Updates to the Alaska Skate Tier 3 model in the Bering Sea and Aleutian Islands Skate Stock Complex

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Introduction

The 2025 operational full assessment for the Bering Sea and Aleutian Island skate stock complex (BSAI skates) will include model updates for the Tier 3 Alaska skate model. The Alaska skate model was first implemented in 2008 and has had significant modifications in 2012 and 2014. The previous author addressed a number of data issues, including creating an updated reconstructed catch history in 2018. The history of model changes have been summarized in tables and Plan Team/SSC comments are compiled to aid in model reviews.

For the 2025 assessment, we focused on three topics:

1. Best practices and procedural errors
2. Over-reliance on limited data
3. Non-convergence

To address these three topics, two new models are presented here with bridging from the previously accepted model (Table 1).

There are a number of previous PT and SSC comments that have not yet been addressed and will not be completed for this assessment cycle. The authors chose to prioritize the above items for this cycle and retain the previous comments for future assessments.

Analytic Approach

Description of the previously accepted model

The age- and size-structured population dynamics model for BSAI Alaska skate, Model 14_2d, is run using the Stock Synthesis platform (SS3, technical details given in Methot and Wetzel 2013 and Methot et al. 2020).

The current update assessment run of Model 14_2d retains the same assumptions as the original model. The entire BSAI is treated as one homogenous area. Because growth and maturity patterns are similar for males and females, only one sex is specified. Spawning is assumed to occur at the midpoint of the year. No informative priors were used. It was assumed that parameters did not vary with season or year and were not influenced by environmental conditions. All estimated parameters are described below.

In the models described here, natural mortality is the only parameter that is explicitly age-based; selectivity, maturity, and mean body weight are length-based parameters. Length-at-age data and estimates of ageing error are used by SS3 to convert the size-based information into age-specific values that can be used to model the population through time.

Parameters Estimated Outside the Assessment Model

Natural mortality (M)

In the 2008 Alaska skate model, an M value of 0.13 was selected from a range of values estimated indirectly from other species-specific life history parameters (Alverson and Carney 1975, Rikhter and Efanov 1976, Pauly 1980, Hoenig 1983, Roff 1984, Charnov 1993, Jensen 1996, Gunderson 2003). The previous assessment author demonstrated that this value of M has consistently provided the best model fit, so we continue to fix M at 0.13.

Length at maturity

SS3 incorporates female maturity parameters into the model using the following equation:

$$proportion\, mature = \frac{1}{1 + e^{b(L - L_{50})}}$$

where L_{50} is the length at 50% maturity and b is a slope parameter. Maturity parameters were obtained from Matta (2006), where $b = -0.548$ and $L_{50} = 93.28$ cm TL. Maturity was estimated directly from paired length and maturity stage data as described in Matta and Gunderson (2007); maturity stage was assessed through macroscopic examination of the reproductive organs.

Ageing error

A fixed ageing error matrix based on paired independent readings of skate vertebrae (Matta and Gunderson 2007) was included in the model. For each age, the standard deviation of the estimated age was calculated from at least two reads of each vertebra and incorporated into the model to account for variability in age determination.

Survey catchability

Survey catchability (q) was fixed at 1 as in previous Alaska skate assessment models. The eastern Bering Sea (EBS) shelf survey appears to sample Alaska skates very reliably, with CVs of approximately 0.05.

Weight at length

Parameters from the allometric length-weight relationship ($W = a\mathrm{TL}^b$, where W is weight in kg and TL is total length in cm) were estimated from data obtained during an Alaska skate tagging project conducted aboard EBS shelf surveys 2008-2010 (O. Ormseth, unpublished data). Parameters were not significantly different between sexes, so data were combined. For sexes combined, a was estimated as 9.0×10^{-6} and b was estimated as 2.9617 ($r^2 = 0.93$, $n = 1{,}515$).

Stock-recruit parameters

The standard Tier 3 approach was followed in which no relationship was assumed between the stock and recruitment. Steepness was therefore fixed at 1.0 to create a mean level of recruitment. The σ_R value was fixed to a value of 0.4.

Parameters Estimated Inside the Assessment Model

Growth parameters

Alaska skate length-at-age (LAA) observations are best fitted by the Gompertz growth model (Matta and Gunderson 2007). In line with previous assessments, the Schnute 4-parameter growth model (Schnute 1981) was used to approximate the Gompertz growth function in SS3 (Methot et al. 2020). The Schnute model is formulated as

$$L(t) = \left\{ L_0^b + \left(L_{inf}^b - L_0^b\right) \frac{1 - exp[-k(t - A_1)]}{1 - exp[-k(A_2 - A_1)]} \right\}^{1/b}$$

where *L(t)* is length at age *t*, L_1 and L_2 are the length at ages A_1 and A_2, respectively, and κ and *b* are parameters that control the shape of the growth curve. In SS3, *k* is referred to as the von Bertalanffy *k* parameter and *b* is referred to as the Richards coefficient. All growth parameters were estimated within the model based on paired length and age data from the EBS shelf bottom trawl surveys in 2003, 2007-2009, and 2015, as were the two uncertainty parameters (CV of length-at-age at ages A_1 and A_2, Table 2).

