Annex 2.2.1: An initial exploration of alternative assessment models for Pacific cod in the Aleutian Islands

Grant G. Thompson

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the joint BSAI and GOA Plan Teams, and the SSC regarding the need to develop an age-structured model of the Pacific cod (*Gadus macrocephalus*) stock in the Aleutian Islands (AI). Throughout the history of management under the Magnuson-Stevens Fishery Conservation and Management Act, Pacific cod in the eastern Bering Sea (EBS) and AI have been managed as a unit. Since at least the mid-1980s, harvest specifications for the combined BSAI unit have been extrapolated from an age-structured model for Pacific cod in the EBS.

Several white papers and a stock structure report provide various lines of evidence suggesting that Pacific cod in the EBS and AI should be viewed as separate stocks. Building on earlier genetic studies by Canino et al. (2005), Cunningham et al. (2009), and Canino et al. (2010), Spies (*in press*) concluded that her "study provides the most comprehensive evidence to date for genetic distinctiveness and lack of gene flow between the Aleutian Islands and Eastern Bering Sea." The importance of recognizing stock distinctions in management of gadids in general has also received attention in recent years (e.g., Fu and Fanning 2004, Hutchinson 2008).

In light of this evidence, in 2010 the SSC requested that a separate assessment be prepared for Pacific cod in the AI. In response, the 2011 assessment contained a Tier 5 assessment of Pacific cod in the AI (Thompson and Lauth 2011). This preliminary assessment marks the first time that an age-structured model of Pacific cod in the AI has been presented in the context of the annual BSAI groundfish management cycle.

Comments from the Plan Teams and SSC

Note: Comments directed exclusively at the assessments for Pacific cod in the EBS or Gulf of Alaska are not included here.

SSC (December, 2011)

SSC1: *"The SSC requested in its December 2010 minutes that a separate assessment for the AI be brought forward because of concerns over diverging trends in the biomass estimates for the AI and EBS. In response, the author provided a Tier-5 assessment for AI cod as an appendix to the current assessment. The author plans to develop an age-structured model for the Aleutians in 2012. We look forward to reviewing a preliminary model in October 2012."* Two age-structured models are presented here (see "Model Structures" below).

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by the National Marine Fisheries Service and should not be construed to represent any agency determination or policy.

Joint Plan Teams (May, 2012)

JPT1: *"For the AI, the Teams recommend that a preliminary assessment be developed with a simple, age-structured model configured in Stock Synthesis* if there is enough time to do so. *This initial attempt at age-structured modeling of the AI stock may serve largely to determine whether the lack of age data prohibits meaningful parameter estimation at the present time"* (emphasis original). See response to comment SSC1.

JPT2: *"The Teams recommend that the AFSC begin production ageing of AI Pacific cod."* A request for production of age data will be filed in the upcoming cycle.

SSC (June, 2012)

SSC2: *"The SSC agrees with the Plan Team recommendation that the author bring forward a preliminary model for the Aleutian Islands* if there is enough time. *The author noted the lack of age data for the Aleutians Pacific cod stock and the SSC agrees that length data should be used for all years (including for any year with age data). Authors should consider age composition sample size needs for the assessment and request ageing of current sample collections for next year's assessment"* (emphasis original). See responses to comments SSC1 and JPT1.

Data

Catch

Total catch data are shown in Table 2.2.1.1 for the years 1977-2011. These are taken from last year's assessment (Thompson and Lauth 2011), so the 2011 datum is slightly incomplete. These are the catch data that were used in the models described in this preliminary assessment. However, they contain two errors which were discovered too late to be changed in this document: 1) the catches in Table 2.2.1.1 do not include catches from the State-managed fishery in 2006-2011; and 2) the datum for 2003 does not included CDQ catches, which would add another 266 t to the reported amount. These errors will be corrected in the final assessment. Table 2.2.1.2 shows catches broken by year, jurisdiction (Federal and State), and gear for the years 1991-2011. Again, data for 2011 are slightly incomplete. Table 2.2.1.3 shows catches broken down by area, both in volume and as proportions of the yearly total for the years 2003-2012. Unlike Tables 2.2.1.1 and 2.2.1.2, the data for 2011 in Table 2.2.1.3 are complete; however, the data for 2012 are current only through August 16. Catches dropped sharply in 2011, which was likely the result of recent management measures designed to protect Steller sea lions.

