Arrowtooth flounder model standardization - Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI) management areas

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Introduction

The Bering Sea and Aluetian Islands (BSAI) stock of arrowtooth flounder is managed separately from the Gulf of Alaska (GOA) stock of arrowtooth flounder. The two stocks are assessed with separate models. The model structure is very similar, but there are several differences. Many of the differences are based on ecological differences between the BSAI and the GOA.

These stock assessments utilize AD Model Builder software to model the population dynamics of Bering Sea and Aleutian Islands arrowtooth flounder. The models apply a length-based approach where survey and fishery length composition observations are used to calculate estimates of population numbers-at-age by the use of a length-age (growth) matrix. The models simulate the dynamics of the population and compare the expected values of the population characteristics to those observed from surveys and fishery sampling programs.

Likelihood components

There are more likelihood components in the BSAI model due to the fact that there is data available from three surveys (BSAI shelf, slope, and Aleutian Islands). In contrast, there is only one survey in the GOA (Tables 1 and 2).

Age data

GOA age data is incorporated into the model from the following years: 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, and 2009. Age data for 2011 and 2013 will be included in the 2015 assessment.

BSAI 1996 and 1998 shelf age data was included in the BSAI model. Additional age data was not available until 2013, which was an off-year for the BSAI assessment. Currently, 2010 age data area available from the Bering Sea shelf and slope and the Aleutian Islands, and will be included in the 2014 assessment. Addition of this data will require adding likelihood equations for age for the Aleutian Islands and the Bering Sea slope. Data from the 2012 surveys for these three areas are currently being processed and will be included in the model if they become available.

Ages

The BSAI model includes ages 1-21+, while the GOA model includes ages 3-15+. This is in part a function of the length frequencies of fish observed in the different regions. Fish less than about 4 years old (< 30 cm) are found only on the Bering Sea shelf. Males from 30-50 cm and females 30-70 cm are found in shelf and slope waters, and males > 50 cm and females > 70 cm are mainly found on the slope. Fish younger than age 3 are rarely observed in the GOA surveys, as well as fewer older fish.

Selectivity

In the BSAI model, sex specific "domed-shaped" selectivity was freely estimated for males and females in the shelf survey due to ages observed in that survey. An asymptotic selectivity pattern was assumed for both sexes in the slope surveys and the Aleutian Islands surveys.

Many of the measurements collected from the fishery represent opportunisti samples of arrowtooth flounder taken as bycatch. This results in sample size problems which may make estimates of fishery selectivity unreliable. Also, a directed fishery would likely target a different segment of the stock. Accordingly, the shape of the selectivity curve is fixed asymptotic for older fish in the fishery since a

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directed fishery would presumably target larger fish. In the Bering Sea, the arrowtooth flounder fishery was closed prior to 2008. Since 2008, Amendment 80 allows arrowtooth to be declared the target fishery if that happens to be the predominant catch. In the Aleutian Islands, a single catcher/processor targeted arrowtooth flounder with hook-and-line gear.

Arrowtooth flounder have been a targeted fishery since the mid 1990's in the GOA. In the GOA model, separate fishery selectivities were estimated for each age, and the shape of the selectivity curve was constrained to be a smooth function. The GOA survey selectivity was estimated using a two parameter ascending logistic function.

Natural mortality
Female arrowtooth flounder are almost always found in higher proportions than males in surveys throughout Alaska. Age data suggest that males do not live as long as females in this species. Estimation methods suggest that males are subject to higher natural mortality, 0.2 for females and 0.35 for males (Wilderbuer and Turnock 2009). Both models assume use these separate values of natural mortality for males and females.

Catchability
Examination of Bering Sea shelf survey biomass estimates indicate that some of the annual variability seemed to positively co-vary with bottom water temperature. Variations in CPUE were particularly evident during the coldest year (1999) and the warmest year (2003). The relationship between average annual bottom water temperature collected during the survey and annual survey biomass estimates can be better understood by modeling survey catchability as:

$$q = e^{-\alpha+\beta T}$$

where q is catchability, α and β are parameters estimated by the model, and T_t is the average annual bottom water temperature.