Length selectivity

Selectivity at length was estimated separately for each fishery (trawl and longline) and the EBS shelf bottom trawl survey using a double-normal function with defined initial and final selectivity levels (Methot et al. 2020) where all parameters were estimated inside the model (Table 2). The six parameters of the double-normal function are: p1 (the peak or ascending inflection size), p2 (the width of the plateau), p3 (the ascending width), p4 (the descending width), p5 (the selectivity at the first length bin, and p6 (the selectivity at the last length bin). The bounds were set to the default values listed in the SS3 documentation (Methot et al. 2020).

Stock-recruit parameters

The natural log of unfished recruitment (R_0) value was estimated inside the Alaska skate model. Recruitment deviations were also estimated for 1950-2023. In SS3, each deviation is considered a separate parameter.

Initial fishing mortality

Initial fishing mortality in the longline and trawl fisheries was set to zero.

Description of Alternative Models

Best Practices and Procedural Errors

Following recommended best practices, we updated the version of Stock Synthesis to the most recent release: v3.30.23.2. There were two other minor changes implemented: the jitter was changed from 1% to 10% and the maximum lambda phase was changed from 4 to 1. These changes were to be consistent with other stock control files and neither change impacted the model output.

The most recent accepted model, 14_2d, and those previous to it, did not include recruitment ramp adjustment model runs.

Model 14_2d1 incorporates the updated best practices and the recruitment ramp adjustment (Table 1). All ensuing models build off of model 14_2d1.

Over-reliance on Limited Data

The Alaska skate model utilizes age data as well as length data. Table 3 shows the number of samples of each available for the model. There are limited age data available, with no new age data since 2015. The limited age data are all from the EBS shelf bottom trawl survey, and there are unlikely to be future collections from this fleet. The North Pacific Groundfish Observer Program began collecting Alaska skate vertebrae in 2025; however, there is no ability to begin ageing those structures at this time. In contrast, length data are abundant for fishery and survey fleets; these data are collected annually and will continue to be collected.

Model 14_2d and 14_2d1 estimate growth inside of the model, but growth parameters hit bounds (Table 2). Model 25_0 builds off of Model 14_2d1 and compensates for limited paired age-length observations. Growth was estimated outside of the model and the parameters fixed within the model (Tables 1 and 2). Growth parameters were estimated separately using the Schnute model parameterized to approximate Gompertz as described in the SS3 manual (Methot et al. 2020).

The external growth function estimates four parameters (L_0, L_{inf}, κ, and b) with the following assumptions:

1. All of the age data are from the EBS shelf bottom trawl survey, and as such, all are collected in the months of June and July. Since SS3 estimates ages at the beginning of the year, all of the ages are adjusted by a factor to represent the fraction of the year between the beginning of the year and date of capture.
2. Nearly all of the aged Alaska skates were 20 years or less and 120 cm total length or less, with the exception of one individual that was aged 26 years and was 137 cm total length. This animal was genetically verified to be an Alaska skate. Growth parameters were estimated including and excluding the data point from that animal (Figure 1). Both survey and fishery data include a small number of specimens up to 160 cm total length, though species identification was not independently confirmed for any of these individuals. Model 25_0, and all ensuing models, used growth parameters fixed at the values estimated using the dataset including the 26 year individual.
3. A_1 was set equal to 0 and A_2 was set equal to 15. The A_2 parameter represents the mean age at which the population reaches L_{inf}. Data were insufficient to estimate this value, therefore it was fixed based on the mean size at age data.

The coefficient of variation of the length-at-age data at ages A_1 and A_2 were calculated and fixed in the control file (i.e., CV_young and CV_old). After conducting sensitivity runs, we determined that the CV estimates were unreasonably narrow for the model and fixed the parameters at the standard deviation instead (Table 2).

Non-Convergence

Multiple selectivity parameters in models 14_2d, 14_2d1 and 25_0 hit bounds (Table 2) or resulted in large parameter standard deviations, suggesting non-convergence. Two approaches were implemented to attempt to remedy the non-convergence issues: fixing catchability at an empirically estimated value supported by research and fixing selectivity parameters.

Catchability (q) has been fixed equal to 1 in all previously accepted models. However, Kotwicki and Weinberg (2005) demonstrated that a significant portion of skates escape the trawl survey net. The 2008 Alaska skate model addressed this by fixing the logistic survey length selectivity such that it mimicked the data in Kotwicki and Weinberg (2005), but the 2014 model switched to a double normal selectivity function and allowed parameters to be estimated. In essence, the information on catchability was no longer informing the model. While the catchability estimates from Kotwicki and Weinberg (2005) were not specific to Alaska skates, that species comprises about 91% of the skate catch on the EBS shelf bottom trawl survey each year and it is reasonable to assume that the estimated catchability would be representative for Alaska skate. Model 25_1 builds from Model 25_0 and has catchability fixed at the empirically estimated 0.836 (Tables 1 and 2) from Kotwicki and Weinberg (2005).

