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Selectivity in Stock Synthesis

FISH 576, Week 8

Why we need to worry about selectivity?

Fishing is selective - fleets capture collections of fish whose composition differs from the mix of species, sizes, and ages that are actually present in the water.

Mechanisms behind the selectivity:

- Fishers deliberately deploy gear that increases their chances of catching those fish that are highly valued and avoiding those that are not.
- Fish are not uniformly distributed, fishers may also be able to deliberately operate their gear in areas with disproportionately high concentrations of the more desirable species or sizes of fish.
- Fish distributions often vary during day or seasonally, the timing of fishing operations is yet another potential factor influencing selectivity.



What is selectivity in stock assessment





















Selectivity: The probability of catching an individual of a given size/age scaled to the maximum probability over all sizes, given that all animals are available to be caught.

Availability: The relative probability, as a function of size/age, of being present in the area in which catching occurs.

A set of parameters that describes the distribution of sizes (ages) of the portion of the population selected by the fleet (fishery or survey).



Selectivity is a complex topic - CAPAM Workshop on selectivity

-  A-comparison-of-parametric-semi-parametric-and-non-parametric-approaches-to-selectivity-in-age-structured-assessment-models_2014_Fisheries-Research.pdf
-  A-historical-review-of-selectivity-approaches-and-retrospective-patterns-in-the-Pacific-halibut-stock-assessment_2014_Fisheries-Research.pdf
-  A-proposed-tested-and-applied-adjustment-to-account-for-bias-in-growth-parameter-estimates-due-to-selectivity_2014_Fisheries-Research.pdf
-  Data-conflict-caused-by-model-mis-specification-of-selectivity-in-an-integrated-stock-assessment-model-and-its-potential-effects-on-stock-status-estim.pdf
-  Direct-calculation-of-relative-fishery-and-survey-selectivities_2014_Fisheries-Research.pdf
-  Estimation-of-time-varying-selectivity-in-stock-assessments-using-state-space-models_2014_Fisheries-Research.pdf
-  Evaluation-of-length-vs-age-composition-data-and-associated-selectivity-assumptions-used-in-stock-assessments-based-on-robustness-of-derived-managemen.pdf
-  Evaluation-of-the-sensitivity-of-biological-reference-points-to-the-spatio-temporal-distribution-of-fishing-effort-when-seasonal-migrations-are-sex-sp.pdf
-  Evaluation-of-virgin-recruitment-profiling-as-a-diagnostic-for-selectivity-curve-structure-in-integrated-stock-assessment-models_2014_Fisheries-Resear.pdf
-  Fishery-selection-and-its-relevance-to-stock-assessment-and-fishery-management_2014_Fisheries-Research.pdf
-  Full-Title-Page-Editorial-Board-_2014_Fisheries-Research.pdf
-  Investigating-the-influence-of-length-frequency-data-on-the-stock-assessment-of-Indian-Ocean-bigeye-tuna_2014_Fisheries-Research.pdf
-  Model-selection-for-selectivity-in-fisheries-stock-assessments_2014_Fisheries-Research.pdf
-  Selectivity-Theory-estimation-and-application-in-fishery-stock-assessment-models_2014_Fisheries-Research.pdf
-  The-ability-of-two-age-composition-error-distributions-to-estimate-selectivity-and-spawning-stock-biomass-in-simulated-stock-assessments_2014_Fisherie.pdf
-  Towards-defining-good-practices-for-modeling-time-varying-selectivity_2014_Fisheries-Research.pdf
-  Tradeoffs-between-bias-robustness-and-common-sense-when-choosing-selectivity-forms_2014_Fisheries-Research.pdf
-  Use-of-likelihood-profiling-over-a-global-scaling-parameter-to-structure-the-population-dynamics-model-An-example-using-blue-marlin-in-the-Pacific-Oce.pdf
-  Use-of-multiple-selectivity-patterns-as-a-proxy-for-spatial-structure_2014_Fisheries-Research.pdf
-  Using-areas-as-fleets-selectivity-to-model-spatial-fishing-Asymptotic-curves-are-unlikely-under-equilibrium-conditions_2014_Fisheries-Research.pdf



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Selectivity settings in Stock Synthesis

- Selectivity can be a function of either length, age or a combination of both
- Selectivity can differ between sexes
 - Male selectivity can be specified as offset from female selectivity
- Parameters of the selectivity curves have all the functionality as other parameters:
 - time blocks, priors, random variation, covariates, etc.

