California Rock Crab: Red Rock Crab Females

Operating Model Report

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Introduction

California's rock crab fishery is comprised of three species, which are managed as a complex: red (Cancer productus), yellow (Metacarcinus anthonyi) and brown (Romaleon antennarium) rock crab. The DLMtool does not currently have the capability to model multiple stocks in one MSE. Therefore, we focused our analysis on only female red rock crab. The fishery is severely data-limited. Landings peaked then fell dramatically in recent years. Parameters were chosen based on published research, expert judgement, fleet communications and proxy species. The following report notes where alternative parameters from the base model values were used in sensitivity testing.

The number of simulations for a final model run (nsim) was 350 and projections looked 50 years to the future (proyears). The management interval tested was 4 years. The maximum instantaneous fishing mortality rate for an age class (maxF) was set unachievably high at 20 to allow full exploration of high mortalities for this short-lived species. 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 any stochastic MPs was set at 0.5, meaning the median recommendation was selected.

Operating Model

Species Information

Species: *Cancer productus*

Common Name: *red rock crab female*

Management Agency:

Region:

OM Parameters

OM Name: Name of the operating model: OMName

nsim: The number of simulations: 100

proyears: The number of projected years: 50

interval: The assessment interval - how often would you like to update the management system? 4

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: 20

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

Julia Coates

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\protect\T1\textdollarplusgroup=0 . Single value. Positive integer.

Specified Value(s): 20

The maximum age estimated for red rock crab by Yamada & Groth (2016) is 5 or more. A maximum age of 20 was used to allow for exploration of a range of age structures. Final natural mortality parameters resulted in near 0 individuals by age 8.

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): 1000

In the absence of a stock assessment, there is currently no estimate for 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 1000.

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): 0.45, 0.55

There are no direct motality estimates available for the three rock crab species, but crabs are known to have relatively high mortality rates. Fitzgerald et al. 2018 assumed a M of 0.2-0.4. Zheng 2005 reviewed the mortality of crab species. Estimates based on maximum age such as Then et al (2015) are probably most reliable, as many of the empirical regression or life history based methods were developed from observations of finfish. The Then et al. method returns M=0.824 with max age of 7. Punt & Methot (2005) report M values for Dungeness crab ranging from 0.7 to 2.26. The method used in the Jonah Crab example OM calculates upper and lower bounds by entering high and low estimates of max age into this equation (-ln(0.01)/age). Using 7 and 5 as the high and low estimates this produces M values of 0.66 and 0.92. Taking all this info into account, we initially used 0.7 and 1 as the lower and upper bounds but found that model results were unstable and this did not allow any crabs to reach the maximum observed size/longevity. M was reduced to balance these concerns with the estimates above.

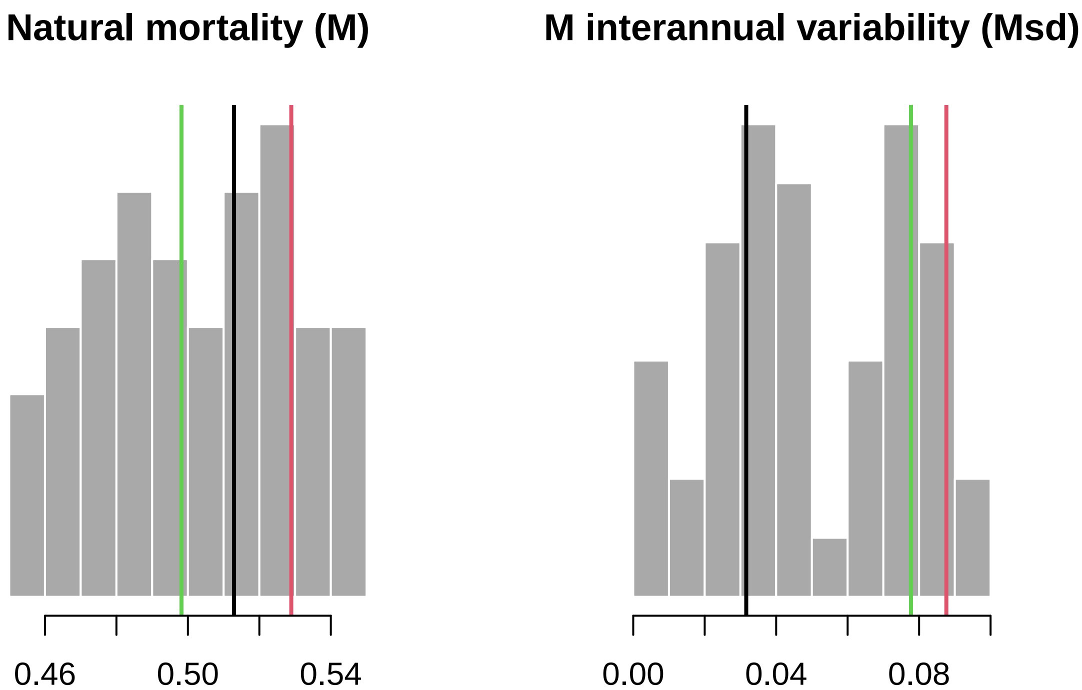
Msd: Inter-annual variation in M expressed as a coefficient of variation of a log-normal distribution. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter is positive, yearly M is drawn from a log-normal distribution 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

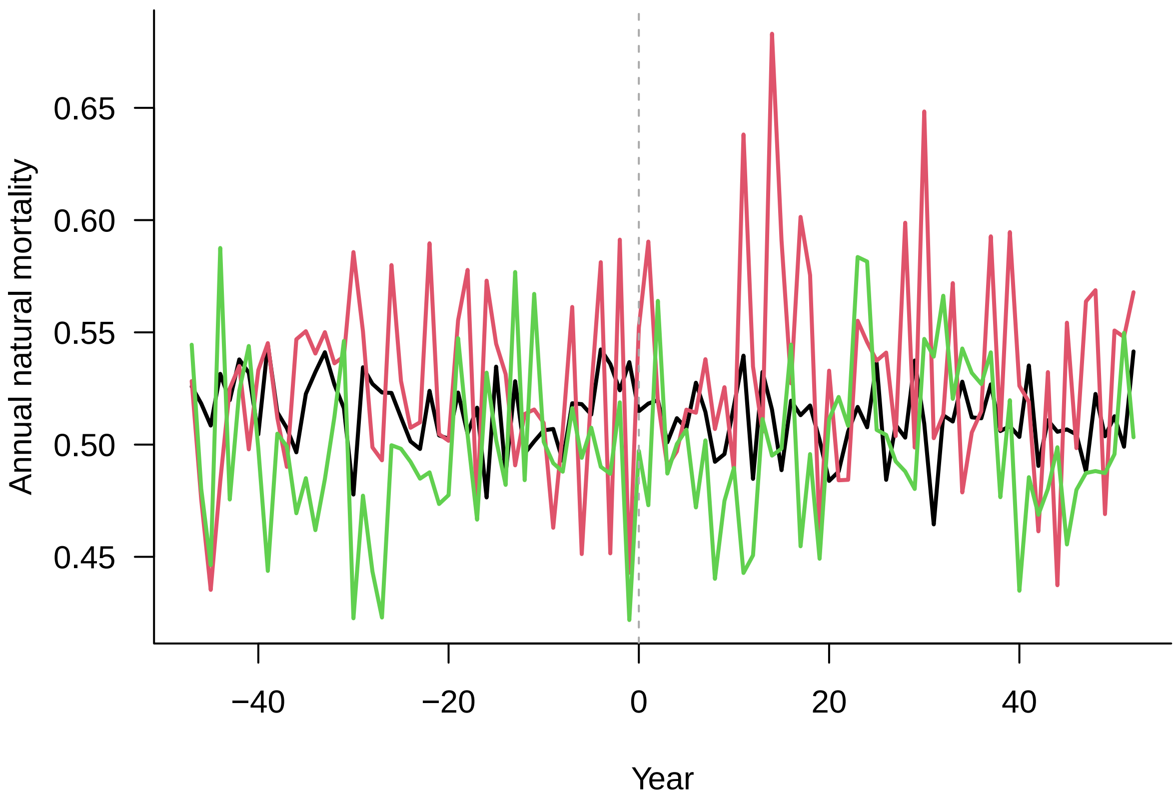
M likely varies based on environmental conditions.

Natural Mortality Parameters

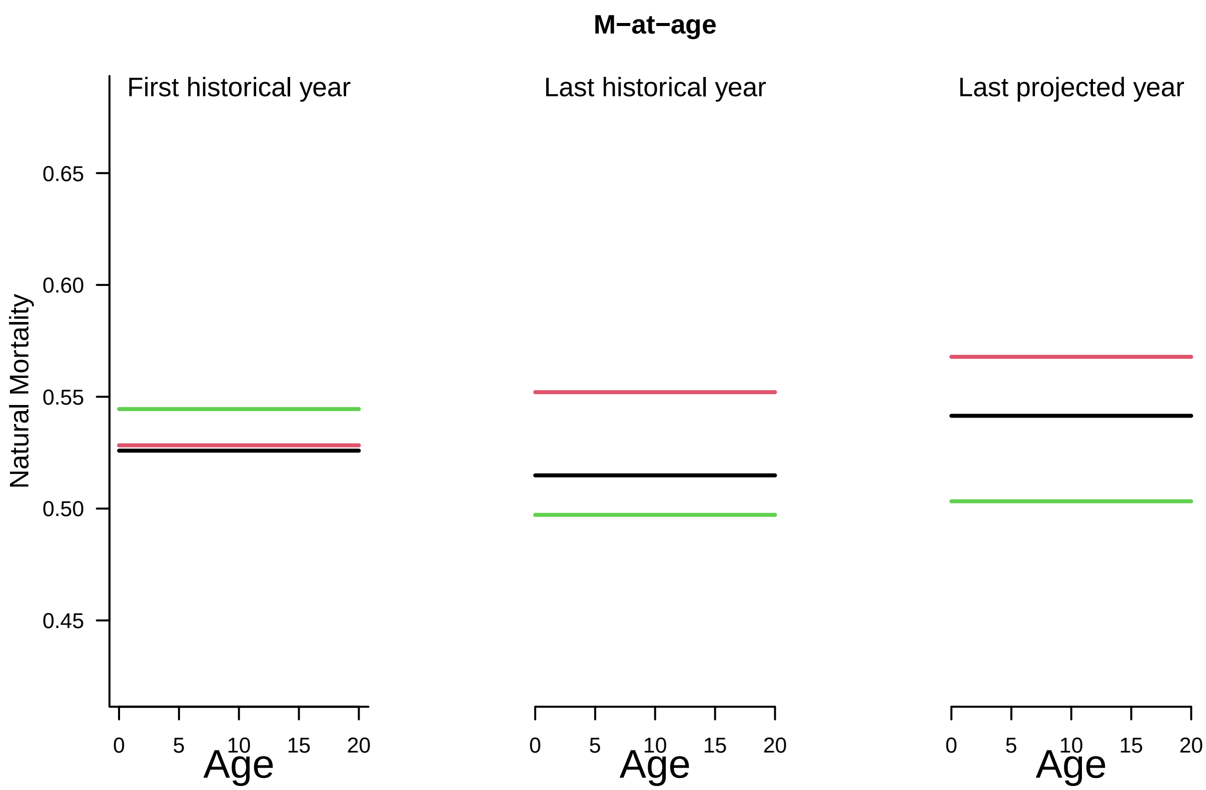
Sampled Parameters Histograms of simulations of `M`, and `Msd` parameters, with vertical colored lines indicating 3 randomly drawn values used in other plots:



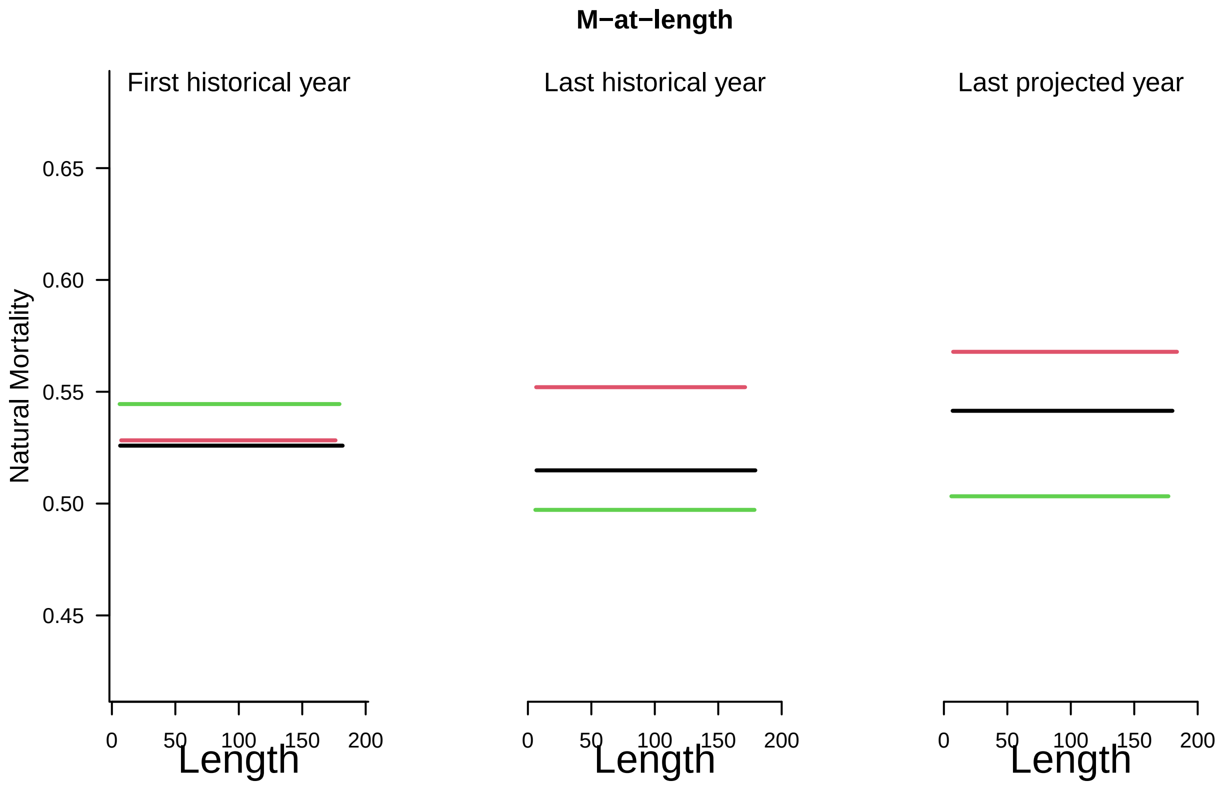
Time-Series The average natural mortality rate by year for adult fish for 3 simulations. The vertical dashed line indicates the end of the historical period:



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): 0.7, 0.9

There is no direct information, but steepness is typically reported to be high in Crustaceans. The Jonah crab MSE detailed in the DLMtool operating model library used 0.9 to 0.95. Slightly lower values were used here because female rock crabs are taken. Reduced steepness was sensitivity tested.

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

Beverton-Holt was used. There is no evidence for hump-shaped stock-recruitment.

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

Specified Value(s): 0.3, 0.6

We suspect high recruitment variability due to variable catch and typically high variability for other crustaceans. Therefore Perr is high in the base model. We also tested an alternative model with Perr relatively low and using the environmentally driven recruitment parameters (Period & Amplitude) to produce most of the variability. This model better simulates the catch data. However, the catch data is likely artificially smooth due to combined landings of all three species.

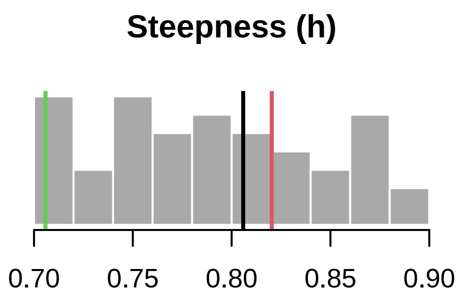
AC: Autocorrelation in the recruitment deviations in log space. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided, and used to add lag-1 auto-correlation to the log recruitment deviations. Uniform distribution lower and upper bounds.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

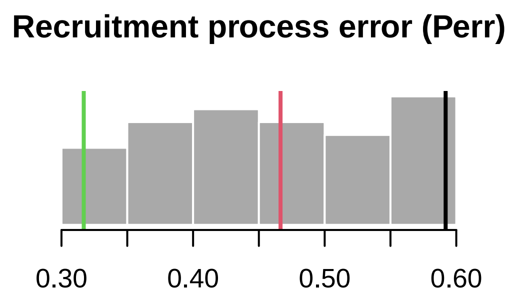
Specified Value(s): 0.1, 0.3

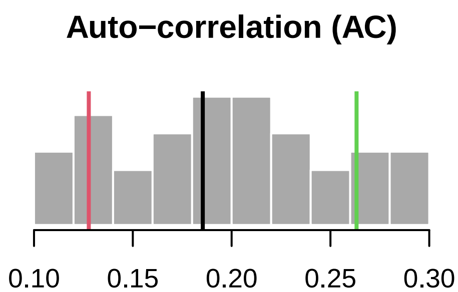
The base model uses a wide range for autocorrelation. Low autocorrelation to allow environmental parameters to drive variation was sensitivity tested.

