California Spiny Lobster

Operating Model Report

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Introduction

California spiny lobster is a relatively data-rich fishery compared to most state-managed invertebrates. It also benefits from management under a fishery management plan (FMP). Most parameters are informed by directed research and fishery-dependent data. Males and females exhibit different growth characteristics. We model only females here. Additionally, we focus fleet parameters only on the commercial fishery. A robust recreational fishery is estimated to account for between 27 and 43% of the catch. All length-based parameters will be given as carapace length (CL) rather than total body length. Historical data that measured lobster by total body length will be converted to CL using sex-specific length-to-CL curves developed from recent CDFW data.

The number of simulations for a final model run (nsim) was set at 120 and fishing was projected 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 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 any stochastic MPs was set at 0.5, meaning the median recommendation was selected.

Operating Model

Species Information

Species: *Panulirus_interruptus*

Common Name: *CA_spiny_lobster_females*

Management Agency:

Region:

OM Parameters

OM Name: Name of the operating model: LobFemCom

nsim: The number of simulations: 120

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: 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

Jenny Hofmeister

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): 25

In the CDFW Spawning Potential Ratio (SPR) model used in the Fishery Management Plan (FMP), the maximum age was set to 25. It is likely that lobsters can live much longer, possibly to 50 years old. However, few lobsters likely reach this age given current fishing pressure. Given that the models used in the FMP have gone through the peer review and public comment requirements of CDFW, this model will match the FMP values whenever possible.

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): 5000

Lobsters have very high recruitment.

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): 0.15, 0.2

These values were taken from the lobster FMP. Natural mortality varies by size using the equation M = (-0.17 - 12.5/weight)

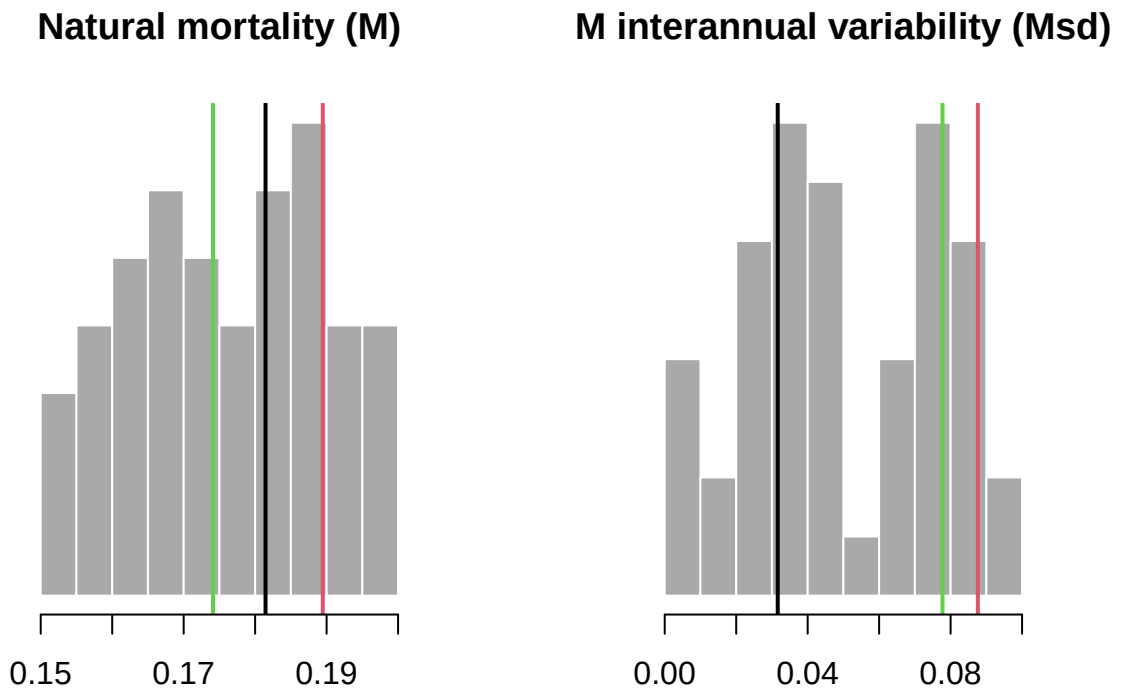
Msd: Inter-annual variation in M expressed as a coefficient of variation of a log-normal distribution. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. If this parameter is positive, yearly M is drawn from a log-normal distribution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

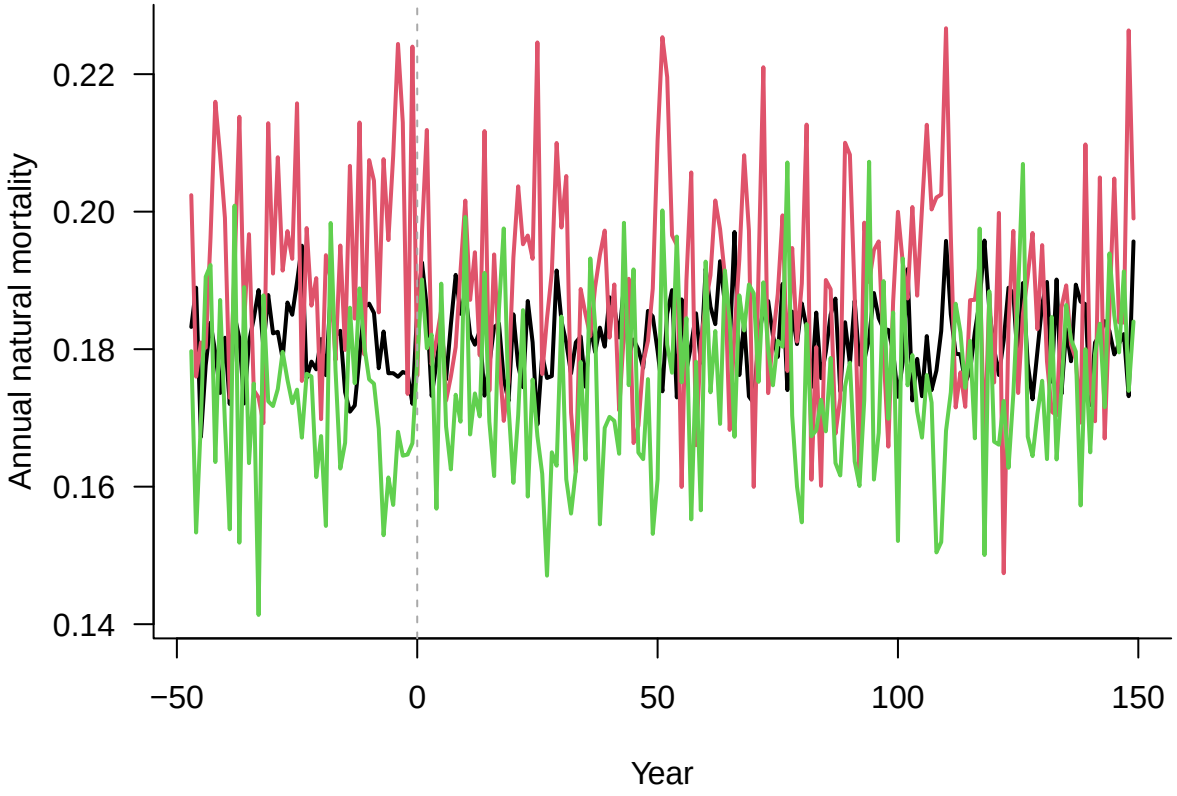
Natural mortality likely has very little year-to-year variation.

Natural Mortality Parameters

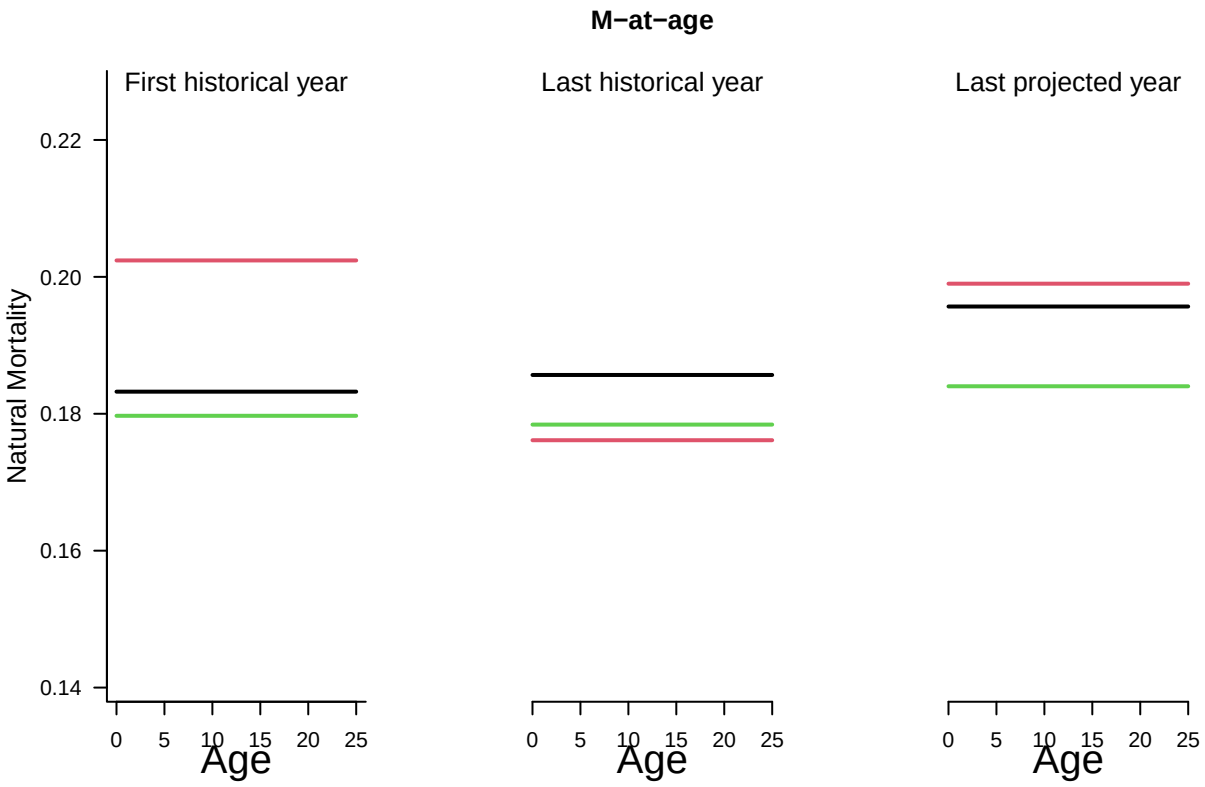
Sampled Parameters Histograms of simulations of `M`, and `Msd` parameters, with vertical colored lines indicating 3 randomly drawn values used in other plots:



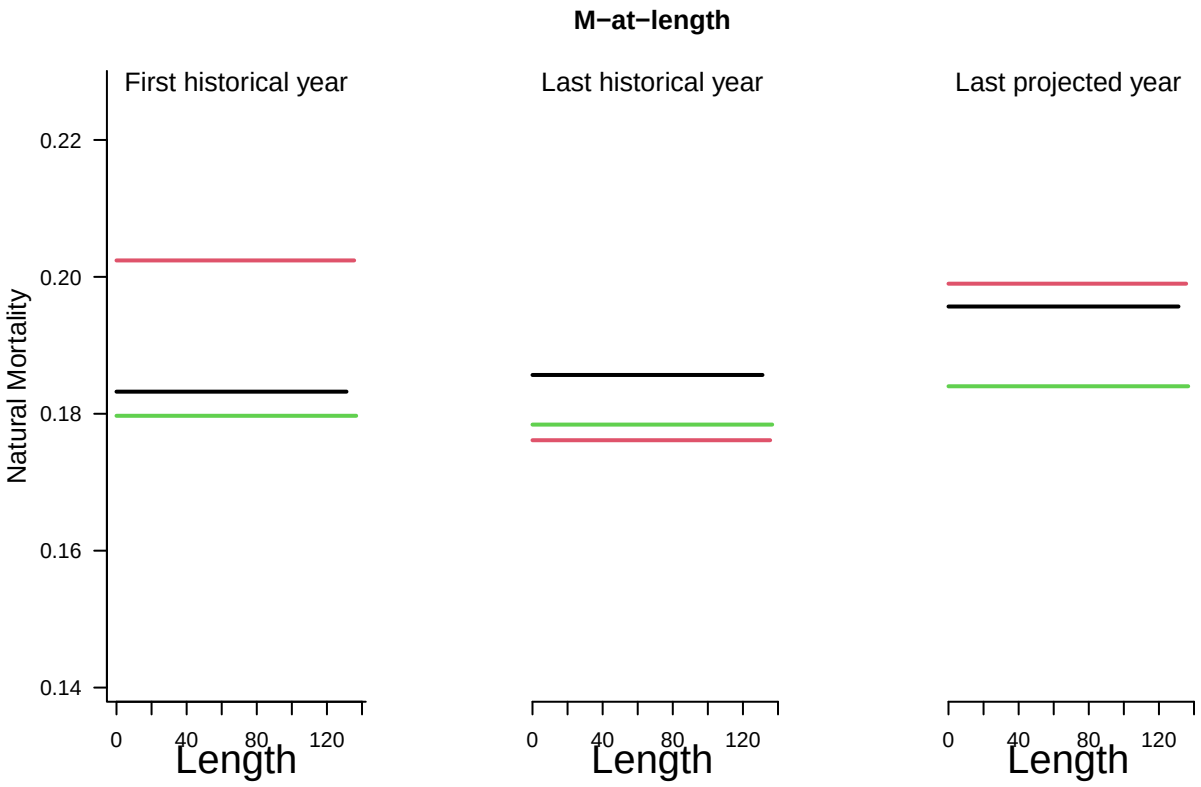
Time-Series The average natural mortality rate by year for adult fish for 3 simulations. The vertical dashed line indicates the end of the historical period:



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): 0.75, 0.95

Lobsters are very productive, even at low population sizes.

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 stock recruitment curve.

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): 0.6, 0.8

Recruitment parameters were tuned to produce similar catch variability to the landings data.

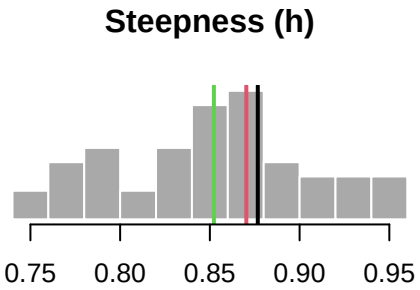
AC: Autocorrelation in the recruitment deviations in log space. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided, and used to add lag-1 auto-correlation to the log recruitment deviations. Uniform distribution lower and upper bounds.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

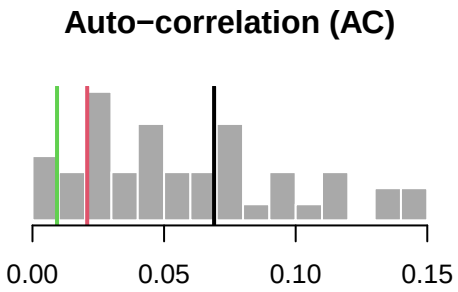
real numbers.

Specified Value(s): 0, 0.15

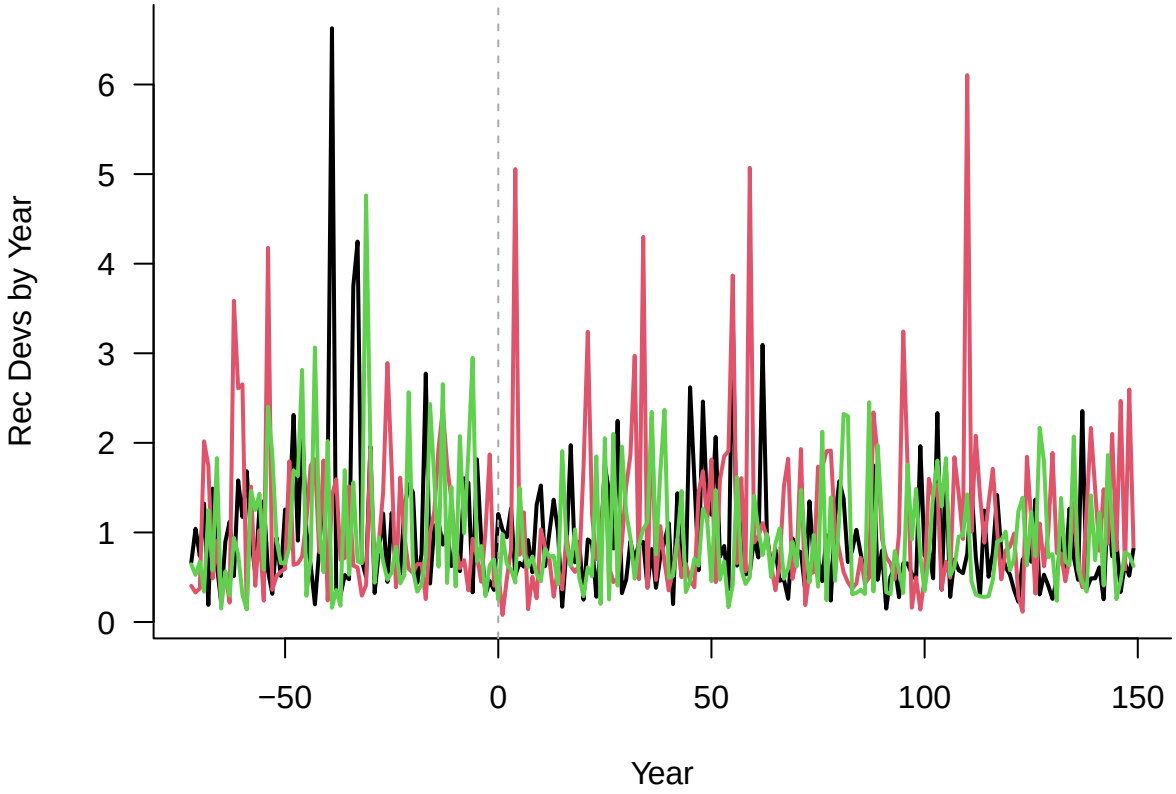
Recruitment Parameters

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): 130, 152

Von Bertalanffy parameters were derived from Vega 2003 which looked at Mexican lobster stocks. Evidence suggests that the von Bertalanffy growth model does fit well to lobster data and a custom growth equation/model needs to be derived.