Combination of both in both of our models

Not the case in either assessments

Time blocks on selex in widow but not in yelloweye

Length selectivity patterns

Pattern	N Parameters	Description
0	0	Selectivity = 1.0 for all sizes.
1	2	Logistic selectivity .
2	6	Older version of selectivity pattern 24 (double normal with peak and tail controls) for backward compatibility in treatment of sex-specific scaling.
5	2	Mirror selectivity . The two parameters select bin range.
6	2 + N breaks	Older non-parametric size selectivity (see also Patterns 21 and 43).
8	8	Double logistic selectivity , with defined peak, uses smooth joiners; special = 1 causes constant selectivity above L_{inf} for morph 1. Recommend
9	6	Simple double logistic selectivity with no defined peak .
11	2	Selectivity = 1.0 for a specified length-bin range .
15	0	Mirror another selectivity (same for age selectivity).
21	2	Newer non-parametric size selectivity (see also Patterns 6 and 43).
22	4	Double normal selectivity ; similar to casal .
23	6	Same as the selectivity pattern 24 (double normal with peak and tail controls) except the final selectivity is now directly interpreted as the terminal selectivity than 1.
24	6	Double normal selectivity with defined initial and final selectivity level - Recommended option .
25	3	Exponential logistic selectivity .
27	3 + 2*N nodes	Cubic spline selectivity with N nodes .
42	5 + 2*N nodes	Selectivity pattern 27 (cubic spline) but with 2 additional scaling parameters .
43	4 + N breaks	Selectivity pattern 6 (non-parametric) but with 2 additional scaling parameters (see also Patterns 6 and 21).

Selectivity settings in SS3

For each fleet and survey, read a definition line for selectivity and retention.

Example Setup for Selectivity:

Size Selectivity:

Pattern	Discard	Male	Special	Label
1	2	0	0	#Fishery1
1	0	0	0	#Survey1
0	0	0	0	#Survey2

Age Selectivity:

Pattern	Discard	Male	Special	Label
11	0	0	0	#Fishery1
11	0	0	0	#Survey1
11	0	0	0	#Survey2