Length frequency

Table 2.2.1.4 shows the number of fish actually measured in each year from both the fishery and the survey, along with the scaled sample sizes used in the models described in this preliminary assessment. The steps used to scale the sample sizes were the same as those used in last year's EBS assessment (Thompson and Lauth 2011), which have changed very little since 2007: 1) Records with fewer than 400 observations were omitted. 2) The sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions after 1998 and all survey length compositions were tentatively set at 34% of the actual sample size. 3) All sample sizes were adjusted proportionally so that the average was 300. It should be noted that the actual fishery sample sizes for Pacific cod in the AI are *much* smaller than the actual fishery sample sizes for Pacific cod in the EBS (average of 1,011 samples per year in the AI versus 210,156 samples per year in the EBS).

Table 2.2.1.5 shows the actual (i.e., not rescaled) number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey. Overall, the AI size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS (AI: 2.5% in the fishery, 0.7% in the survey; EBS: 0.6% in the fishery, 0.1% in the survey).

Trawl survey abundance and biomass estimates

As in recent assessments of Pacific cod in the EBS, the models developed here use survey estimates of population size measured in units of individual fish. These estimates are shown below, along with the coefficient of variation (CV) for each estimate.

Year	Numbers (1000s)	CV
1980	57,036	0.157
1983	70,402	0.131
1986	109,969	0.229
1991	70,557	0.216
1994	62,333	0.271
1997	28,724	0.137
2000	47,231	0.210
2002	30,560	0.140
2004	29,224	0.133
2006	24,649	0.154
2010	24,617	0.121

Table 2.2.1.6 shows the time series of survey biomass estimates, broken down by area, along with coefficients of variation.

In terms of both biomass and numbers, the CVs for the AI surveys tend to be much larger than the CVs for the EBS surveys, as shown below:

	EBS		AI	
Statistic	Biomass	Numbers	Biomass	Numbers
Min.	0.055	0.060	0.126	0.121
Mean	0.084	0.107	0.179	0.173
Max.	0.183	0.267	0.264	0.271

Model Structures

Two models (labeled Model 1 and Model 2) are presented in this preliminary assessment, both estimated using Stock Synthesis (SS), and both based largely on last year's accepted model for Pacific cod in the EBS (Thompson and Lauth 2011). The natural mortality rate was fixed at 0.34 in both models, borrowing the accepted value in the EBS.

In both models, weight (kg) at length (cm) was assumed to follow the usual form weight=$\alpha\times$length$^{\beta}$ and to be constant across the time series, with α and β estimated at 5.68×10^{-6} and 3.18, respectively, based on 8,126 samples collected between 1974 and 2011.

In both models, length bins (1 cm each) were extended out to 150 cm instead of the limit of 120 cm that is used in the EBS assessment, because of the higher proportion of large fish observed in the AI.

In addition to differences in the data between the AI and EBS, Model 1 differs from last year's accepted EBS model in the following respects:

- Each year consists of a single season instead of five.
- A single fishery is defined (with forced asymptotic selectivity) instead of nine season-and-gear-specific fisheries (with forced asymptotic selectivity for six of them).
- Fishery selectivity is constant over time instead of variable in multiple time blocks.
- The survey samples age 1 fish at true age 1.5 instead of 1.41667.
- Ageing bias is not estimated (no age data) instead of estimated.
- Survey catchability *Q* is tuned to match the value of 0.92 estimated by Nichol et al. (2007) for the AI survey net instead of the value of 0.47 estimated for the EBS survey net.