A normally distributed range was implemented using cpars.

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): 0.09, 0.11

Von Bertalanffy parameters were derived from Vega 2003 which looked at Mexican lobster stocks. A normally distributed range was implemented using cpars.

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): 0.01, 0.01

Von Bertalanffy parameters were derived from Vega 2003 which looked at Mexican lobster stocks. A normally distributed range was implemented using cpars.

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): 0.05, 0.1

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.

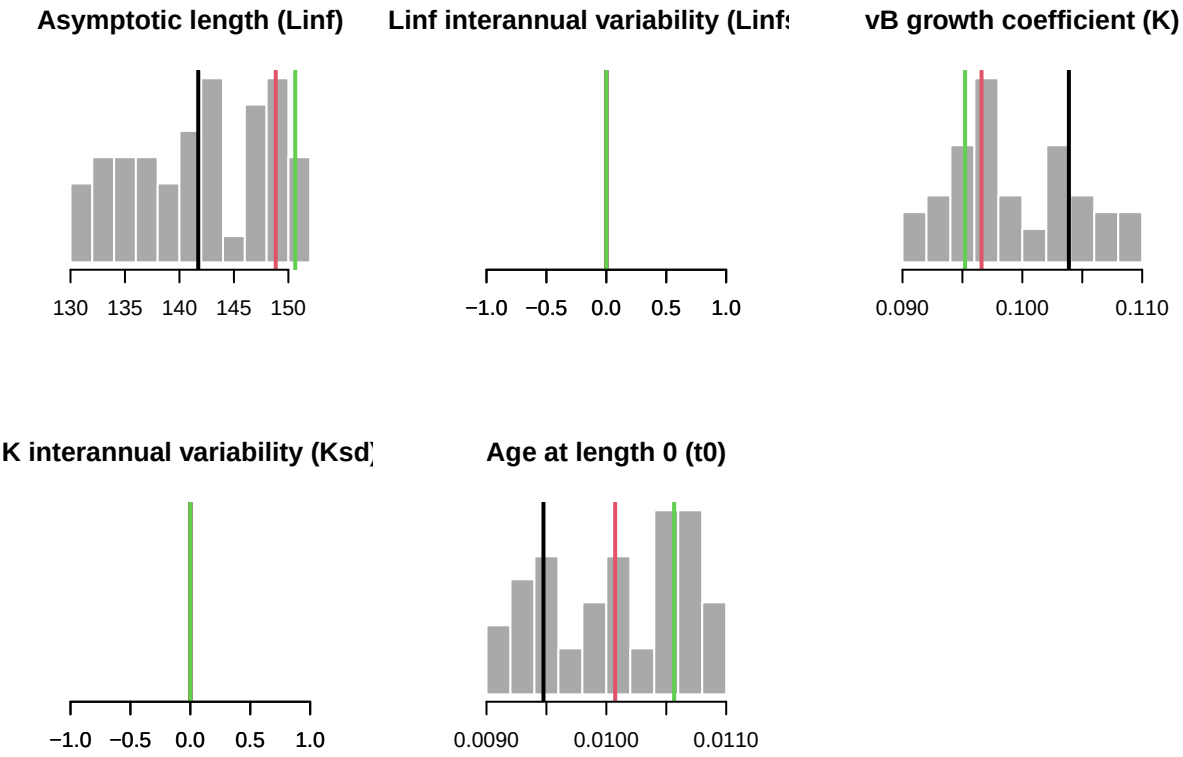
Specified Value(s): 0, 0

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.

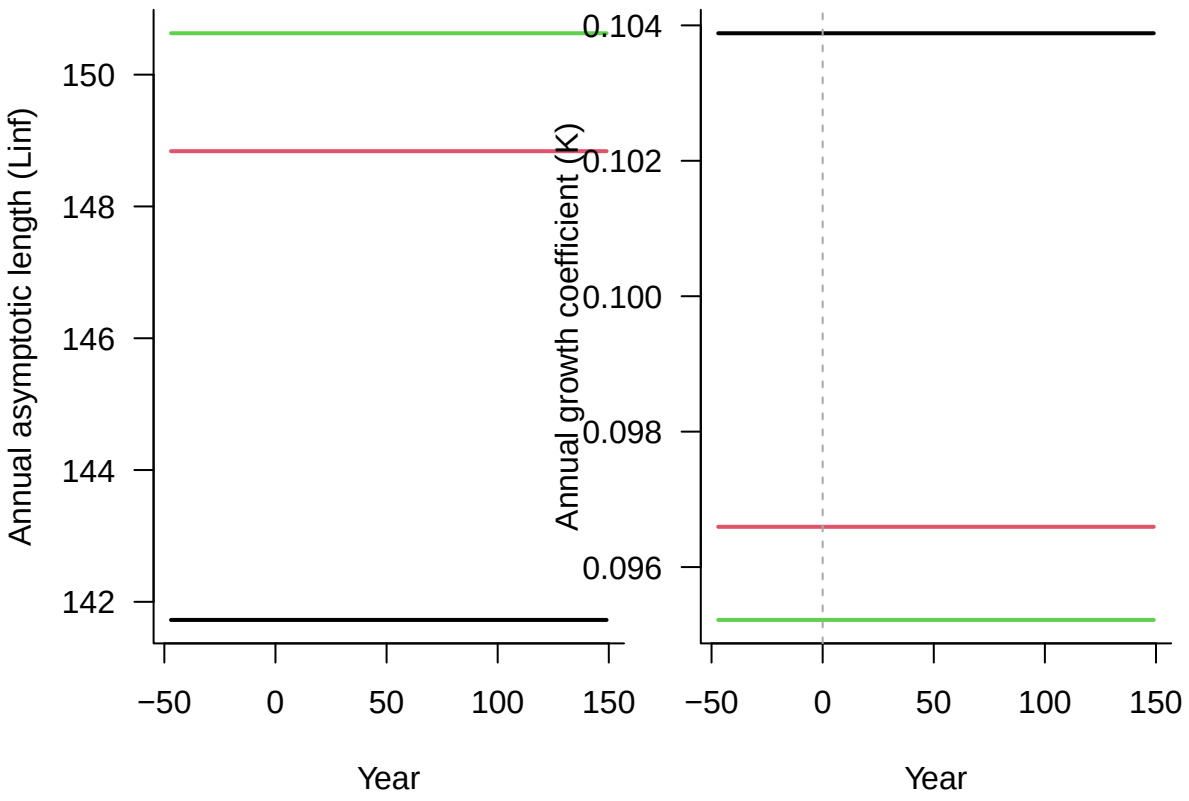
Specified Value(s): 0, 0

Growth Parameters

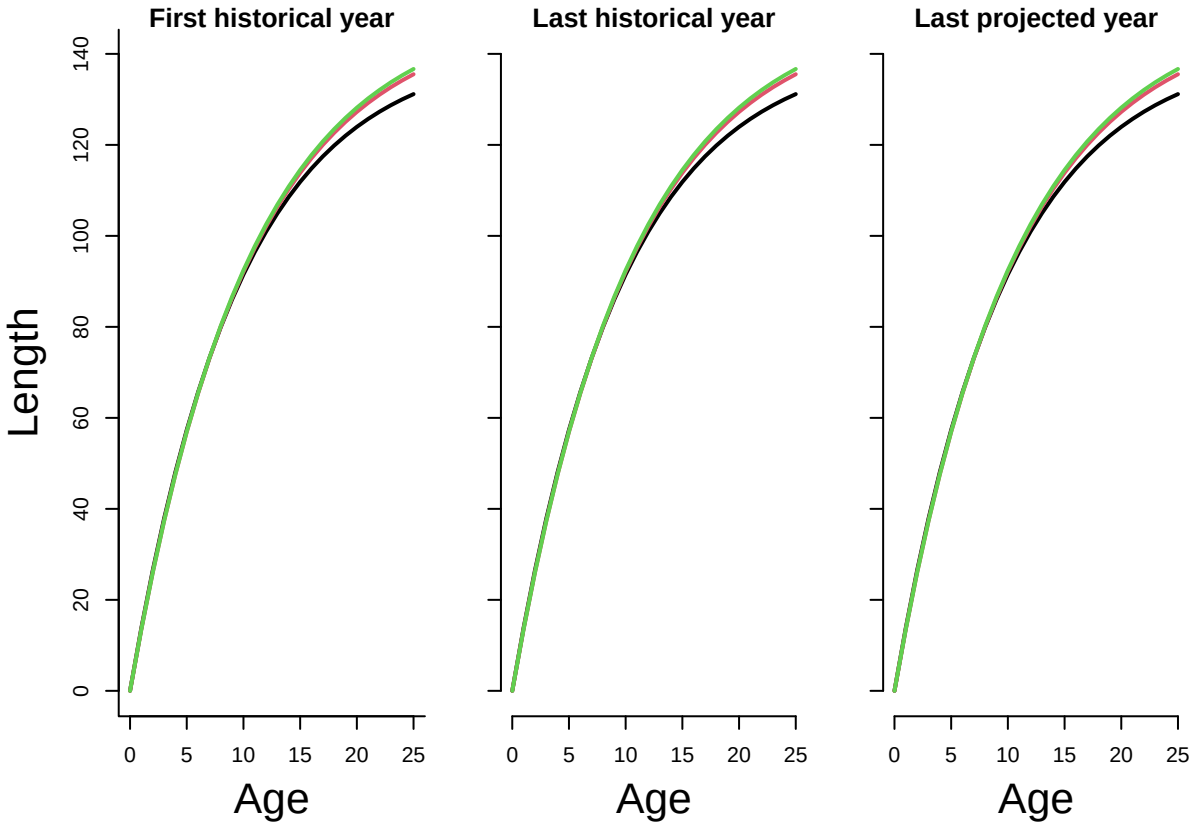
Sampled Parameters Histograms of simulations of von Bertalanffy growth parameters `Linf`, `K`, and `t0`, and inter-annual variability in Linf and K (`Linfsd` and `Ksd`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



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): 69.5, 85

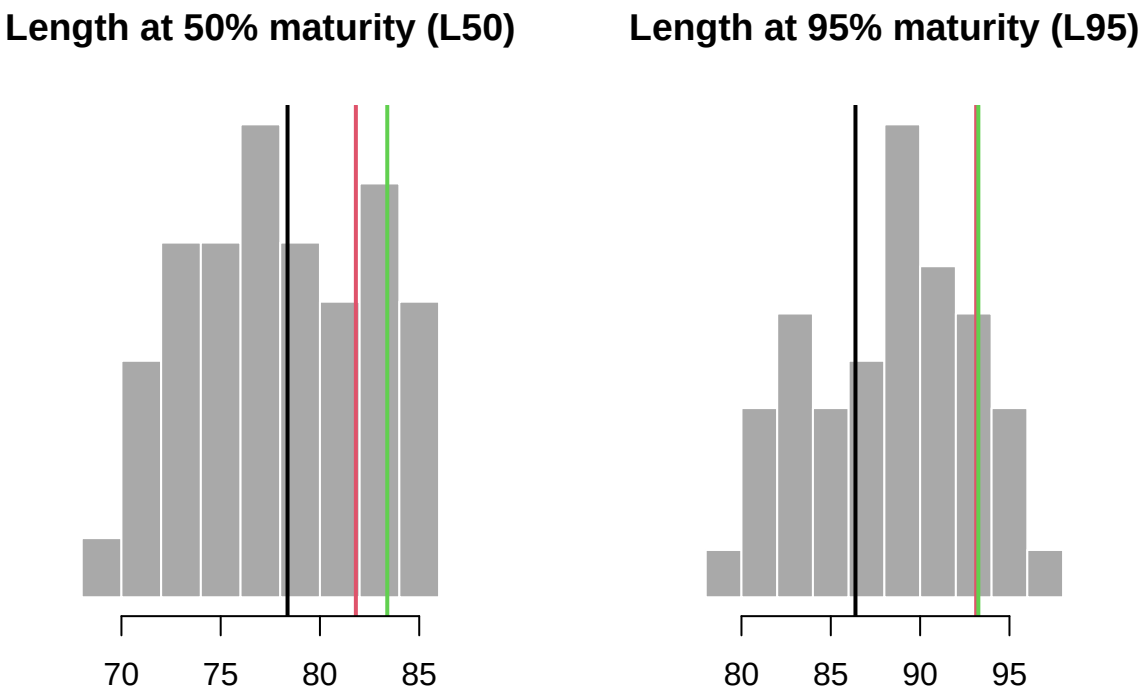
Upper and lower bound of ranges presented in the FMP.

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.

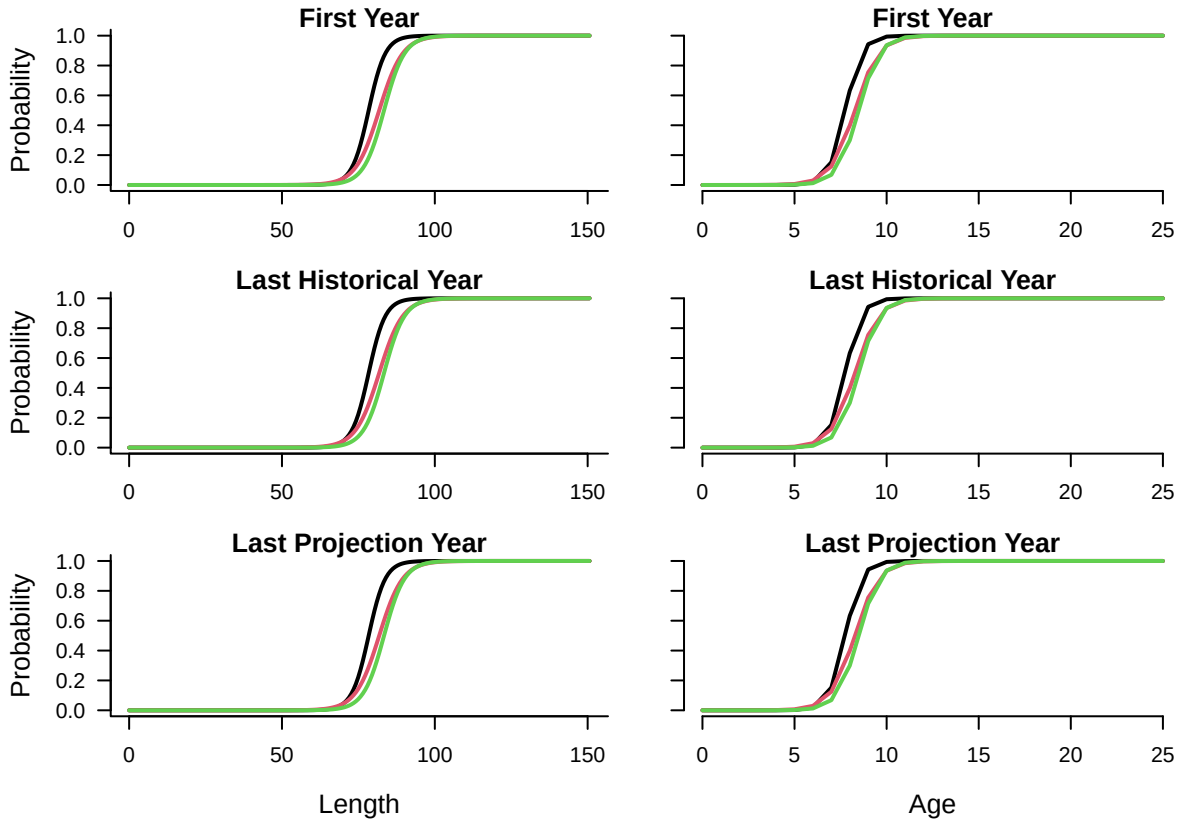
Specified Value(s): 8, 12

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): 0.15, 0.25

Evidence for the range of depletion tested comes from fishery-dependent information on the average size of the catch and resulting estimates of spawning potential ratio being low. Depletion was modified by cpars.

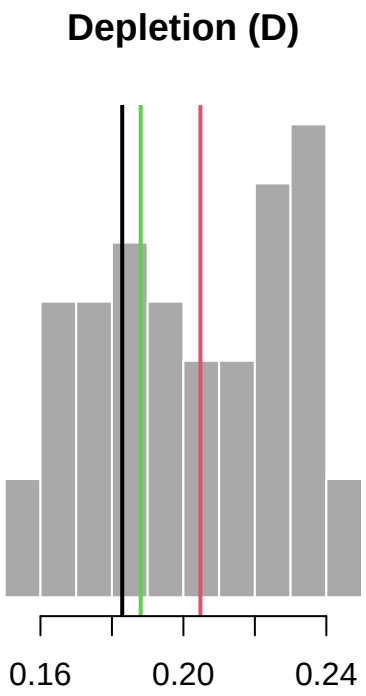
Fdisc: The instantaneous discard mortality rate the stock experiences when fished using the gear type specified in the corresponding fleet object and discarded. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. Uniform distribution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

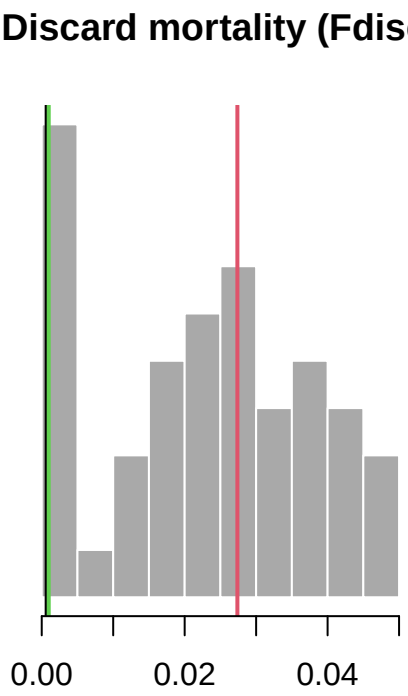
Specified Value(s): 0, 0.05

Tag-recapture studies indicate low discard mortality.