Length selectivity patterns in our models

Yelloweye rockfish

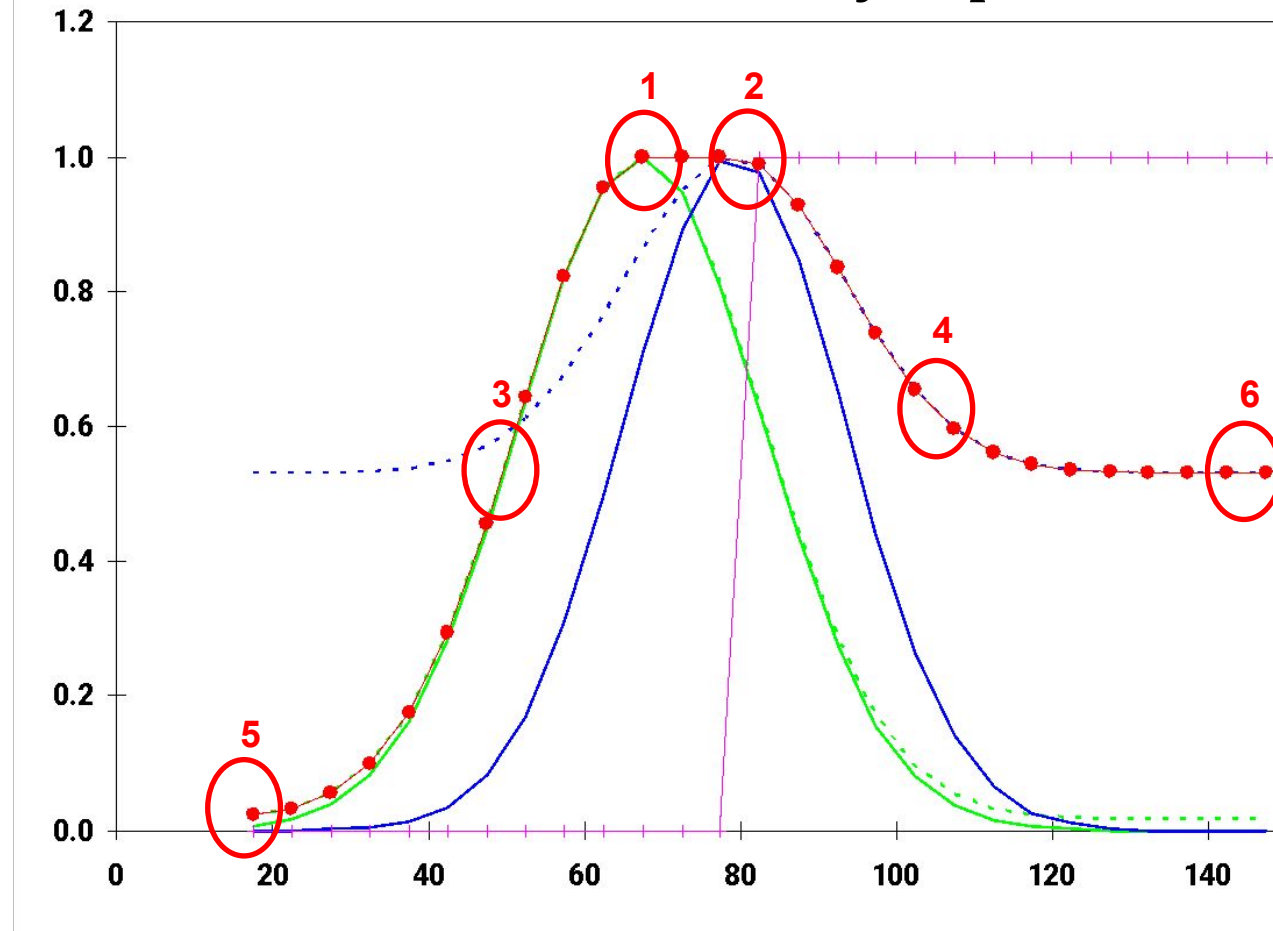
#_Pattern	Discard	Male	Special	
24	0	0	0	# 1_CA_TWL
24	0	0	0	# 2_CA_NONTWL
24	0	0	0	# 3_CA_REC
24	0	0	0	# 4_ORWA_TWL
24	0	0	0	# 5_ORWA_NONTWL
24	0	0	0	# 6_OR_REC
24	0	0	0	# 7_WA_REC
15	0	0	3	# 8_CACPFV
24	0	0	0	# 9_OR_RECOB
24	0	0	0	# 10_TRI_ORWA
24	0	0	0	# 11_NWFSC_ORWA
24	0	0	0	# 12_IPHC_ORWA

Widow rockfish

#_Pattern	Discard	Male	Special	
24	1	0	0	# 1 BottomTrawl
24	1	0	0	# 2 MidwaterTrawl
24	0	0	0	# 3 Hake
24	0	0	0	# 4 Net
24	1	0	0	# 5 HnL
0	0	0	0	# 6 JuvSurvey
27	0	0	3	# 7 Triennial
27	0	0	3	# 8 NWFSC
5	0	0	3	# 9 ForeignAtSea

Double normal selectivity curve

- Most commonly used pattern
- Can be made asymptotic by fixing some parameters.
- Shape is defined by 6 parameters.
- Current assessments use a formulation with only 3 parameters estimated.