In the GOA, catchability, q, is assumed to be 1. Temperature varies throughout the GOA, and clear trends are not apparent; therefore, estimating catchability based on temperature is not a valid option in the GOA.

Model standardization
Several steps could be taken to standardize the BSAI and the GOA models. They are presented in the following table:

	BSAI	Timeline
Selectivity	Examine the effects of logistic vs. selectivity estimated for each age. Standardize models with one method.	Apply best method in BSAI model in 2014, GOA in 2015.
Ages in model	Consider the effect of starting the GOA model at age 1.	Apply to GOA model in 2015.

Age data will be added to the BSAI model, and the age-length transition matrix will be updated in 2014. In addition, the BSAI model estimates recruitment based on a mean from 1956-1975 and again 1975-2014. This will be updated and checked in 2014.

Selectivity
Two different methods of modeling fishery selectivity were evaluated for the BSAI and the GOA model.

Model 1: Separate fishery selectivities were estimated for each age and the shape of the selectivity curve was constrained to be a smooth function.
Model 2: Fishery selectivity was modeled using a two parameter ascending logistic function.

The same weights were used for GOA and BSAI for smooth selectivity likelihoods. BSAI results are shown in Figures 1a and 1b. The GOA selectivities are shown in Figure 2.

Changing how the fishery selectivity is estimated can be evaluated in several ways. The slope and AI survey selectivity are affected by the fishery selectivity estimates (Figure 1b). The GOA survey selectivity estimates are not affected by how the fishery selectivity is estimated (Figure 2). The logistic fishery selectivity provides a better fit to the data in the AI survey, but the difference is equivocal for the slope and shelf surveys (Figure 3). The model fit to GOA survey data does not change with differences in fishery selectivity (Figure 4). The GOA model that estimates fishery selectivity separately for each age has lower total objective function value, but it requires more parameters to be estimated (Table 1). In the BSAI model, the logistic fishery model has fewer parameters, and lower objective function value (Table 2).

Calculating AIC from the hessian and objective function value (ADMB output)
The Laplace approximation can be applied to the penalized likelihood of estimated parameters (i.e. objective function value, OFV) in combination with the matrix of second derivatives (i.e. the model Hessian) to calculate the marginal likelihood. The hessian, the matrix of second mixed derivatives in transformed space, is created as output from each ADMB model run. The hessian was transformed back into the original parameter space ($Hess_T$) and the marginal likelihood ($Likelihood_{MAR}$) was estimated using a Laplace approximation (Thorson et al. 2014) as follows, where OFV is the objective function value from the ADMB .par file:

$$\text{likelihood}_{MAR} = \log(2p) - 0.5 Hess_T - OFV .$$

The marginal likelihood can be used to calculate AIC, as follows:

$AIC = 2k - 2 * likelihood_{MAR}$, where k is the number of parameters used in the model.

Conclusions
Two different methods were used to estimate fishery selectivity, a two-parameter increasing logistic function and a smoothed function with separate parameters for each age. The logistic function requires fewer parameters and results in a higher AIC in the GOA but a lower AIC in the BSAI. The logistic selectivity is the better choice in the BSAI (Table 2). In the GOA, the smoothed function with separate parameters for each age results in a lower AIC, and therefore a better fit to the data. The nature of the fishery is different in the GOA due to several decades of targeted arrowtooth flounder fishing; therefore, different methods to estimate selectivity in the fishery may be warranted.

No changes are recommended to the BSAI model for the 2014 assessment, based on the model comparisons, other than new age data and updating the age-length matrix and recruitment means.

References
Thorson, J., Hicks, A.C., and Methot, R. 2014. Random effect estimation of time-varying factors in Stock Synthesis. ICES Journal of Marine Science; doi: 10.1093/icesjms/fst211.

Wilderbuer, T., and Turnock, J. 2009. Sex-specific natural mortality of arrowtooth flounder in Alaska: Implications of a skewed sex ratio on exploitation and management. North American Journal of Fisheries Management 29: 306-322.