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): 0.01

Parameterized from CDFW sport creel census data in 1992 and 2007. This value was used in the CDFW management model.

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): 2.45

Parameterized from CDFW sport creel census data in 1992 and 2007. This value was used in the CDFW management model.

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): 0.13, 0.16

We assume that the fraction of lobsters protected by MPAs is equal to the percent habitat protected (same assumption as in the FMP). The FMP indicates 14.6% of lobster habitat is protected.

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): 0.13, 0.16

Assumed equal distribution of lobsters across the areas.

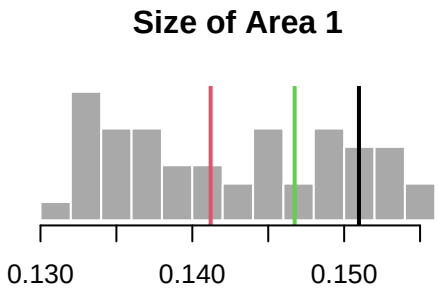
Prob_staying: The probability of individuals in area 1 remaining in area 1 over the course of one year. Please specify numbers between 0 and 1. For each simulation a single value is drawn from a uniform distribution specified by the upper and lower bounds provided. For example, in an area with a Prob_staying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

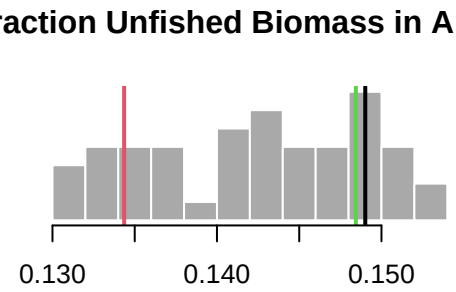
Specified Value(s): 0.9, 0.98

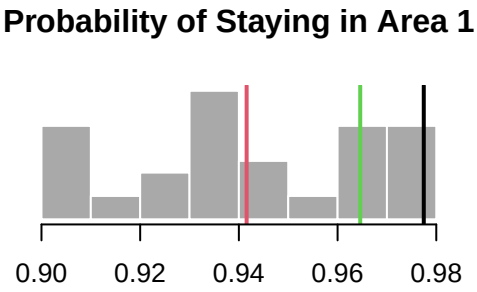
From Lindberg 1955 looking at movement outside of MPA boundaries, calculated an estimated 2% of the lobster population would move in or out of the MPA over 3 months, 2%x4=8% over a year, rounded to 10% for lower bound.

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): 147

The species has a long history of exploitation back to 1877.

Spat_targ: Distribution of fishing in relation to vulnerable biomass (VB) across areas. The distribution of fishing effort is proportional to VBˆSpat_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 vulnerable biomass assumed to experience fishing effort.

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).

Effort values were created to tune simulated historic catch patterns to match the landings history. While values were informed by logbook data, this data could not directly be used because of temporal gaps in data collection and regulatory changes that bias estimates.

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).

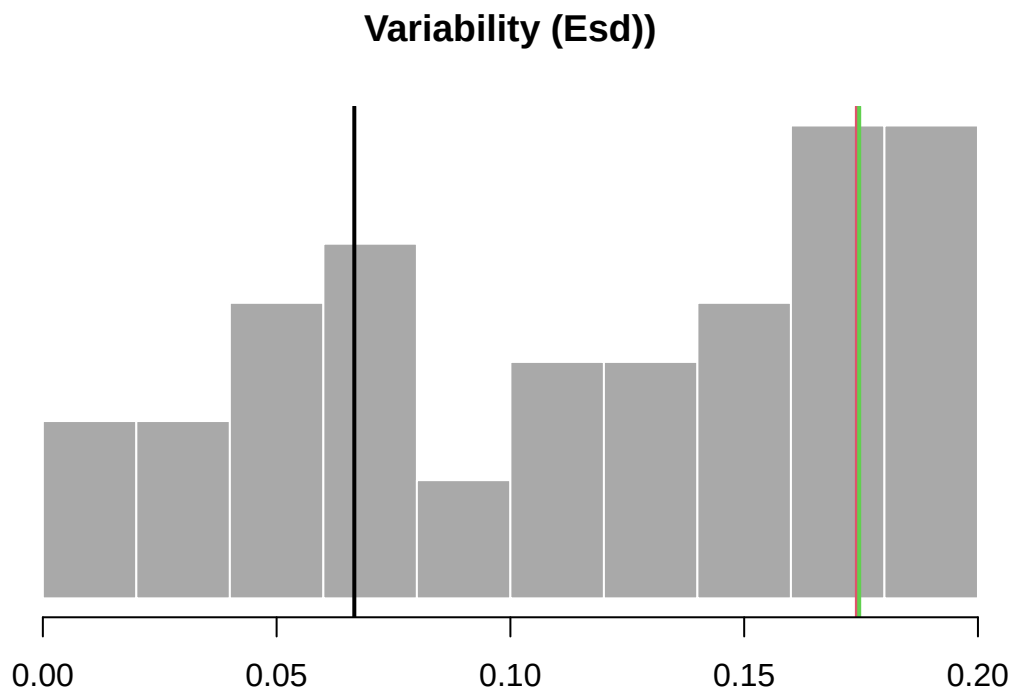
EffYears	EffLower	EffUpper
1872	0.00	0.00
1935	0.05	0.15
1942	0.10	0.20
1949	0.80	1.30
1955	0.50	0.80
1961	0.20	0.50
1973	0.05	0.20
1975	0.05	0.20
1976	0.05	0.20
1977	0.10	0.25
1978	0.15	0.35
1980	0.20	0.40
1982	0.20	0.40
1986	0.20	0.40
1988	0.35	0.50
1989	0.40	0.60
1990	0.40	0.60
1991	0.45	0.65
1995	0.45	0.65
1996	0.50	0.70
1997	0.60	0.80
1998	0.45	0.65
2000	0.50	0.65
2003	0.50	0.65
2004	0.65	0.70
2005	0.50	0.65
2009	0.65	0.70
2010	1.00	1.00
2016	2.00	2.00
2017	3.00	3.00
2018	4.00	4.00

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.

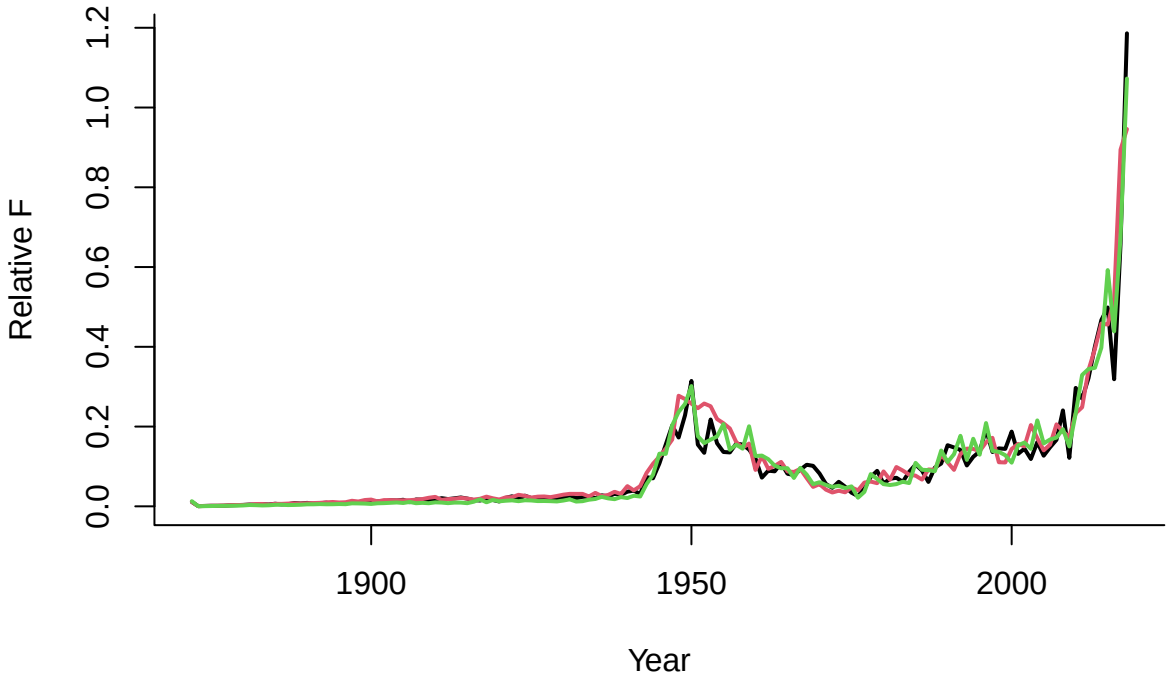
Specified Value(s): 0, 0.2

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): -0.01, 0.01

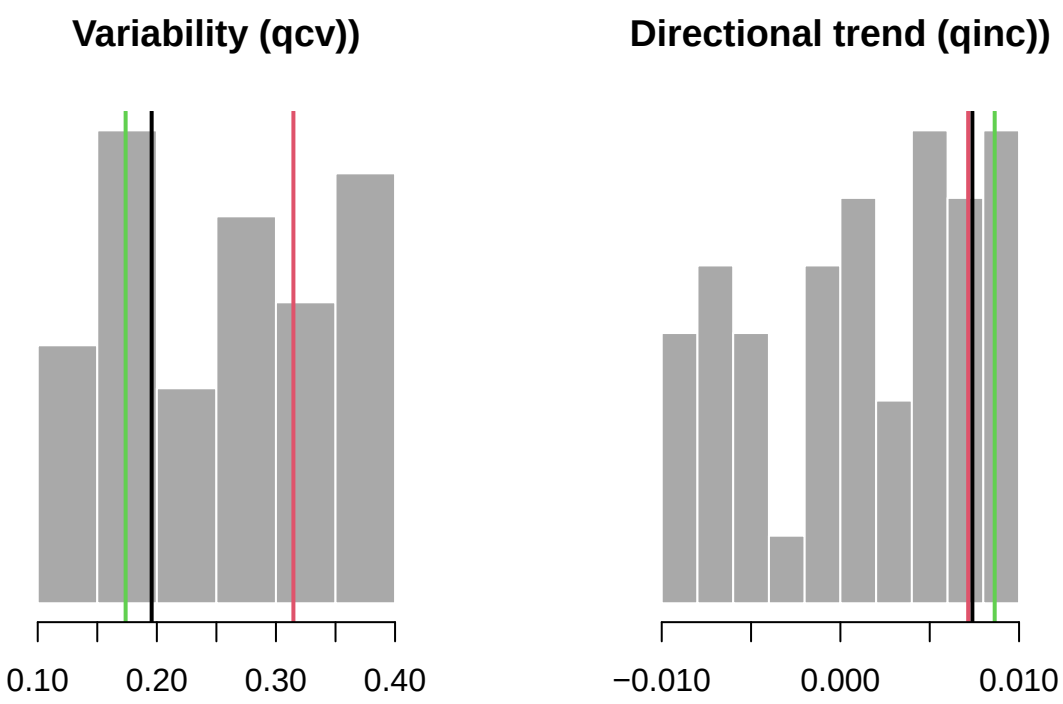
No increase in catchability over time was assumed.

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.

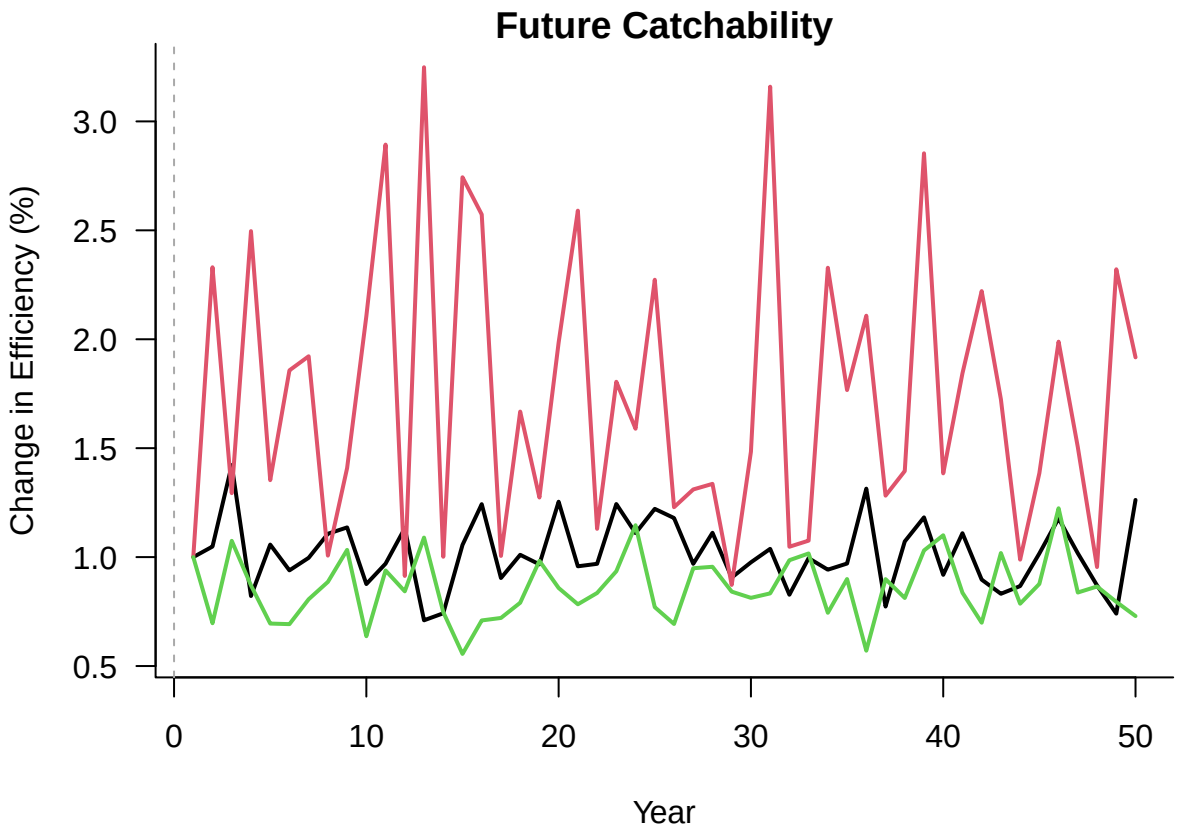
Specified Value(s): 0.1, 0.4

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): 50, 56

Dome shaped selectivity is modeled allowing up to 30% of lobsters to be selected by the gear at their maximum size.

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): 78, 82

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): 0.28, 0.32

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): 0

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): 81, 82

Lobsters are assumed to be fully vulnerable at the minimum legal size.

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): 82.5, 82.5

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

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, 0.01

The discard rate for legal-sized lobster is probably close to zero since there is currently no known shell disease that may affect a fisher's ability to sell a lobster.

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

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 2x3 matrix specifies the timing of MPA closures during the fishery history and the proportion of fishing grounds removed for two areas. Historical years are specified in column 1. Proportion of grounds closed in areas 1 and 2 are specified in columns 2 and 3. Area 1 represents MPAs and area 2 represents open fishing grounds. 55% of all currently protected areas were closed in 2003, and the remaining 45% of these protected areas were closed in 2012.

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, 0.05

Total catch for the commercial lobster fishery is well known because fishers are required to submit logbooks and landing receipts for all catch. Total catch for the recreational lobster fishery is not well known. Recreational fishers are required to submit catch report cards at the end of the season but compliance is low. Only about 50% of recreational fishers turn in report cards.

We model only commercial harvest here.

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

Estimation of commercial catch is likely accurate.

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

Not applicable to the lobster fishery.

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

Not applicable to the lobster fishery.

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): 2000, 2000

A high, static sample size was set to simulate a representative sample of lengths. CDFW does not sample lengths but does collect data on the total weight and number of lobsters with each landing. This provides many samples of average lobster weight. MPs tested in this analysis converted simulated length samples to average weights to simulate CDFW's current management strategy.

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): 2000, 2000

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): 0.05, 0.15

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, 0

Not applicable to the lobster fishery.

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, 0

Not applicable to the lobster fishery.

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, 0

Not applicable to the lobster fishery.

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

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

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

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

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

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

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

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

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

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

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

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

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

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, 0

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

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, 0

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

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.

Slot not used.

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.

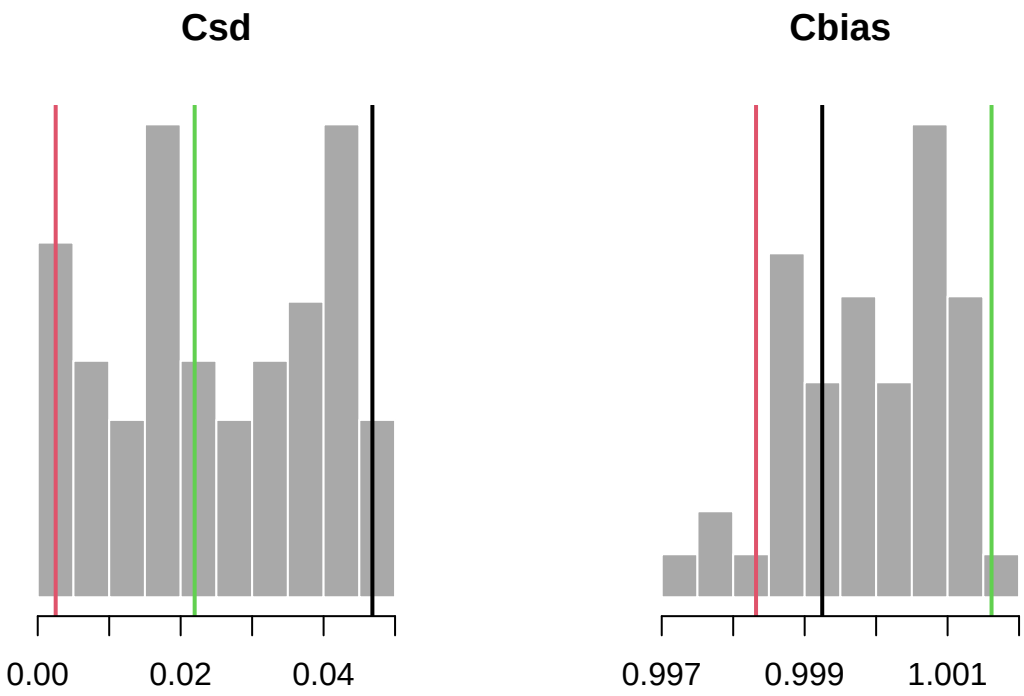
Slot not used.