This text is from the Stock Assessment handbook available at:

<https://pfmc-assessments.github.io/pfmc-assessment-handbook/02-model-choices.html>

To explore double-normal and logistic selectivity, there is this shiny tool:

<https://connect.fisheries.noaa.gov/ss3-helper/>

2.7.3 Guidelines for SS3 double normal initial setup

- Fix parameters 5 and 6 (negative phase).
 - If selectivity is thought to be zero at the youngest/smallest or the oldest/biggest fish set the value to zero (e.g. -15)
 - If selectivity is thought to be larger than zero at the youngest/smallest or the oldest/biggest fish set the value to -999 (does not scale the selectivity for the youngest or oldest age, independently from the normal curve).
- Fix the plateau (parameter 2) to be small values (e.g. -15).
- Set the initial value for the peak (parameter 1) at the age/length equal to the mode of the composition data
- Set the ascending (parameter 3) and descending (parameter 4) slopes at $\log(8 \cdot (a_{peak} - a_{min}))$ and $\log(8 \cdot (a_{max} - a_{peak}))$ (substitute min and max lengths and length at peak when modeling length-base selectivity).
- Don't estimate selectivity at youngest age/size (parameter 5) unless there are observations of fish in the smallest age- or length-bins, either fix at -5 or -999
- Use the double normal instead of the logistic for asymptotic selectivity to have flexibility of dome shape without major changes to control file. This also provides control over selectivity at the youngest age. To force a logistic shape, you can do one of the following (where parameters 2, 4, and 6 should not be estimated under any of the options):
 - Fix descending slope (parameter 4) at a large number (e.g. 15)
 - Alternative 1: Fix plateau (parameter 2) to a large number (e.g. 15)
 - Alternative 2: Fix selectivity of the oldest age (parameter 6) at a large number (e.g. 15).

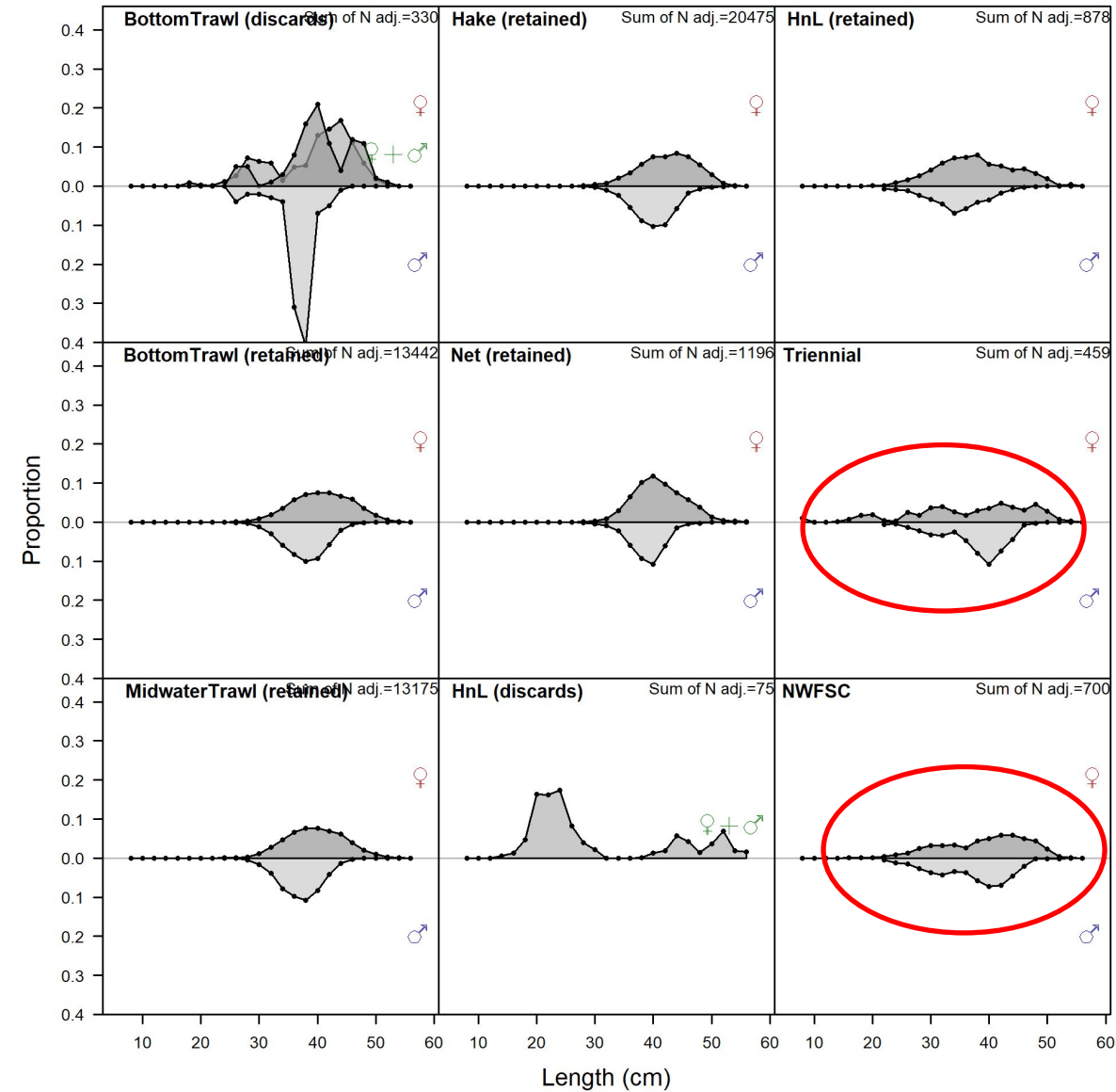
Cubic spline – used in widow rockfish model