A number of selectivity scenarios were conducted to attempt to determine the best approach to solving the bounds and high standard deviations of the selectivity function parameters. When allowed to estimate more freely (i.e., essentially limitless bounds), the model tended to estimate unrealistic selectivity curves, including fully selected at all ages, all curves essentially logistic, or knife-edge declines to zero. Ultimately, the combination which resulted in reasonable fits and parameter estimates were double normal functions with the following:

- Fixing survey selectivity to be logistic (i.e., setting the ending value = 1)
- Fixing the starting value equal to 1 for all fleets

- Fixing the top width and descending limb width parameters for all fleets (acknowledging that these two parameters are meaningless when survey selectivity is fixed to be logistic)

This resulted in Model 25_2 having three estimated parameters for both the trawl and longline fisheries (peak, ascending limb, and ending values) and two estimated parameters for the survey (peak and ascending limb, Table 2).

Model 25_3 is a combination of Models 25_0 and 25_2. In this case, growth was estimated externally and the selectivities were fixed as described above, but catchability was left equal to one.

Model Selection

As shown in Table 2, Models 14_d through 25_1 resulted in parameters that hit bounds, suggesting non-convergence. These models also had parameters with high standard deviations and poor gradients, which are not reported in this document, but can be reviewed in the model folders located at the assessment's online repository (AFSC_BSAI_SKATE_Assessment). Given that, the only models which are viable for management advice are Model 25_2 and 25_3.

Both of the models include growth parameters estimated externally and many of the selectivity parameters fixed. The only difference in the model specification between Models 25_2 and 25_3 is the value for catchability. Model 25_2 used the empirically estimated value of 0.836 based on Kotwiki and Weinberg (2005), while Model 25_3 is consistent with the previously accepted models assuming catchability is equal to one. The result of this difference is a scaling up of the biomass when catchability is reduced, but fits to the indices are similar (Figures 2 and 3).

Due to the change in the selectivity curves from the Model 14_2d to Models 25_2 and 25_3, the fits to the length composition data are degraded (Figure 4 and Figure 5). Each of the Model 14_2d length selectivity functions had parameters that hit the bounds or had large standard deviations, suggesting that while the fit was improved, the model did not converge to a global minimum for those parameters and the better fit was an artifact of a mis-specified model.

Based on the bridging steps, the consistent trends and fit to indices, model convergence, and use of data-informed catchability, the author's preferred model is 25_2.

Research Priorities

While the 2025 assessment is focused on the non-convergence issues with the Tier 3 Alaska skate model, there are number of high-priority research tasks, some of which have been requested by the SSC. We will not be addressing these in this assessment cycle, but we have prioritized the below for the following assessment cycle. A complete list of Plan Team and SSC requests over the years, along with responses where applicable, is available on the "PT_SSC_comments" tab of the Alaska_skate_model_history.xlsx file.

1. Complete a stock structure evaluation for Alaska skate
2. Explore using catchability tuned to temperature [to account for the model mismatch to the survey index]
3. Further explore the declining trend of leopard skate in the Aleutian Islands
4. Update natural mortality
5. Investigate including the northern Bering Sea survey index in the Alaska skate model (author recommended)

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Tables and Figures

Table 1. List of models for consideration with specific changes to the SS3 files included for reference.

Model Name	Description	Comments	Specific ss3 programming changes
14_2d	2023 accepted model	Multiple parameters hitting bounds	
14_2d1	14_2d plus: ● Updated from ss3 version 3.30.21 to v3.30.23.2 ● Conducted the recruitment ramp correction ● Changed jitter from 1% to 10% ● Changed the max lambda phase from 4 to 1	Minimal changes to model results Multiple parameters hitting bounds	Starter file: 0.1 # jitter initial parm value by this fraction Control file: 1 #_maxlambdaphase
25_0	14_2d1 plus: ● Estimated growth outside of the model and fixed the parameters ● Estimated the CV for young and old age classes as standard deviation in growth data and fixed the parameters	Scaled model results, but no major changes in trends Selectivity parameters hitting bounds	Control file: 0 #_sd_offset 2 #_CV_Growth_Pattern All growth section parameters set to negative
25_1	25_0 plus: ● Fixed survey catchability to the empirically estimated value from Kotwicki and Weinberg 2005	Scaled model results, but no major changes in trends Selectivity parameters hitting bounds	Control file: LnQ_base_SURV = -0.179
25_2	25_1 plus: ● Fixed top width parameter (all) ● Fixed start value = 0 for (all) ● Fixed descending width (all) ● Fixed ending value = 1 (survey)	Scaled model results, but no major changes in trends Converged model with no parameters hitting bounds.	Control file: Size_DblN_top_logit = -1 (trawl and longline fleets) Size_DblN_top_logit = -1 (survey) Size_DblN_descend_se = 4 (all fleets) Size_DblN_start_logit = -999 (all fleets) Size_DblN_end_logit = 99 (survey)
25_3	25_0 plus 25_2 (i.e., model 25_2 with q = 1)		

Table 2. Selected parameter values for the models presented in this analysis. Bounds for parameters estimated within the model are in parentheses. Parameter estimates that are within 10% of the bounds are considered limited and noted with "*" and those models are greyed out. Fixed parameters do not have bounds in parentheses.