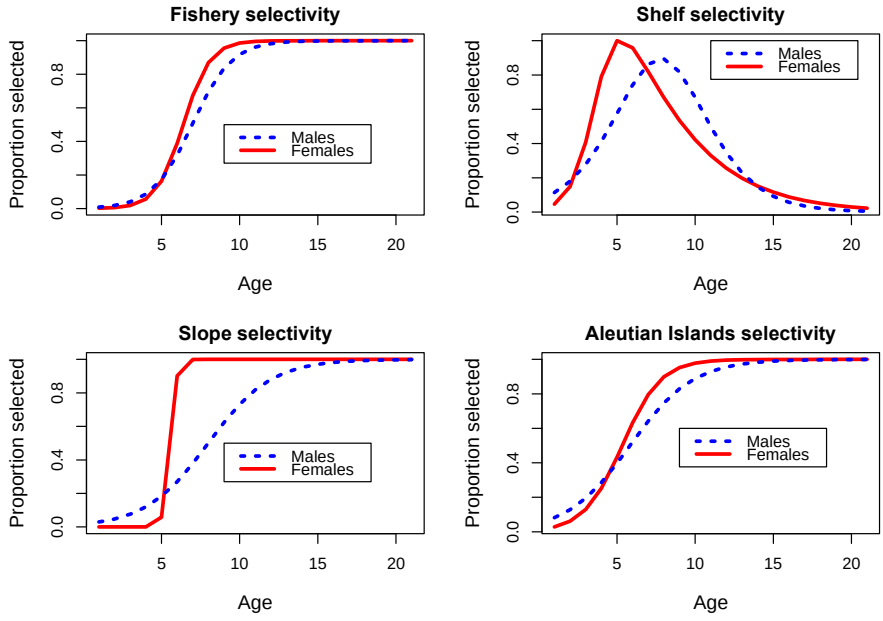

Figure 1a. Fishery selectivity estimated using a two parameter ascending logistic function. Age-specific fishery selectivity (top left panel), shelf survey selectivity (top right panel) slope survey selectivity (bottom left panel) and Aleutian Islands survey selectivity (bottom right panel), by sex, estimated within the stock assessment model.

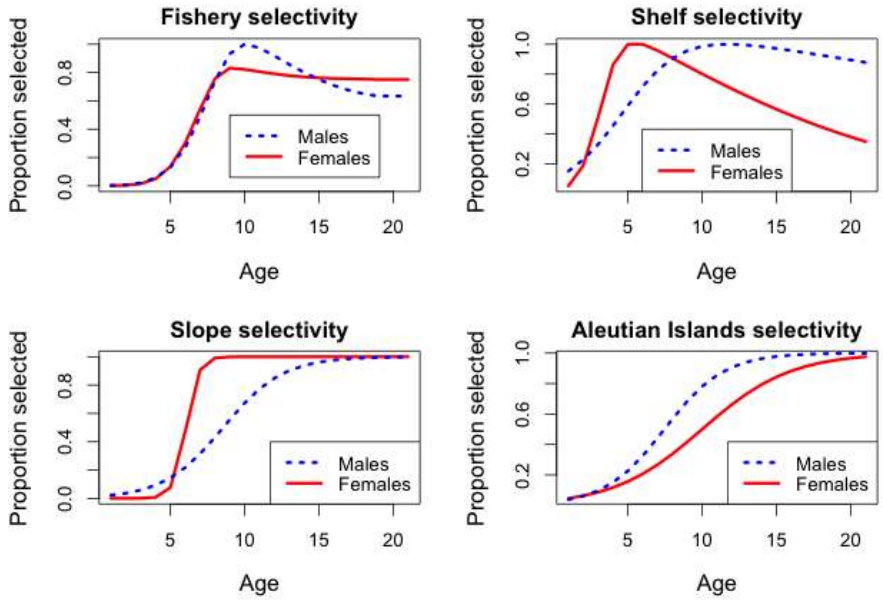

Figure 1b. Fishery selectivity estimated for all ages separately. Age-specific fishery selectivity (top left panel), shelf survey selectivity (top right panel) slope survey selectivity (bottom left panel) and Aleutian Islands survey selectivity (bottom right panel), by sex, estimated within the stock assessment model.