Model 2 was chosen from a set of seven candidate models, all of which were identical to Model 1 except that they each allowed at least one of the three length-at-age parameters (length at age 1, *L1*; asymptotic length, *Linf*; and Brody's growth coefficient, *K*) to vary annually from 1977-2010, using multiplicative *dev*s with $\sigma = 0.1$. The candidate models were structured as follows:

Model	*L1 dev*s	*Linf dev*s	*K dev*s
A	yes	yes	yes
B	yes	yes	no
C	yes	no	yes
D	no	yes	yes
E	yes	no	no
F	no	yes	no
G	no	no	yes

The candidate model with the lowest value of Akaike's information criterion (AIC) was chosen as Model 2 (see "Results," below).

All models used the same data file.

Development of the final versions of Models 1 and 2 included calculation of the Hessian matrix. These models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.1. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and 3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Prior to selection of one of the candidate models A-G to constitute Model 2, development of these models did not include calculation of the Hessian matrix, and they were not subjected to a jitter test. As a weak test for convergence, each of these models was re-run from its respective ending values (in the control file, not the parameter file), and confirmed to return the same objective function value.

Except for *dev* parameters, all parameters in all models were estimated with uniform prior distributions. Bounds were non-constraining except in a very few unimportant cases.

All models used a double-normal curve to model selectivity. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

1. *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2. *width_of_peak_region* (where the curve first departs from a value of 1.0)
3. *ascending_width* (equal to twice the variance of the underlying normal distribution)
4. *descending_width* (equal to twice the variance of the underlying normal distribution)
5. *initial_selectivity* (at minimum length/age)
6. *final_selectivity* (at maximum length/age)

All but *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.

The software used to run all models was SS V3.23b, as compiled on 11/5/2011 (Methot 2005, Methot 2011, Methot and Wetzel *in press*). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Results

Selection of one of the time-varying growth models to constitute Model 2

The seven candidate models with time-varying growth gave the following results ("Δ(–lnLike)" represents the negative log likelihood relative to the model with the lowest negative log likelihood, and "Δ(AIC)" represents the value of Akaike's information criterion relative to the model with the lowest AIC; note that, with respect to both of these measures, lower values are better):

Model	*L1 dev*s	*Linf dev*s	*K dev*s	Parameters	Δ(-lnLike)	Δ(AIC)
A	yes	yes	yes	183	0.00	61.09
B	yes	yes	no	149	3.45	0.00
C	yes	no	yes	149	22.31	37.71
D	no	yes	yes	149	101.72	196.52
E	yes	no	no	115	83.10	91.28
F	no	yes	no	115	115.96	157.01
G	no	no	yes	115	147.73	220.55

Model A has the lowest negative log likelihood overall, followed by Models B and C, respectively. However, Model A's negative log likelihood is only 3.45 units lower than Model B, an improvement which is achieved at a cost of 34 additional parameters. It should be noted, though, that the differences listed in the "parameters" column (above) all represent differences in the number of *dev*s, which, being constrained by σ, are not true parameters, meaning that the differences in number of parameters are overstated to some unknown extent. Unfortunately, use of a more rigorous method of model selection in this preliminary assessment was precluded by time limitations, so AIC will be taken here to represent the best available method. Model B has the lowest AIC overall, followed by Models C and A, respectively, so Model B was chosen to constitute Model 2 in this preliminary assessment.

Overview

The following table summarizes the status of the stock as estimated by Models 1 and 2 ("Estimate" is the point estimate, "St. Dev." is the standard deviation of the estimate, "SB(2011)" is female spawning biomass in 2011 (t), and "Bratio(2011)" is the ratio of SB(2011) to $B_{100\%}$):

	Model 1		Model 2	
Quantity	Estimate	St. Dev.	Estimate	St. Dev.
SB(2011)	26,444	6,451	28,171	7,603
Bratio(2011)	0.211	0.021	0.381	0.067

Although 2011 spawning biomass is only 7% higher under Model 2 than Model 1, *relative* spawning biomass in 2011 is 81% higher under Model 2 than Model 1, implying quite a big difference in how stock status is estimated by these two models.