Recruitment Parameters

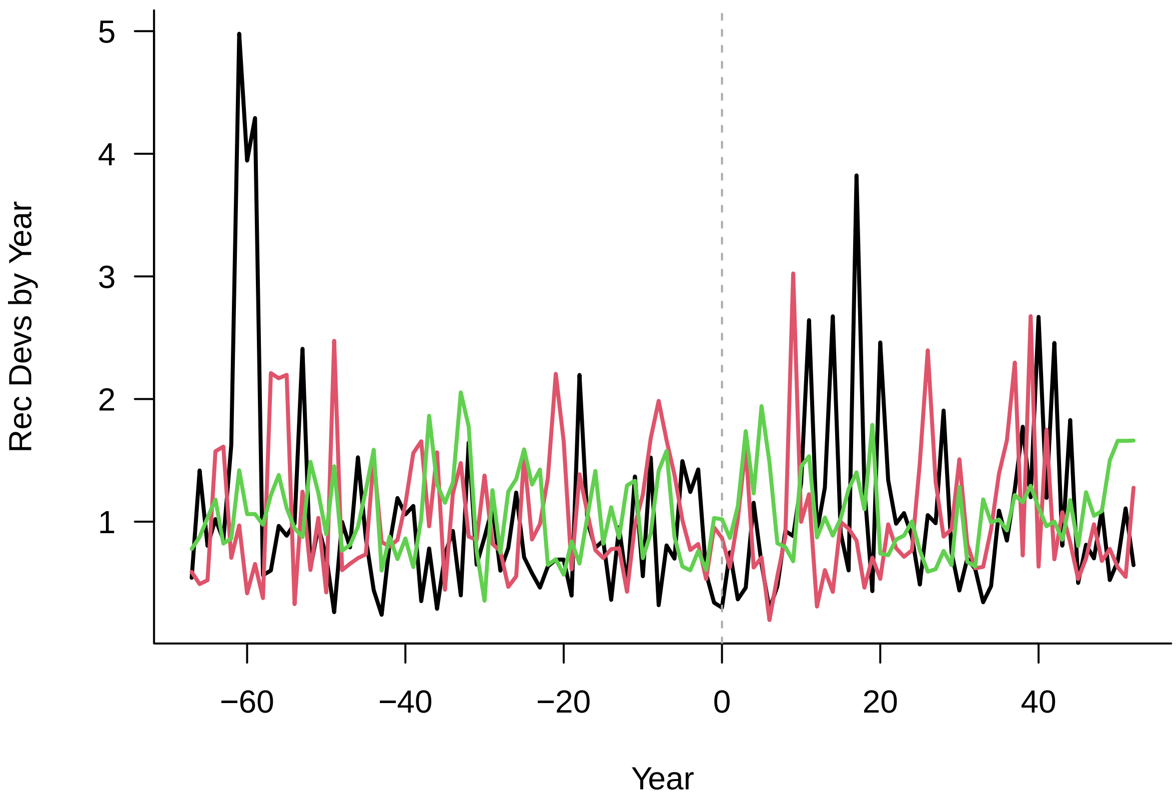
Sampled Parameters Histograms of 48 simulations of steepness (`h`), recruitment process error (`Perr`) and auto-correlation (`AC`) for the Beverton-Holt stock-recruitment relationship, with vertical colored lines indicating 3 randomly drawn values used in other plots:







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): 175, 185

Studies report maximum observed female red rock crab sizes of 150 mm in Washington (Yamada & Groth 2016) and 168 in California (CDFW 2003). A range of sizes slightly larger than these reported sizes was used to reflect the assumption that fishing pressure has influenced these reported maximums. Red rock crab maximum carapace width is reported to be larger at California's Northern Channel Islands than the adjacent mainland (Culver et al. 2010).

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): 0.2, 0.34

The value was adjusted to produce Von Bertalanfy curves that result in sizes at 4-5 years of age corresponding to the peaks in the size distribution of catch plots shown in Culver et al. (2010).

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): -0.1, -0.15

The value was adjusted to produce Von Bertalanfy curves that result in sizes at 4-5 years of age corresponding to the peaks in the size distribution of catch plots shown in Culver et al. (2010).

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, 0.12

Default values were used.

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, 0.05

We allowed only a small amount of variability due to some model instability due to high recruitment variability.

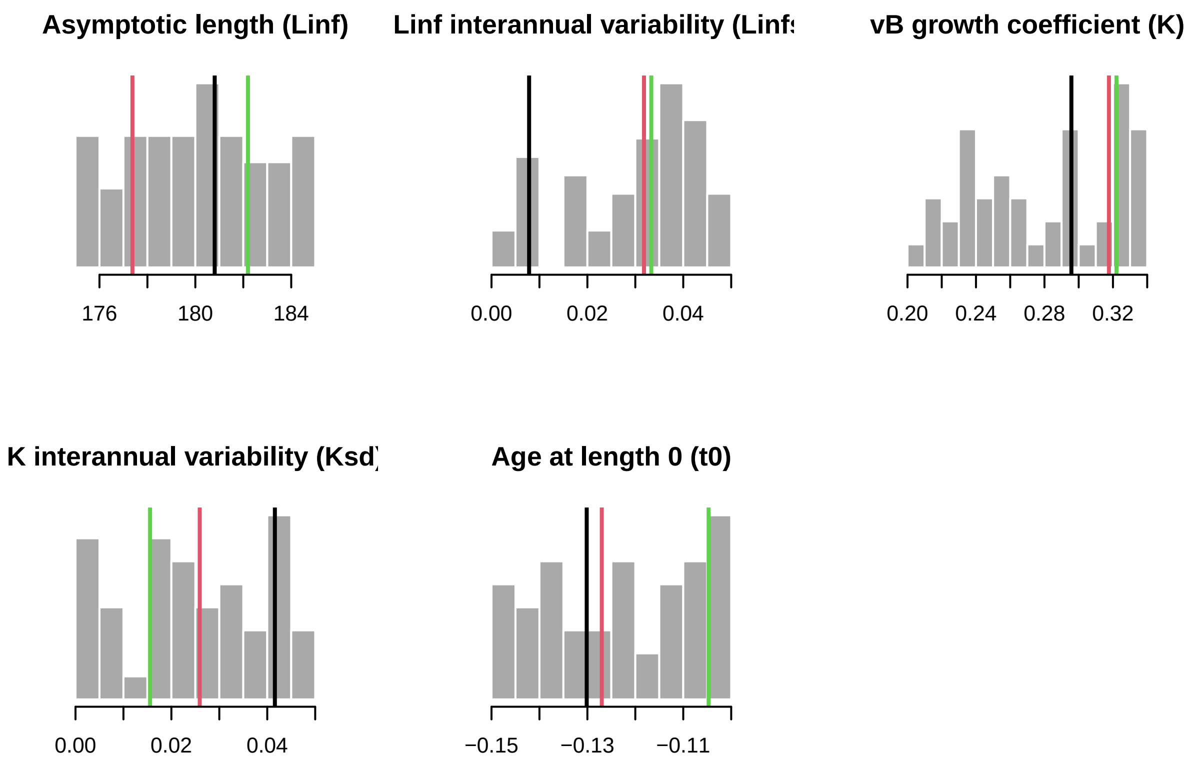
Linfsd: Inter-annual variation in Linf. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter has a positive value, yearly Linf is drawn from a log-normal distribution with a mean specified by the value of Linf drawn 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, 0.05

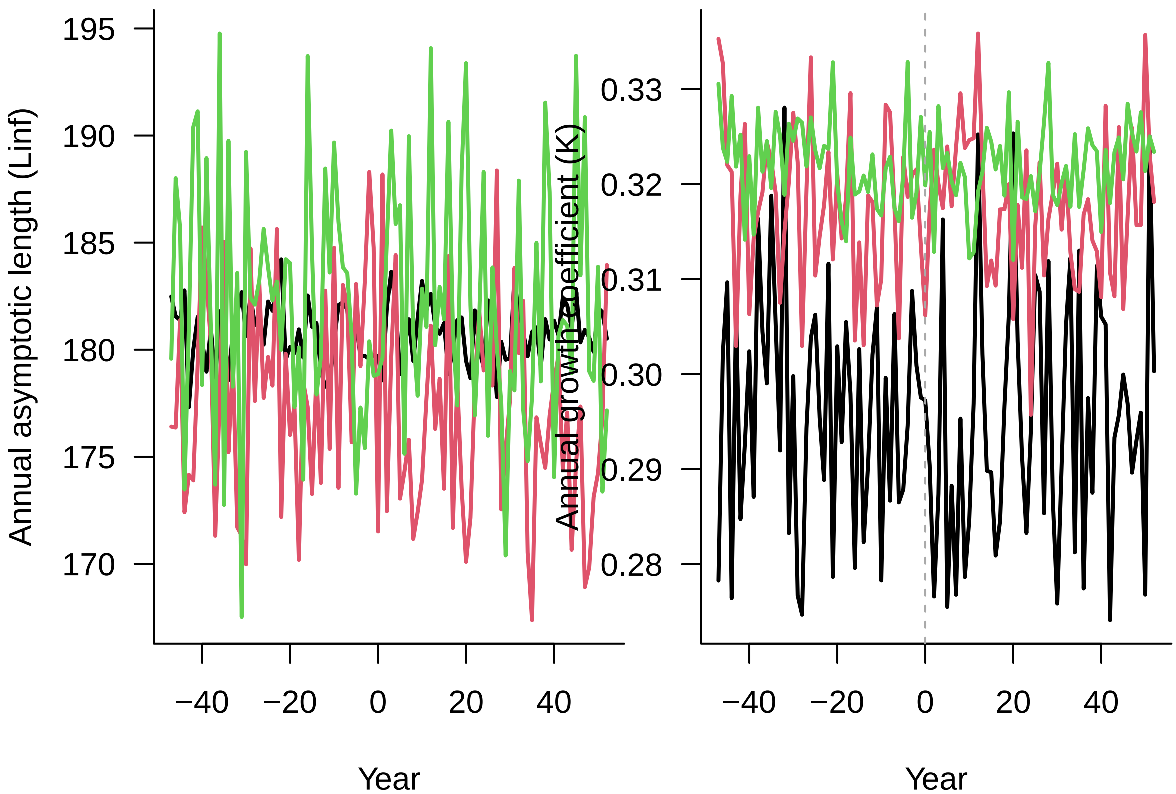
We allowed only a small amount of variability due to some model instability due to high recruitment variability.

Growth Parameters

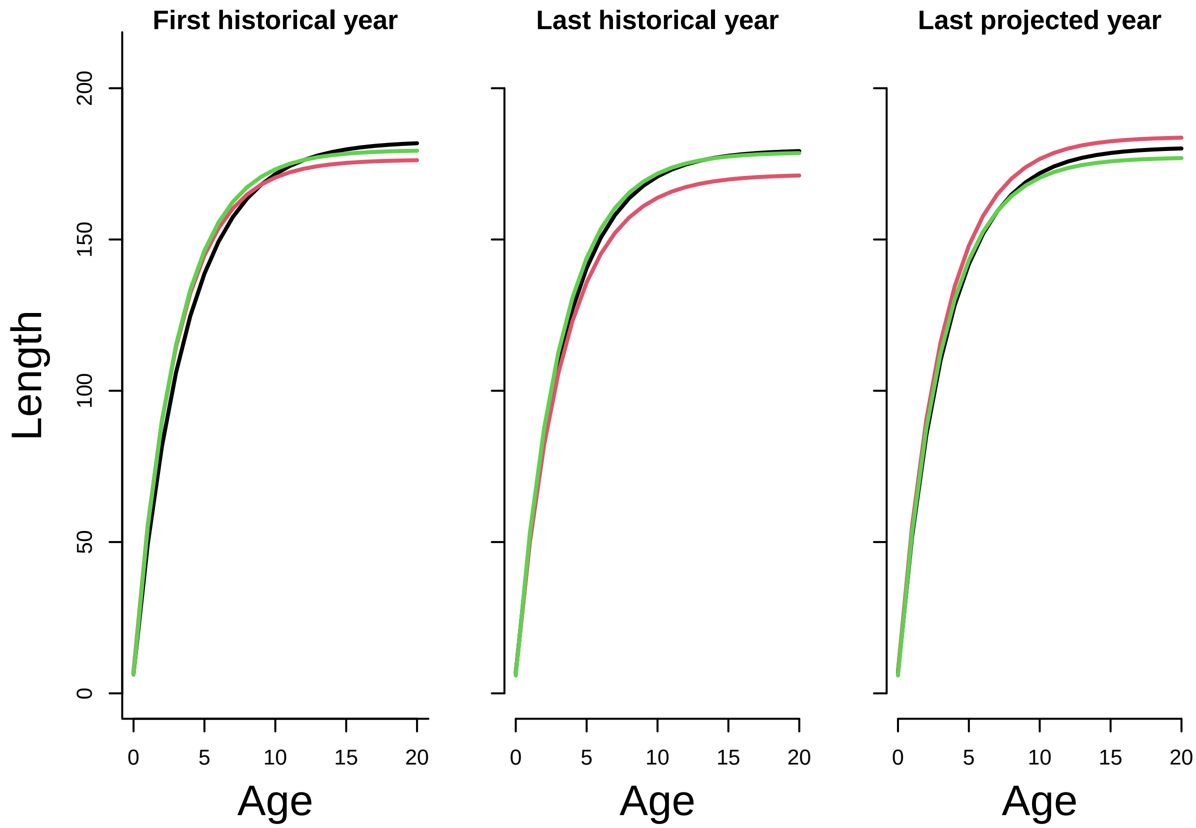
Sampled Parameters Histograms of simulations of von Bertalanffy growth parameters `Linf`, `K`, and `t0`, and inter-annual variability in Linf and K (`Linfsd` and `Ksd`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



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): 40, 55

Sexual maturity for female red rock crabs is reported at 65 mm (Orensanz and Gallucci 1988). No male estimate is provided. Yamada and Groth (2016) report that red rock crabs settle in the spring, are 5-15mm CW at the end of their first summer, and are mature at 65mm. They reach this size sometime in their second year.

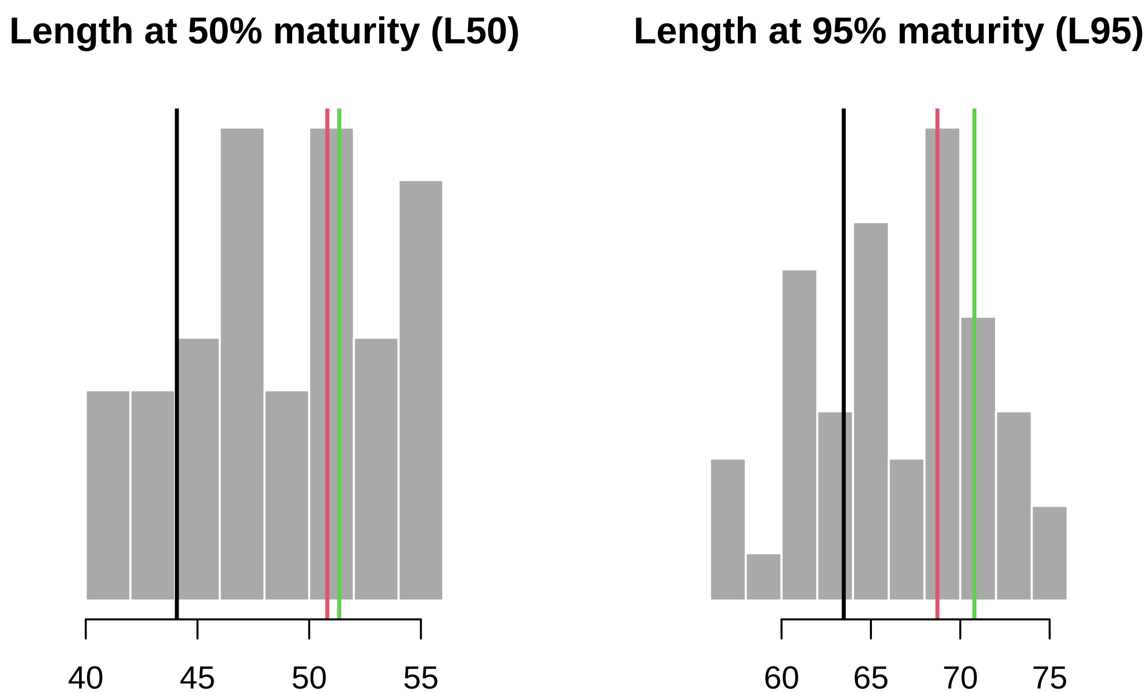
L50_95: Difference in lengths between 50% and 95% maturity. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. The value drawn is then added to the length at 50% maturity to determine the length at 95% maturity. This parameterization 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): 15, 20

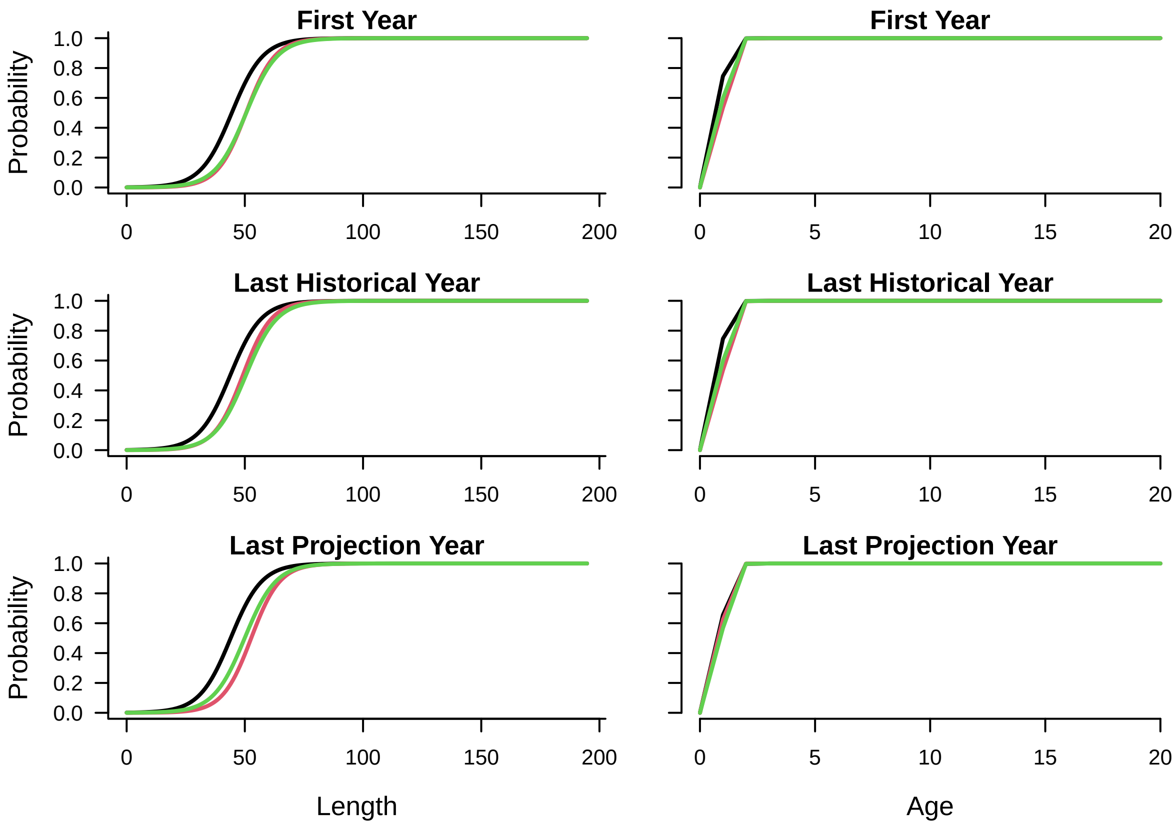
By their second summer all observed female reds were between 70 mm (early summer) and 99 mm (late summer).

