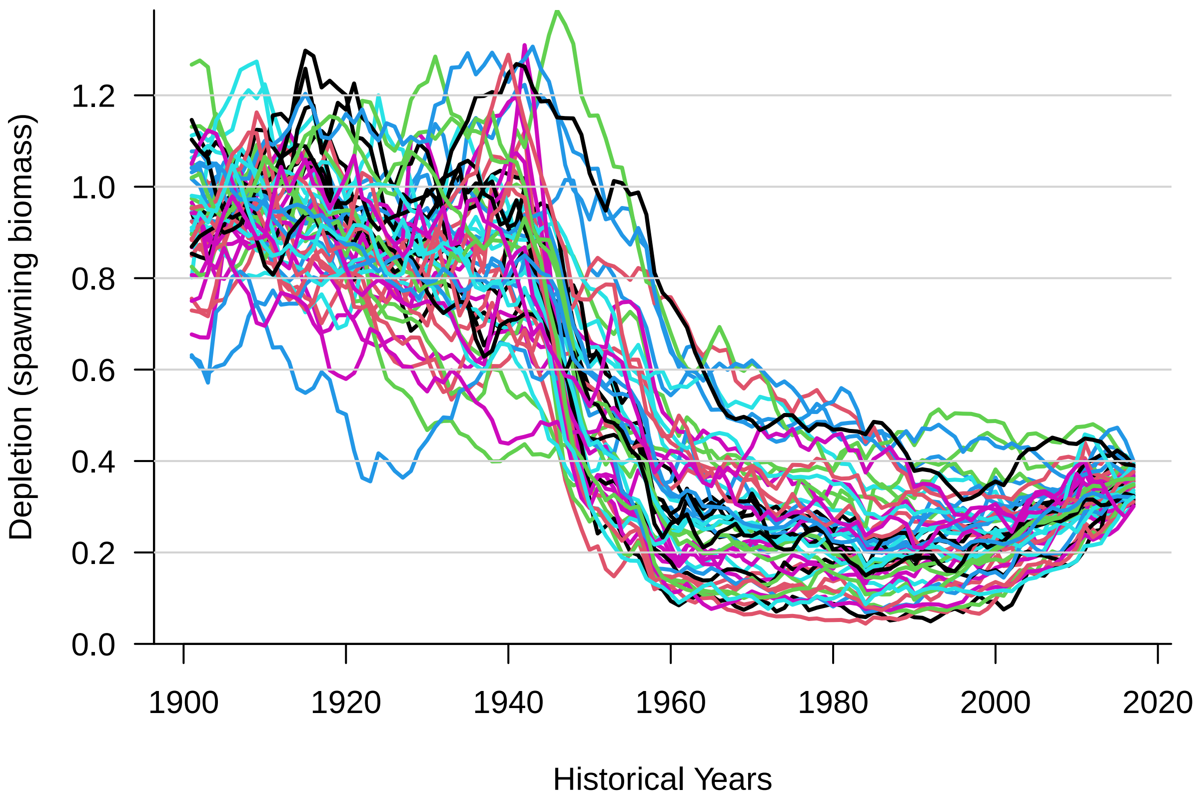


Historical Simulation Plots

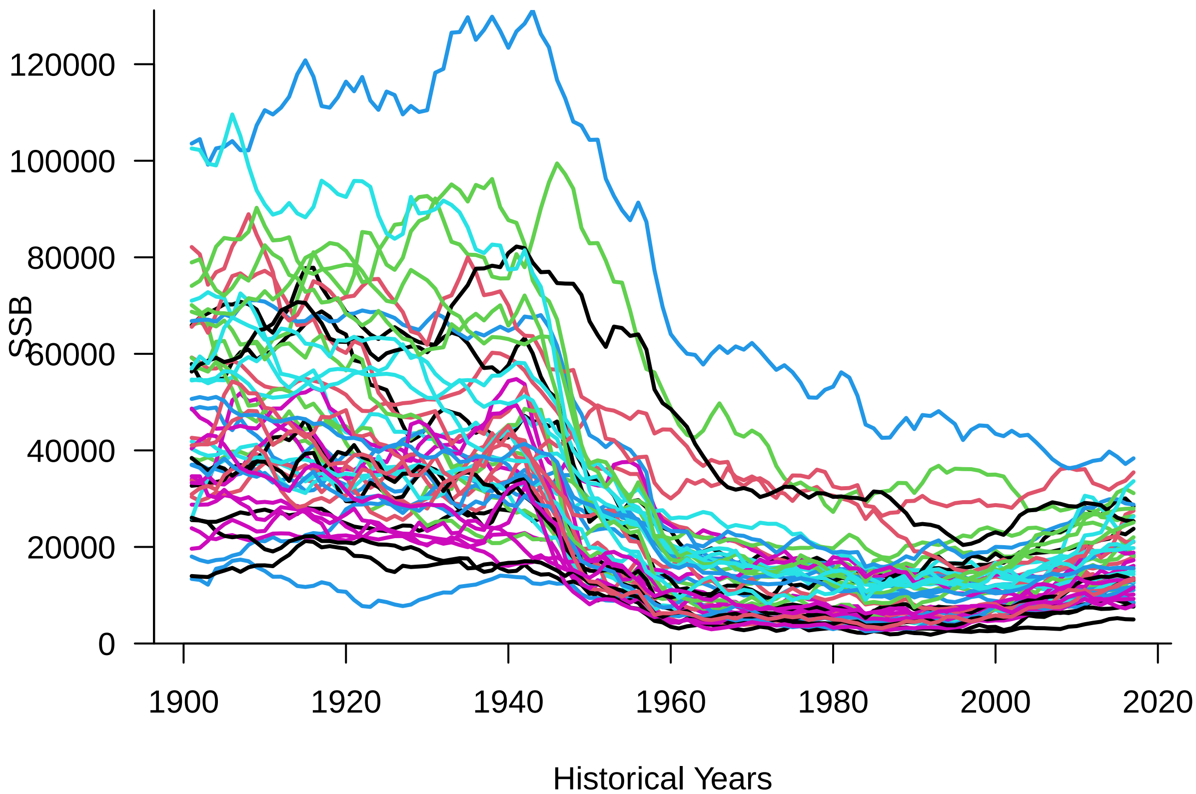
Historical Time-Series