Function	Parameter	14_2d	14_2d1	25_0	25_1	25_2	25_3
Growth	L1	14.98 (-10.00-30.00)	14.27 (-10.00-30.00)	23.95	23.95	23.95	23.95
	L2	102.10 (70.00-150.00)	101.67 (70.00-150.00)	104.77	104.77	104.77	104.77
	k	0.37 (0.05-0.50)	0.38 (0.05-0.50)	0.36	0.36	0.36	0.36
	B	-1.00* (-1.00-2.00)	-1.00* (-1.00-2.00)	-1.90	-1.90	-1.90	-1.90
	CV/SD L1	CV=0.32 (0.05-0.35)	CV=0.35* (0.05-0.35)	SD=1.93	SD=1.93	SD=1.93	SD=1.93
	CV/SD L2	CV=0.05*(0.05-0.25)	CV=0.05*(0.05-0.25)	SD=13.72	SD=13.72	SD=13.72	SD=13.72
Catchab.	q	1.00	1.00	1.00	0.836	0.836	1
longline length select	peak (p1)	92.32 (7.60-126.20)	90.99 (7.60-126.20)	97.43 (7.60-126.20)	100.40 (7.60-126.20)	92.37 (7.60-126.20)	92.95 (7.60-126.20)
	top (p2)	-1.20 (-6.00-4.00)	-1.05 (-6.00-4.00)	-0.05 (-6.00-4.00)	-5.97* (-6.00-4.00)	-1	-1
	ascending (p3)	7.05 (-1.00-9.00)	7.03 (-1.00-9.00)	6.84 (-1.00-9.00)	6.88 (-1.00-9.00)	6.85 (-1.00-9.00)	6.85 (-1.00-9.00)
	descending (p4)	0.18 (-1.00-9.00)	-0.31 (-1.00-9.00)	0.10 (-1.00-9.00)	3.69 (-1.00-9.00)	4	4
	start (p5)	-5.00* (-5.00-9.00)	-5* (-5.00-9.00)	-3.33 (-5.00-9.00)	-3.39 (-5.00-9.00)	-999	-999
	end (p6)	1.51 (-5.00-9.00)	1.90 (-5.00-9.00)	-3.56 (-5.00-9.00)	-3.40 (-5.00-9.00)	-4.09 (-9.00-9.00)	-4.14 (-9.00-9.00)
trawl length select	peak (p1)	73.10 (7.60-126.20)	56.13 (7.60-126.20)	99.31 (7.60-126.20)	99.01 (7.60-126.20)	89.82 (7.60-126.20)	90.16 (7.60-126.20)
	top (p2)	-0.17 (-6.00-4.00)	1.73 (-6.00-4.00)	-5.95* (-6.00-4.00)	-5.94* (-6.00-4.00)	-1	-1
	ascending (p3)	7.22 (-1.00-9.00)	6.26 (-1.00-9.00)	7.07 (-1.00-9.00)	7.13 (-1.00-9.00)	7.70 (-1.00-9.00)	7.70 (-1.00-9.00)
	descending (p4)	0.07 (-1.00-9.00)	4.52 (-1.00-9.00)	3.85 (-1.00-9.00)	3.90 (-1.00-9.00)	4	4
	start (p5)	-5.00* (-5.00-9.00)	-5* (-5.00-9.00)	-1.31 (-5.00-9.00)	-1.26 (-5.00-9.00)	-999	-999
	end (p6)	0.72 (-5.00-9.00)	5.66 (-5.00-9.00)	-3.53 (-5.00-9.00)	-3.59 (-5.00-9.00)	-3.86 (-9.00-9.00)	-3.87 (-9.00-9.00)
survey length select	peak (p1)	60.01 (7.60-126.20)	58.52 (7.60-126.20)	103.86(7.60-126.20)	106.45 (7.60-126.20)	97.03 (7.60-126.20)	98.90 (7.60-126.20)
	top (p2)	-1.18 (-6.00-4.00)	-1.10 (-6.00-4.00)	-1.36 (-6.00-4.00)	-5.96* (-6.00-4.00)	-1	-1
	ascending (p3)	6.38 (-1.00-9.00)	6.30 (-1.00-9.00)	7.81 (-1.00-9.00)	7.84 (-1.00-9.00)	8.02 (-1.00-9.00)	8.04 (-1.00-9.00)
	descending (p4)	0.08 (-1.00-9.00)	0.28 (-1.00-9.00)	0.33 (-1.00-9.00)	-0.99* (-1.00-9.00)	4	4
	start (p5)	-5.00* (-5.00-9.00)	-5* (-5.00-9.00)	-1.89 (-5.00-9.00)	-1.86 (-5.00-9.00)	-999	-999
	end (p6)	3.30 (-5.00-9.00)	2.67 (-5.00-9.00)	-3.50 (-5.00-9.00)	-2.96 (-5.00-9.00)	99	99

Table 3. Alaska skate survey and fishery hauls sampled, number of lengths and vertebrae collected, number of vertebrae aged, and input sample sizes for Model 14.2d. Input sample size is fixed at 200 for survey and the square root of the number of hauls for fishery. Survey length data are available from 2000 to present, and ages in 2003, 2004, 2007-2009 and 2015. There was no survey in 2020. Fishery length data are available since 2009, and there are no fishery ages used in the model.