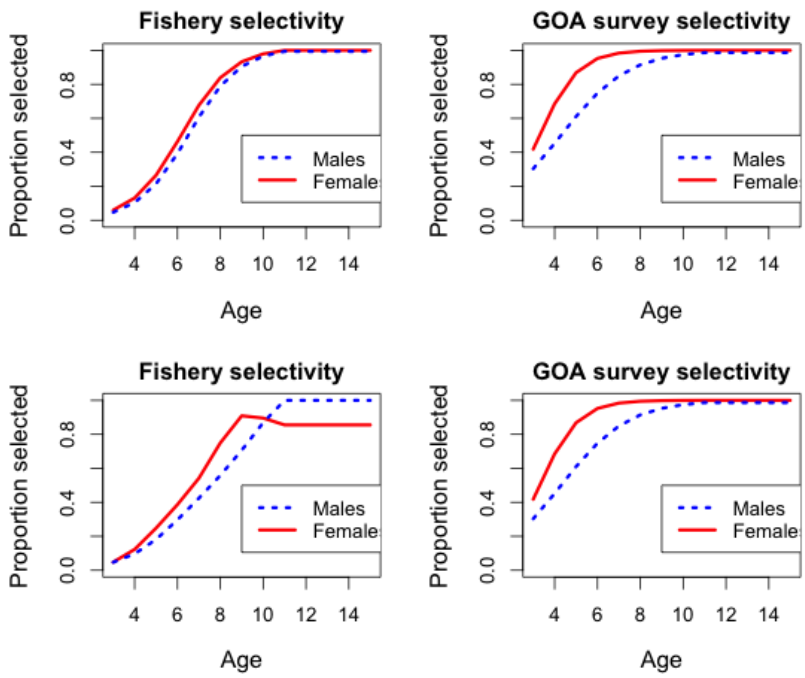

Figure 2. Estimates of sex-specific selectivity using logistic fishery selectivity (top row) and separate estimates of fishery selectivity for each age (bottom row). Fishery selectivity is shown on the left and GOA survey selectivity on the right.