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): 0.43, 0.5

Several indicators suggest stock depletion. Fitzgerald et al. (2018) saw some evidence of serial depletion (by species and fishing region). Fitzgerald et al. (2019) reported reductions in CPUE and average size for some combinations of species and sex between 2008 and 2018. Fishermen also report reduction in average size. However, while catch has fallen from a peak in 2014, it remains within a historically normal range. This and the short life span would suggest that the stock isn't extremely depleted. Simulations are unable to achieve low depletion values (suggesting low stock size) given other specified parameters and data. Depletion was redefined based on vulnerable biomass using cpars and different values were tested in simulation. Resulting vulnerable biomass to spawning stock biomass ratios were examined. Lower ratios would indicate that fishermen are seeing reduced available stock leading to unsatisfactory fishing conditions even if overall stock biomass is not greatly reduced. Stock reduction analysis in MSEtool was also used to estimate depletion.

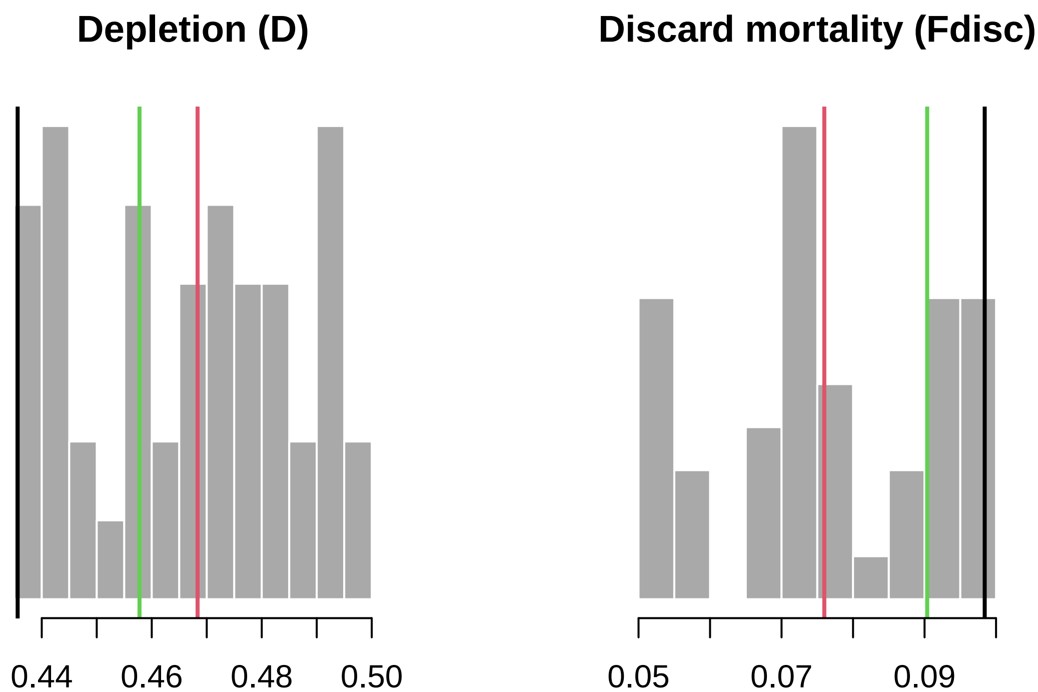
Fdisc: The instantaneous discard mortality rate the stock experiences when fished using the gear type specified in the corresponding fleet object and discarded. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Uniform distribution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

Specified Value(s): 0.05, 0.1

Relatively high discard rates were chosen because there are a variety of reasons crabs may be thrown back - berried females, broken limbs, recent molt.

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): 0.95

Carroll (1982) published a linear equation for the length-weight relationship for brown rock crab. I translated this equation into the power equation needed for the a and b parameters. First I used the linear equation to generate vectors of length and weight then ran the following code:

Dat <- read.csv("BrownLengthWeight.csv")

CW<- select(Dat,CW) W<-select(Dat,Weight)

CW<-unlist(CW, recursive=TRUE, use.names=TRUE) W<-unlist(W, recursive=TRUE, use.names=TRUE)

mod<-nls(W~a*CW^b, data=Dat, start=list(a=1, b=1)) summary(mod)

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): 1.34

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): 0.02, 0.08

Discussions with fishermen suggest that MPAs removed about 5% of red rock crab fishing grounds.

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): 0.02, 0.08

Assumed equal distribution of crabs across MPA and non-MPA areas.

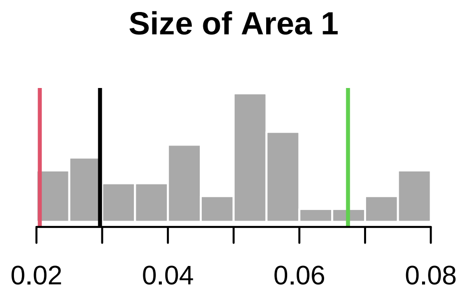
Prob_staying: The probability of individuals in area 1 remaining in area 1 over the course of one year. Please specify numbers between 0 and 1. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. For example, in an area with a Prob_staying 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.

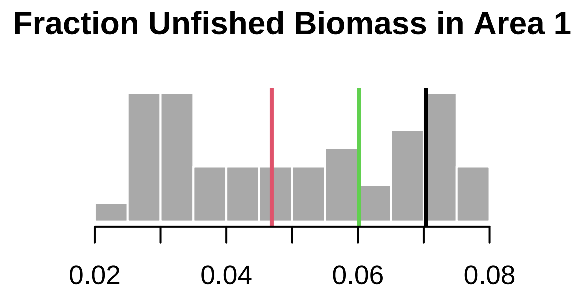
Specified Value(s): 0.5, 0.5

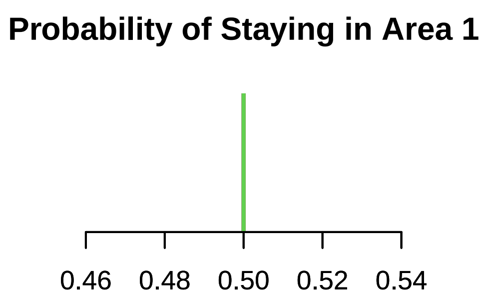
No information on movement is available.

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

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): 50

CDFW has 50 years of landings data from 1969 to 2018. While the fishery was operating before the first landings data were collected, no additional "warm up" years were added prior to first landings. Impacts of early fishing are likely minimal on this short-lived species.

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

All of the stock was considered to be vulnerable to fishing. MPAs probably provide little protection to rock crabs.

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).

Notable peaks and valleys in effort (landings/year) were observed in these years.

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).

Effort was initially described by the number of landing receipts submitted in each year. Without an at-sea logbook for this fishery, we have no data on the number of traps or trap-hours associated with landings. The number of receipts was thought to not reflect anecdotal information from fishermen on recent increases in effort. As a proxy for increasing numbers of traps being used to achieve each landing, information on the number of lobster trap pulls was taken from the lobster logbook. The number of trap pulls was normalized by the year with the greatest number and this was multiplied by the number of rock crab landing receipts to produce an assumed effort index. Trap pulls was assumed to remain at peak (2015) level in subsequent years. EffLower is 10% below and EffUpper is 10% above this value.

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).

See EffLower.

EffYears	EffLower	EffUpper
1969	0.125	0.153
1972	0.218	0.266
1975	0.411	0.502
1978	0.421	0.515
1981	0.527	0.644
1984	0.700	0.855
1987	0.478	0.585
1990	0.662	0.809
1993	0.509	0.622
1996	0.470	0.575
1999	0.427	0.522
2002	0.423	0.518
2005	0.339	0.414
2008	0.461	0.563
2011	0.567	0.693
2014	0.900	1.100
2017	0.900	1.100
2018	0.900	1.100

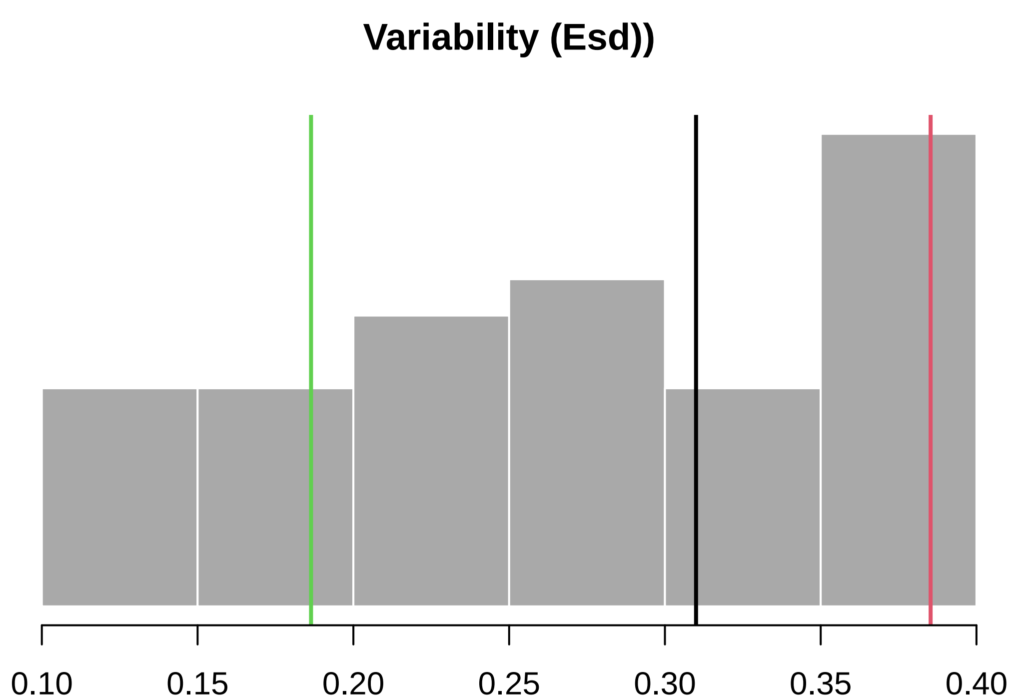
Esd: Additional inter-annual variability in fishing mortality rate. For each historical simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter has a positive (non-zero) value, the yearly fishing mortality rate is drawn from a 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): 0.1, 0.4

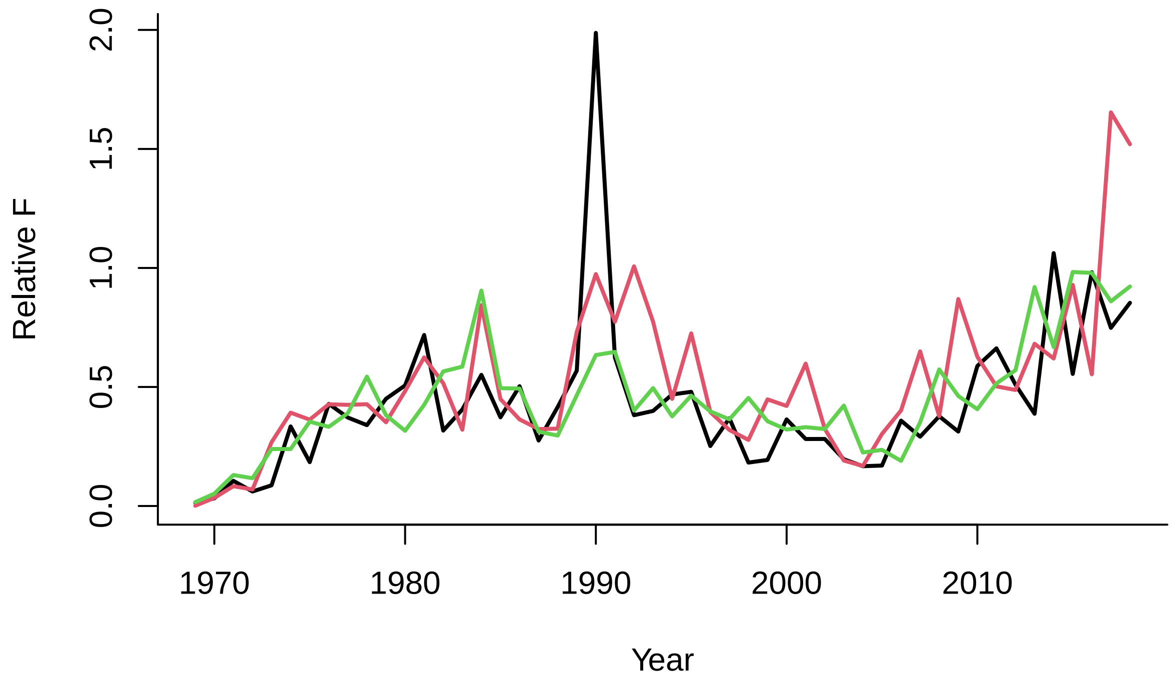
Default values were used.

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, 0

No increase in catchability over time was assumed.

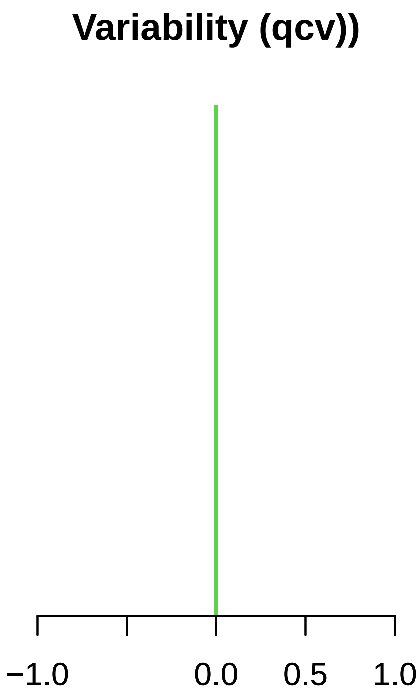
qcv: Inter-annual variability in catchability expressed as a coefficient of variation. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. This parameter applies only to forward projections.

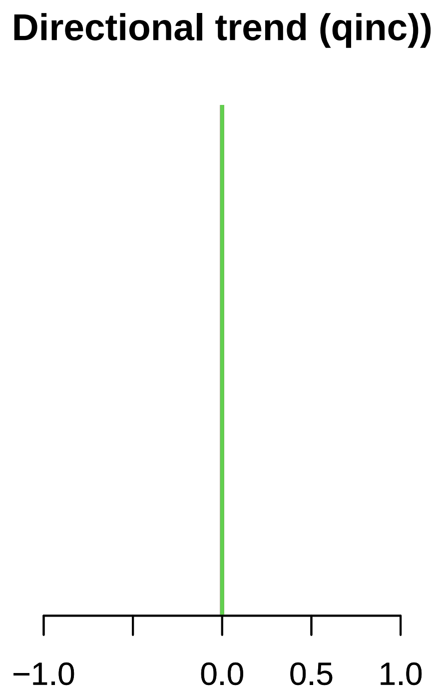
Specified Value(s): 0, 0

Default values were used.

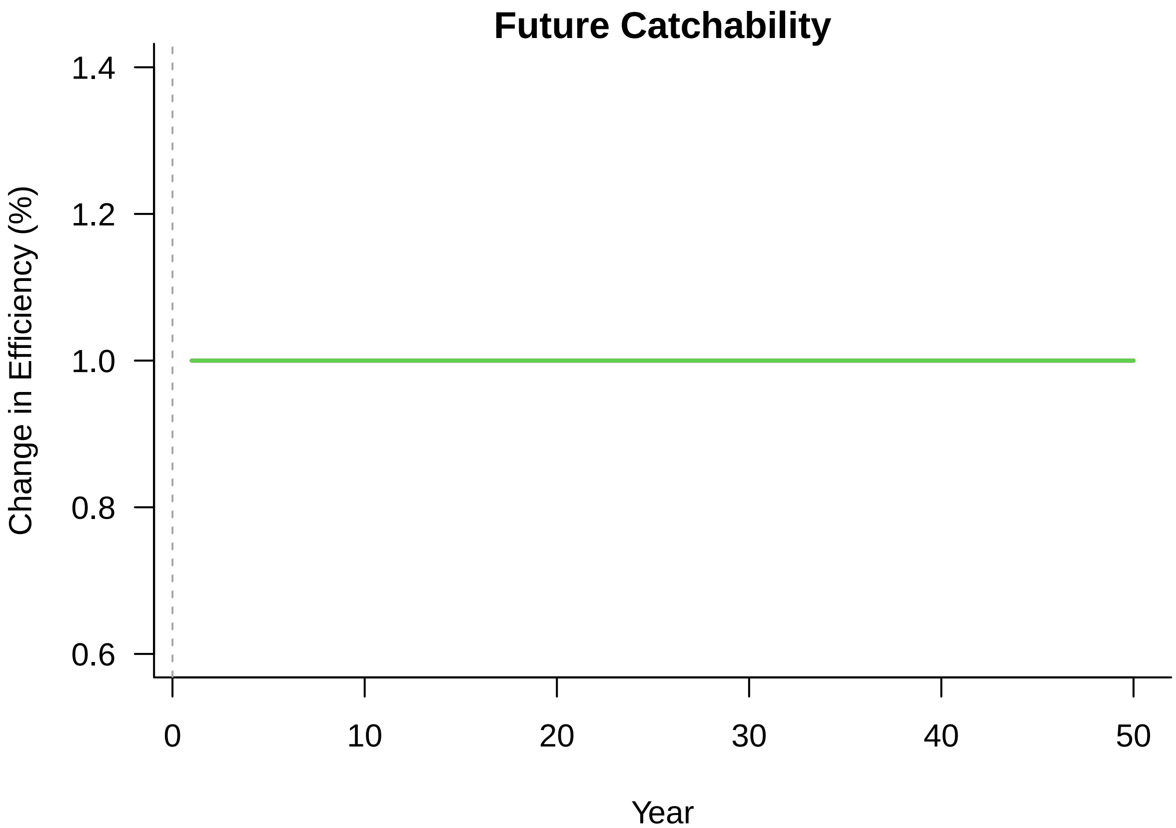
Future Catchability

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): 90, 90

The minimum legal size is 108mm. Few below that size are caught in traps.