	EBS Shelf Survey					Longline			Trawl		
Year	**Hauls**	**Vert coll**	**Aged**	**Lengths**	**Input N**	**Hauls**	**Lengths**	**Input N**	**Hauls**	**Lengths**	**Input N**
2000	319			2,135	200						
2001	339			3,188	200						
2002	335			2,669	200						
2003	335	306	182	2,818	200						
2004	348	292	28	4,180	200						
2005	344			4,491	200						
2006	339			4,759	200						
2007	363	252	244	4,997	200						
2008	347	181	175	4,131	200						
2009	334	350	337	4,584	200	4,496	18,934	67.1	3,082	8,476	55.5
2010	348			3,610	200	4,255	16,972	65.2	3,752	9,633	61.3
2011	343			4,522	200	5,156	22,166	71.8	3,181	6,601	56.4
2012	337			3,704	200	5,934	26,462	77	2,495	5,338	49.9
2013	356			3,797	200	7,252	31,269	85.2	3,705	7,721	60.9
2014	349			3,576	200	7,594	32,481	87.1	2,925	6,025	54.1
2015	353	323	313	3,906	200	7,536	31,189	86.8	2,043	3,910	45.2
2016	353			4,246	200	6,448	27,892	80.3	2,040	4,134	45.2
2017	360			4,243	200	6,198	26,250	78.7	3,096	6,375	55.6
2018	363			4,593	200	4,445	20,254	66.7	5,152	11,758	71.8
2019	348			3,651	200	3,034	12,847	55.1	6,246	16,057	79
2020						2,374	10,627	48.7	4,333	10,646	65.8
2021	356			3,855	200	2,363	11,209	48.6	4,156	10,994	64.5
2022	365			3,783	200	2,729	12,895	52.2	3,749	8,757	61.2
2023	351			3,688	200	1,363	6,508	36.9	1,726	4,771	41.5