Obs Plots

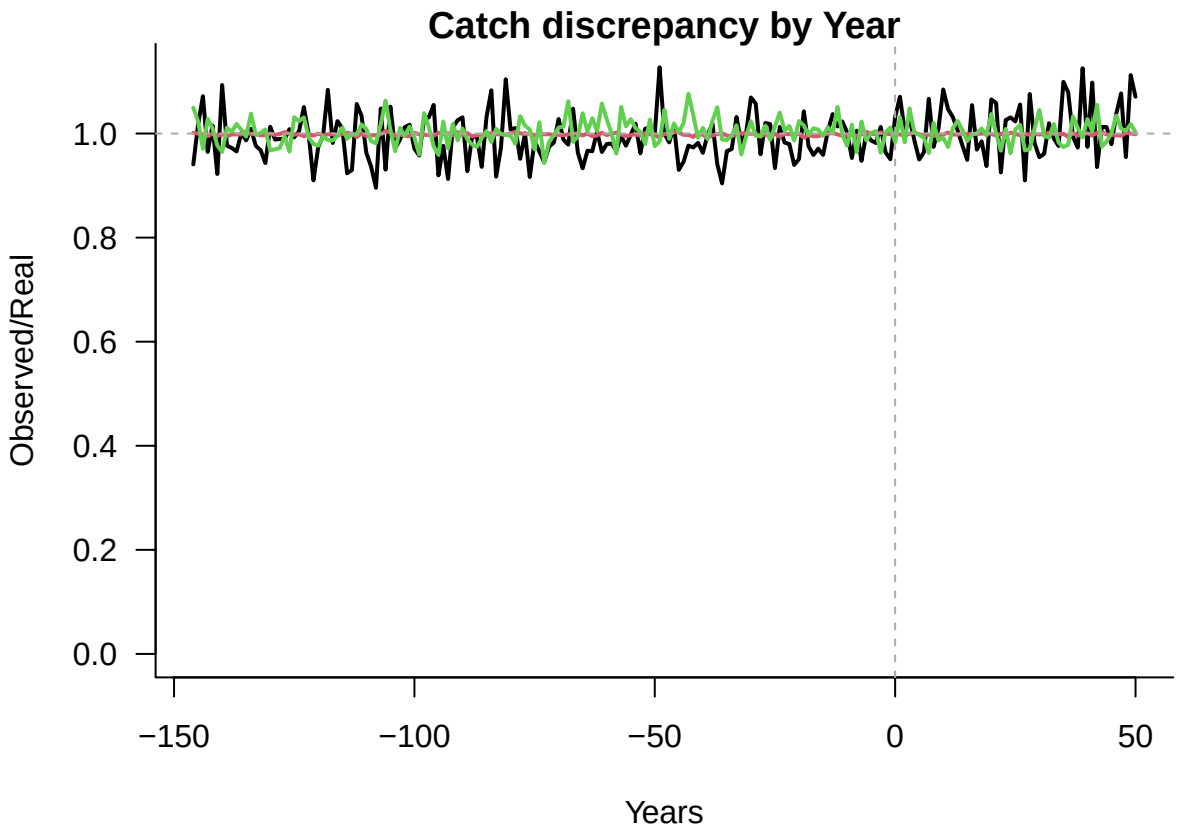
Observation Parameters

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:

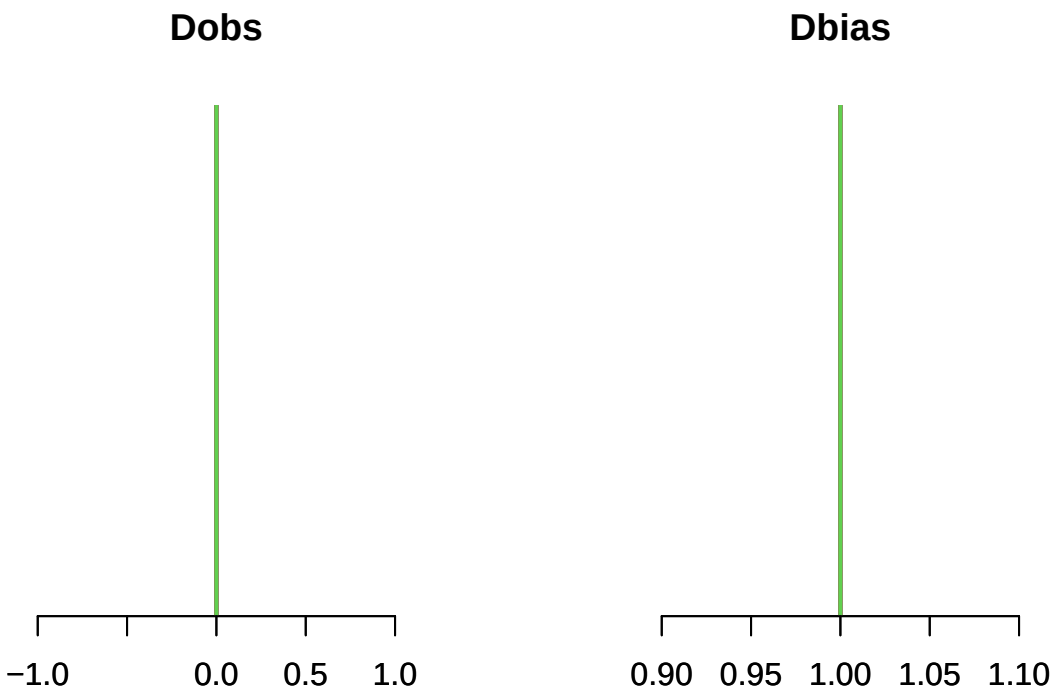


Time-Series Time-series plots of catch observation error for historical and projection years:

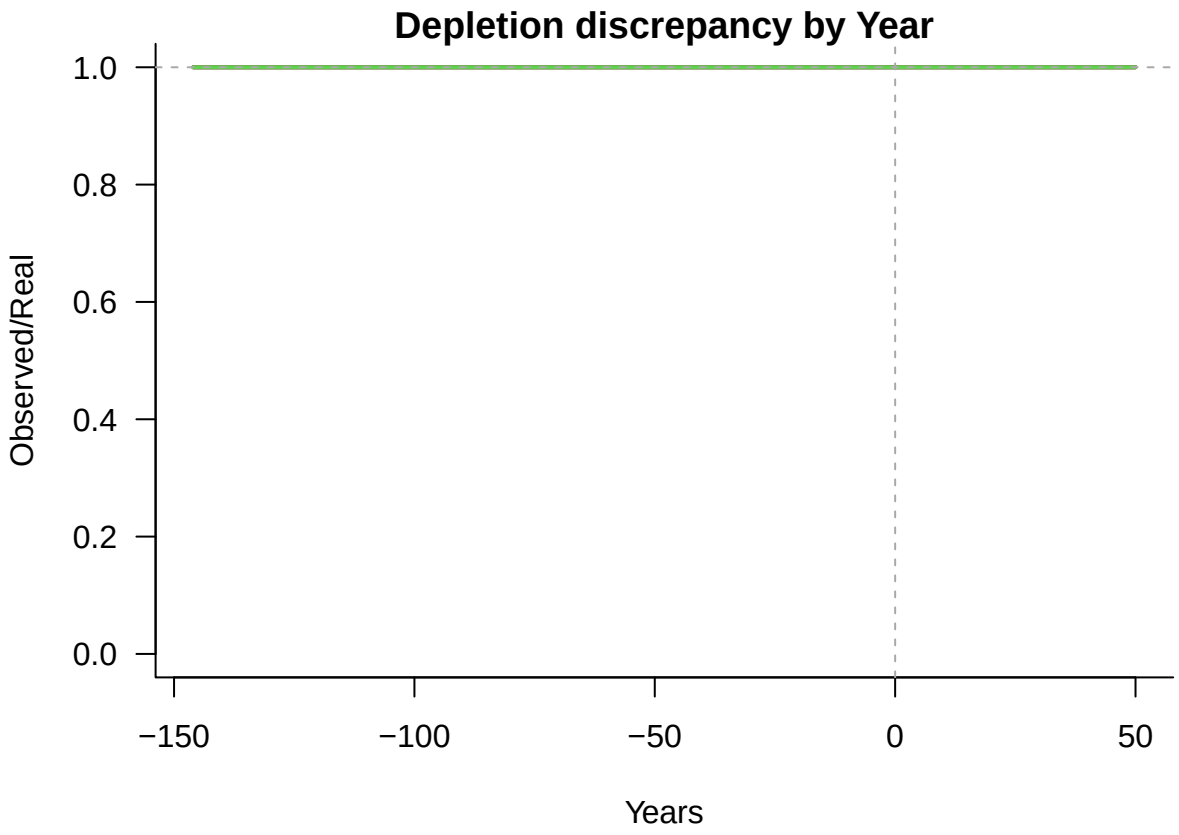


Depletion Observations

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:

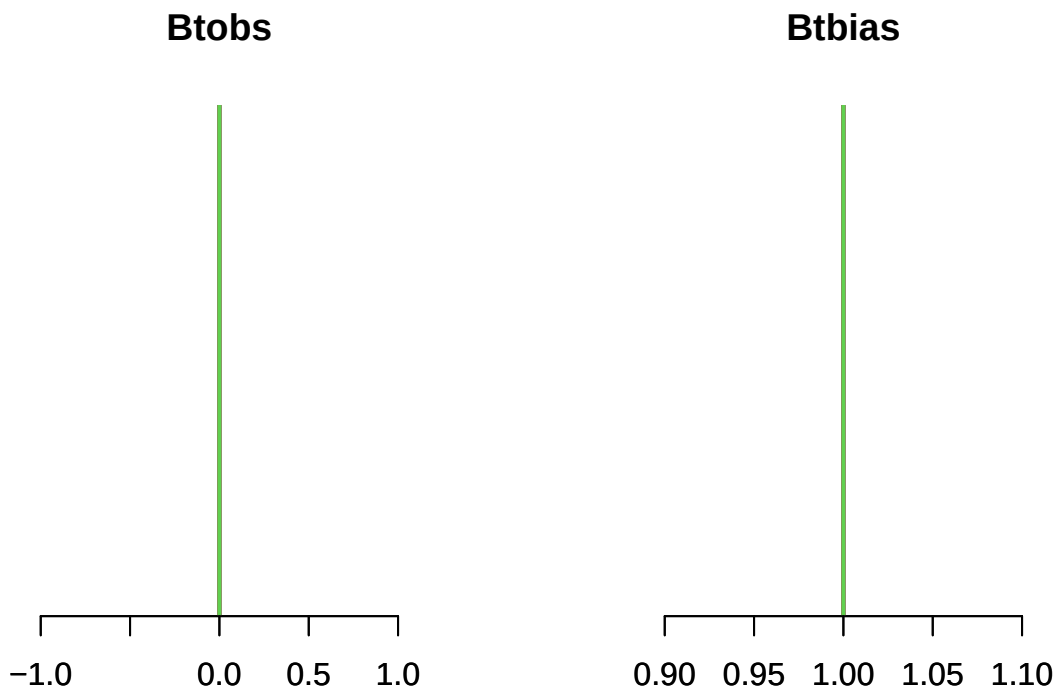


Time-Series Time-series plots of depletion observation error for historical and projection years:

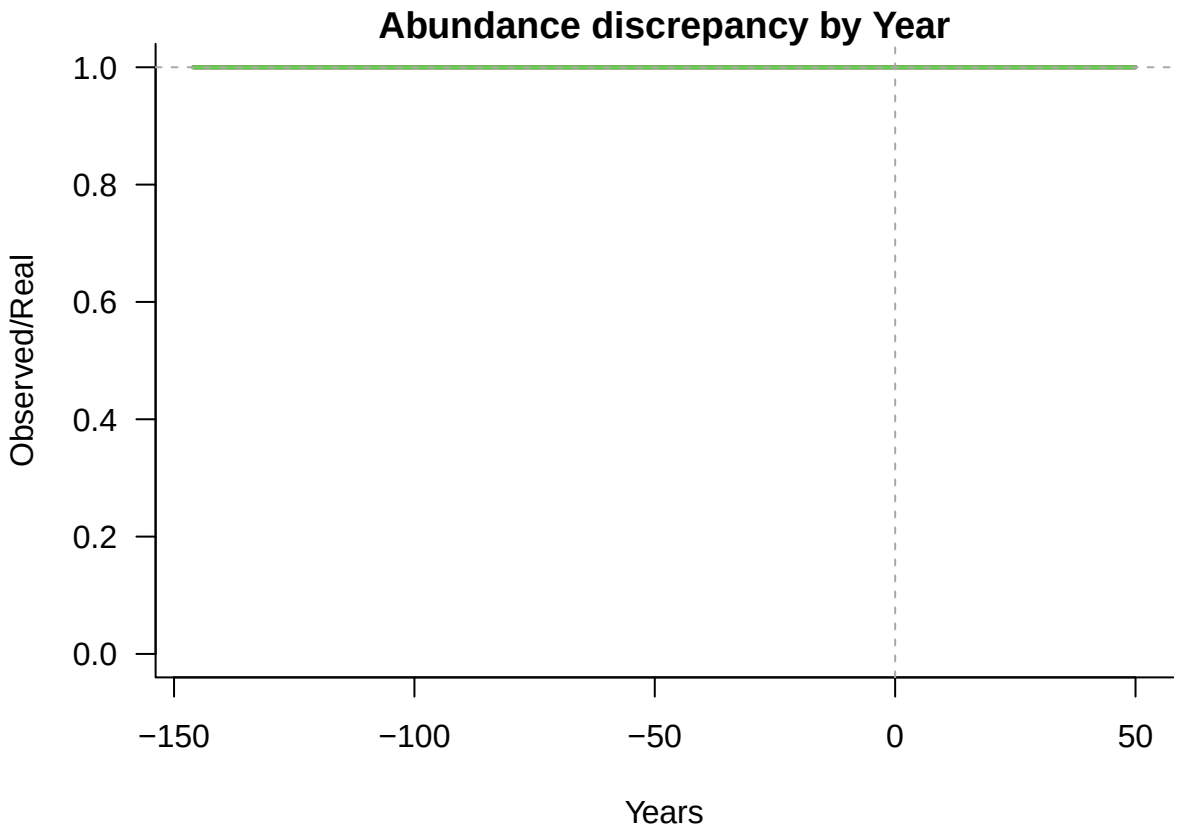


Abundance Observations

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:

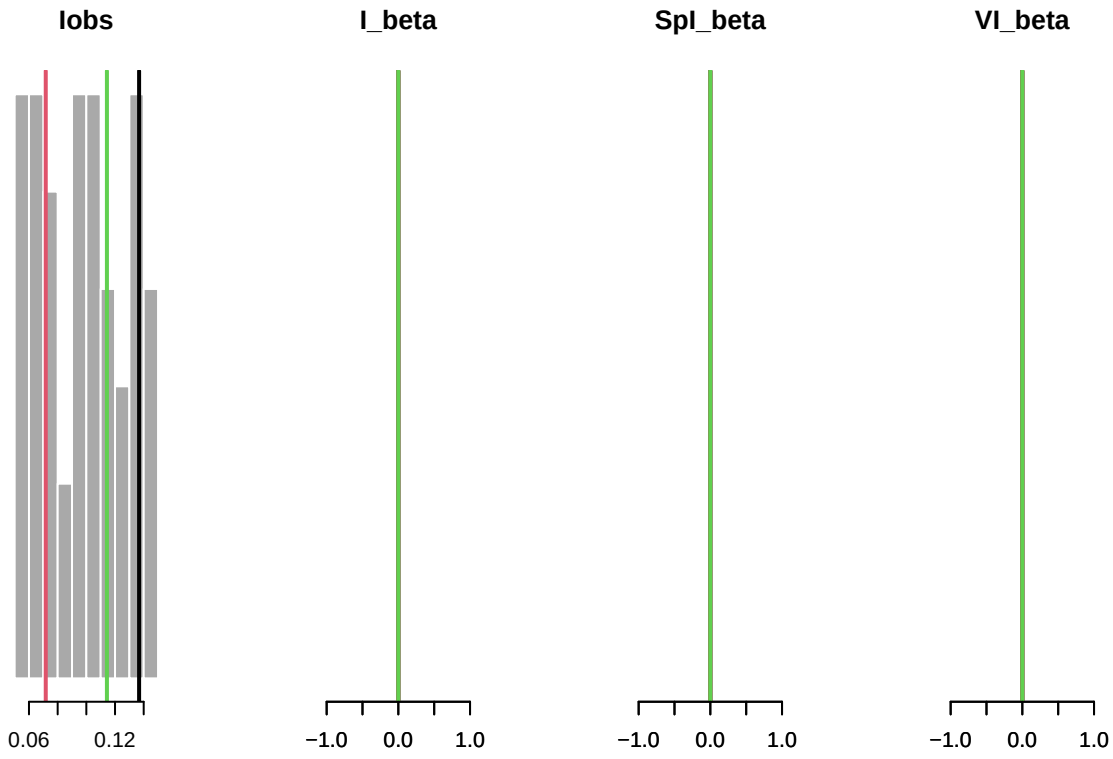


Time-Series Time-series plots of abundance observation error for historical and projection years:

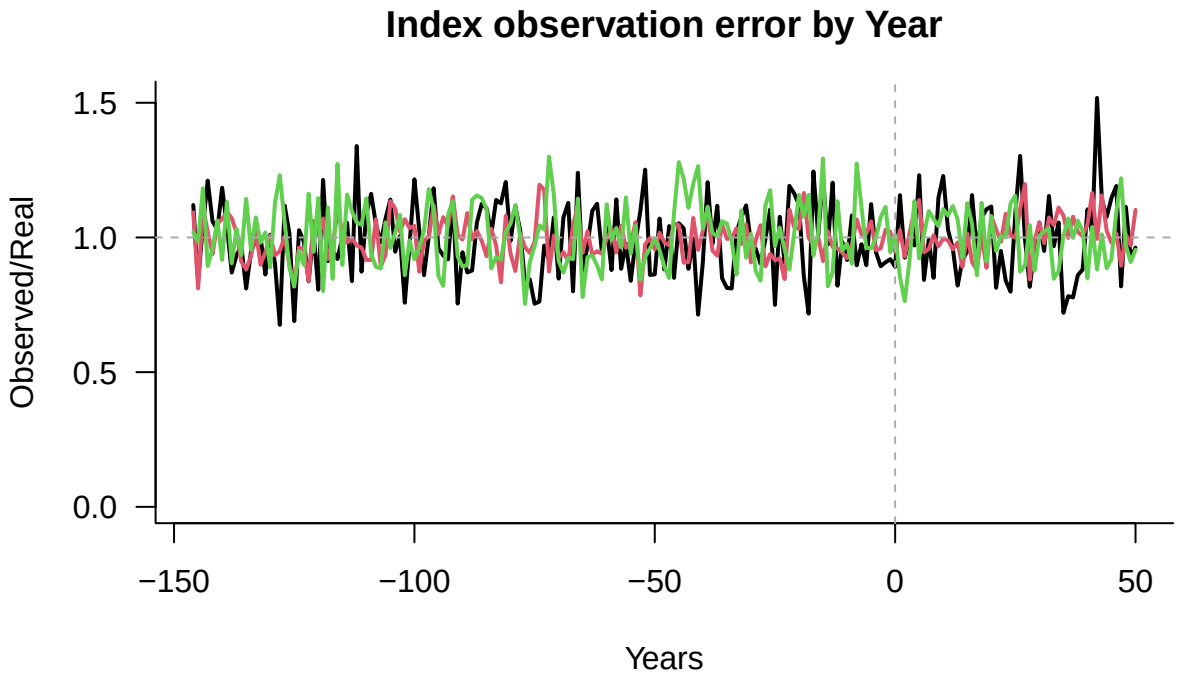


Index Observations

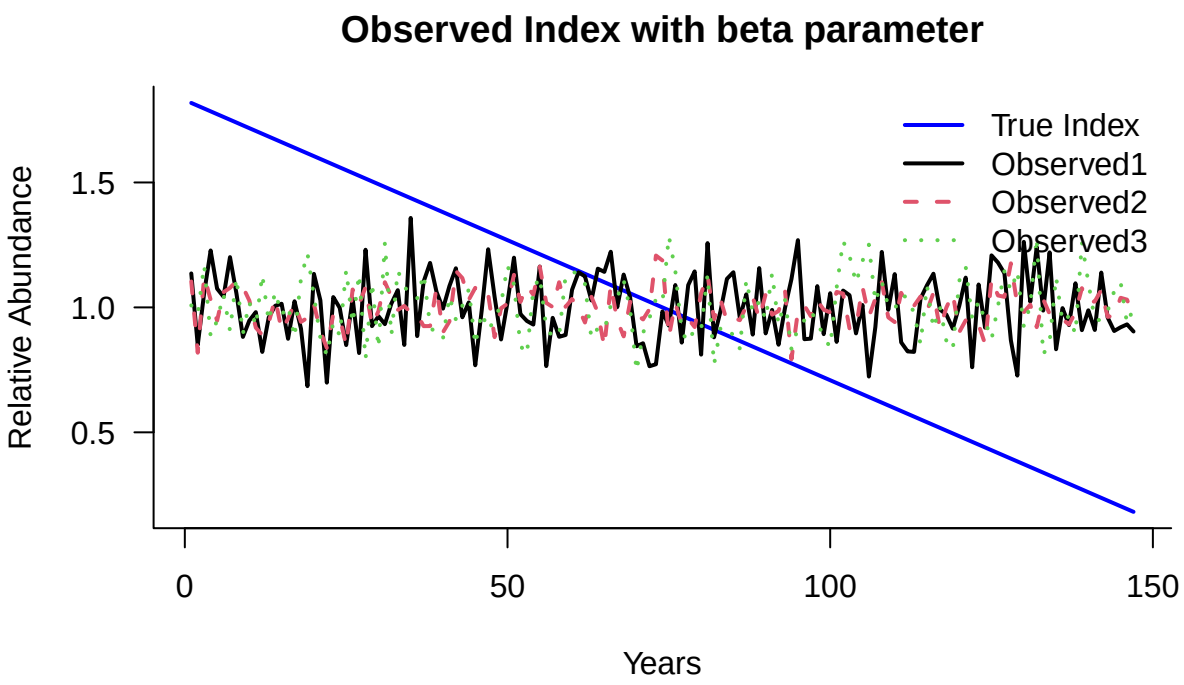
Sampled Parameters Histograms of 48 simulations of inter-annual variability in index observations (`Iobs`) and hyper-stability/depletion in observed index (`beta`), with vertical colored lines indicating 3 randomly drawn values used in other plots:



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

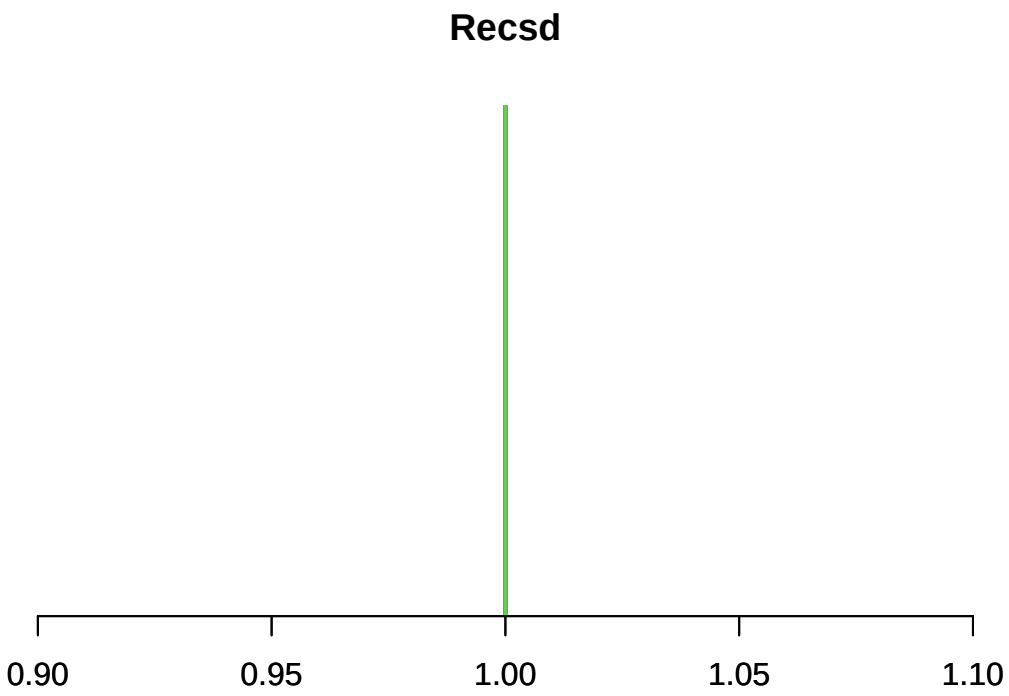


Plot showing an example true abundance index (blue) with 3 samples of index observation error and the hyper-stability/depletion parameter (`beta`):

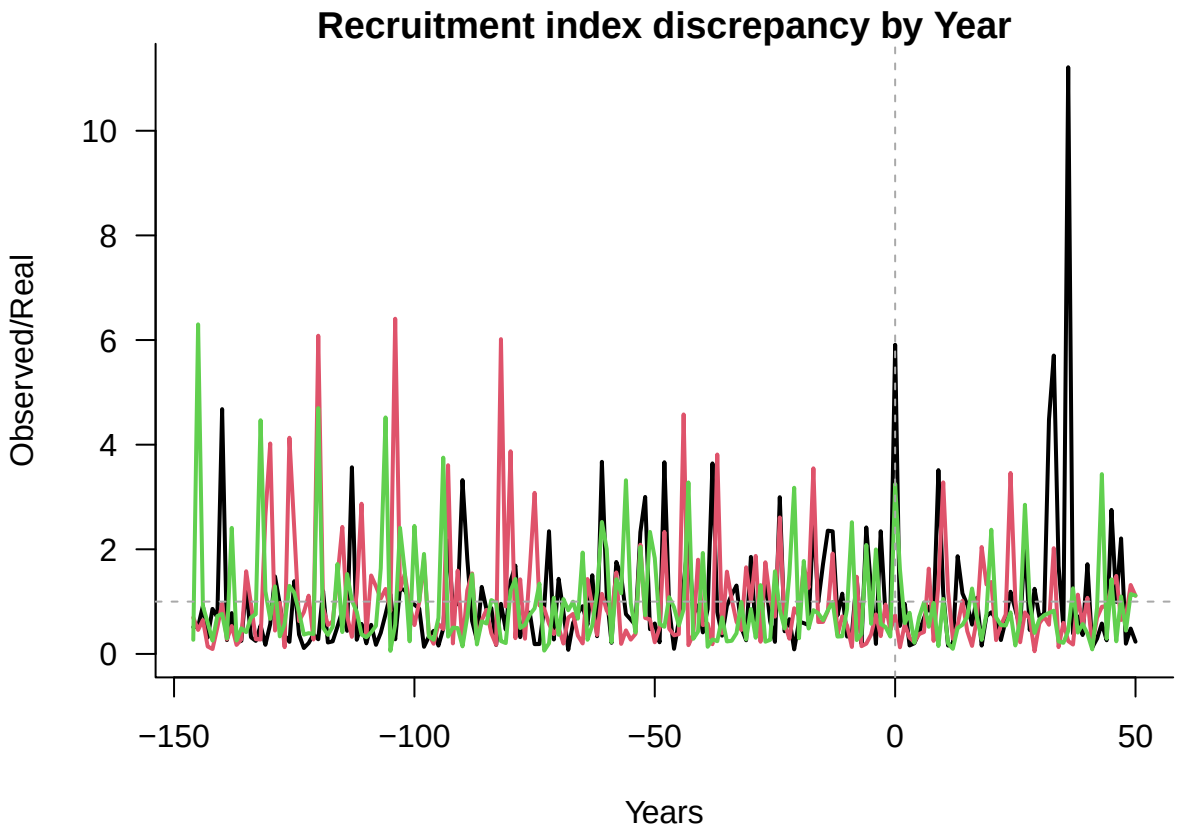


Recruitment Observations

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:

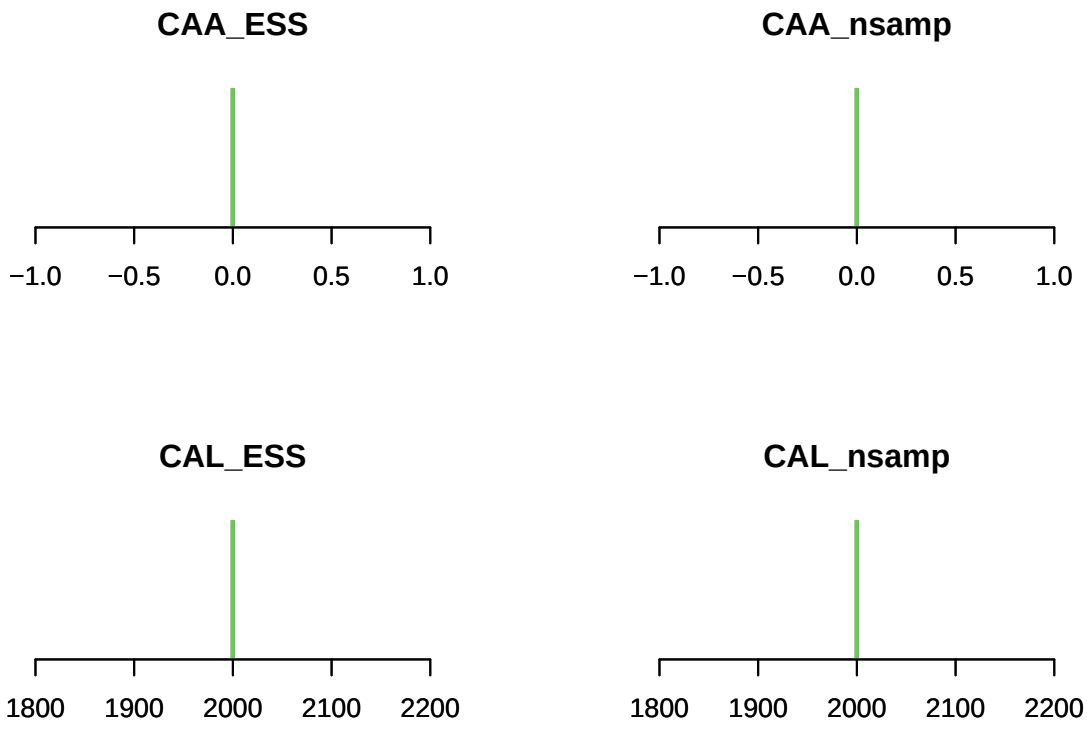


Time-Series Timeseries plots of observeration error for recruitment:



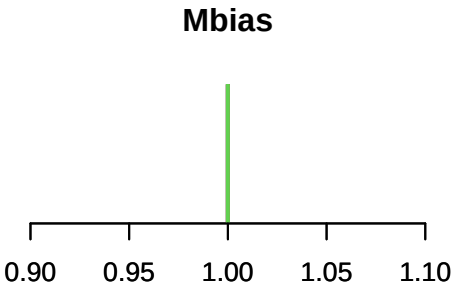
Composition Observations

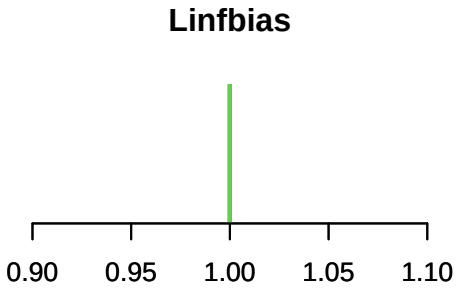
Sampled Parameters Histograms of 48 simulations of catch-at-age effective sample size (`CAA_ESS`) and sample size (`CAA_nsamp`) and catch-at-length effective (`CAL_ESS`) and actual sample size (`CAL_nsamp`) with vertical colored lines indicating 3 randomly drawn values:

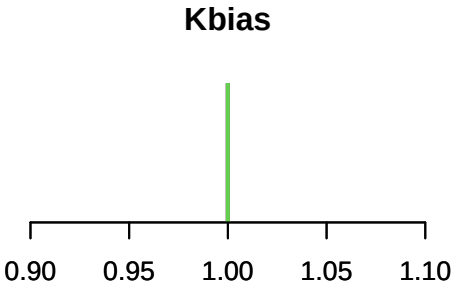


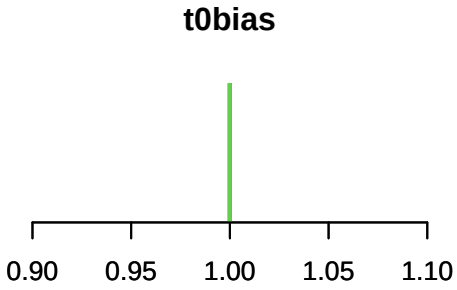
Parameter Observations

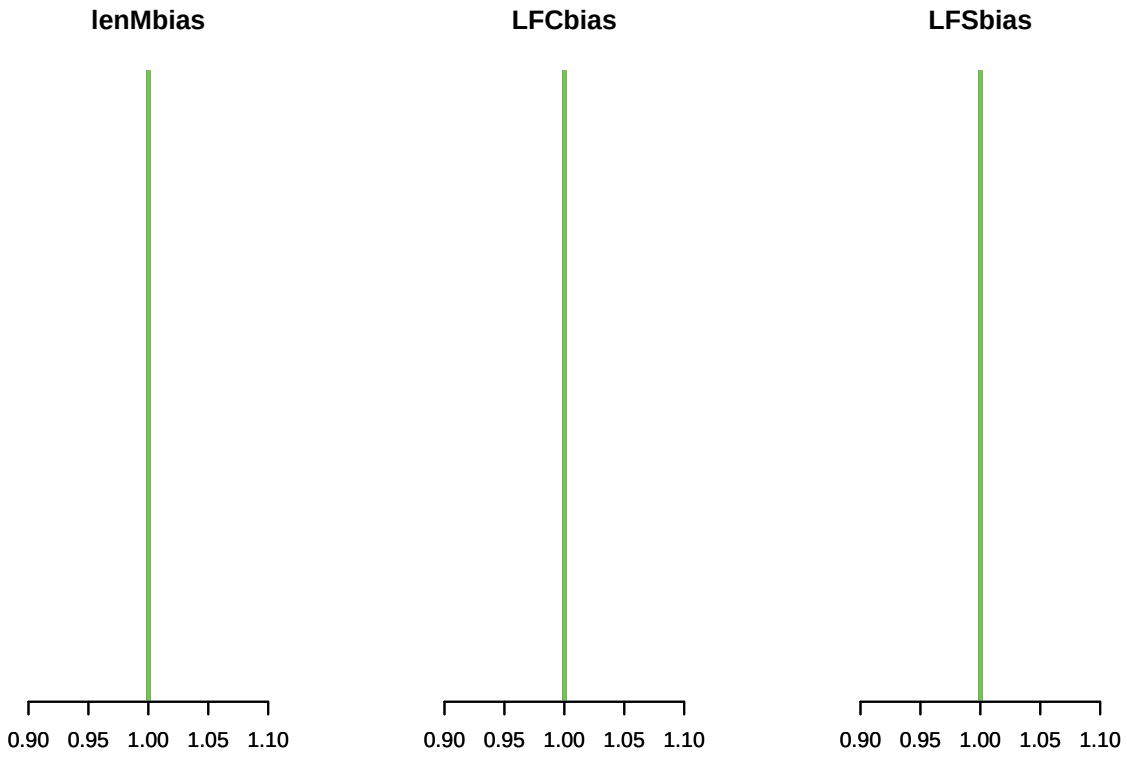
Sampled Parameters Histograms of 48 simulations of bias in observed natural mortality (`Mbias`), von Bertalanffy growth function parameters (`Linfbias`, `Kbias`, and `t0bias`), length-at-maturity (`lenMbias`), and bias in observed length at first capture (`LFCbias`) and first length at full capture (`LFSbias`)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