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): 108, 108

Size at full vulnerability was estimated based on peaks in size distribution plots in Culver et al. 2010.

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

It is possible that this fishery is experiencing dome shaped selectivity, because crabs may get too big to fit into traps, but there is no information suggesting this is true. Assumed logistic selectivity. Culver et al. (2010) provides info on what size crabs are vulnerable to traps.

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

Selectivity values are in absolute terms.

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): 107, 107

Knife edged retention above the size limit.

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): 108, 108

Assumed that no sublegal crabs are retained.

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

Assumed the largest crabs are fully retained.

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): 0.1, 0.3

Assumed a moderate amount of discarded crabs above the legal size limit. Legal sized crabs are discarded when they molted recently and some fishermen discard females with eggs.

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): 2018

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

No justification provided.

Obs Parameters

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

The generic observation model was used for all parameters.

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

cpars was used to adjust Cbias adding a 5% negative bias in catch information due to recreational take that is unaccounted for. Generic Cbiascv was used.

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): 100, 200

No justification provided.

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): 25, 50

No justification provided.

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): 100, 200

No justification provided.

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): 25, 50

No justification provided.

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

No justification provided.

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

No justification provided.

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): 0.2, NA

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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

No justification provided.

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): 0.1, 0.3

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): 0.1

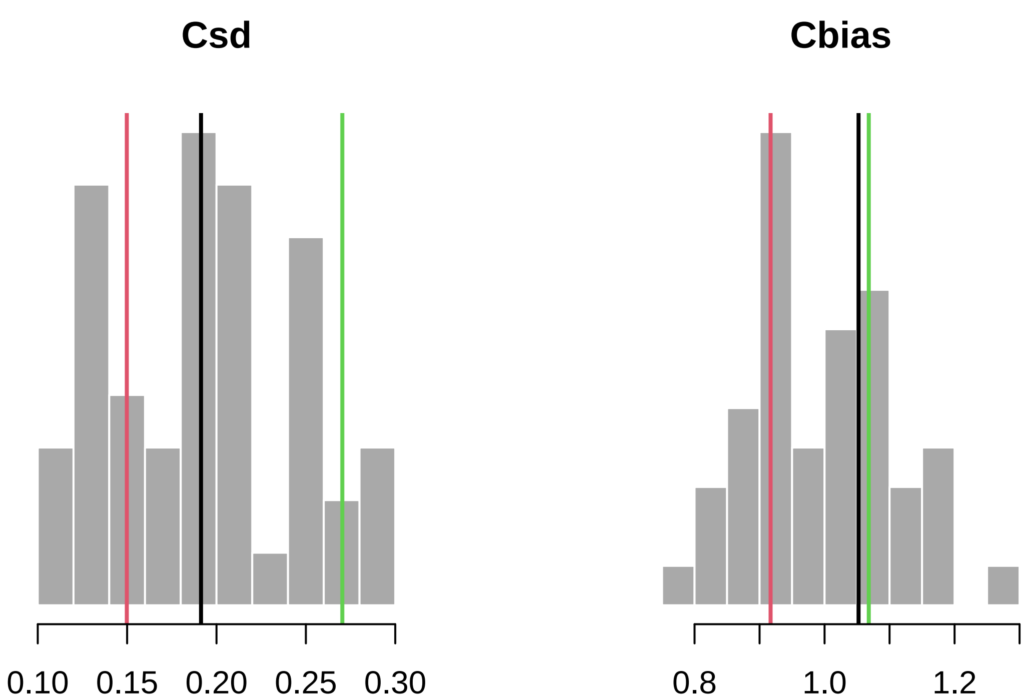
No justification provided.

Obs Plots

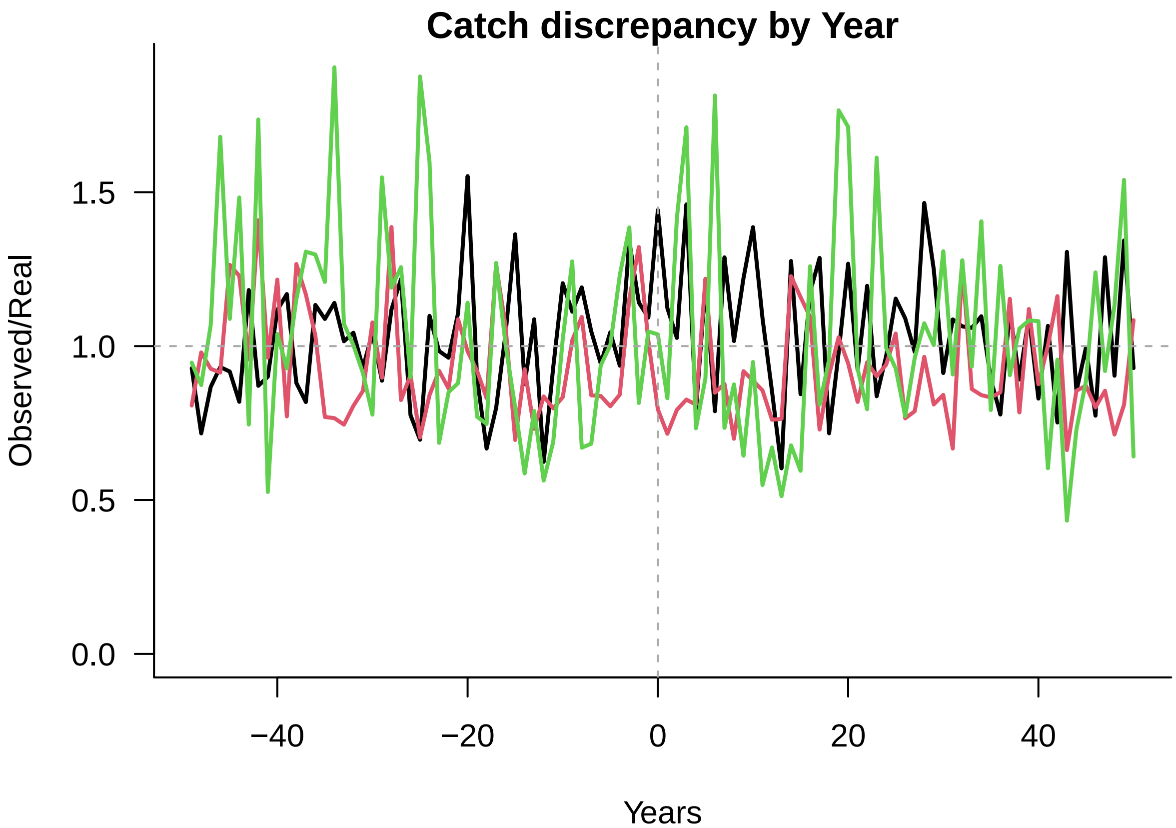
Observation Parameters

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:

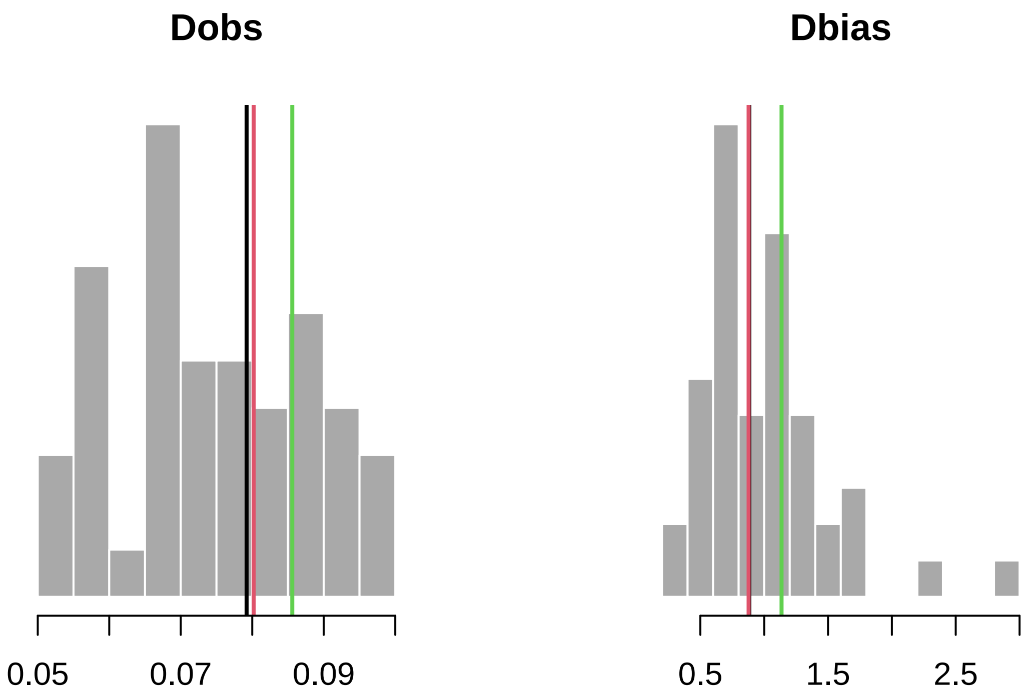


Time-Series Time-series plots of catch observation error for historical and projection years:

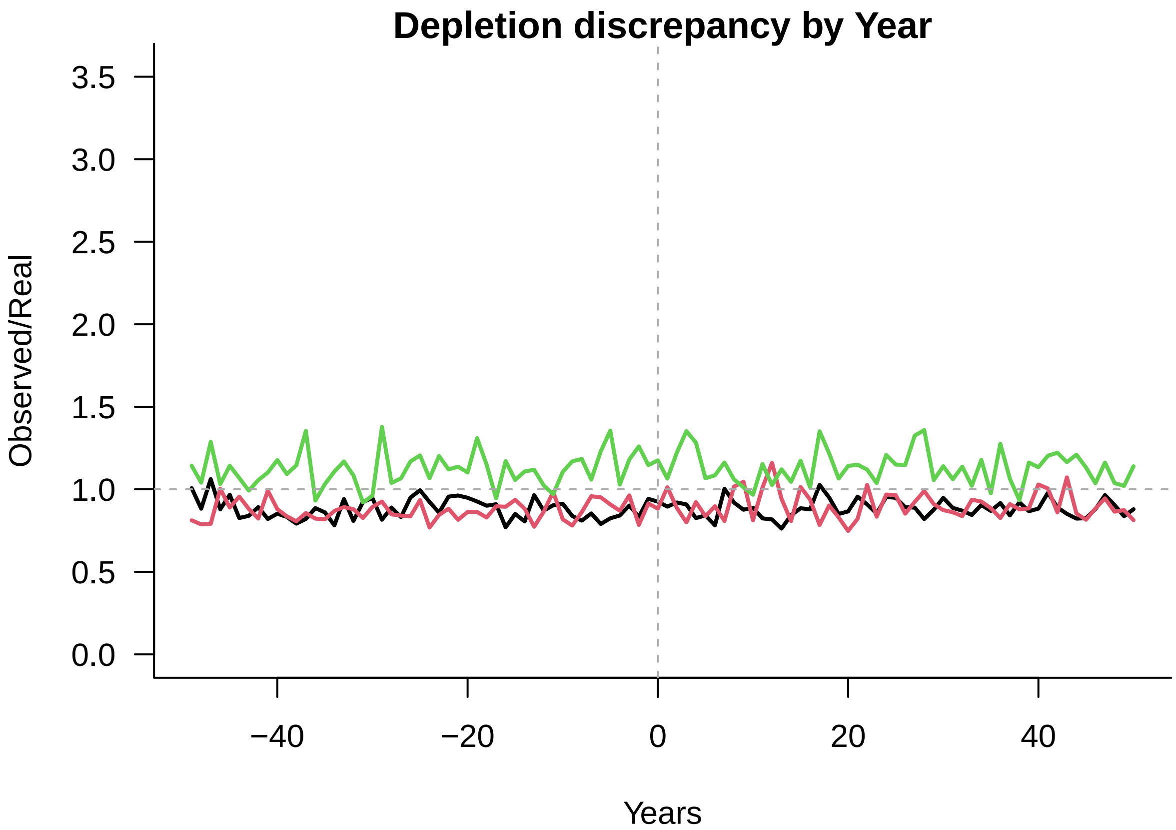


Depletion Observations

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:

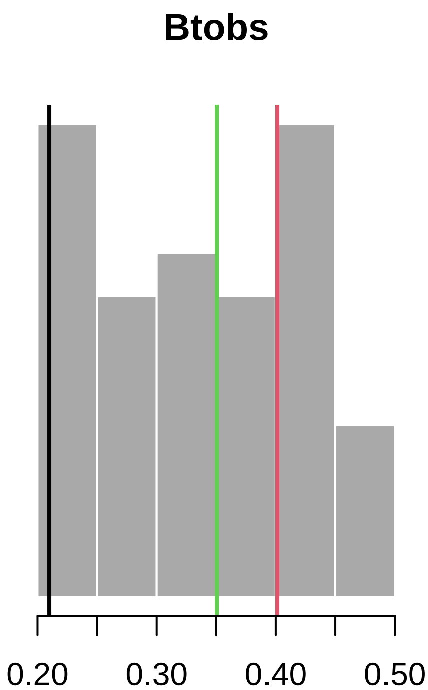


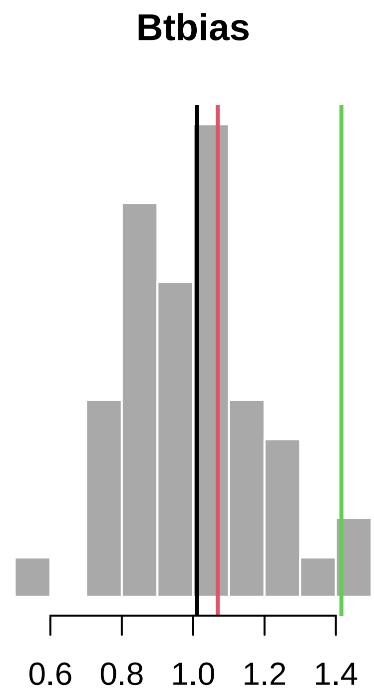
Time-Series Time-series plots of depletion observation error for historical and projection years:



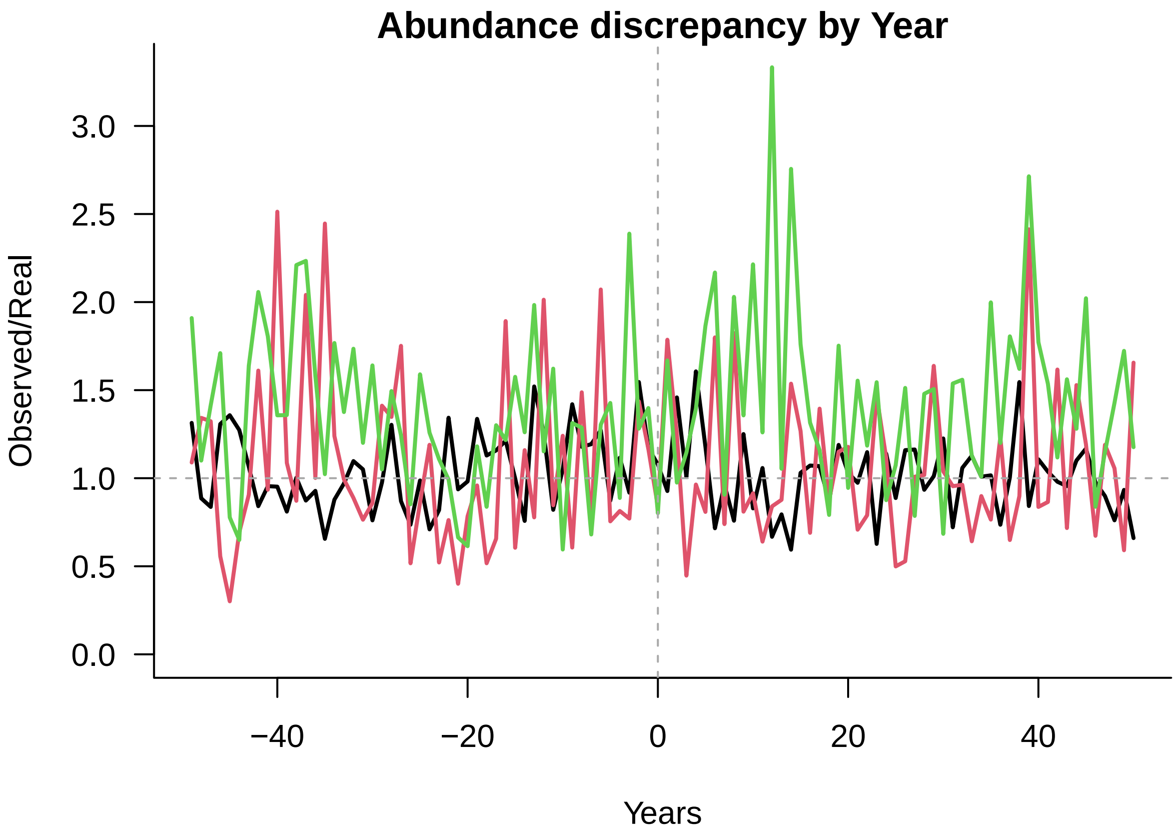
Abundance Observations

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:



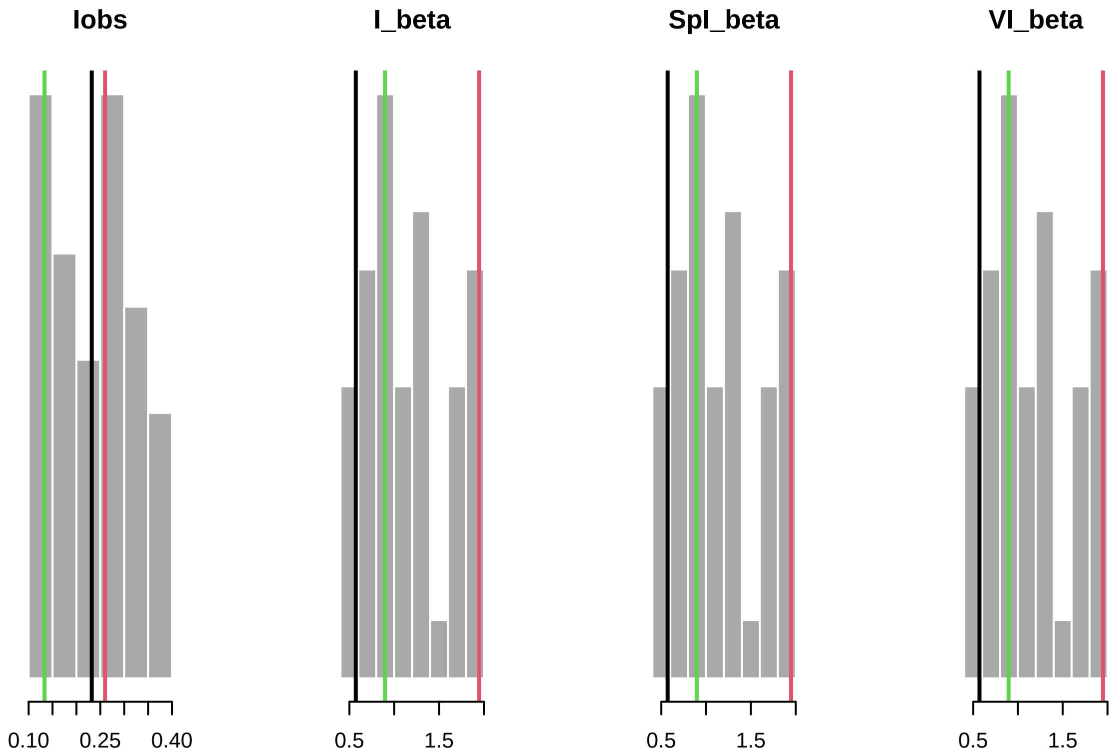


Time-Series Time-series plots of abundance observation error for historical and projection years:

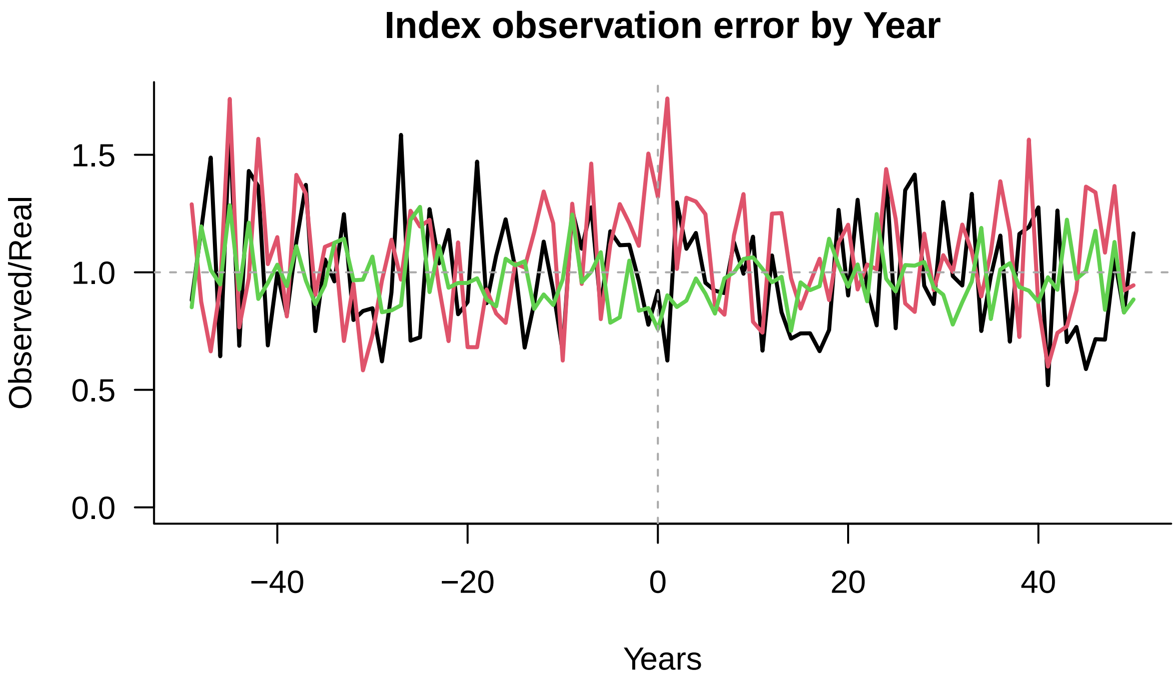


Index Observations

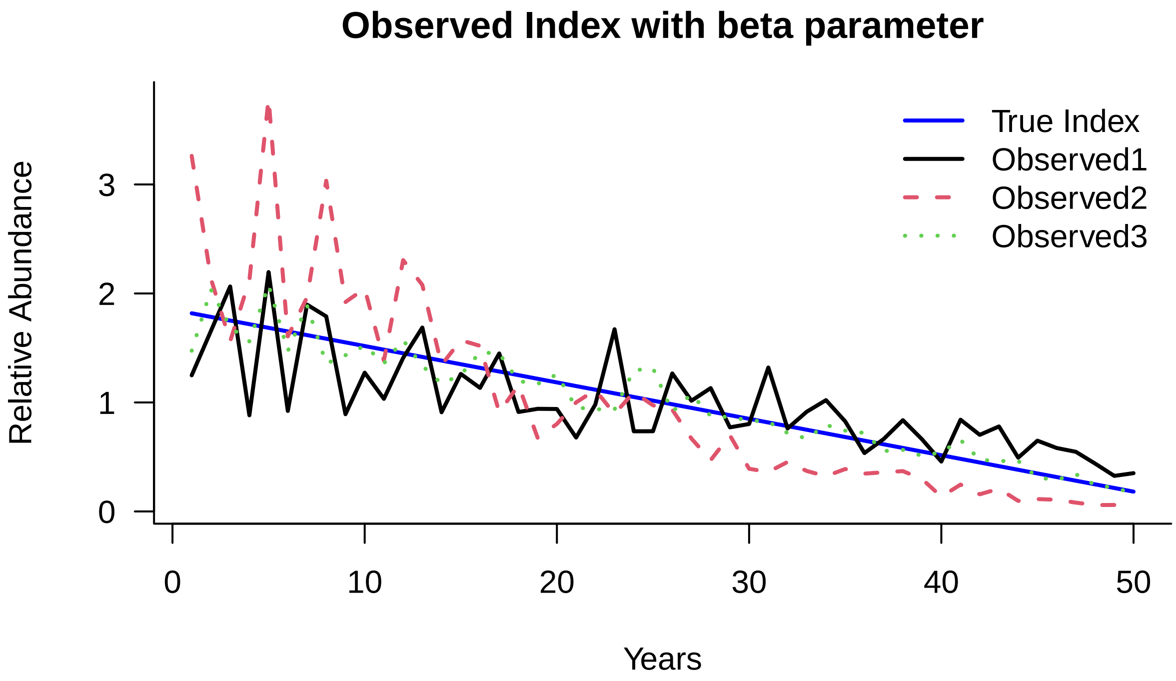
Sampled Parameters Histograms of 48 simulations of inter-annual variability in index observations (`Iobs`) and hyper-stability/depletion in observed index (`beta`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



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

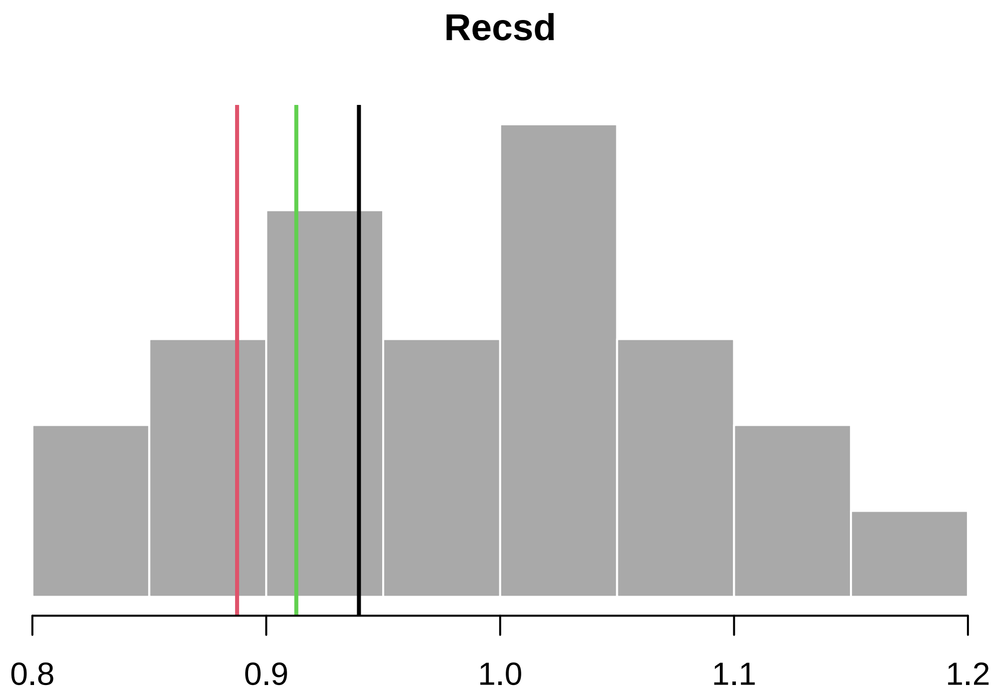


Plot showing an example true abundance index (blue) with 3 samples of index observation error and the hyper-stability/depletion parameter (`beta`):

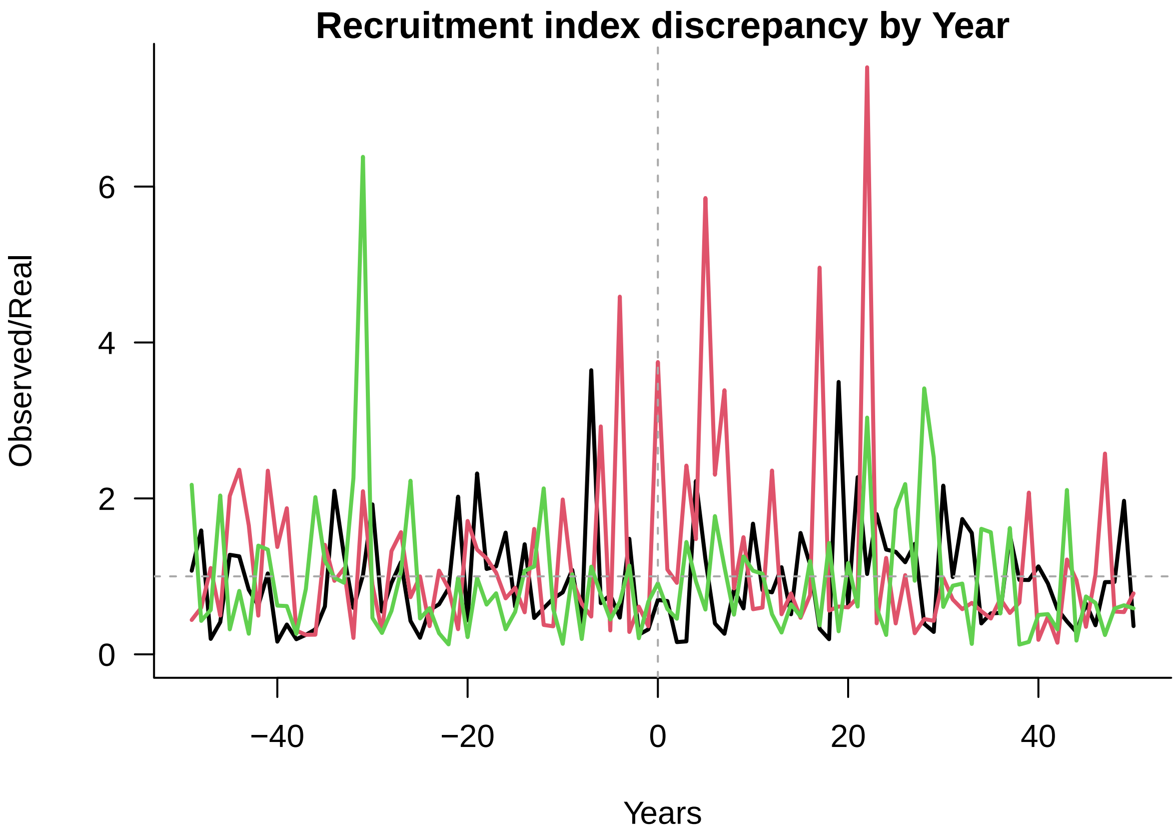


Recruitment Observations

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:

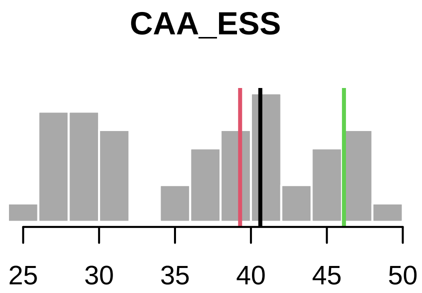


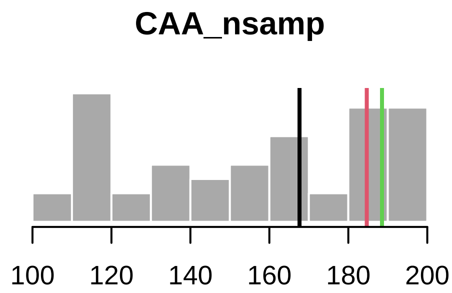
Time-Series Timeseries plots of observeration error for recruitment:

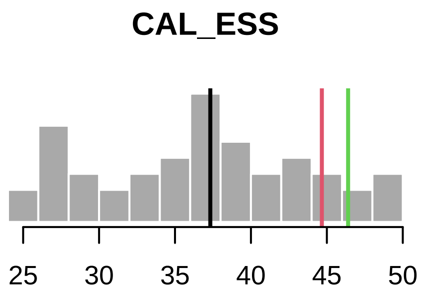


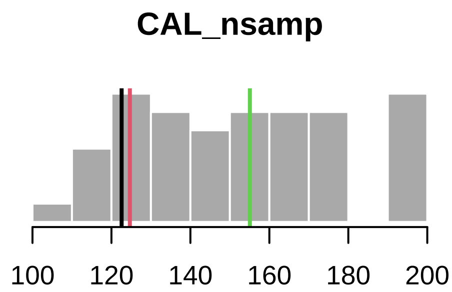
Composition Observations

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:



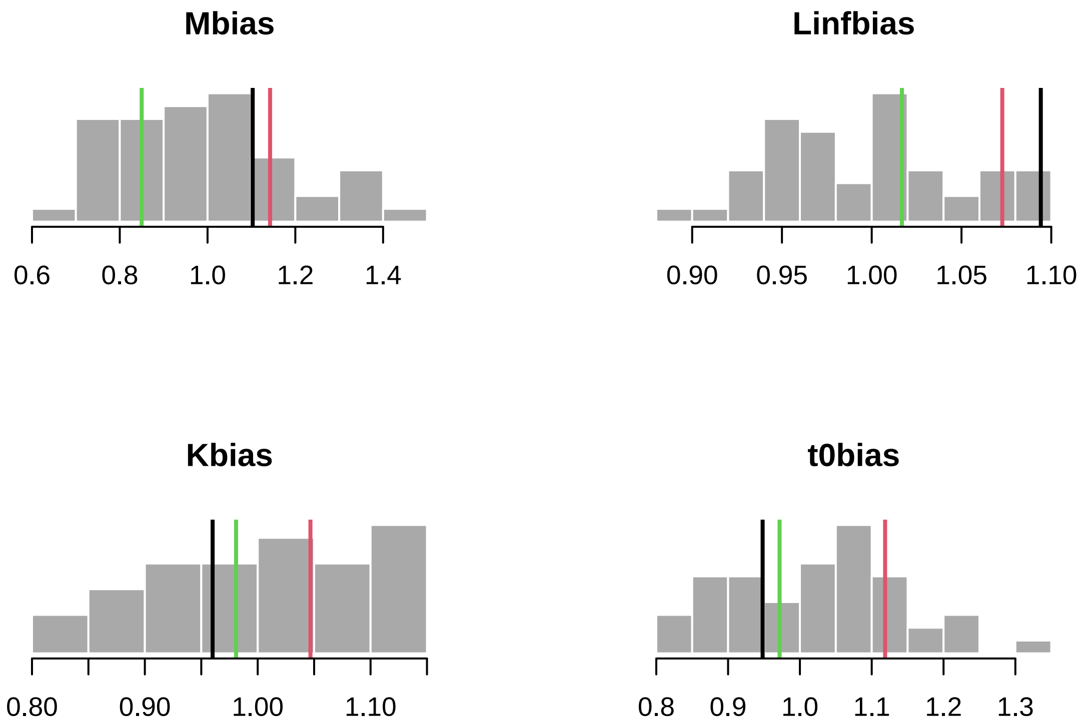


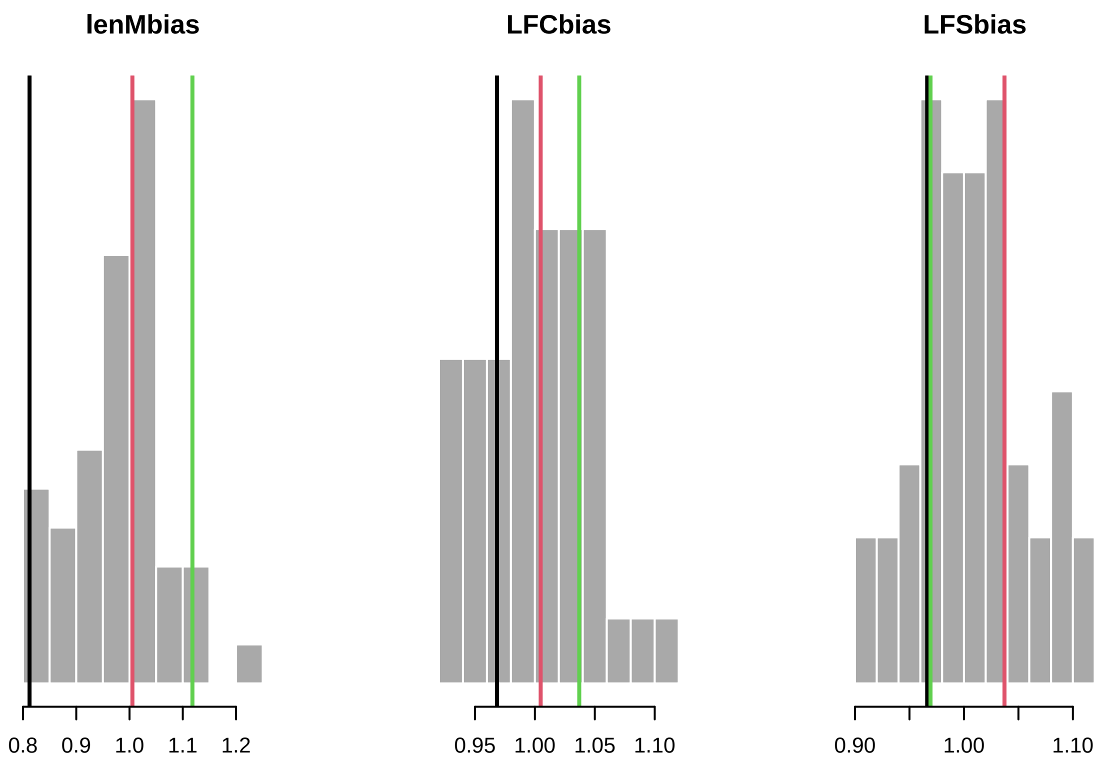




Parameter Observations

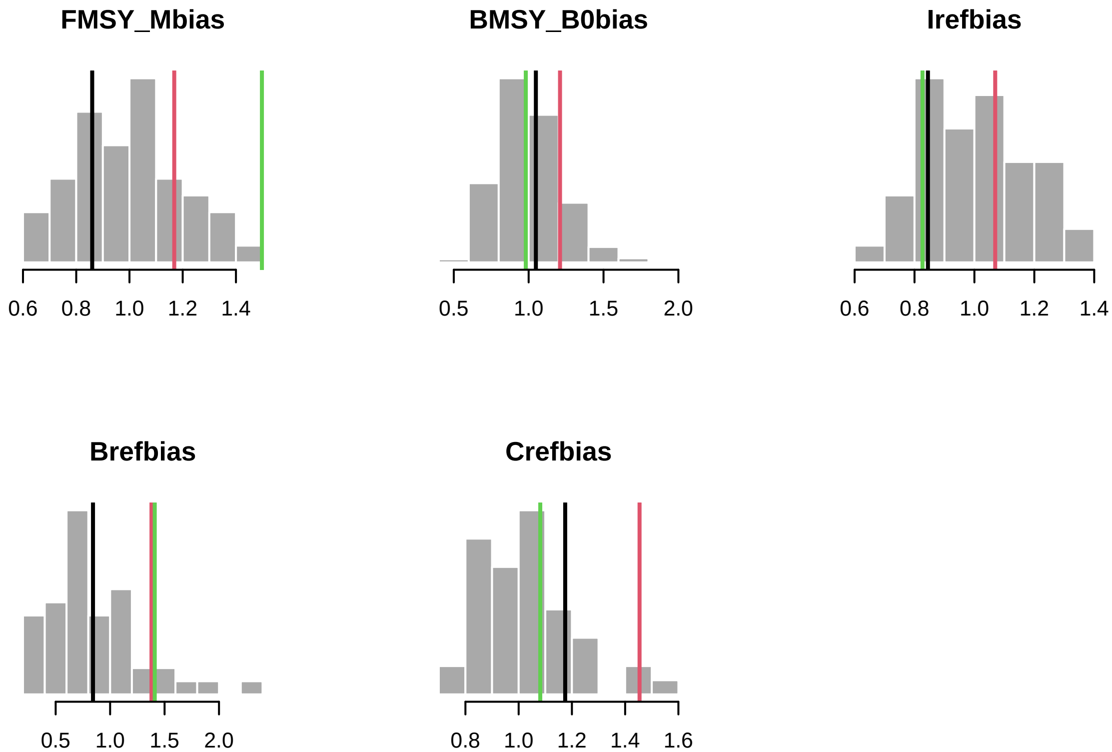
Sampled Parameters Histograms of 48 simulations of bias in observed natural mortality (`Mbias`), von Bertalanffy growth function parameters (`Linfbias`, `Kbias`, and `t0bias`), length-at-maturity (`lenMbias`), and bias in observed length at first capture (`LFCbias`) and first length at full capture (`LFSbias`)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


Mbias
0.6
0.8
1.0
1.2
1.4
Linfbias
0.90
0.95
1.00
1.05
1.10
Kbias
0.80
0.90
1.00
1.10
t0bias
0.8
0.9
1.0
1.1
1.2
1.3



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

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): 0.9, 1.1

Ability to enforce at TAC was assumed to be within 10%.

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): 0.05, 0.1

No justification provided.

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): 0.8, 1.2

Effort is more difficult to enforce than a TAC for trap fisheries, thus up to 20% error was assumed.

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): 0.05, 0.1

No justification provided.

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): 0.95, 1.05

The current size limit is thought to be well adhered to. Up to 5% error was assumed.

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): 0.05, 0.1

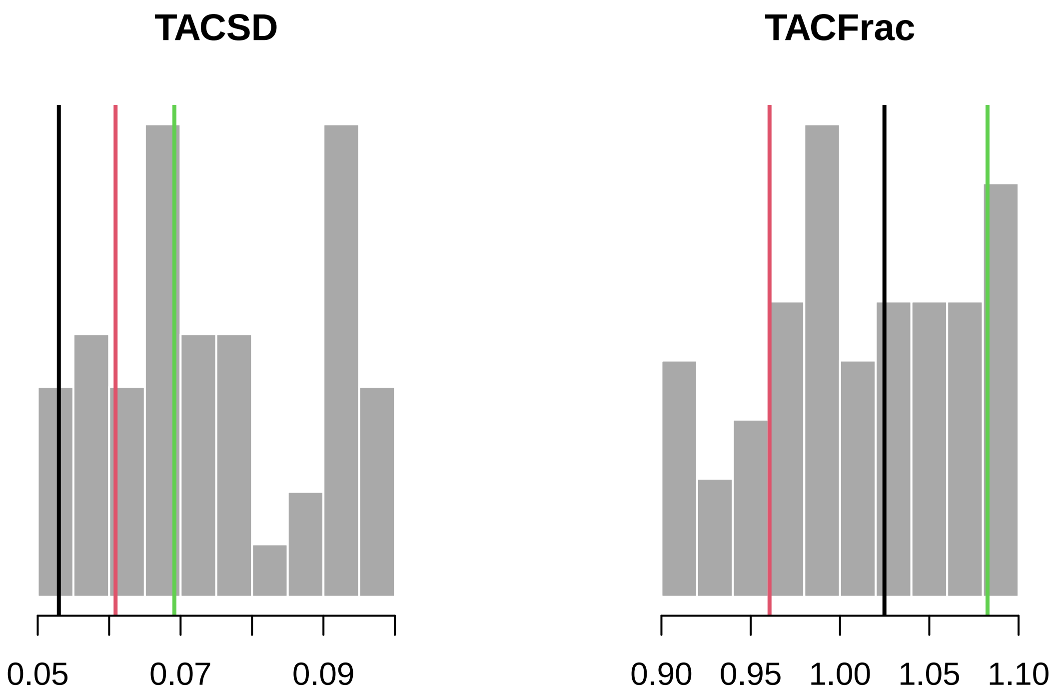
No justification provided.

Imp Plots

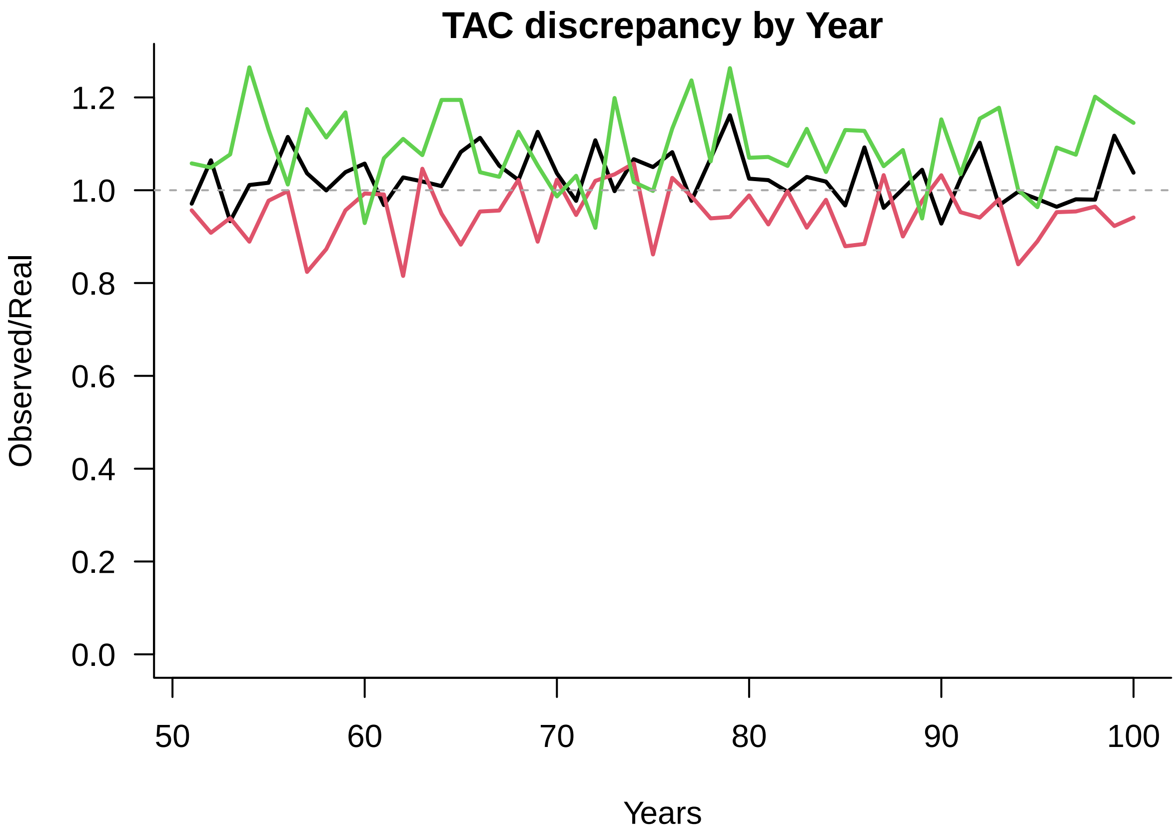
Implementation Parameters

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:

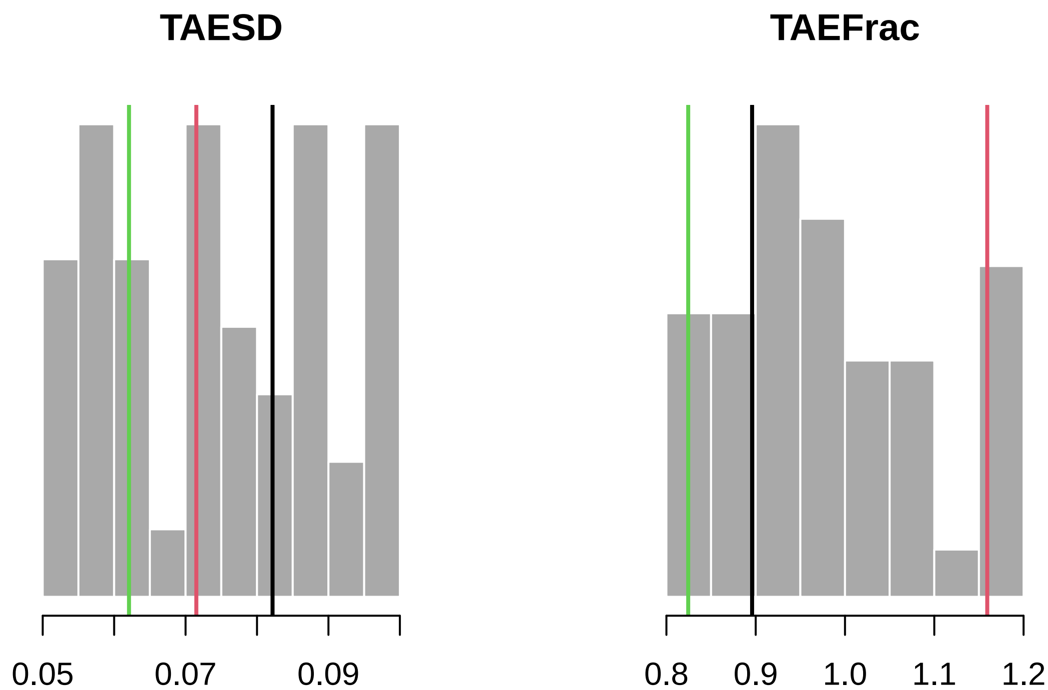


Time-Series Time-series plots of 0 samples of TAC implementation error by year:

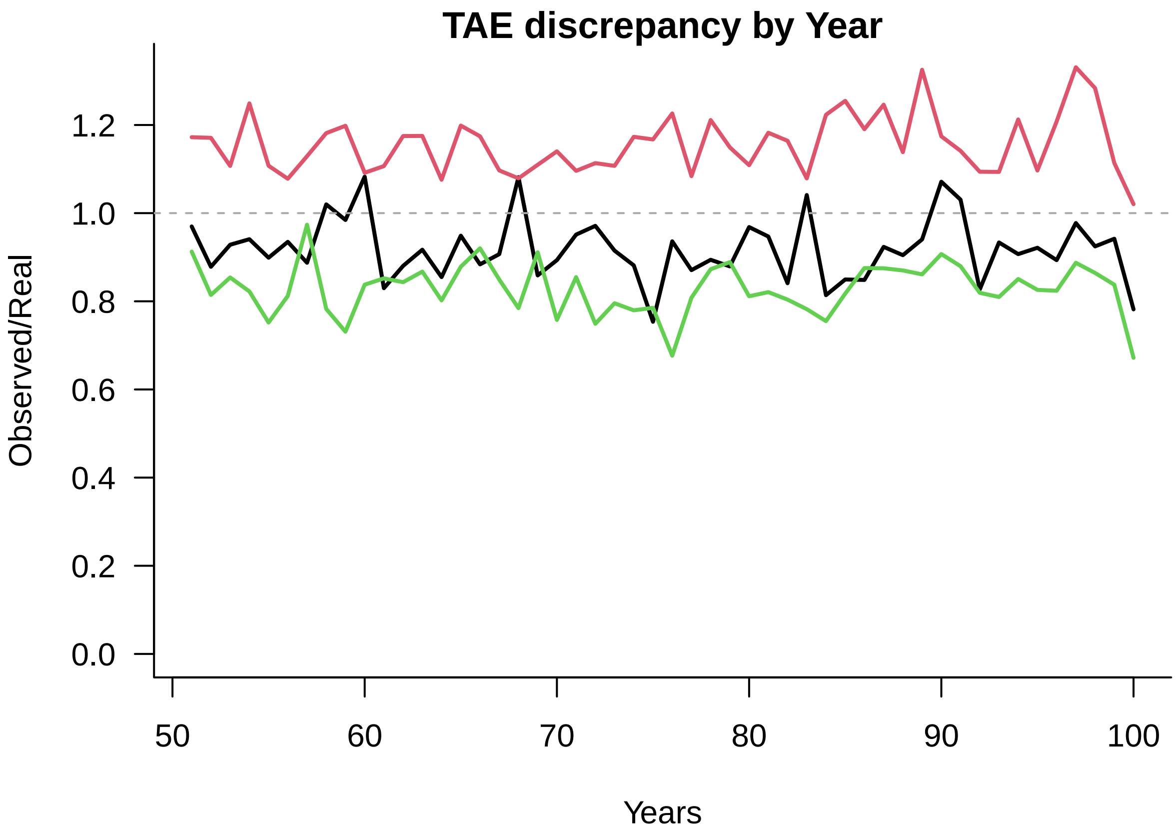


TAE Implementation

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:

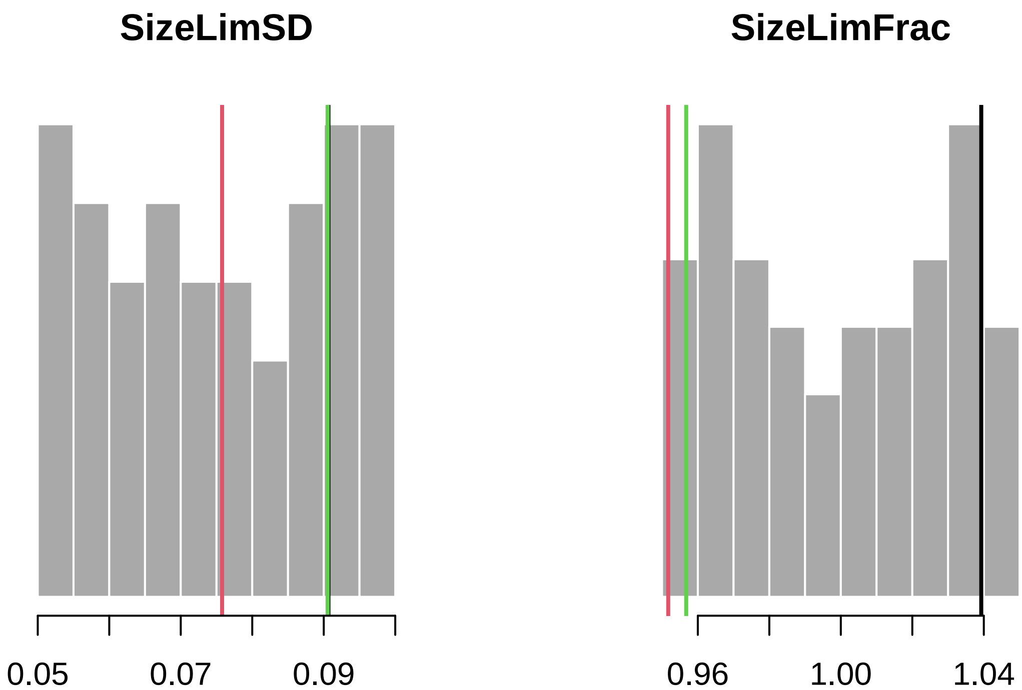


Time-Series Time-series plots of 0 samples of TAE implementation error by year:

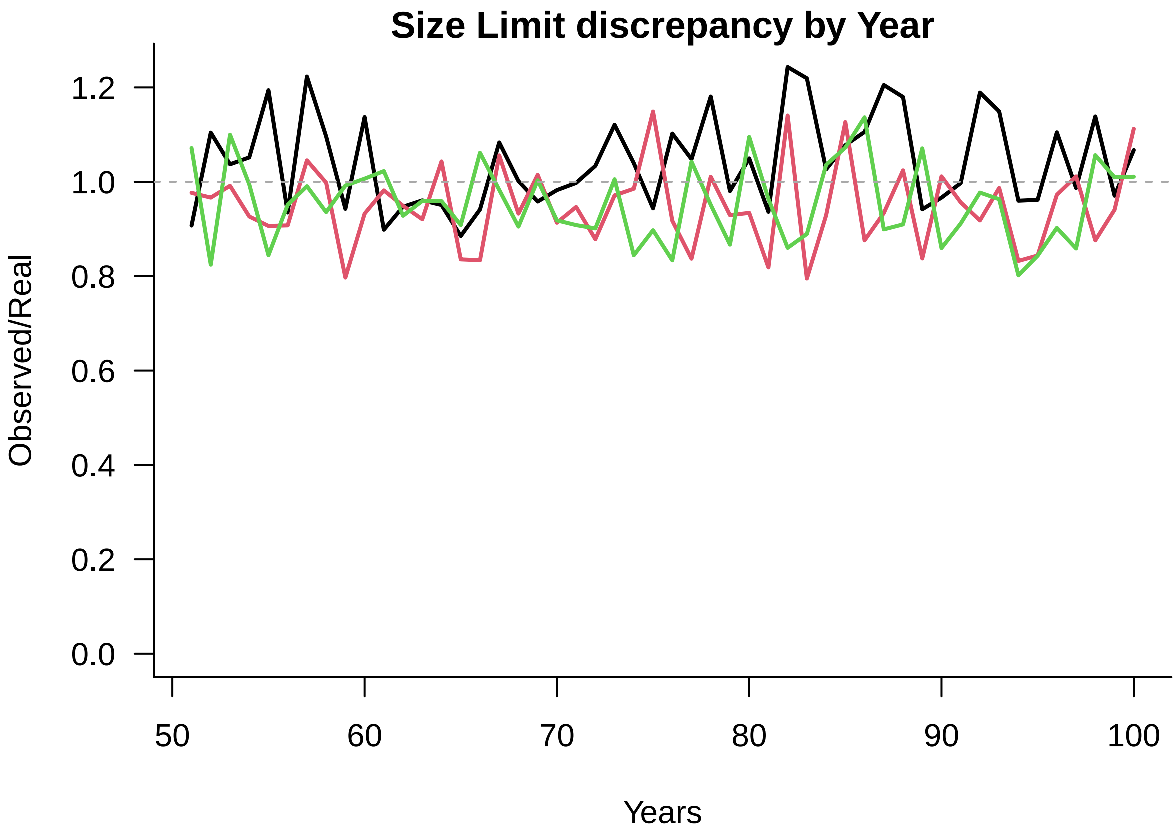


Size Limit Implementation

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:

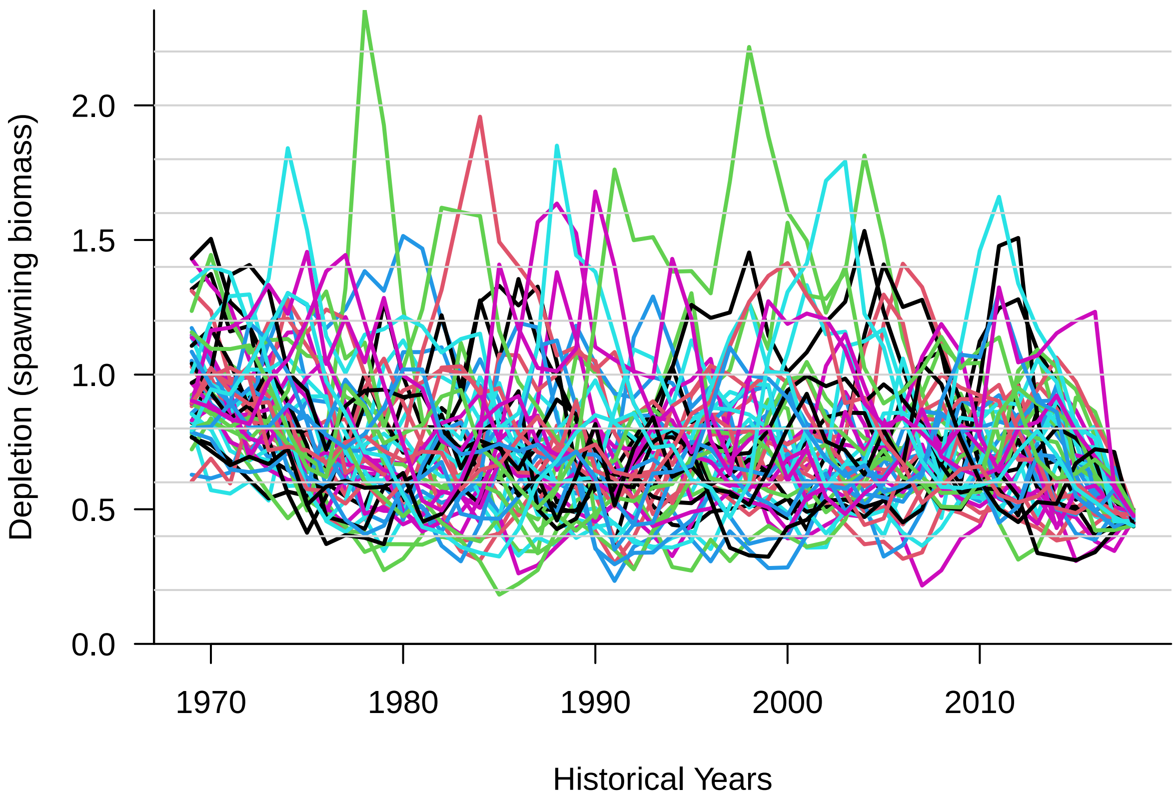


Historical Simulation Plots

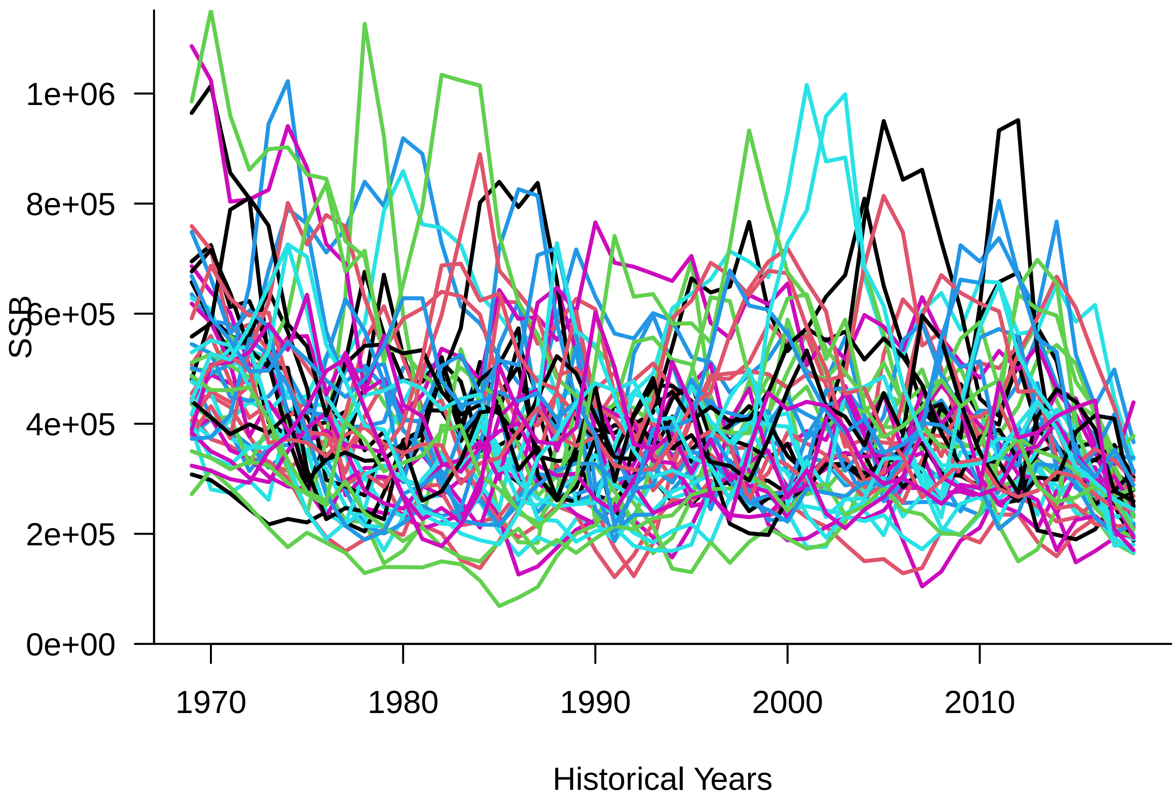
Historical Time-Series

Spawning Biomass

Depletion Time-series plots of SB/SB0:

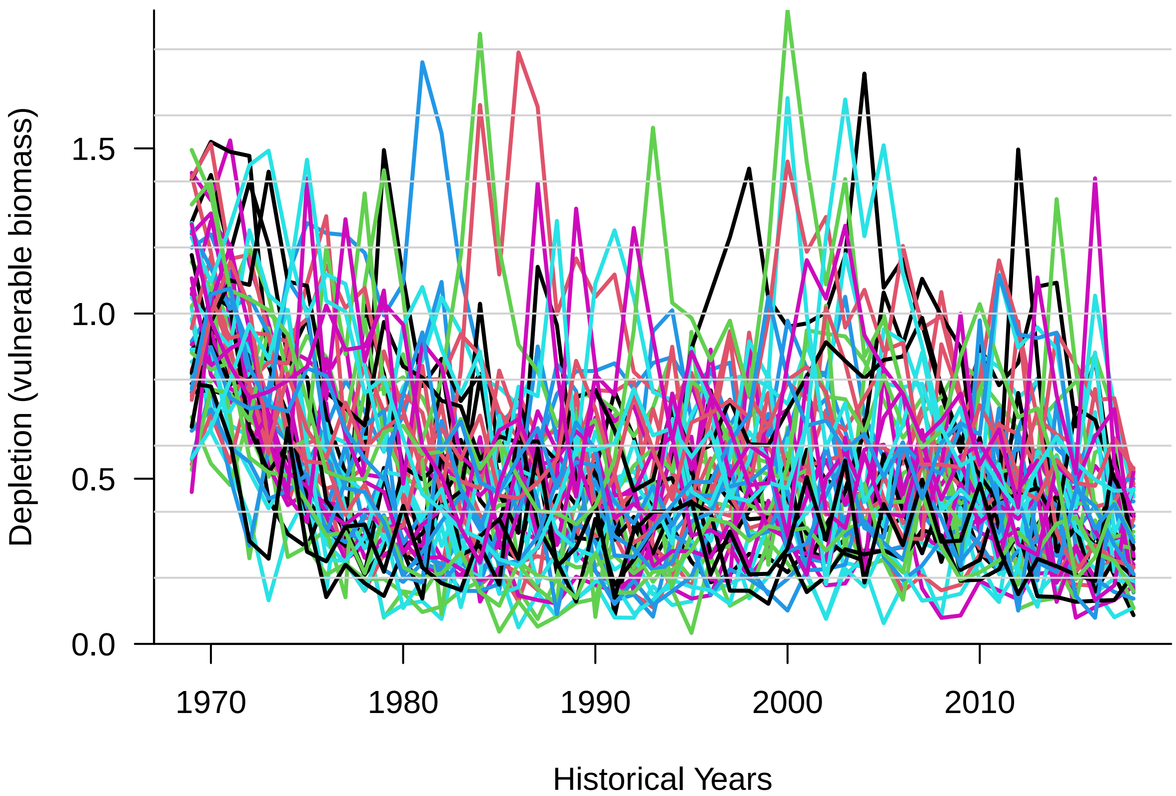


Absolute Time-series plots of absolute SB:

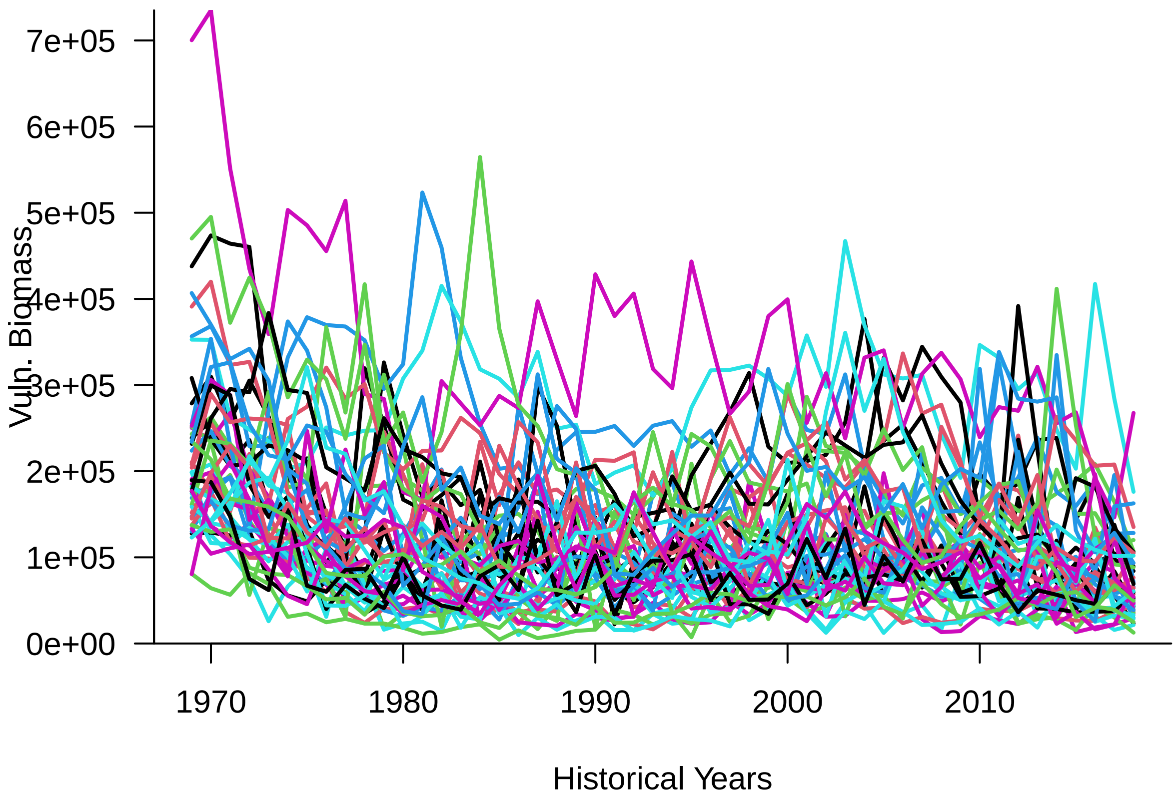


Vulnerable Biomass

Depletion Time-series plots of VB/VB0:

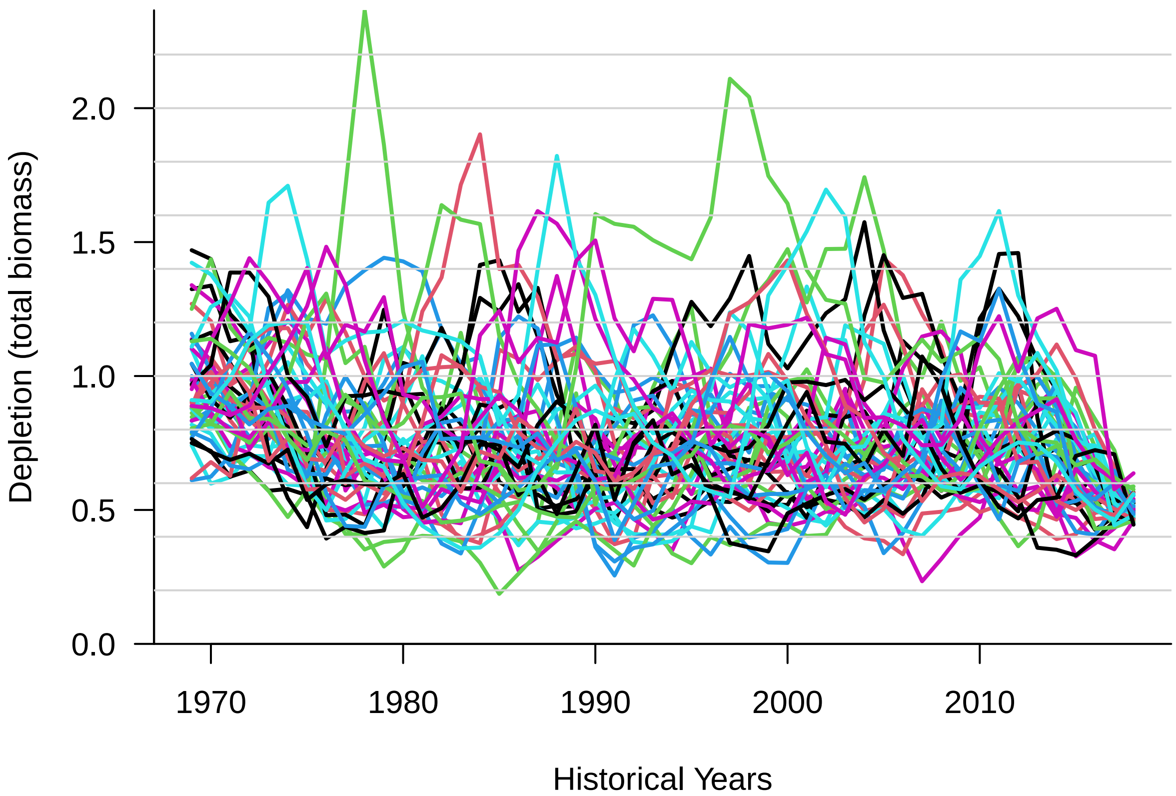


Absolute Time-series plots of absolute VB:

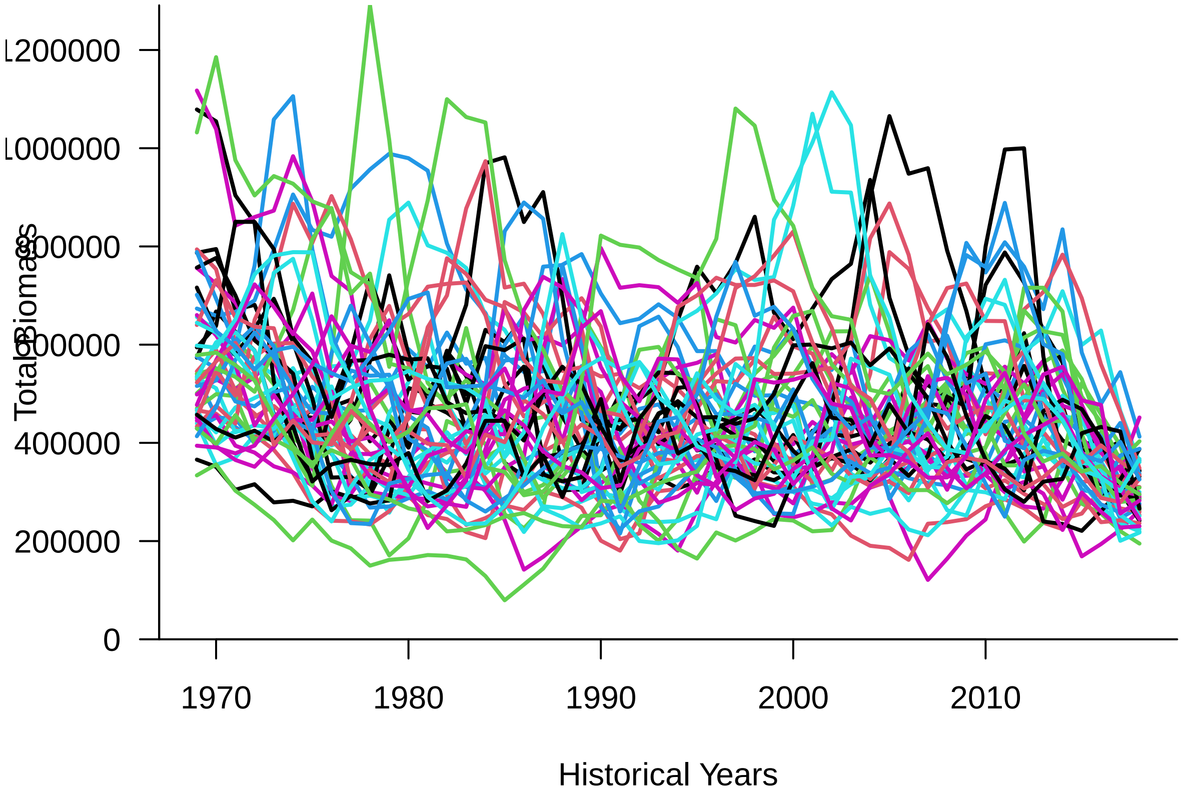


Total Biomass

Depletion Time-series plots of B/B0:

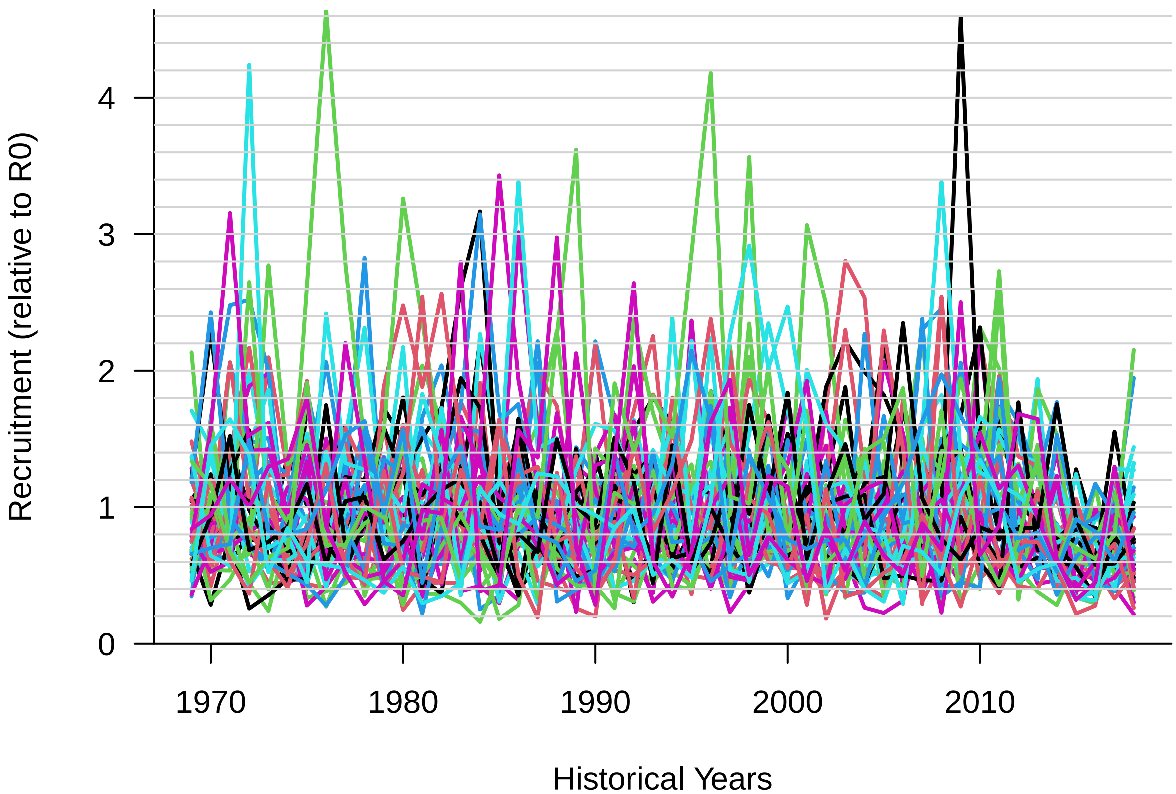


Absolute Time-series plots of absolute B:

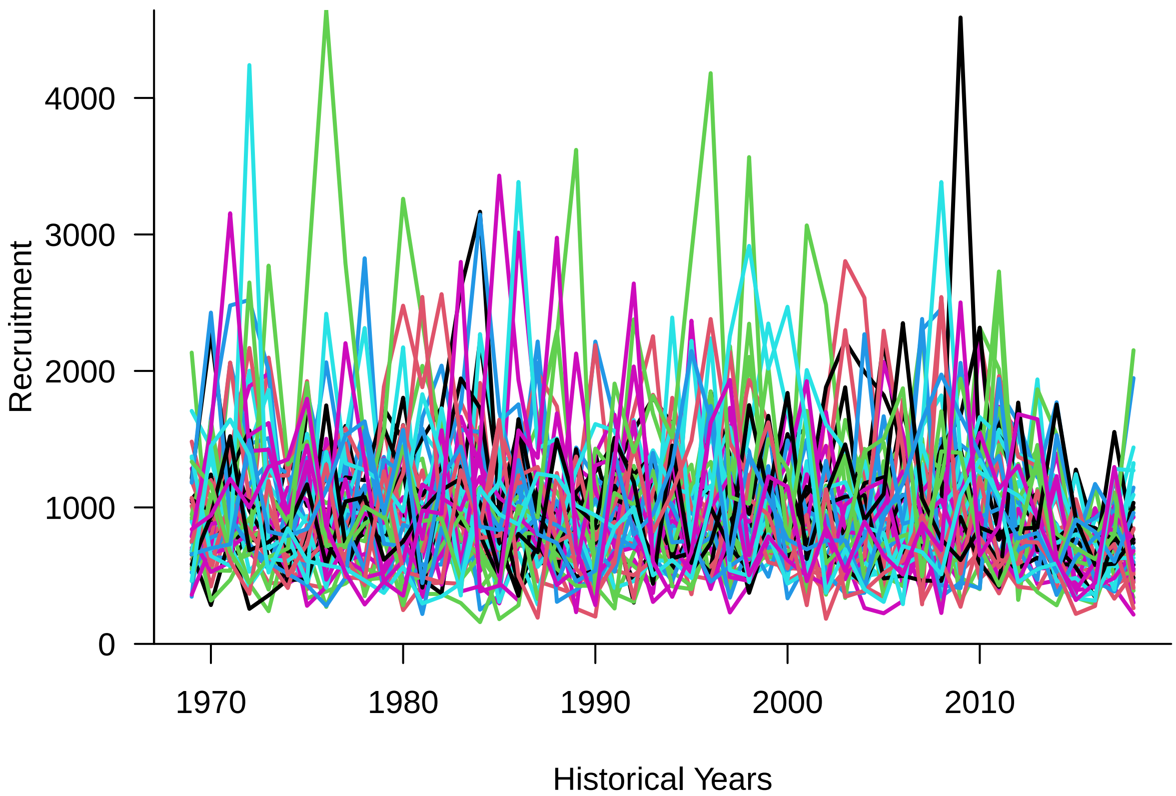


Recruitment

Relative Time-series plot of recruitment relative to R0:

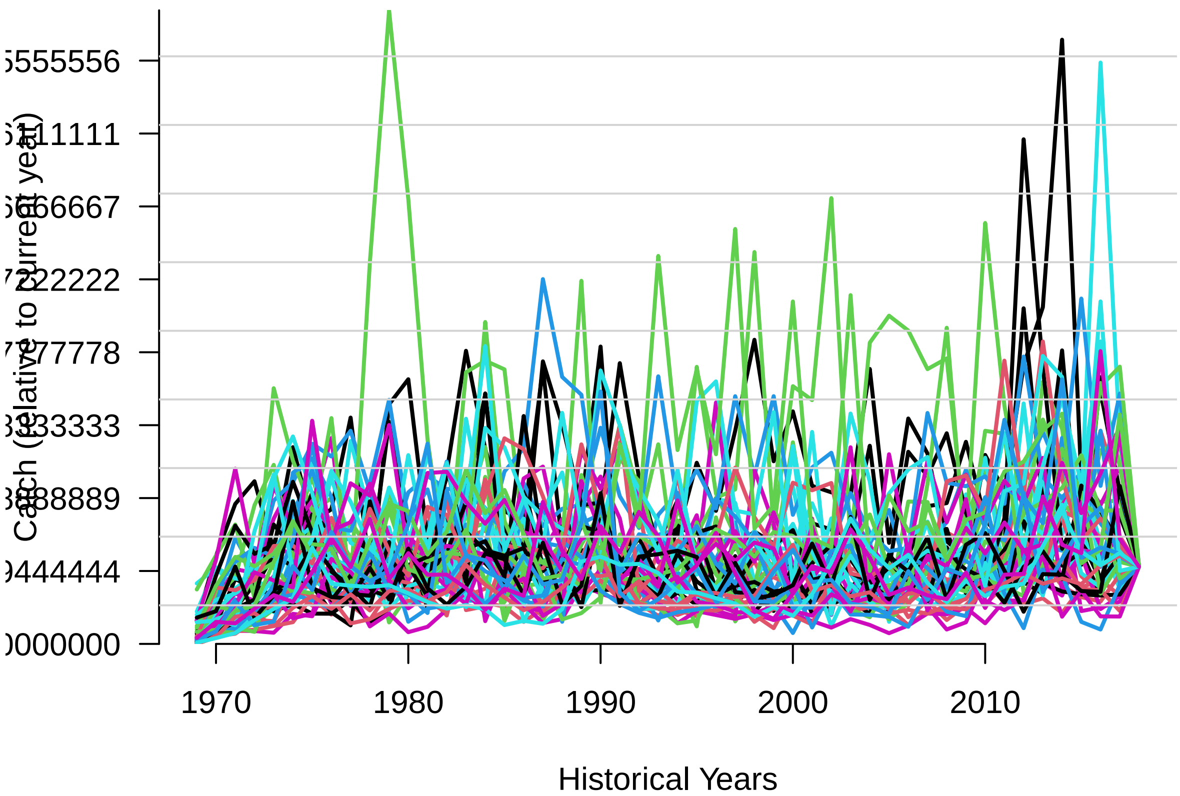


Absolute Time-series plot of absolute recruitment:

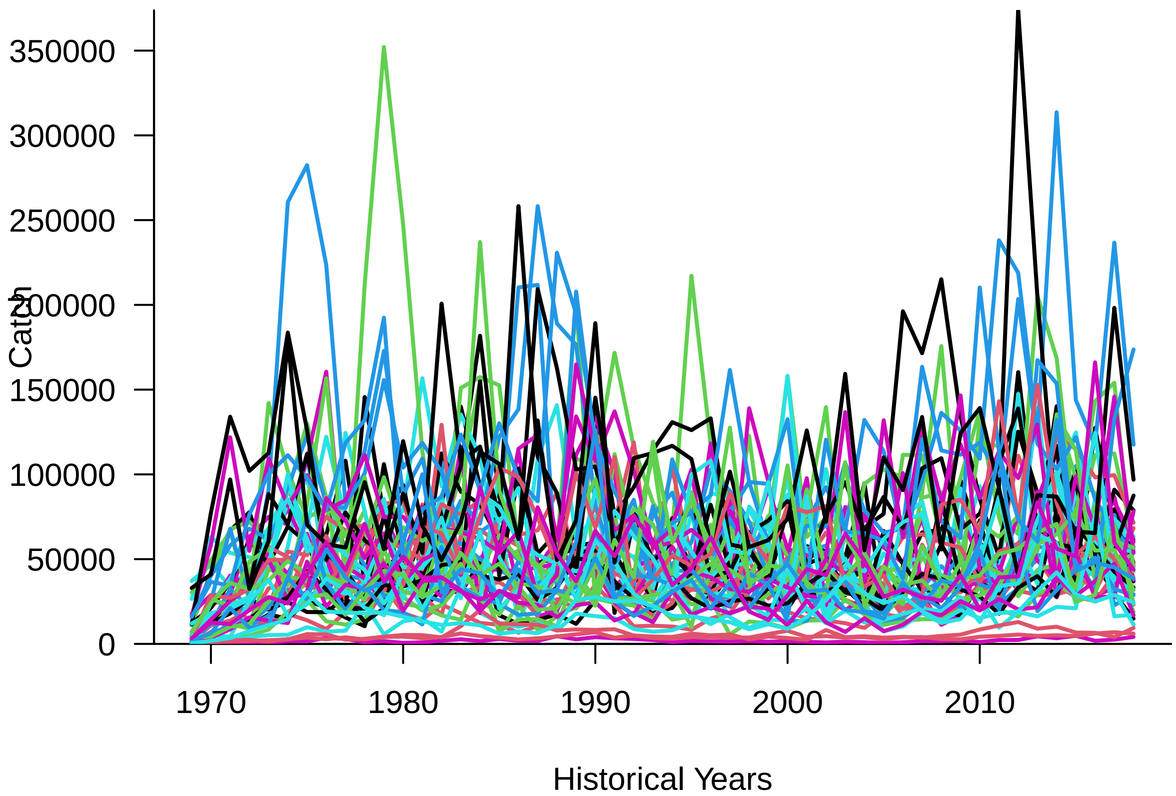


Catch

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

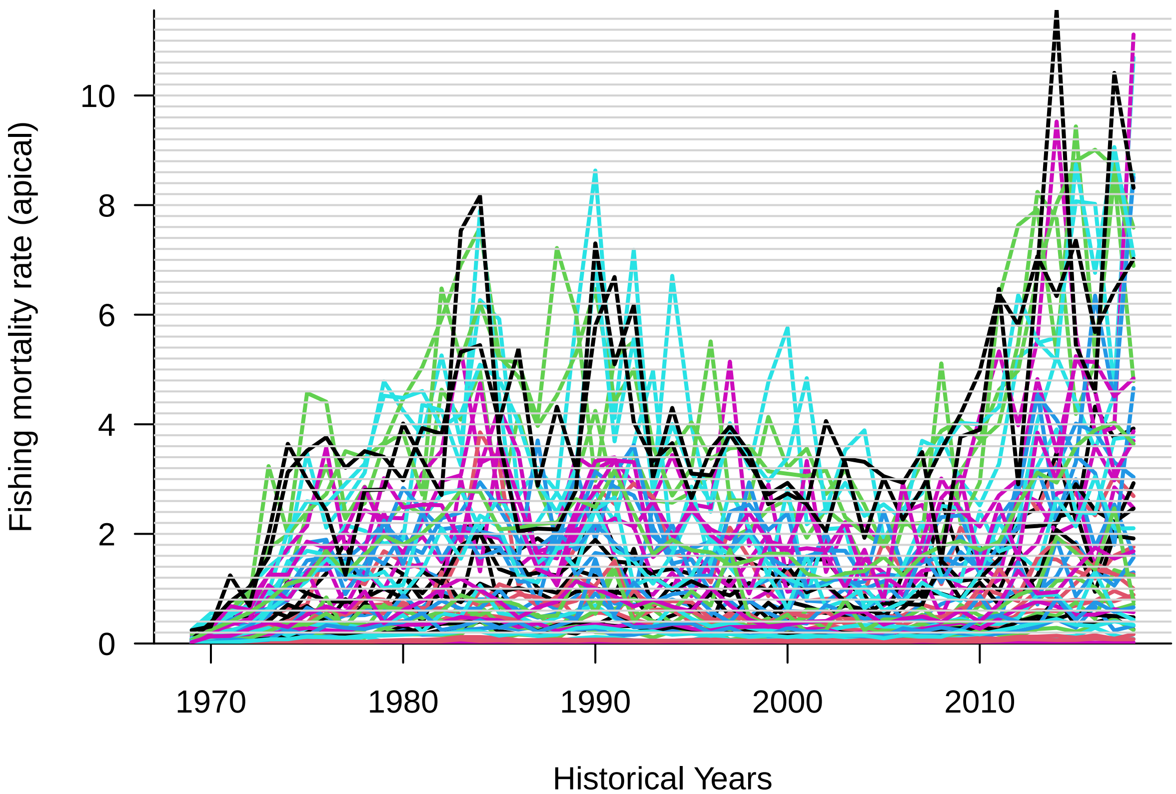


Absolute Time-series of absolute catch:



Historical Fishing Mortality

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



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