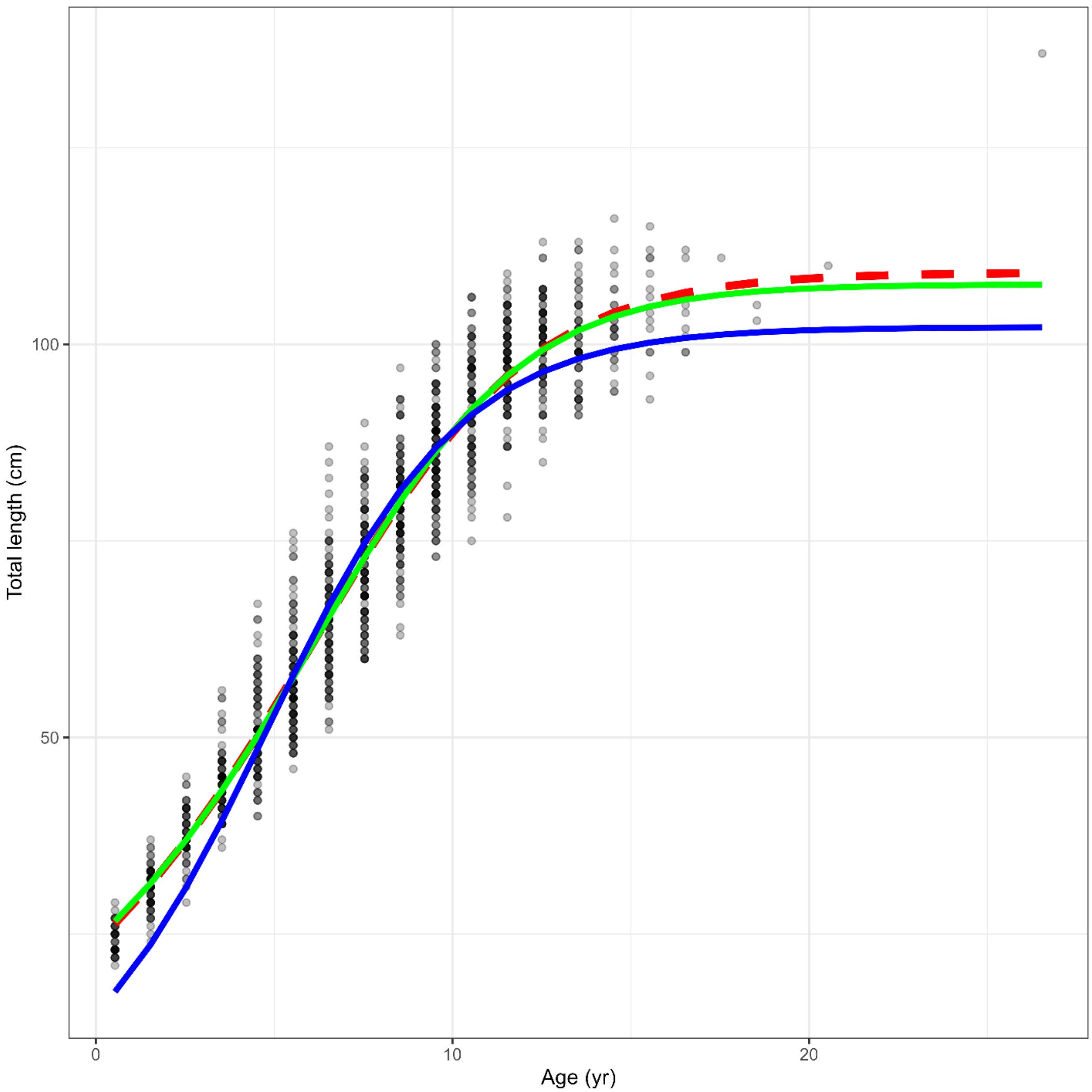

Figure 1. Growth model results for Alaska skate. Dashed red line includes the data point from the 137 cm total length individual, while the green solid line does not. The blue line is from the 2023 accepted model.

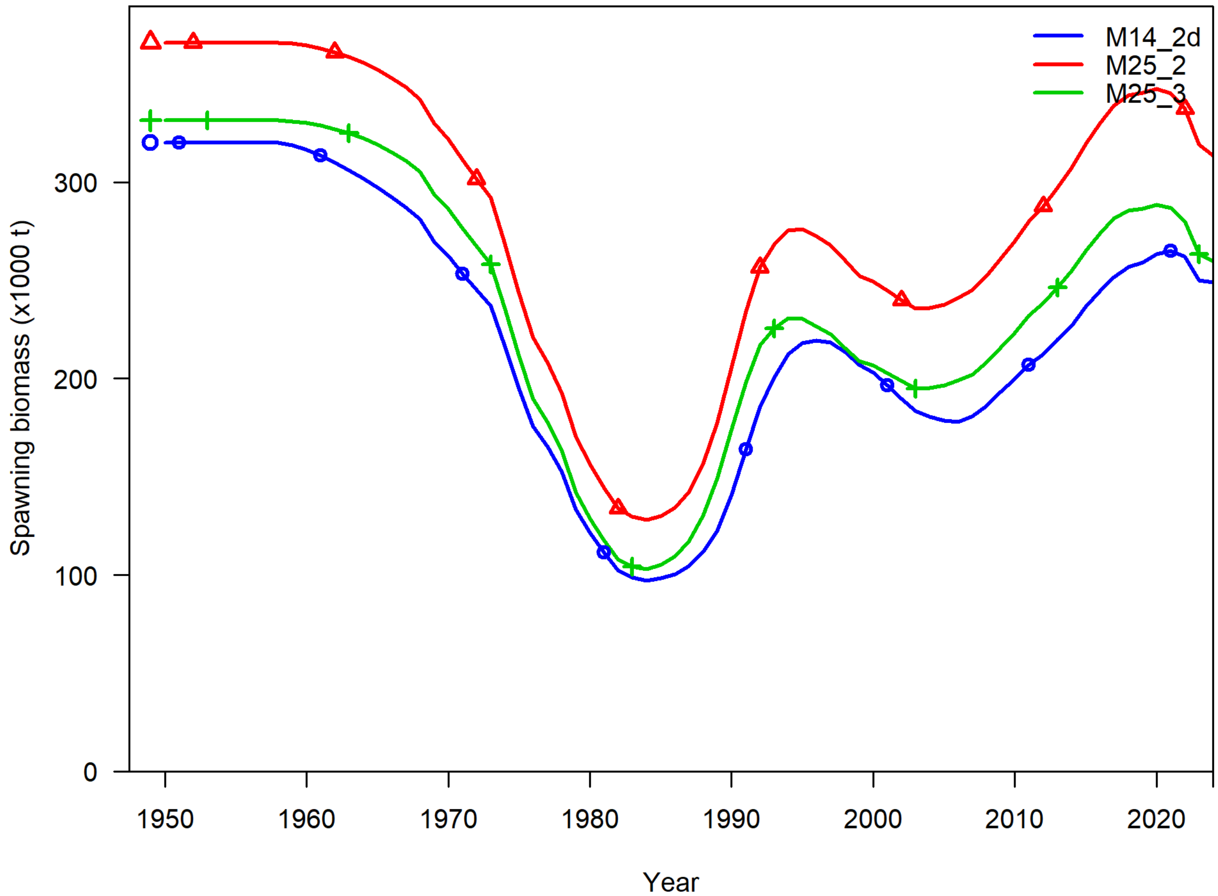

Figure 2. Comparison of spawning biomass for Alaska skate from the previously accepted model (14_2d) and the two proposed models (25_2 and 25_3).