Estimates of parameters and derived quantities

Tables 2.2.1.7-2.2.1.10 show all parameters estimated internally by either Model 1 or Model 2. Table 2.2.1.7 shows parameters other than recruitment *dev*s, growth *dev*s (Model 2 only), and fishing mortality rates, with standard deviations. Table 2.2.1.8 shows recruitment *dev*s, with standard deviations. Table 2.2.1.9 shows growth parameter *dev*s for mid-year length at age 1 (*L1*) and asymptotic length (*Linf*) estimated by Model 2, with standard deviations. These two sets of *dev*s exhibited a correlation of –0.064. Table 2.2.1.10 shows fishing mortality rates (without standard deviations, because SS does not treat fishing mortality rates as true parameters and therefore does not produce standard deviations for them).

In Model 1, *Q* was tuned to a value of 1.01, which set the average product of *Q* and survey selectivity across the 60-81 cm size range equal to the estimate of 0.92 obtained by Nichol et al. (2007). Model 2 did not re-tune *Q*, and exhibited an average product of *Q* and survey selectivity across the 60-81 cm size range equal to 0.98, slightly above the target value.

Figure 2.2.1.1 shows time-varying length at age as estimated by Model 2, both as a surface plot (upper panel) and as a contour plot (lower panel).

Figure 2.2.1.2 shows fishery selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel). Figures 2.2.1.3a-b show time-varying survey selectivity as estimated by the two models. In both figures, Model 1 is shown in the upper panel and Model 2 in the lower panel. Figure 2.2.1.3a shows time-varying selectivity as a surface plot, while Figure 2.2.1.3b shows it as a contour plot.

Overall, the most obvious differences in parameter estimates between Models 1 and 2 seem to be the growth *dev*s estimated by Model 2 (not present in Model 1) and differences in survey selectivity.

Figures 2.2.1.4-7 show various time series as estimated by the two models. Figure 2.2.1.4 shows the time series of total (age 0+) biomass (t), where both models have similar endpoints, but Model 1 increases to a much higher peak in the middle of the time series than does Model 2. Figure 2.2.1.5 shows the time series of spawning biomass relative to $B_{100\%}$, where Model 2 starts at a much higher initial value, then both models peak at about the same place and height, then both models descend at about the same rate until about 2005, after which Model 2 estimates a higher relative spawning biomass than Model 1 (note also that SS computes a time-varying value for $B_{100\%}$ whenever growth is time varying; however, $B_{100\%}$ for 2011 in Model 2 is within 1% of the value in Model 1). Figure 2.2.1.6 shows the time series of age 0 recruits (1000s), where Model 1 shows much higher variability than Model 2. Figure 2.2.1.7 shows the

time series of relative spawning per recruit corresponding to the estimated fishing mortality rates, where the two models have similar endpoints, but Model 2 is at least 10 percentage points less than Model 1 in all years between 1992 and 2005 except for 1995. The abrupt change from 2010 to 2011 which occurs for both models in Figure 2.2.1.7 (the symbol for Model 2 over-plots the symbol for Model 1 in 2011) is due to the fact that catch fell by 58% between 2010 and 2011.

Goodness of fit

Objective function values for the two models, both total and by component, are shown below:

Component	Model 1	Model 2
Survey CPUE	13.96	-9.63
Size composition	699.89	423.87
Recruitment	23.96	6.19
"Softbounds"	0.01	0.01
Deviations	6.33	29.76
Total	744.15	450.20

Model 2 has a lower (better) overall objective function value than Model 1. The only component where Model 2 has a higher value is the "Deviations" component, which would be expected, given that Model 2 has many more *dev*s that Model 1 (see below).