This function requires

- input of the number of nodes,
- the positions of those nodes,
- the parameter values at those nodes, and
- the slope of the function at the first and last node.

Already set in the control file,
keep it as is

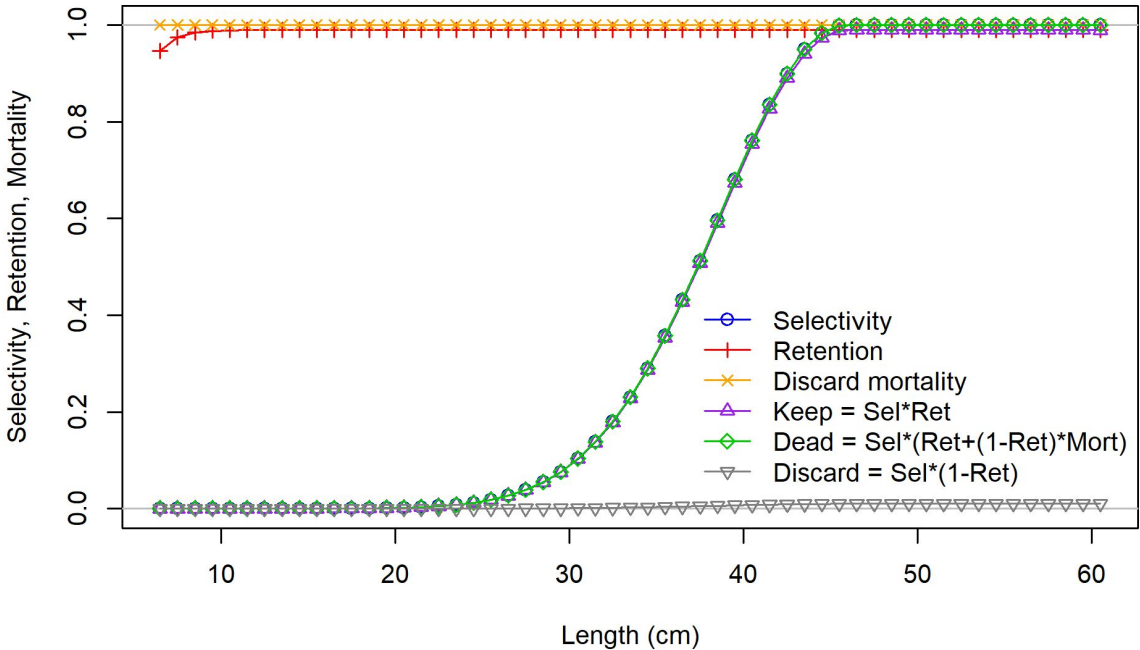
2019 widow rockfish length comps



Retention and discard mortality

- Retention is estimated in widow rockfish model
- a logistic function of size controlled by 4 parameters
- Discard mortality – no parameters needed here, all discarded fish assumed dead

#	Pattern	Discard	Male	Special
24	1 0 0	# 1	BottomTrawl	
24	1 0 0	# 2	MidwaterTrawl	
24	0 0 0	# 3	Hake	
24	0 0 0	# 4	Net	
24	1 0 0	# 5	HnL	
0	0 0 0	# 6	JuvSurvey	
27	0 0 3	# 7	Triennial	
27	0 0 3	# 8	NWFSC	
5	0 0 3	# 9	ForeignAtSea	



Age selectivity patterns

Pattern	N Parameters	Description
0	0	Selectivity = 1.0 for ages 0+.
10	0	Selectivity = 1.0 for all ages beginning at age 1. If it is desired that age-0 fish be selected, then use selectivity_pattern 11 and set minimum age to 0.0
11	2	Selectivity = 1.0 for a specified age range.
12	2	Logistic selectivity.
13	8	Double logistic selectivity, IF joiners. Use discouraged. Use selectivity_pattern 18 (double logistic selectivity) instead.
14	N ages + 1	Separate parameter for each age (empirical) , value at age is $\frac{1}{1 + \exp(-x)}$.
15	0	Mirror another age-specific selectivity pattern.
16	2	Coleraine single Gaussian Selectivity.