Mbias
0.90
0.95
1.00
1.05
1.10


Linfbias
0.90
0.95
1.00
1.05
1.10

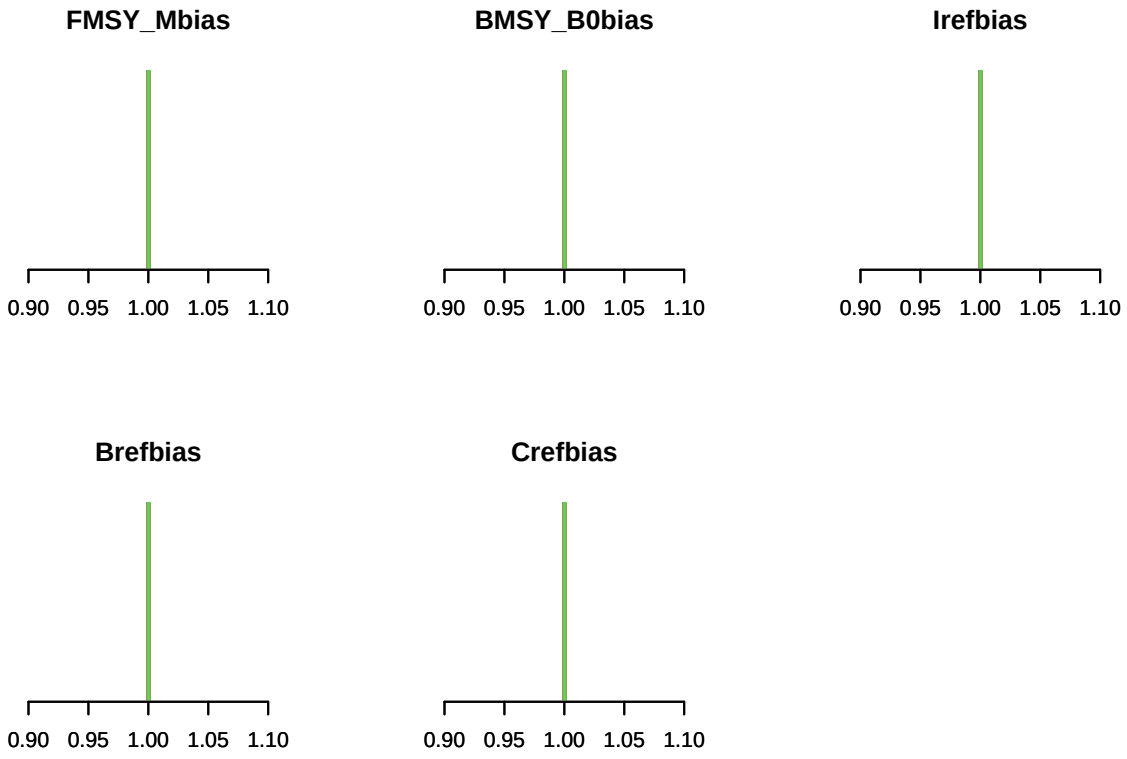

Kbias
0.90
0.95
1.00
1.05
1.10


t0bias
0.90
0.95
1.00
1.05
1.10



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): 0.95, 1.05

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, 0.05

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): 0.9, 1.2

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, 0.05

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): 0.98, 1

A lobster that is a couple mm short of legal size would have about an 80mm CL. This is about 97% of legal size (82.5mm CL).

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.

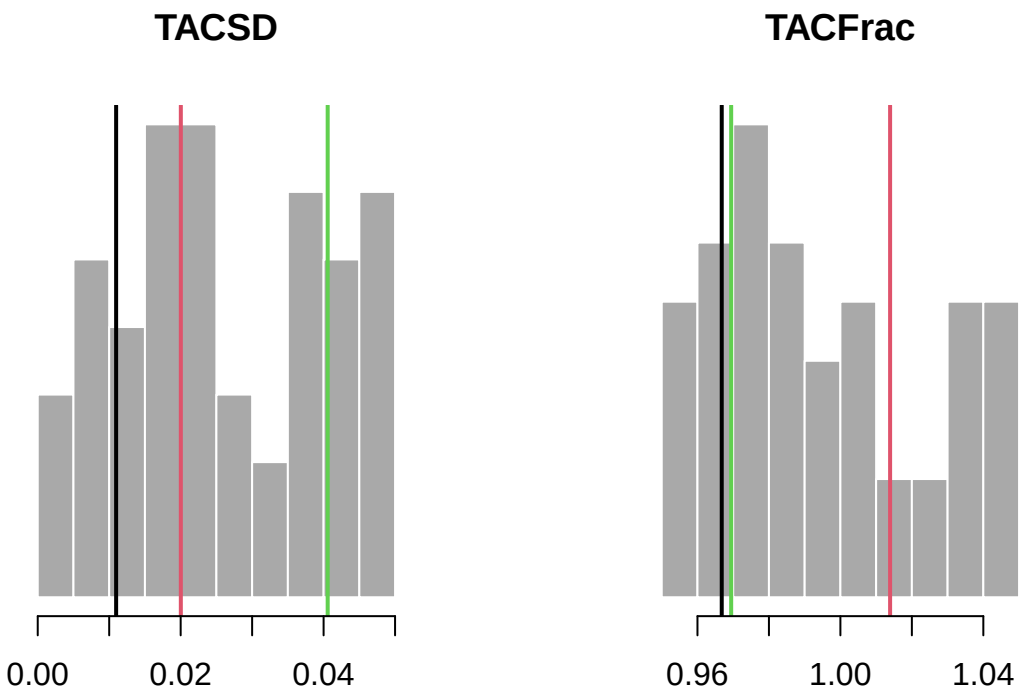
Specified Value(s): 0, 0

Imp Plots

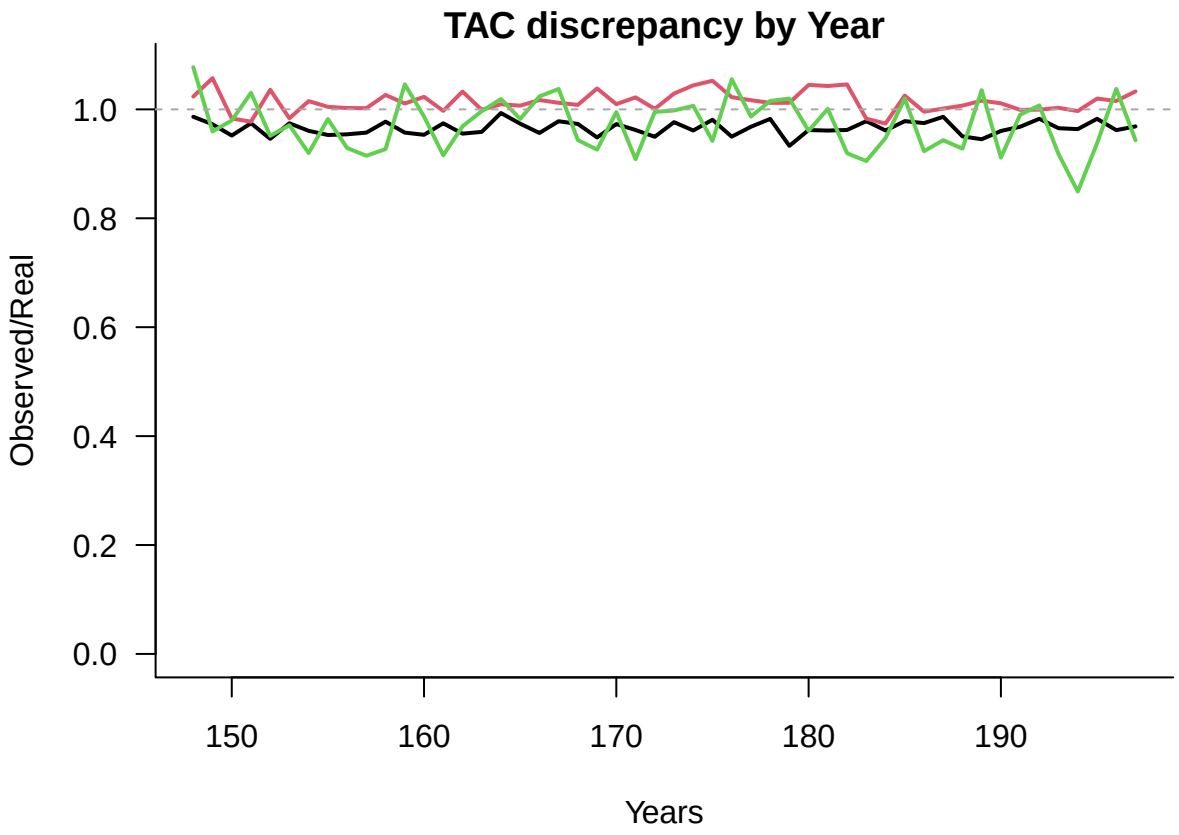
Implementation Parameters

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:

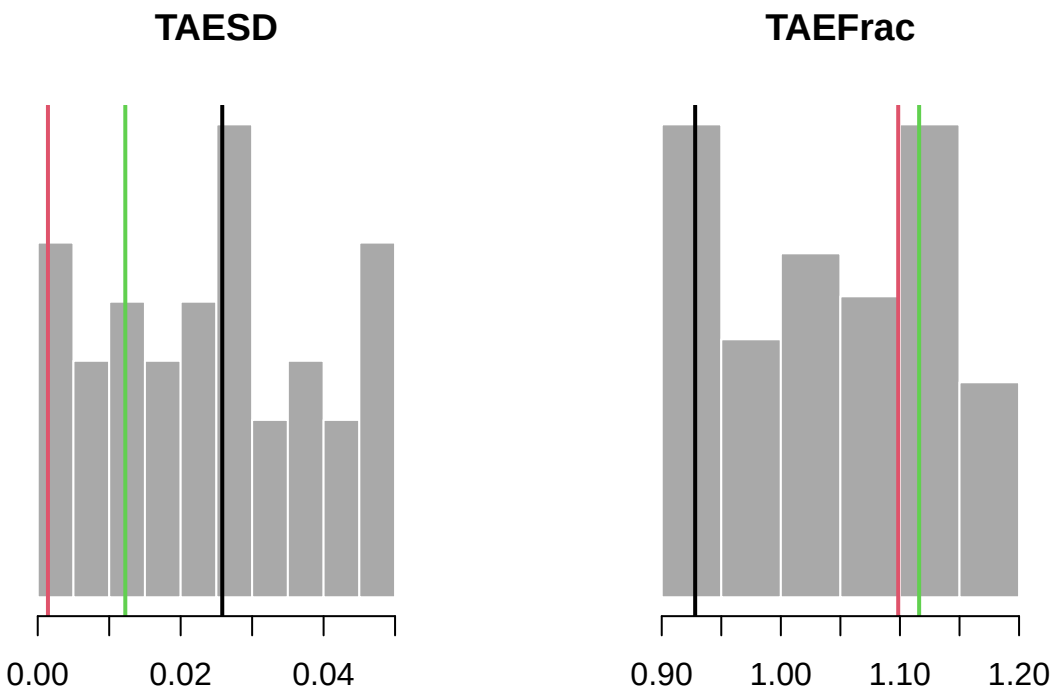


Time-Series Time-series plots of 0 samples of TAC implementation error by year:

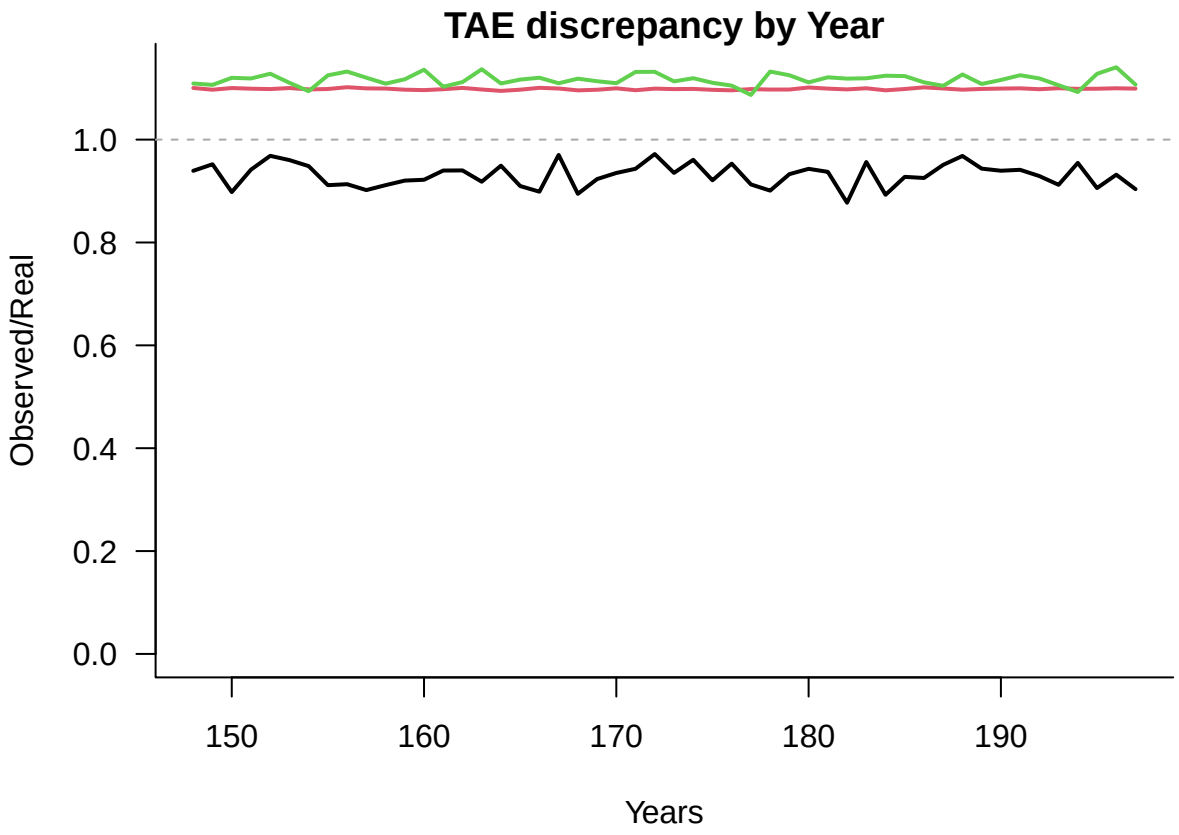


TAE Implementation

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:

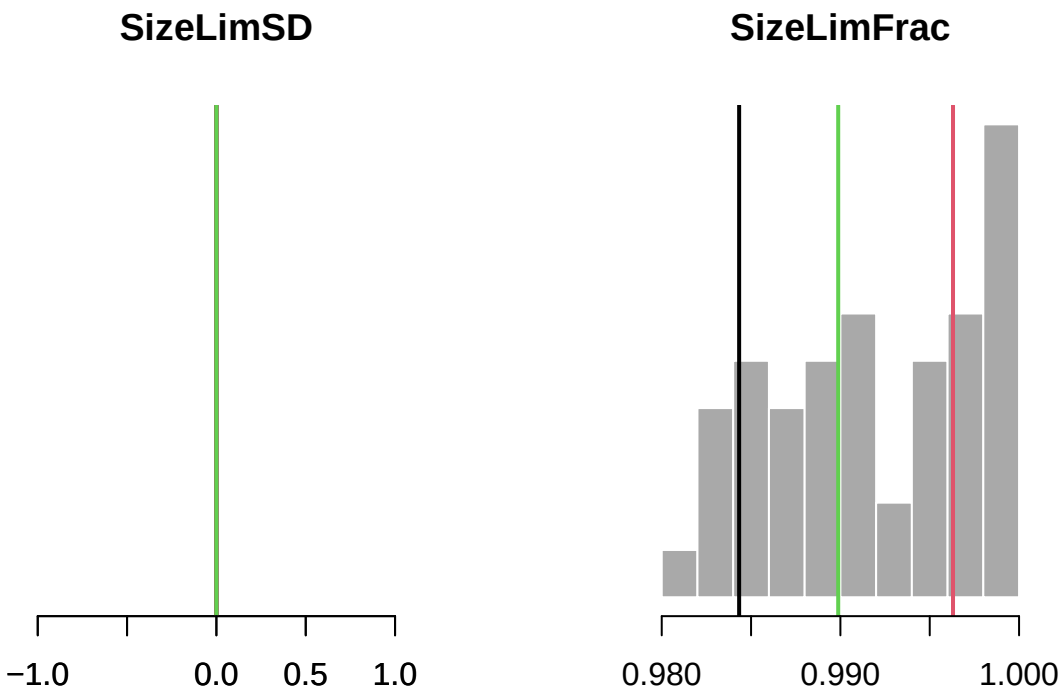


Time-Series Time-series plots of 0 samples of TAE implementation error by year:

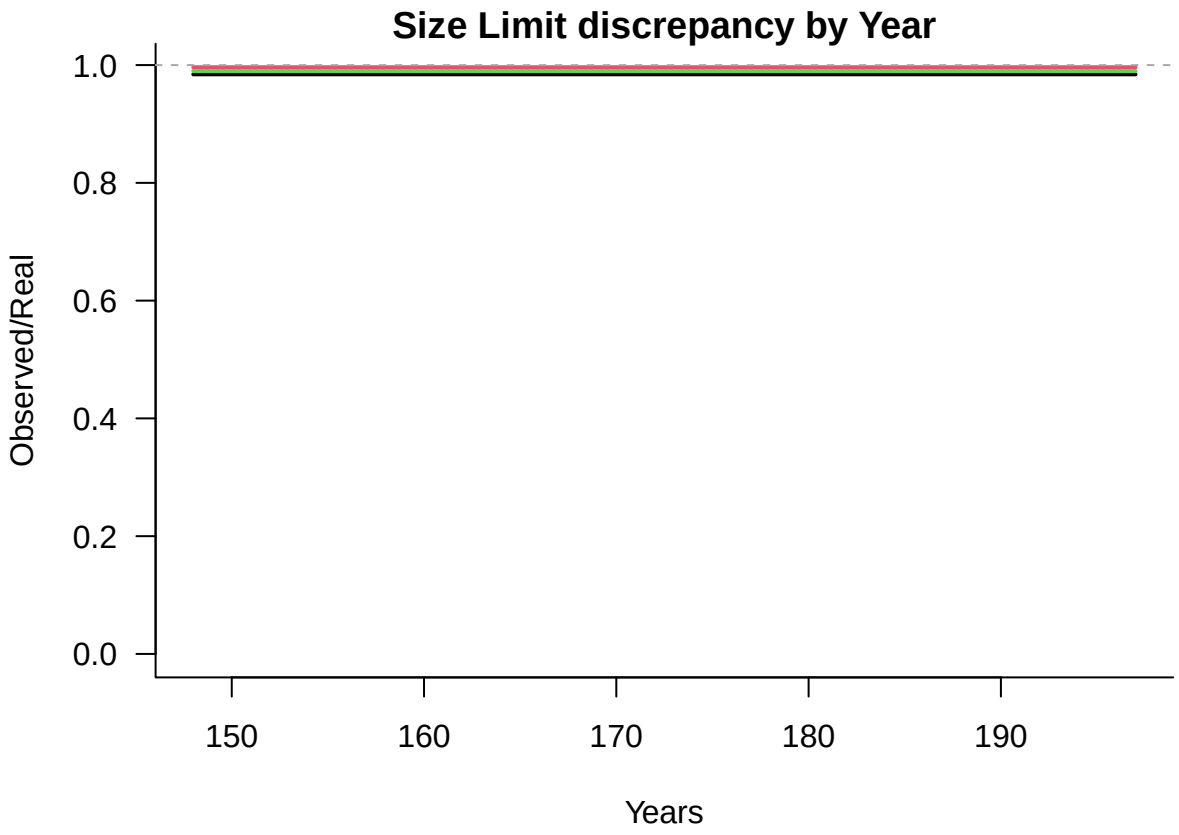


Size Limit Implementation

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:

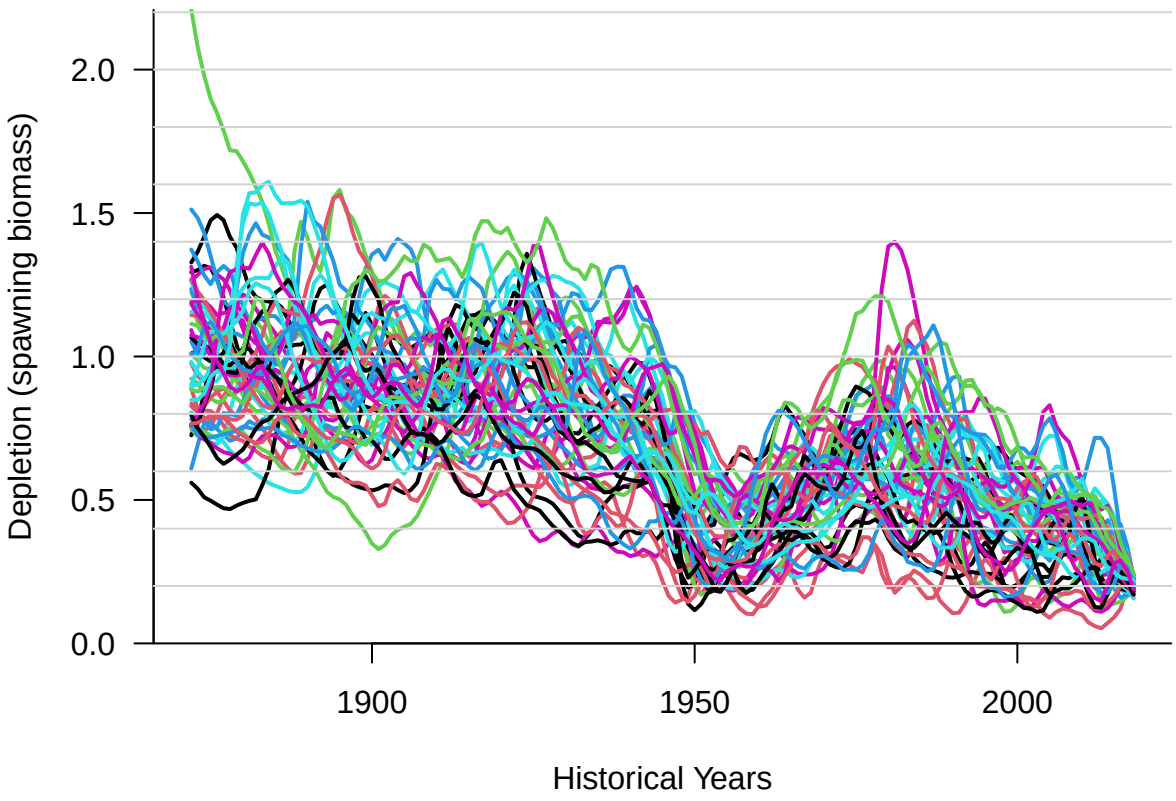


Historical Simulation Plots

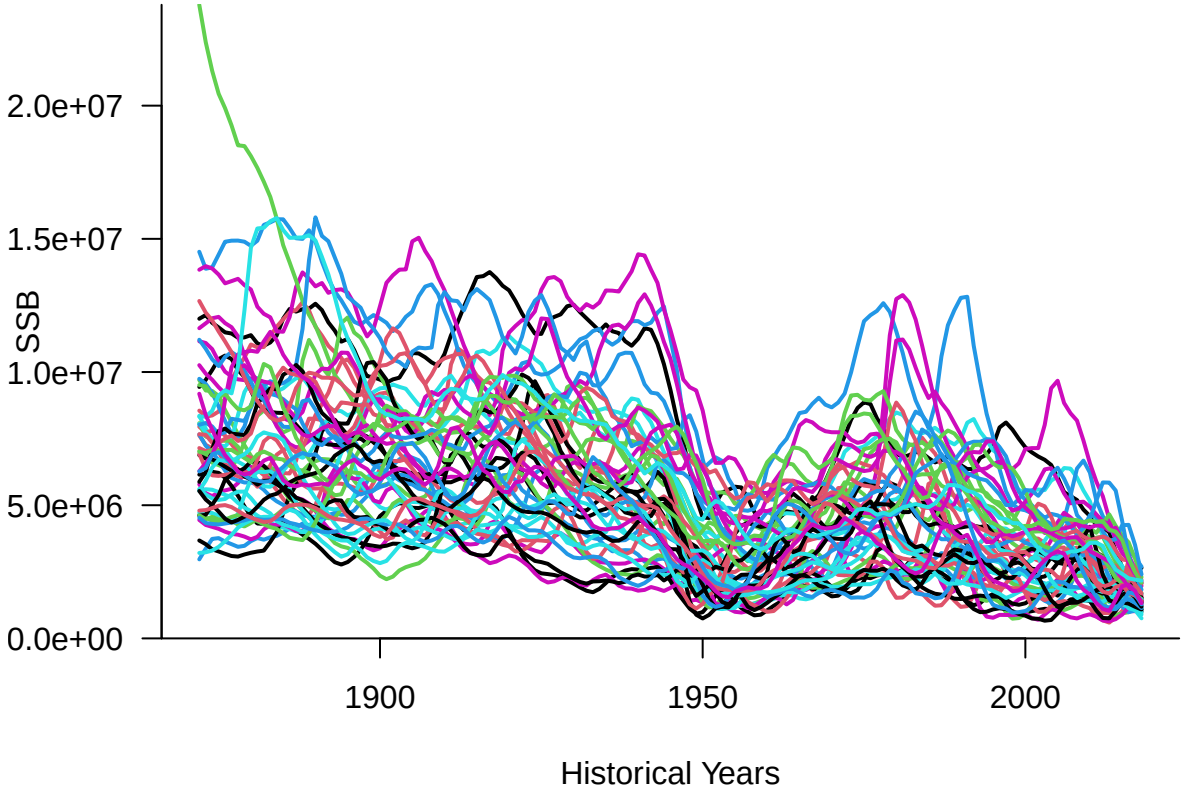
Historical Time-Series

Spawning Biomass

Depletion Time-series plots of SB/SB0:

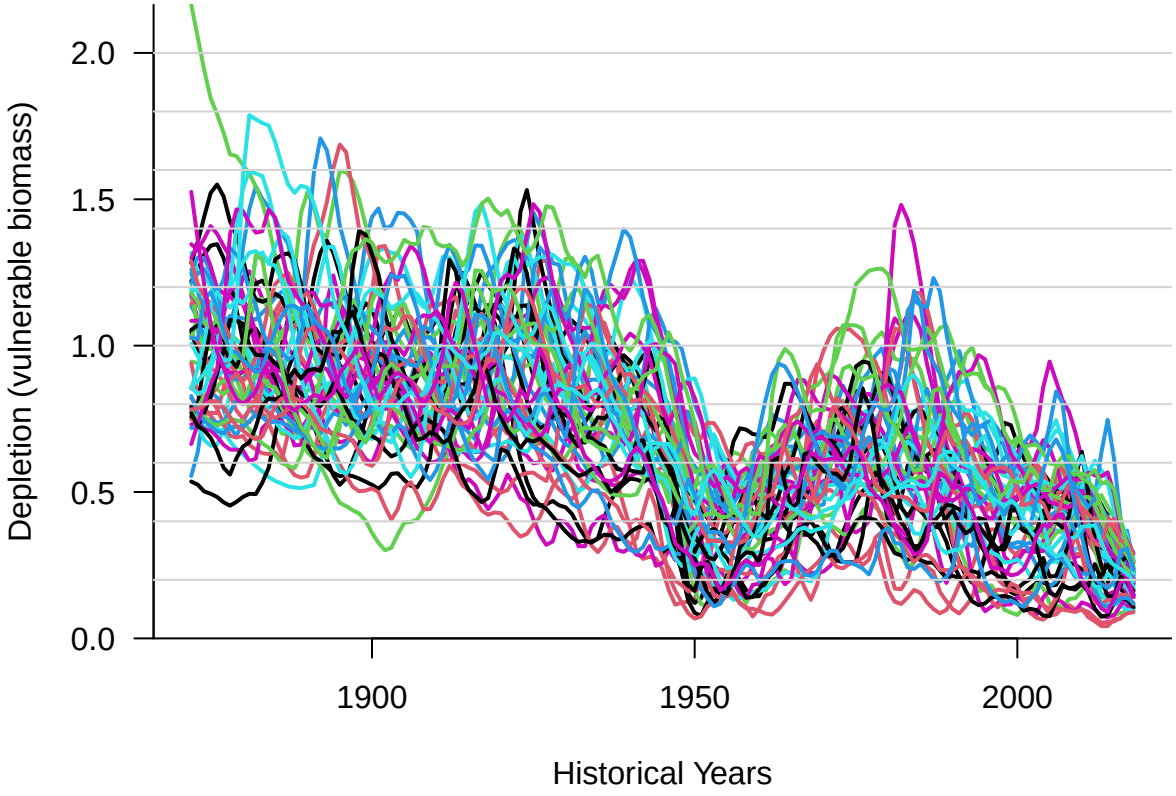


Absolute Time-series plots of absolute SB:

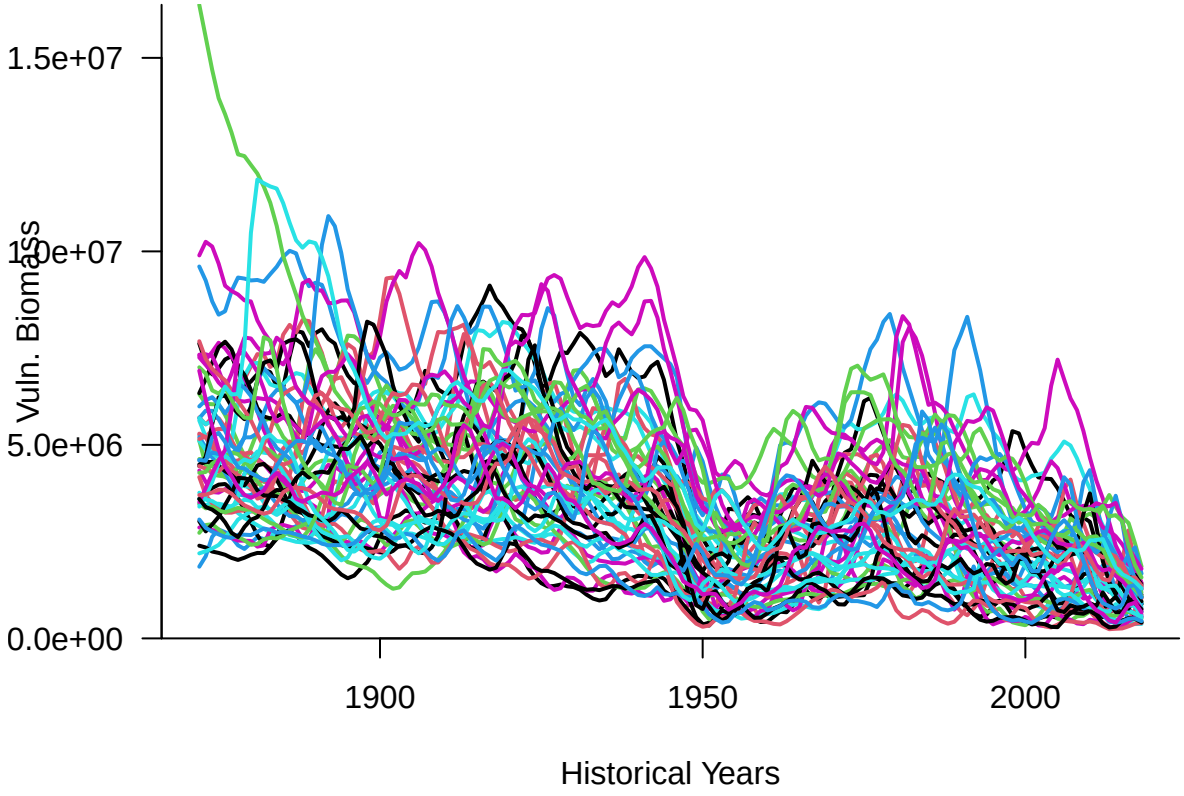


Vulnerable Biomass

Depletion Time-series plots of VB/VB0:

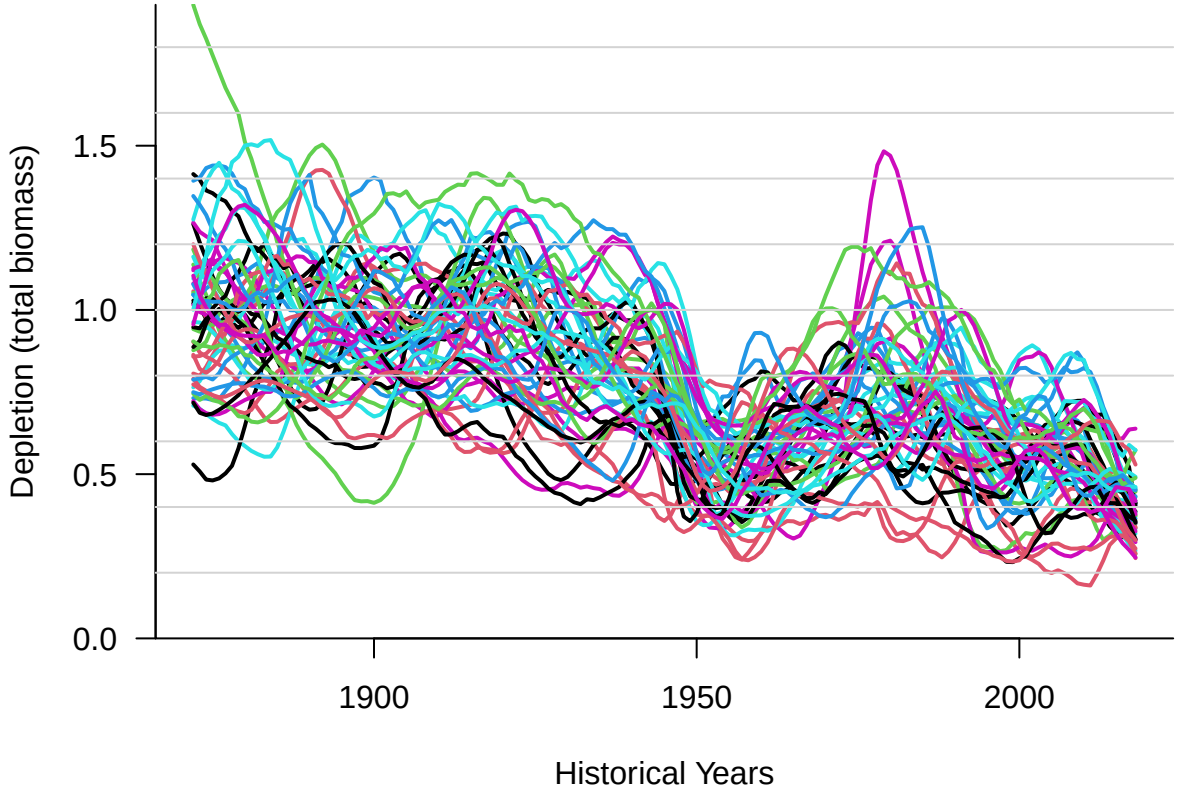


Absolute Time-series plots of absolute VB:

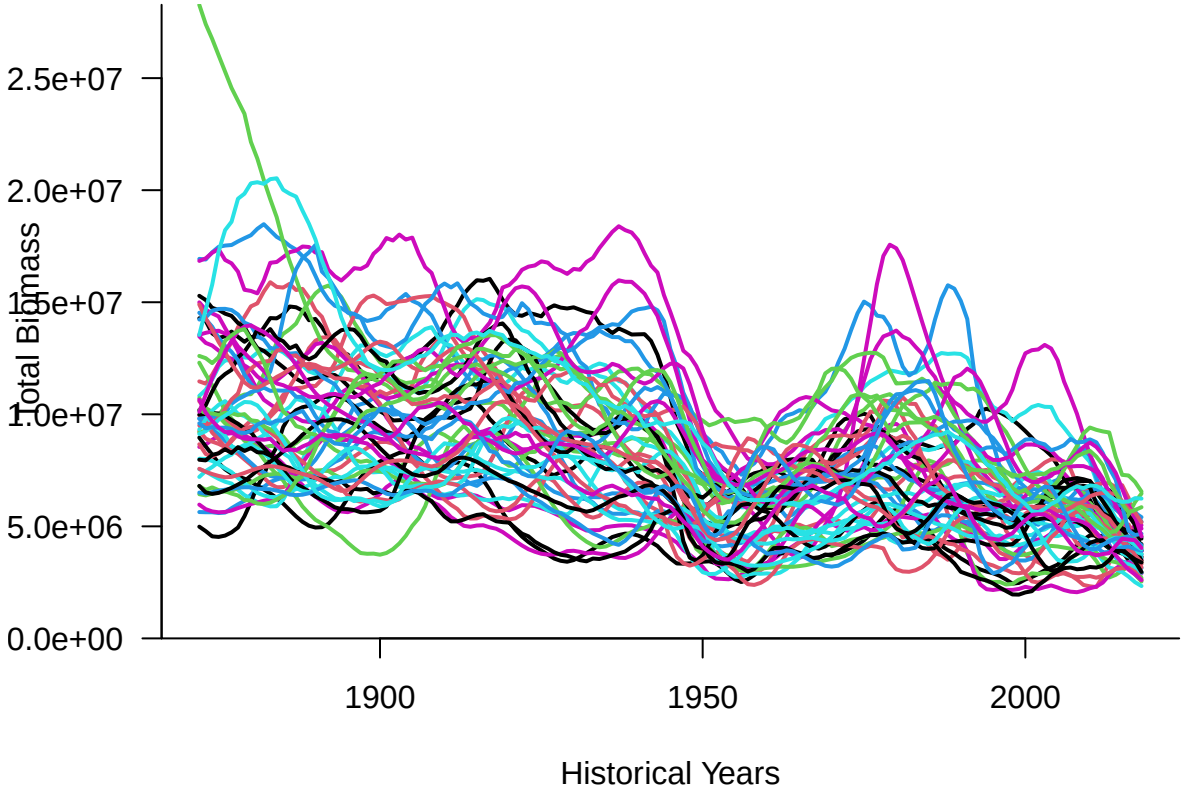


Total Biomass

Depletion Time-series plots of B/B0:

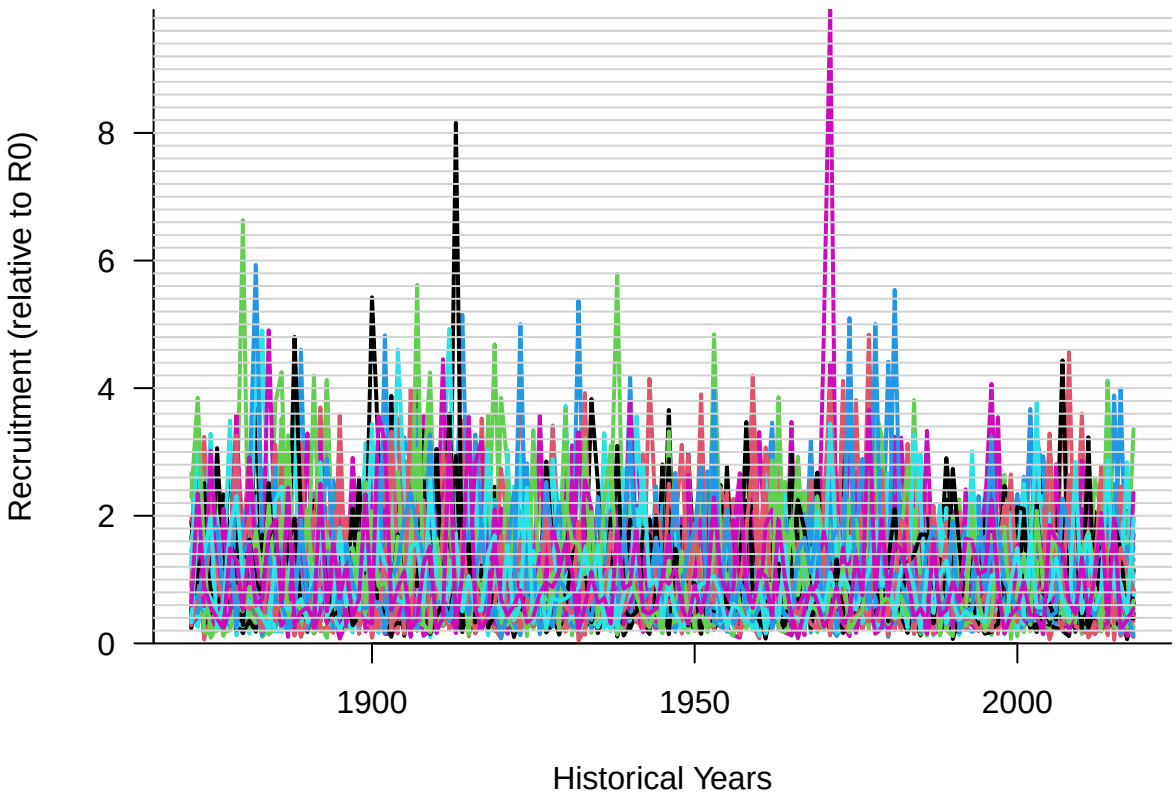


Absolute Time-series plots of absolute B:

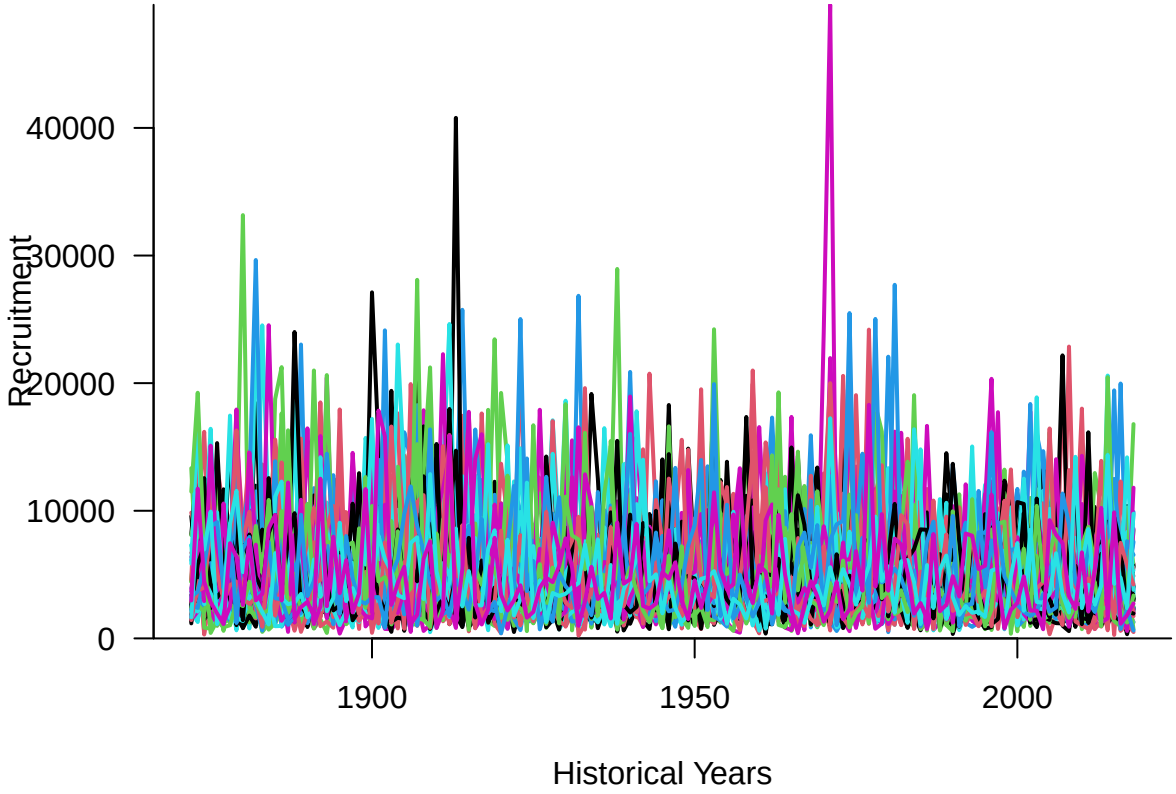


Recruitment

Relative Time-series plot of recruitment relative to R0:

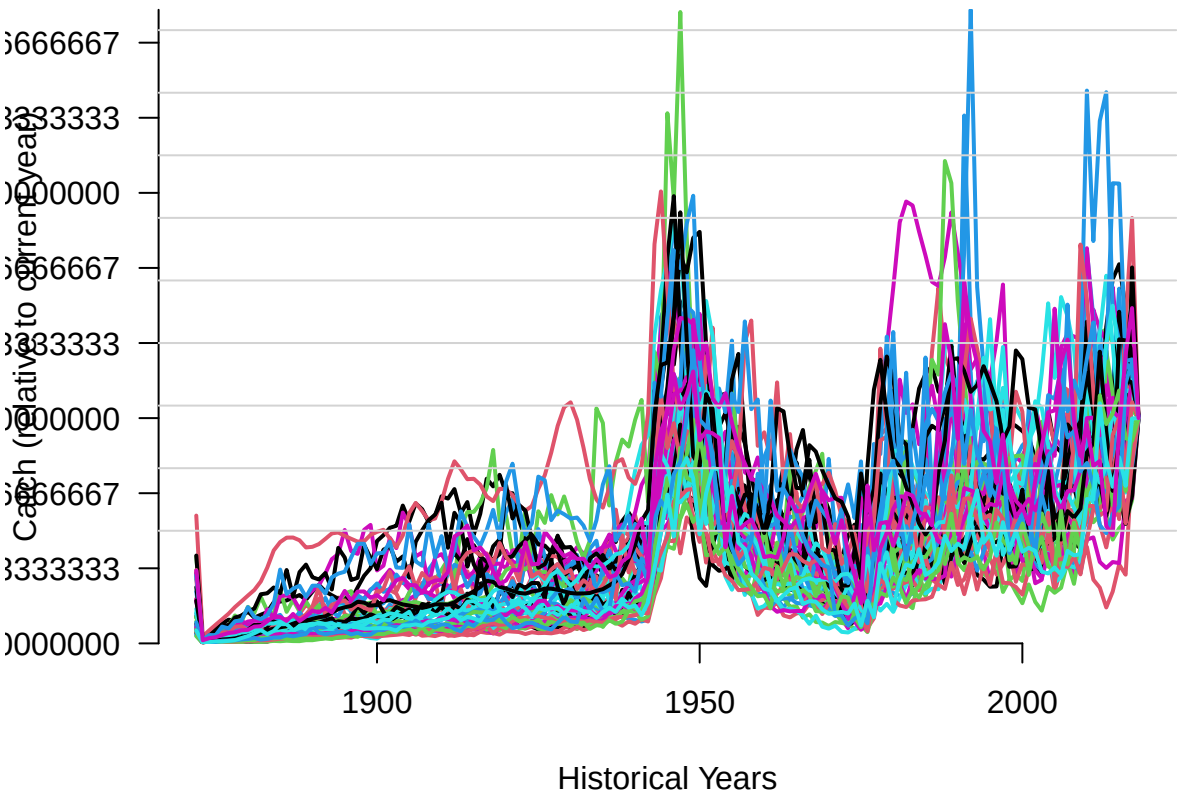


Absolute Time-series plot of absolute recruitment:

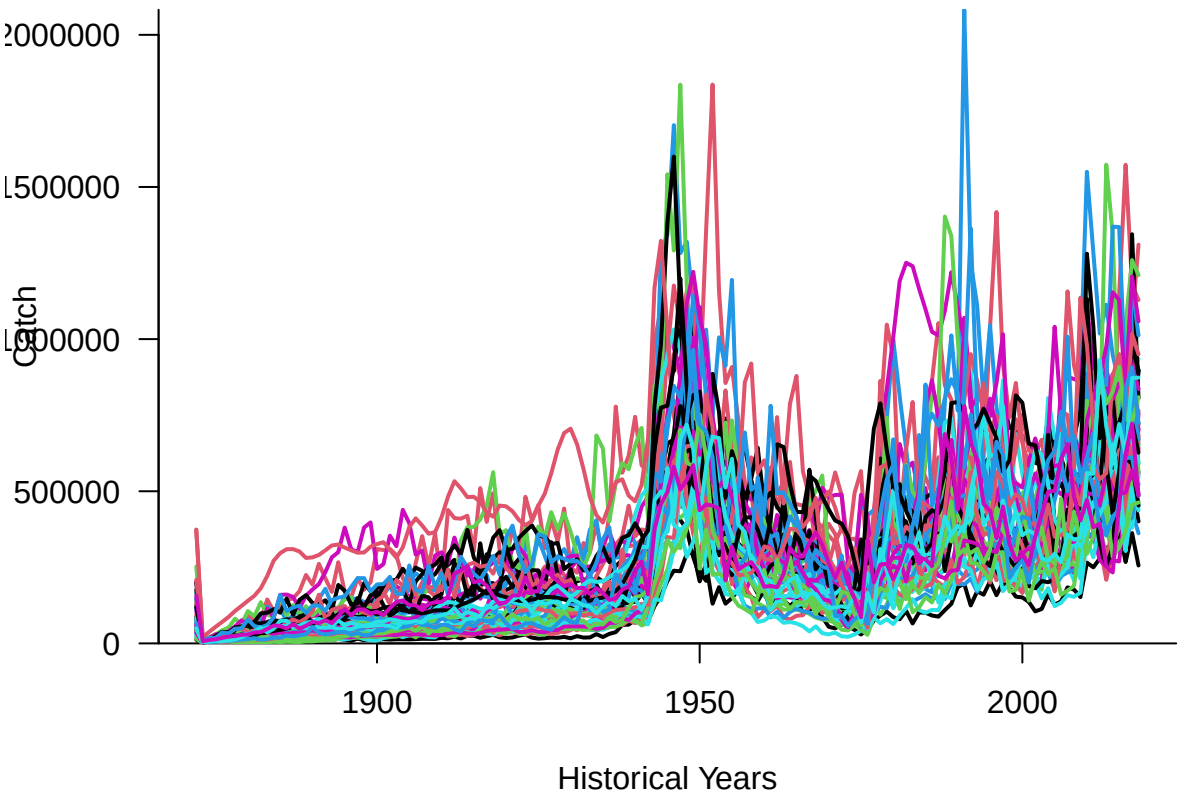


Catch

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

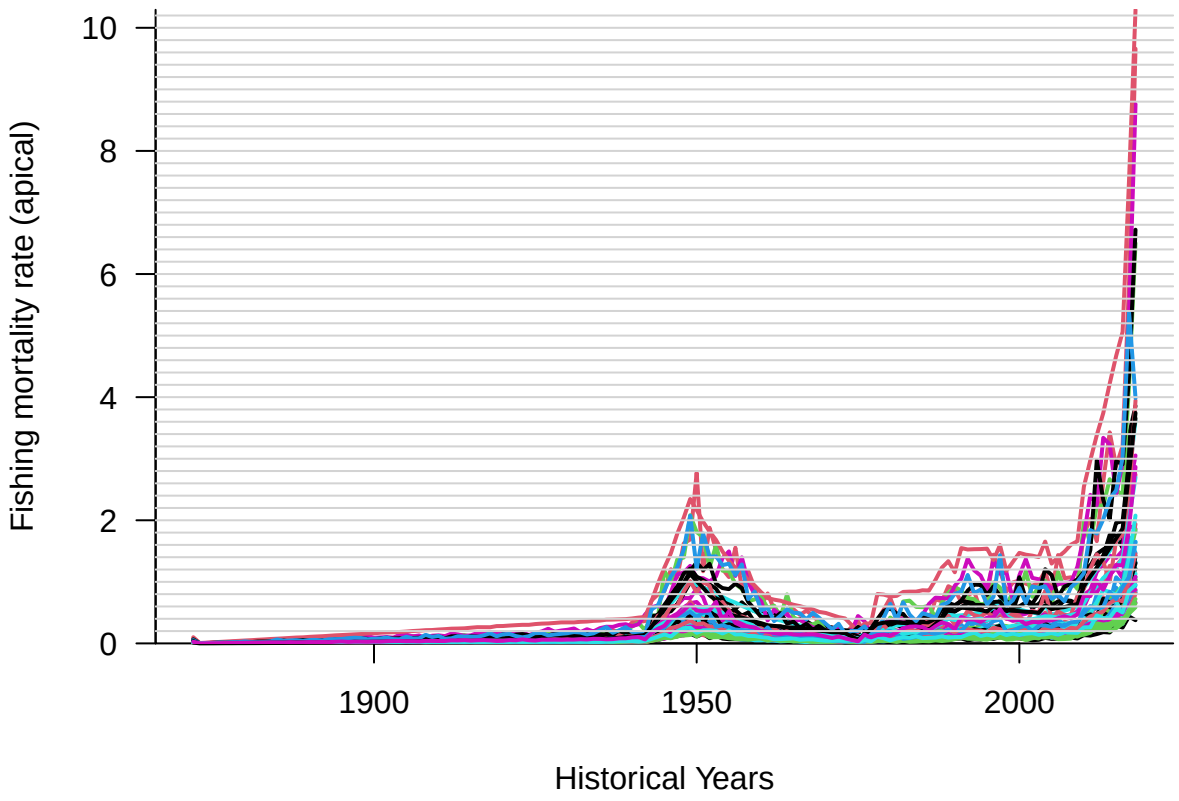


Absolute Time-series of absolute catch:



Historical Fishing Mortality

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



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Lindberg, R.G. 1955. Growth, population dynamics, and field behavior in the spiny lobster, Panulirus interruptus (Randall). Univ. California Publications in Zoology 59:157-247.

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centralde la peninsula de Baja California. Informe tecnico finaldel proyecto de investigacion SIMAC-20000-7009. 86 p.