The number of parameters in the two models, both *dev*s and non-*dev*s, are shown below:

Parameter count	Model 1	Model 2
No. non-*dev* parameters	17	17
No. *dev*s	64	132
Total no. parameters	81	149

If *dev*s are counted as true parameters, then Models 1 and 2 have AIC values of 1650.31 and 1198.41.

Figure 2.2.1.8 shows the fits to the survey abundance (1000s of fish) time series. The estimates obtained by Model 1 fall within the 95% confidence interval 73% of the time, compared to 82% for Model 2.

Table 2.2.1.11 shows the fits to survey abundance (measured in 1000s of fish) obtained by Models 1 and 2. The columns labeled "Expected" show the estimates for each model. The columns labeled "Residual" show ln(observed/expected). The bottom row under "Residual" shows the mean for each column. Ideally, this value should be close to zero. Model 2 comes closer to this ideal than Model 1. The columns labeled "Squared std. res." show $(\ln(\text{observed/expected})/\sigma)^2$. The bottom row under "Squared std. res." shows the root mean squared error. Ideally, this value should be close to unity. Again, Model 2 comes closer to this ideal than Model 1.

The following table shows the number of size composition records, the mean of the input sample size, and the mean ratio between effective sample size and input sample size for the fishery and the survey:

			Mean(Neff/Ninput)	
Fleet	Records	Mean(Ninput)	Model 1	Model 2
Fishery	24	44.17	20.30	18.43
Survey	11	883.36	1.48	2.43

Model 1 has a higher ratio than Model 2 for the fishery, while Model 2 has a higher ratio than Model 1 for the survey. However, all ratios are greater than unity.

Discussion

This initial exploration of age-structured modeling for Pacific cod in the AI indicates that model structure can have a large impact on the estimated status of the stock. To some extent, this is characteristic of stock assessment modeling in general. However, it may also be a product of the degree to which the available data for Pacific cod in the AI are uninformative. Relative to Pacific cod in the EBS, Pacific cod in the AI have much larger survey CVs, much smaller length composition sample sizes, and virtually no age data.

Acknowledgments

Mary Furuness and Josh Keaton provided the catch data. Angie Greig provided the size composition and weight-length data. Jennifer Calahan helped to code the query for the weight-length data. Michael Martin provided the survey data. Rick Methot developed the SS software used to conduct this assessment. Anne Hollowed reviewed an earlier draft. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used here.

References

Canino, M. F., I. Spies, and L. Hauser. 2005. Development and characterization of novel di- and tetranucleotide microsatellite markers in Pacific cod (*Gadus macrocephalus*). *Molecular Ecology Notes* 5: 908-910.

Canino, M.F., I. Spies, K. Cunningham, L. Hauser, and W. S. Grant. 2010. Multiple ice-age refugia in Pacific cod, *Gadus macrocephalus*. *Molecular Ecology* 19: 4339-4351.

Cunningham, K., M. F. Canino, I. Spies, and L. Hauser. 2009. Genetic isolation by distance and localized fjord population structure in Pacific cod (*Gadus macrocephalus*): limited effective dispersal in the northeast Pacific Ocean. *Canadian Journal of Fisheries and Aquatic Sciences* 66: 153-166.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27:233-249.

Fu, C., and L. P. Fanning. 2004. Spatial considerations in the management of Atlantic cod off Nova Scotia, Canada. *North American Journal of Fisheries Management* 24:775–784.

Hutchinson, W. F. 2008. The dangers of ignoring stock complexity in fishery management: the case of the North Sea cod. *Biology Letters* 4:693-695.

Methot, R. D. 2005. Technical description of the Stock Synthesis II Assessment Program. Unpubl. manuscr. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 54 p.

Methot, R. D. 2011. *User Manual for Stock Synthesis, Model Version 3.23b.* Unpublished manuscript, available from NOAA Fisheries Stock Assessment Toolbox website: http://nft.nefsc.noaa.gov/. 167 p.