Spawning Biomass

Depletion Time-series plots of SB/SB0:

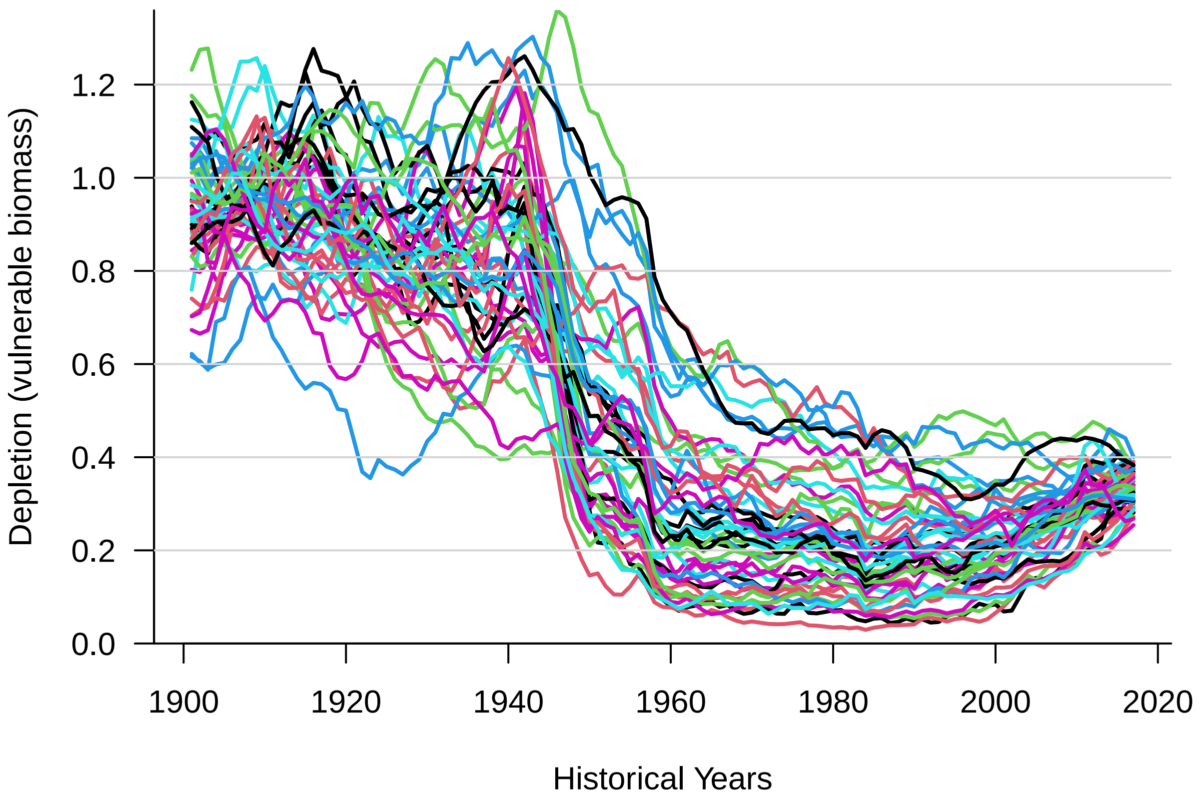


Absolute Time-series plots of absolute SB:

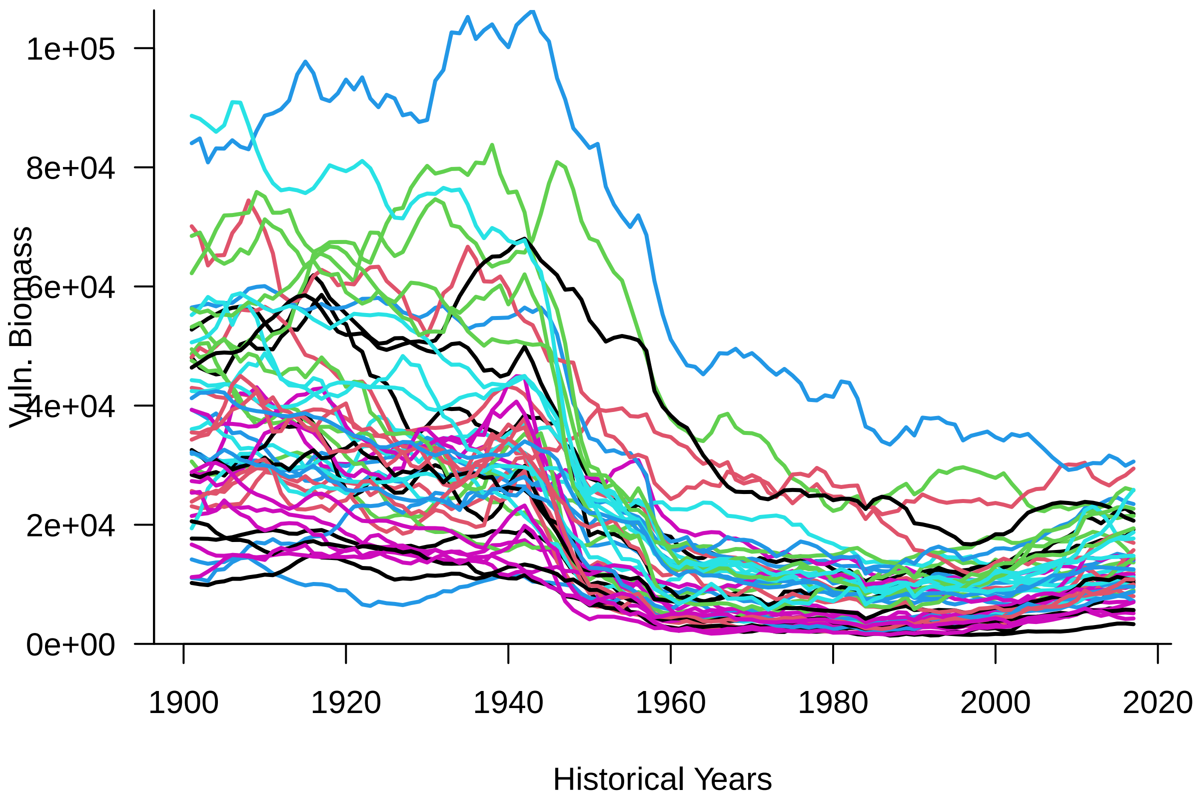


Vulnerable Biomass

Depletion Time-series plots of VB/VB0:

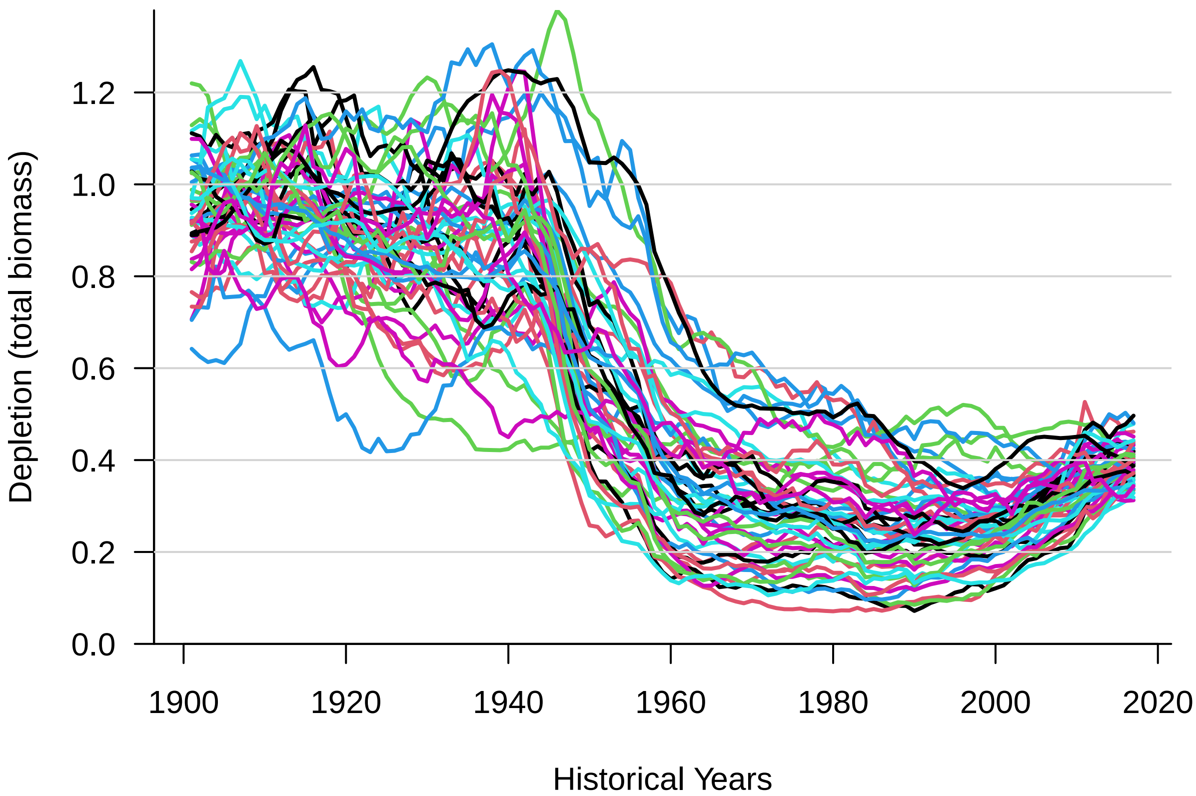


Absolute Time-series plots of absolute VB:

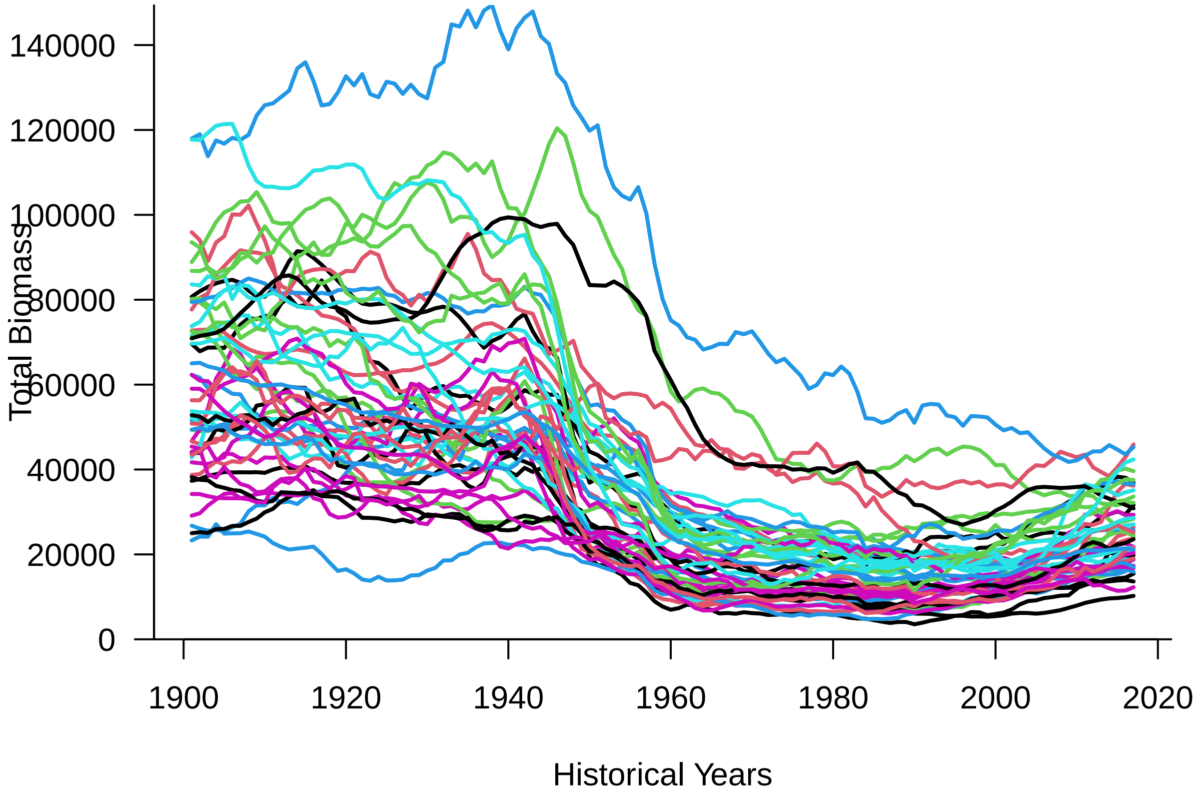


Total Biomass

Depletion Time-series plots of B/B0:

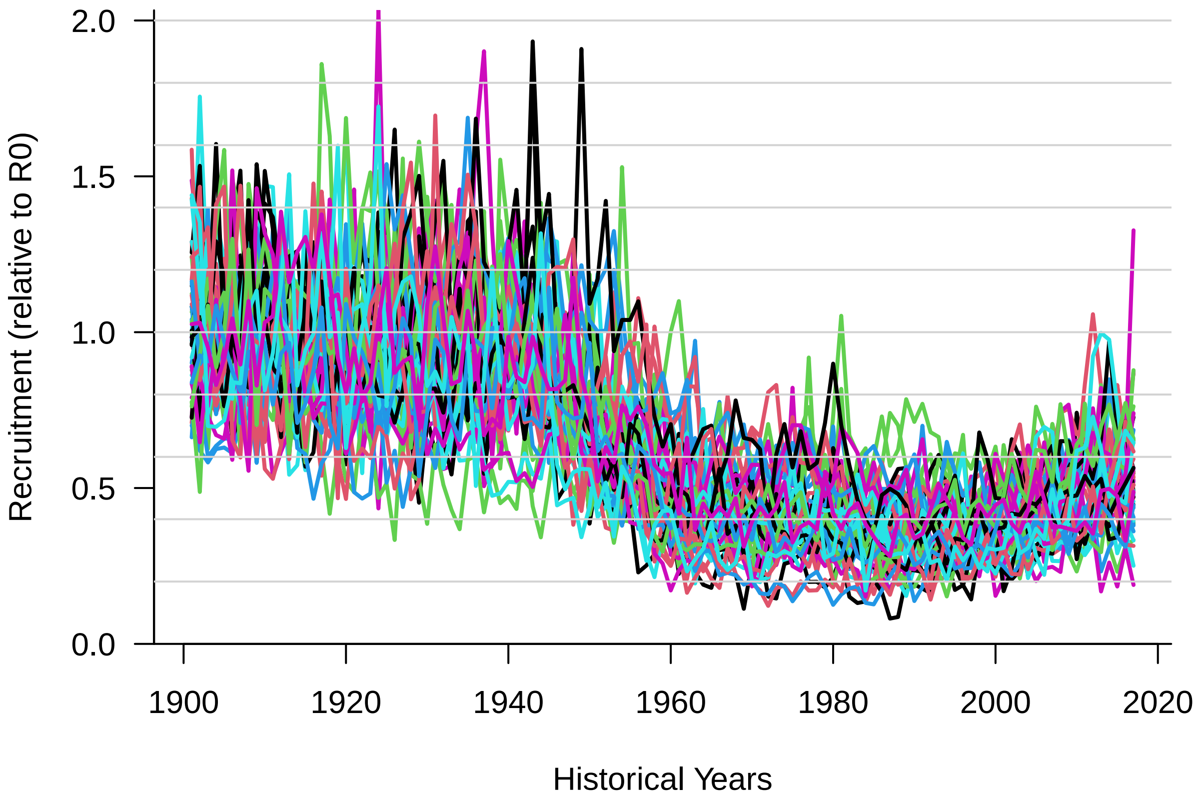


Absolute Time-series plots of absolute B:

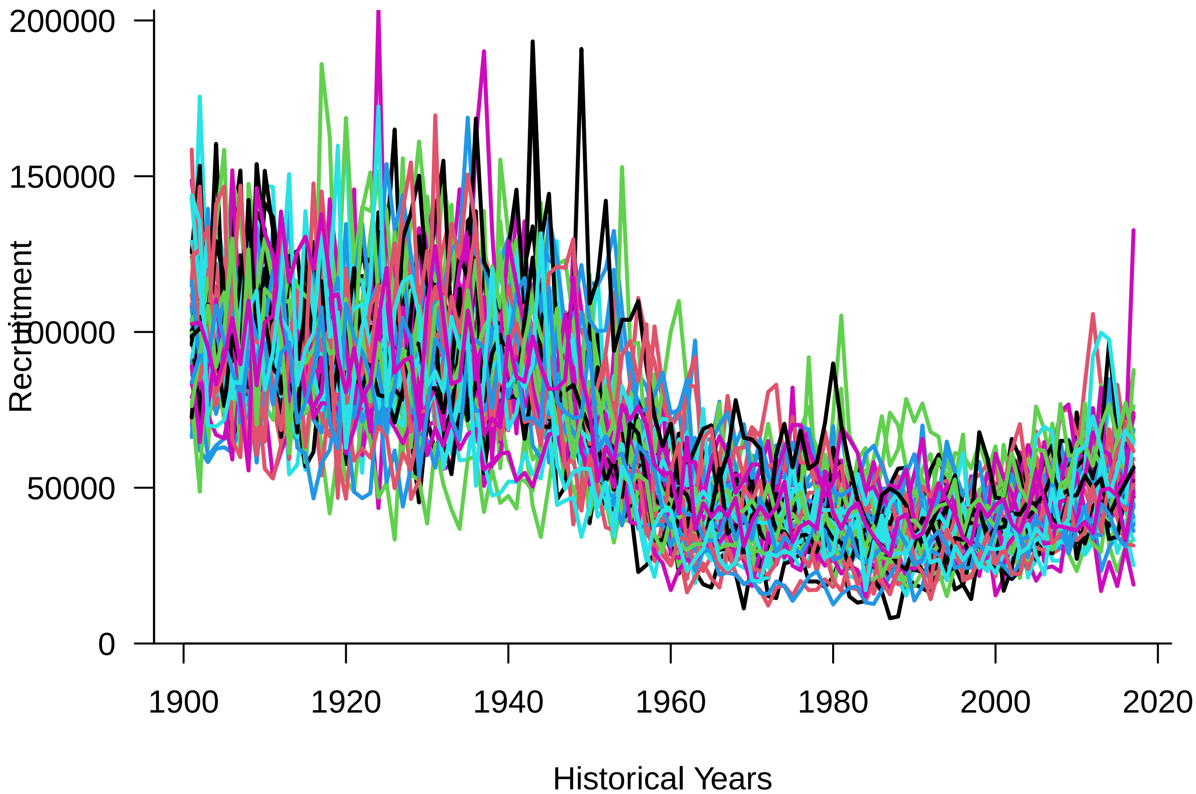


Recruitment

Relative Time-series plot of recruitment relative to R0:

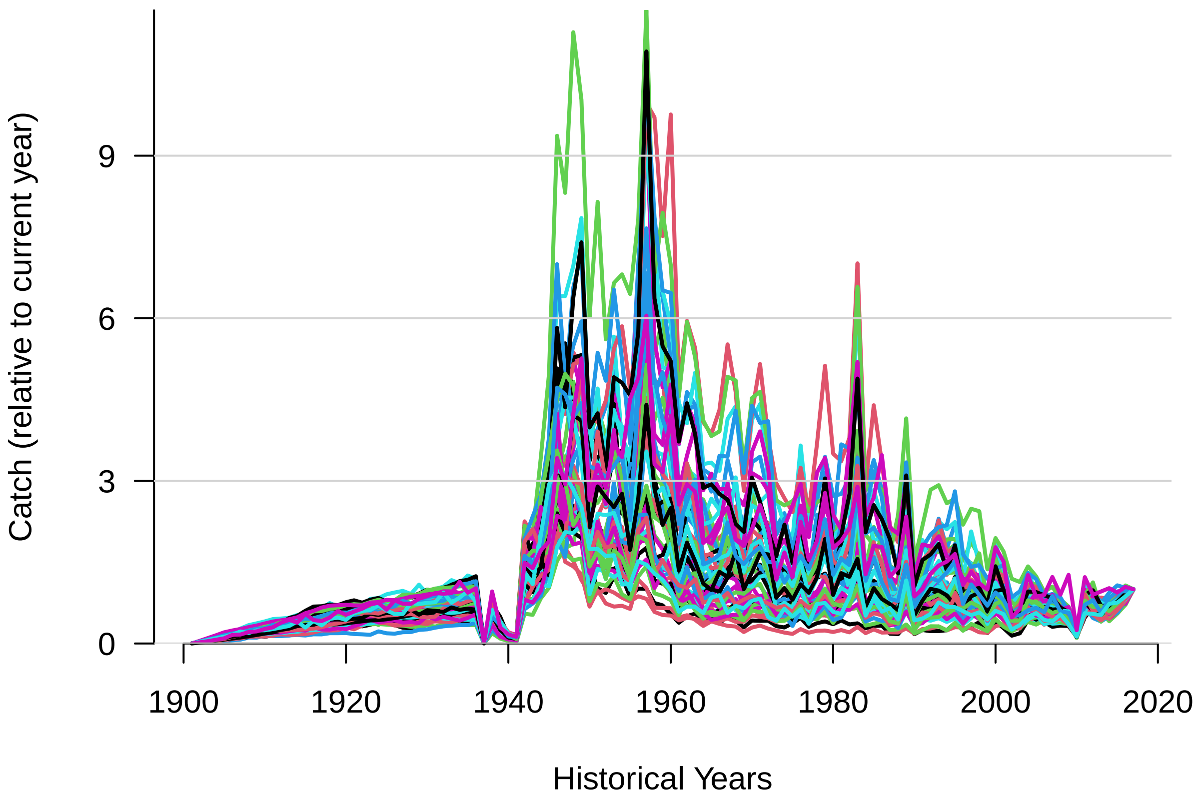


Absolute Time-series plot of absolute recruitment:

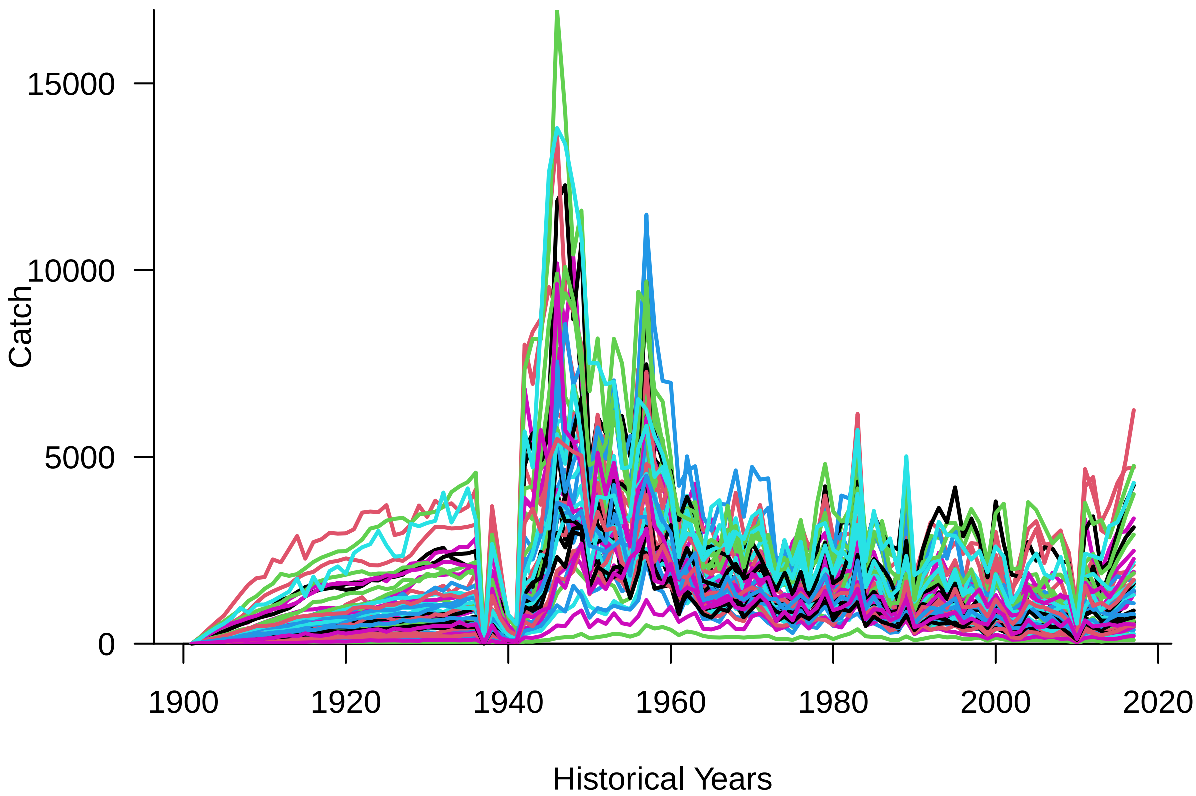


Catch

Relative Time-series of catch relative to the current year:

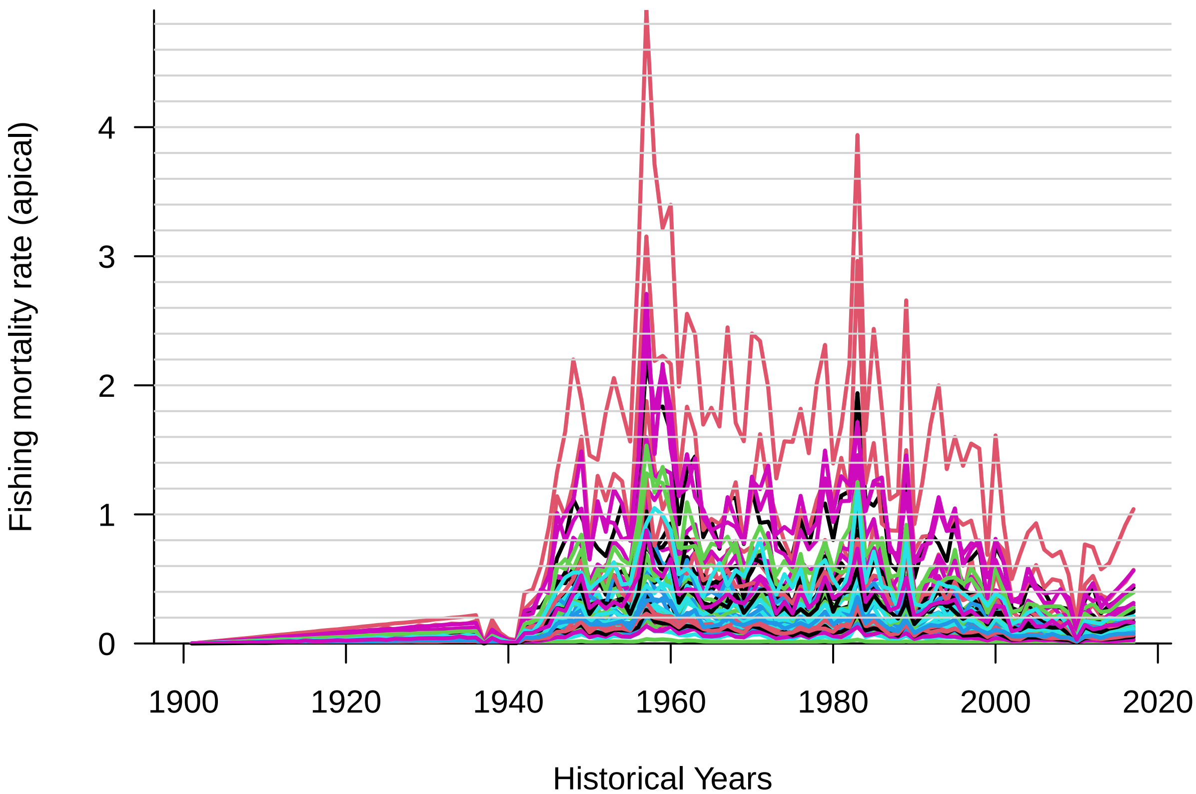


Absolute Time-series of absolute catch:



Historical Fishing Mortality

Historical Time-Series Time-series of historical fishing mortality:



References

Alverson, D. L. and M. J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36: 133-143.

Baltz DM. 1983. Life history variation among female surfperches (Perciformes: Embiotocidae). Env. Biol. Fish. Vol 10, 3:159-171.

Bennett DE, Wydoski RS. 1977. Biology of the Redtail Surfperch (Amphistichus rhodoterus) from the Central Oregon Coast. U.S. Fish Wildl. Serv. Tech. Pap. 90: 1-23.

Brookins K. 1995. Population dynamics and reproductive ecology of the redtail surfperch Amphistichus rhodoterus (Embiotocidae) [PhD dissertation]. Oregon State University. 213 p.

Carlisle JR., JG, Schott JW, Abramson NJ. 1960. The barred surfperch (Amphistichus argenteus Agassiz) in southern California. Calif. Fish Game, Fish Bull. 109: 1-79 p.

Carruthers TR, Punt AE, Walters CJ, MacCall A, McAllister MK, Dick EJ, Cope J. 2014. Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research 153:48-68.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Hordyk A, Ono K, Valencia S, Loneragan N, Prince J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science. 72(1):217-31.

Karpov KA, Albin DP, Van Buskirk WH. 1995. The marine recreational fishery in northern and central California. California Department of Fish and Game. Fish Bull. No 176: 1-192 p.

Ngoile M. 1978. Biology of the redtail surfperch, Amphistichus rhodoterus in northern California. M.S. Thesis. Humboldt State University, Arcata California. 56 p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer: 175-192.

Pruden D. 2000. Southern Oregon Surfperch Studies. Marine Resource Program. Oregon Fish and Wildlife. 25 p.

Then, A. Y., J. M. Hoenig, N. G. Hall, D. A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. Mar. Sci. 72: 82-92.

Triplett EL. 1960. Notes on the life history of the barred surfperch, Amphistichus argenteus Agassiz, and a technique for culturing embiotocid embryos. Calif. Fish Game. 46:433-439.