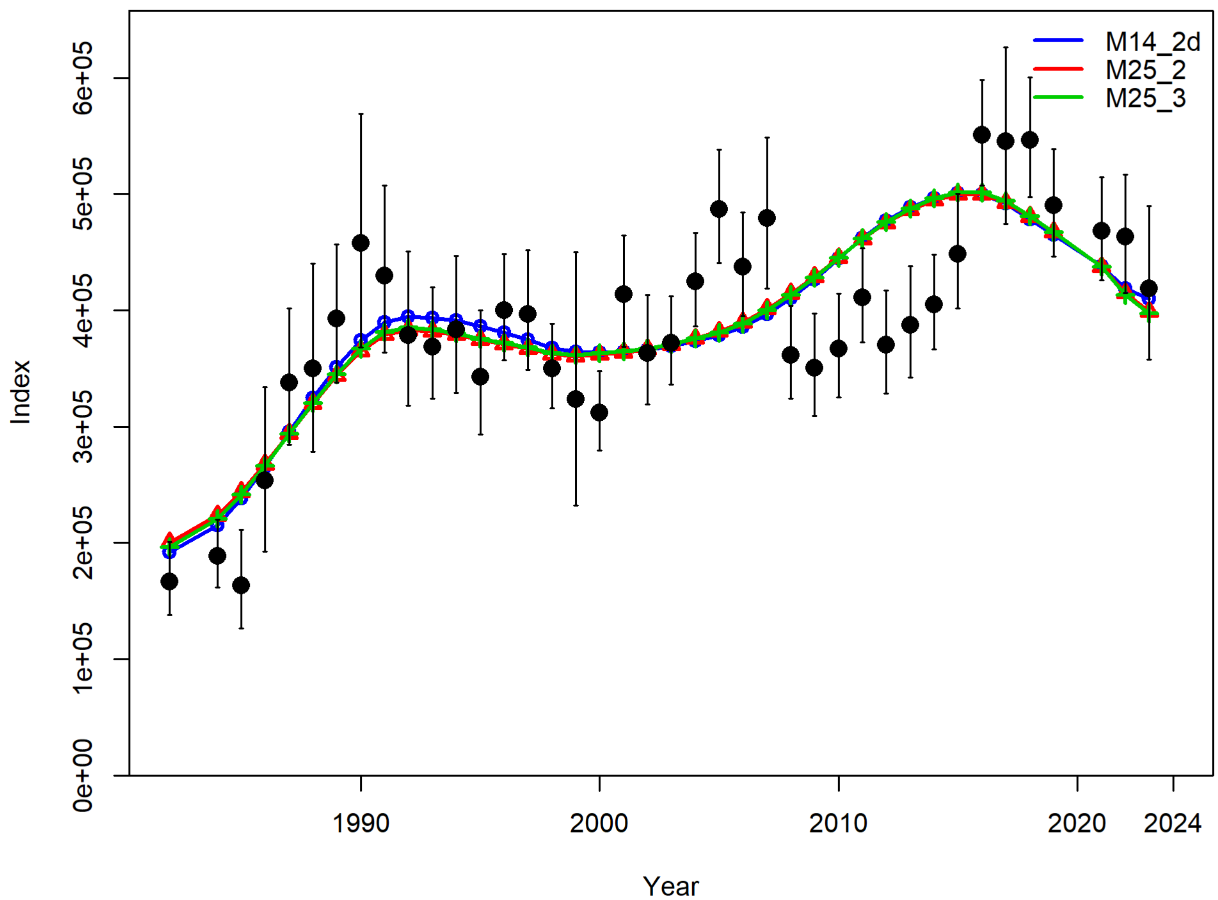

Figure 3. Comparison of the fit to the survey index for Alaska skate from the previously accepted model (14_2d) and the two proposed models (25_2 and 25_3).