Methot, R. D., and C. R. Wetzel. In press. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. To appear in *Fisheries Research*.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Spies, I. In press. A landscape genetics approach to Pacific cod *Gadus macrocephalus* population structure in the Bering Sea and Aleutian Islands reveals isolation-by-distance and distinct populations. To appear in *Transactions of the American Fisheries Society.*

Thompson, G. G., and R. R. Lauth. 2011. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 269-476. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.2.1.1. Total catch (t) of Pacific cod in the Aleutian Islands as used in Models 1 and 2, 1977-2011 (data for 2011 were current through October 3, 2011). These data do not include catches from the State-managed fishery in 2006-2011 (see Table 2.2.1.2). Failure to include catches from the State-managed fishery in this preliminary assessment was an oversight, which will be corrected in the final assessment. Also, catch for 2003 does not include CDQ, which would add 266 t.

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1977	3,262	1986	6,906	1995	16,534	2004	28,873
1978	3,295	1987	13,207	1996	31,609	2005	22,699
1979	5,593	1988	5,165	1997	25,164	2006	20,493
1980	5,788	1989	4,542	1998	34,726	2007	30,221
1981	7,434	1990	7,541	1999	28,130	2008	26,597
1982	8,397	1991	9,798	2000	39,685	2009	26,507
1983	8,430	1992	43,068	2001	34,207	2010	25,122
1984	7,981	1993	34,205	2002	30,801	2011	10,444
1985	6,937	1994	21,539	2003	32,193		

Table 2.2.1.2. Catches (t) of Pacific cod in the Aleutian Islands by year, jurisdiction, and gear, 1991-2011 (data for 2011 were current through October 3, 2011).

	Federal					State					
Year	Trawl	LLine	Pot	Other	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1991	3,414	3,203	3,180	0	9,798						9,798
1992	14,559	22,108	6,317	84	43,068						43,068
1993	17,312	16,860	0	33	34,205						34,205
1994	14,383	7,009	147	0	21,539						21,539
1995	10,574	4,935	1,025	0	16,534						16,534
1996	21,179	5,819	4,611	0	31,609						31,609
1997	17,349	7,151	575	89	25,164						25,164
1998	20,531	13,771	424	0	34,726						34,726
1999	16,437	7,874	3,750	69	28,130						28,130
2000	20,362	16,183	3,107	33	39,685						39,685
2001	15,827	17,817	544	19	34,207						34,207
2002	27,929	2,865	7	0	30,801						30,801
2003	31,215	976	2	0	32,193						32,193
2004	25,770	3,103	0	0	28,873						28,873
2005	19,613	3,073	0	13	22,699						22,699
2006	16,956	3,128	401	8	20,493	3,106	455	156	0	3,717	24,210
2007	25,725	4,182	313	1	30,221	2,907	529	383	6	3,824	34,045
2008	19,291	5,471	1,679	156	26,597	2,540	234	1,634	53	4,462	31,059
2009	20,284	5,469	754	0	26,507	537	279	1,237	20	2,074	28,580
2010	16,757	7,638	727	0	25,122	2,113	77	1,688	0	3,878	29,000
2011	9,250	1,194	1	0	10,444	4	14	30	0	48	10,492

Table 2.2.1.3. Catches of Pacific cod in Areas 541 (eastern Aleutians), 542 (central Aleutians), and 543 (western Aleutians), in metric tons and as proportions of the yearly total, 2003-2012 (2012 catches are current through August 16, 2012).