17	N ages + 1 or special + 1	Empirical as a random walk from previous age.
18	8	Double logistic selectivity , with defined peak, uses smooth joiners.
19	6	Simple double logistic selectivity with no defined peak.
20	6	Double normal selectivity with defined initial and final level . Recommended option.
26	3	Exponential logistic selectivity.
27	3 + 2*N nodes	Cubic spline selectivity in age based on N nodes.
41	2 + N ages + 1	Selectivity_pattern 17 (random walk) but with 2 additional scaling parameters.
42	5 + 2*N nodes	Selectivity_pattern 27 (cubic spline) but with 2 additional scaling parameters.
44	4 + N ages	Selectivity_pattern 17 (random walk) but with separate parameters for males and females and with revised controls.
45	4 + N ages	Selectivity_pattern 14 (revise age) but with separate parameters for males and females and with revised controls.

Age selectivity patterns in our models

Yelloweye rockfish

```
#_Pattern Discard Male Special
10 0 0 0 # 1_CA_TWL
10 0 0 0 # 2_CA_NONTWL
10 0 0 0 # 3_CA_REC
10 0 0 0 # 4_ORWA_TWL
10 0 0 0 # 5_ORWA_NONTWL
10 0 0 0 # 6_OR_REC
10 0 0 0 # 7_WA_REC
10 0 0 0 # 8_CACPFV
10 0 0 0 # 9_OR_RECOB
10 0 0 0 # 10_TRI_ORWA
10 0 0 0 # 11_NWFSC_ORWA
10 0 0 0 # 12_IPHC_ORWA
```

Widow rockfish

```
#_Pattern Discard Male Special
10 0 0 0 # 1 BottomTrawl
10 0 0 0 # 2 MidwaterTrawl
10 0 0 0 # 3 Hake
10 0 0 0 # 4 Net
10 0 0 0 # 5 HnL
11 0 0 0 # 6 JuvSurvey
10 0 0 0 # 7 Triennial
11 0 0 0 # 8 NWFSC
10 0 0 0 # 9 ForeignAtSea
```