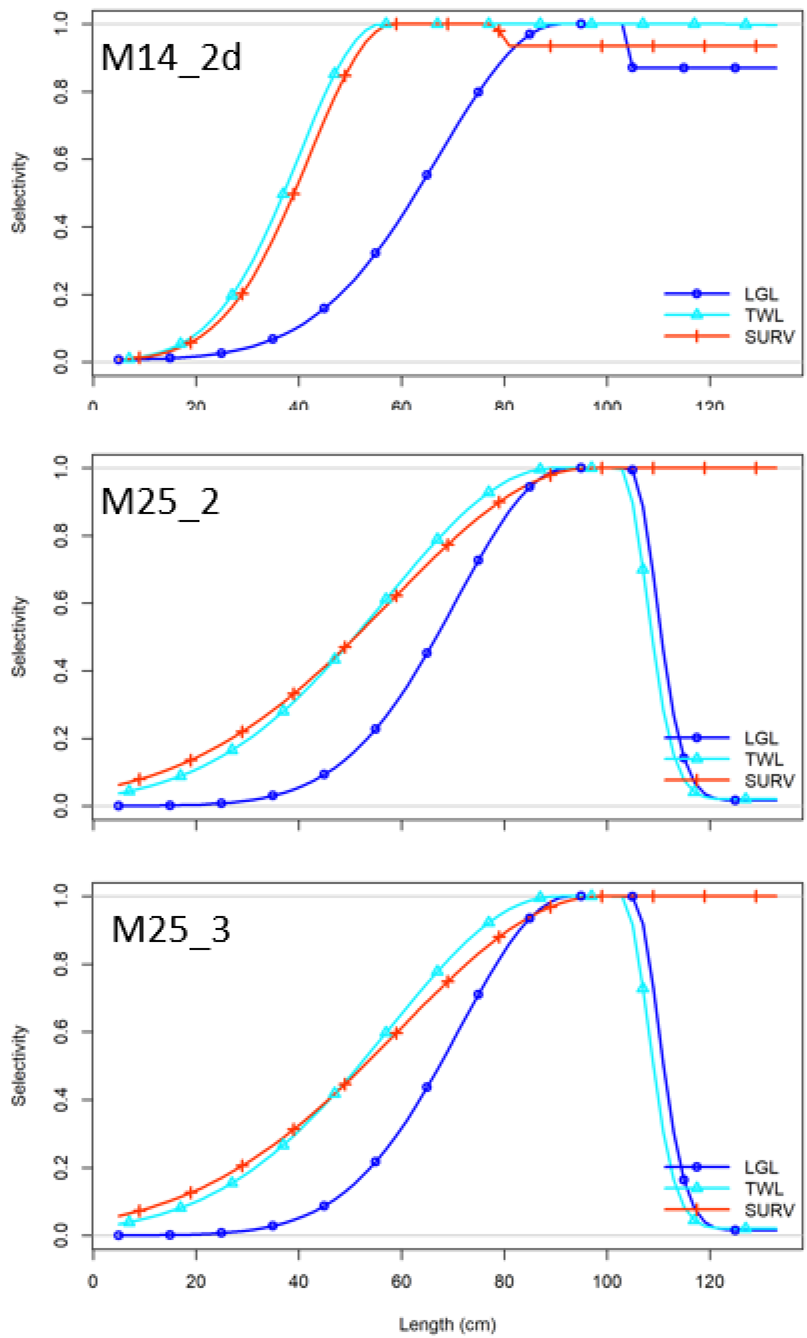

Figure 4. Selectivity curves for Alaska skate from the previously accepted model (14_2d) and the two proposed models (25_2 and 25_3).

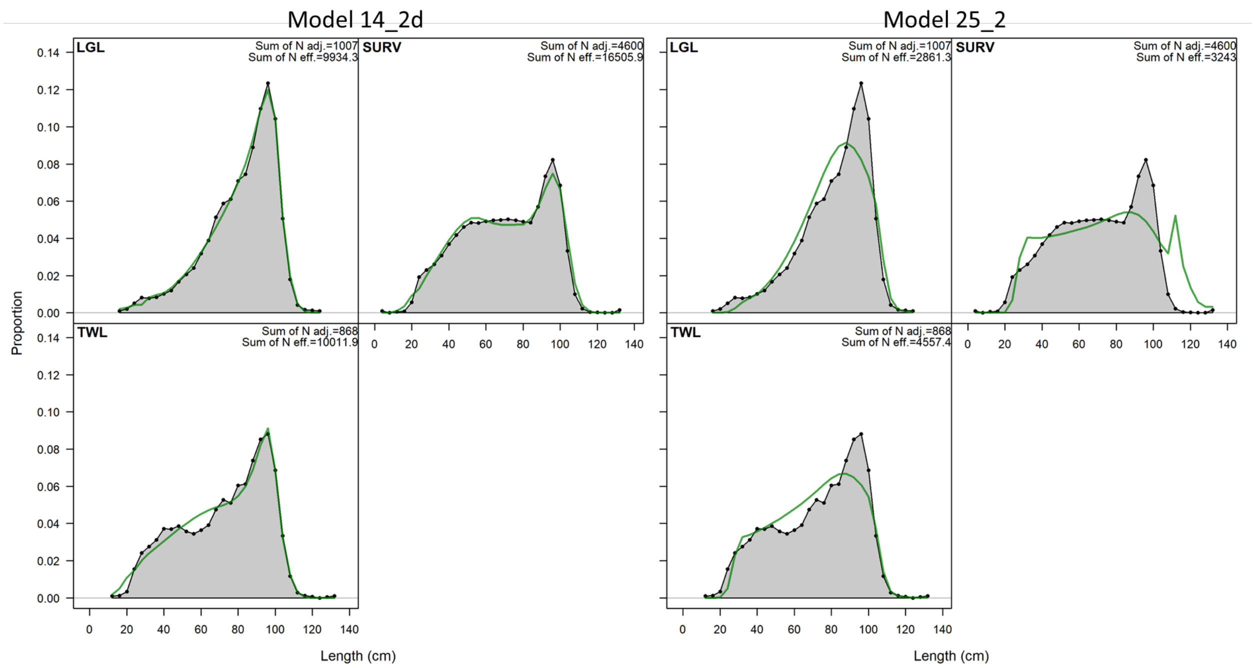

Figure 5. Model fits to the length composition data of Alaska skate from the previously accepted model (14_2d) and the author preferred model (25_2). Model fits to the length composition data for model 25_3 are not shown because they are nearly indistinguishable from model 25_2. LGL = longline fishery, TWL = trawl fishery, SURV = eastern Bering Sea shelf bottom trawl survey.