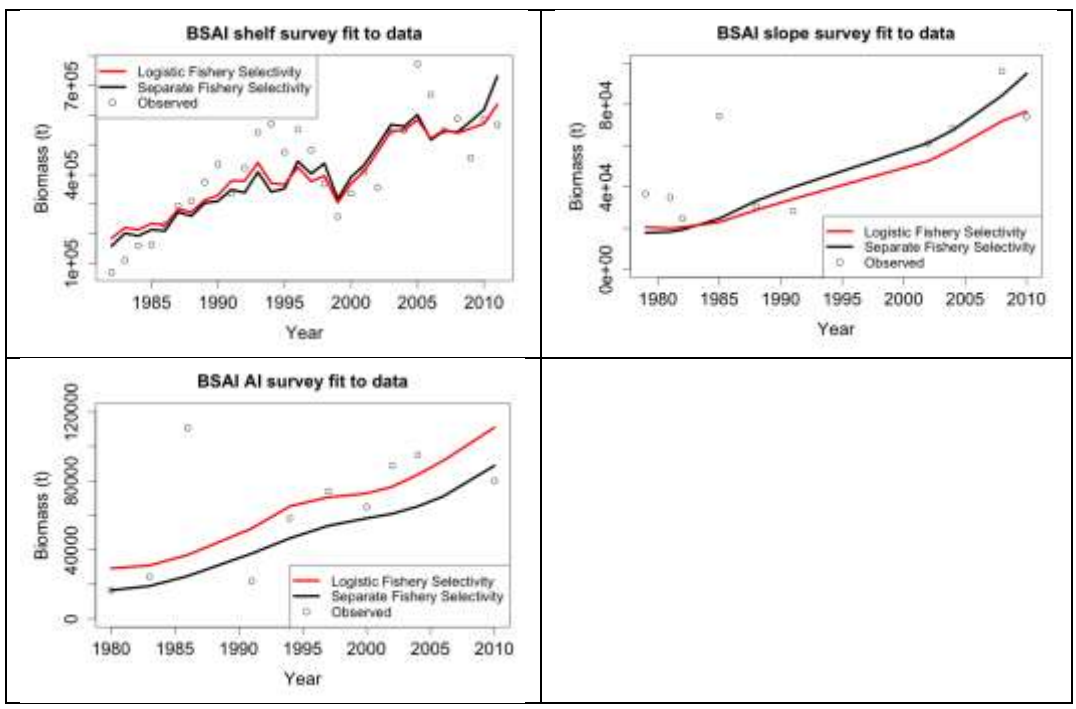

Figure 3. Fit to BSAI shelf, slope, and AI survey biomass estimates, with fishery selectivity estimated with both models.

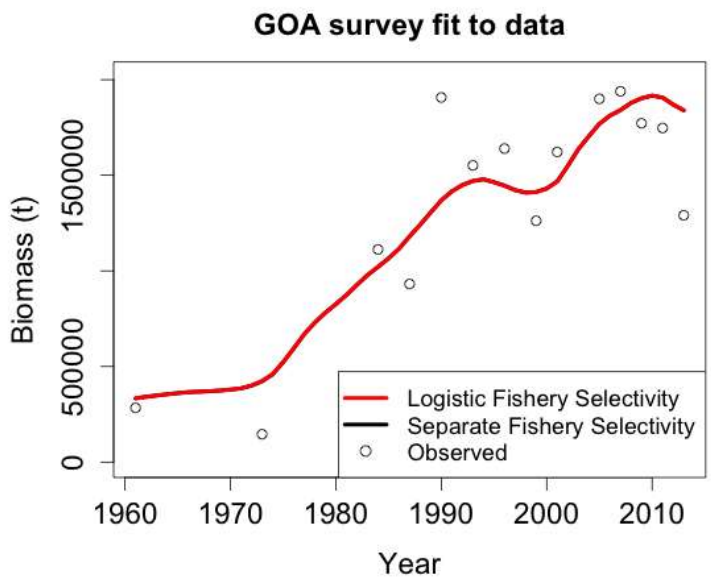

Figure 4. Fit to GOA survey biomass estimates, with fishery selectivity estimated with both models.

Table 1. Likelihood components for the Gulf of Alaska arrowtooth flounder model run with two configurations: fishery selectivity estimated separately for each age, and fishery selectivity estimated as an increasing logistic function. Lower values indicate a better fit; green is the lower value and red is higher, for each row of the table.

	Separate fishery selectivity	Logistic fishery selectivity
Recruitment	34.0889	33.9685
Fishery lengths	1296.93	1330.2
Survey lengths	135.511	135.769
Survey ages	299.316	299.009
Fishing mortality	34.0034	33.989
Catch	0.0120603	0.0120585
Survey biomass	44.5027	44.5987
Fishery selectivity	5.59499	0
Survey selectivity	0	0
Total Obj. Fun. value	877.852	880.486
Number of Parameters	144	130
AIC	2501.367	2506.635

Table 2. Likelihood components for the Bering Sea and Aleutian Islands arrowtooth flounder model run with two configurations: fishery selectivity estimated separately for each age, and fishery selectivity estimated as an increasing logistic function. Lower values indicate a better fit; green is the lower value and red is higher, for each row of the table.

	Separate fishery selectivity	Logistic fishery selectivity
Shelf survey biomass	134.4	134.4
Slope survey biomass	79.5	64.0
AI biomass	43.1	47.2
Shelf survey lengths	2050.7	1854.1
Slope survey lengths	1021.4	1042.5
AI survey lengths	1187.4	1083.0
Fishery lengths	227.5	301.2
Recruitment	38.9	27.8
Catch	0.002596	0.001257
Sex ratio	49.9	46.7
Shelf survey ages	142.9	140.4
Total Obj. Fun. value	5056.3	4759.74
Number of Parameters	158	120
AIC	10665.71	9990.455