Selectivity settings in SS3

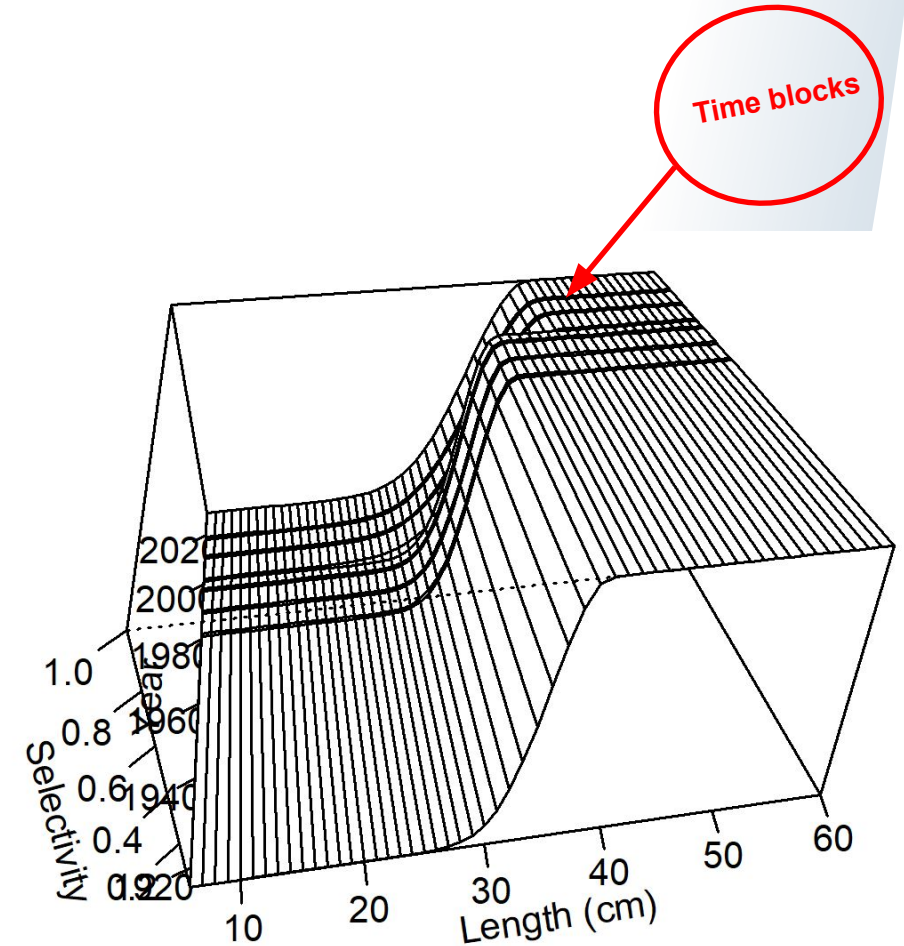
The usual parameter line for each of selectivity parameter.

The list of parameters to be read from the above setup would be:

LO	HI	INIT	PRIOR	<other entries>	Block Fxn	Parameter Label
19	80	53.5	50	...	0	#SizeSel p1 fishery 1
0.01	60	18.9	15	...	0	#SizeSel p2 fishery 1
20	70	38.6	40	...	0	#Retain p1 fishery 1
0.1	10	6.5	1	...	0	#Retain p2 fishery 1
0.001	1	0.98	1	...	0	#Retain p3 fishery 1
-10	10	1	0	...	0	#Retain p4 fishery 1
0.1	1	0.6	0.6	...	0	#DiscMort p1 fishery 1
-2	2	0	0	...	0	#DiscMort p2 fishery 1

Time-varying selectivity

- Widow rockfish uses blocks to allow selectivity and retention parameters to vary with management changes.
- For each block, new parameter values are estimated.
- Blocks were explored in yelloweye model, but there was not enough data to estimate additional parameters.



Time-varying selectivity for Bottom Trawl fleet in 2019 widow rockfish model

What information model uses to estimate selectivity parameters?