	Catch				Proportion of total		
Year	541	542	543	Total	541	542	543
2003	22,748	6,713	2,997	32,459	0.701	0.207	0.092
2004	18,391	6,825	3,657	28,873	0.637	0.236	0.127
2005	14,879	3,552	4,268	22,699	0.655	0.157	0.188
2006	12,902	3,118	4,474	20,493	0.630	0.152	0.218
2007	21,087	4,136	4,998	30,221	0.698	0.137	0.165
2008	15,411	4,025	7,162	26,597	0.579	0.151	0.269
2009	13,208	5,376	7,923	26,507	0.498	0.203	0.299
2010	13,170	3,959	7,993	25,122	0.524	0.158	0.318
2011	8,940	1,657	24	10,621	0.842	0.156	0.002
2012	11,103	420	28	11,551	0.961	0.036	0.002
Average:	15,184	3,978	4,352	23,514	0.646	0.169	0.185

Table 2.2.1.4. True ("Ntrue") and input ("N") sample sizes for length composition data from the fishery and the survey. Input N is scaled so that the average is 300 across all fleets and years.

Year	Fleet	Ntrue	N
1982	fishery	577	15
1983	fishery	438	11
1984	fishery	571	15
1991	fishery	1,038	27
1992	fishery	1,217	31
1993	fishery	721	18
1994	fishery	740	19
1995	fishery	1,303	33
1996	fishery	1,446	37
1997	fishery	701	18
1998	fishery	1,289	33
1999	fishery	1,349	73
2000	fishery	1,663	90
2001	fishery	1,407	76
2002	fishery	982	53
2003	fishery	861	47
2004	fishery	993	54
2005	fishery	947	51
2006	fishery	956	52
2007	fishery	1,125	61
2008	fishery	1,504	82
2009	fishery	1,116	61
2010	fishery	1,362	74
2011	fishery	536	29
2012	fishery	438	24
1980	survey	30,233	1,641
1983	survey	28,868	1,567
1986	survey	25,399	1,379
1991	survey	15,603	847
1994	survey	18,048	980
1997	survey	11,691	635
2000	survey	10,767	585
2002	survey	13,450	730
2004	survey	8,573	465
2006	survey	6,598	358
2010	survey	9,759	530

Table 2.2.1.5 (page 1 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1982	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	4
1983	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	1	2	3	1	2	2
1984	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	1	1	3	1
1991	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	4	2	2	4
1992	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	3	4
1993	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	2	4	5	4
1994	fish.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	2	3	3	4	2	4	3
1995	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	2	1	3	2	2	2	2	2	3	4	3	3	4
1996	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	2	2	3	4	4	3	4
1997	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	4	1	3	4	4
1998	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	1	3	3	4	4	4	5	8	7
1999	fish.	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	2	1	3	3	3
2000	fish.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	3	3	6	6	4
2001	fish.	0	3	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	4	5	6	7	9
2002	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1	2	4	3	4	5	7
2003	fish.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	2	2	3	2	3	3	2
2004	fish.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	1	1	1	2	3	3	4	5	5	5
2005	fish.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	2	3	2	2
2006	fish.	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	2	3	0	3	3
2007	fish.	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	1	0	4	1	2	1	3	5	5	5
2008	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	2	0	3	2	6	4
2009	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	3	4	6	6
2010	fish.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0	1	1	0	3	2	5
2011	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2012	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
1980	surv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	38	35	31	91	100	68
1983	surv.	0	0	7	96	33	4	0	0	0	0	0	0	0	0	0	3	0	7	6	3	8	31	52	126	139	184	335	413	197	280	228	199
1986	surv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	58	4	117	90	43	68	178	352	474	648	691	858
1991	surv.	0	0	0	0	0	0	0	0	0	0	0	5	5	30	29	31	45	33	40	46	34	22	26	23	54	167	231	300	440	511	607	666
1994	surv.	0	0	0	0	0	0	0	0	0	129	533	833	1246	1106	497	445	349	134	26	34	16	8	9	10	8	7	21	50	81	103	119	135
1997	surv.	0	0	0	0	0	0	0	0	0	0	0	0	6	27	11	41	79	190	177	242	222	179	92	42	4	25	18	33	64	79	90	139
2000	surv.	0	0	0	0	0	0	0	0	0	0	12	72	63	72	99	38	6	20	0	3	3	7	14	8	8	27	22	28	33	43	53	38
2002	surv.	0	0	0	0	0	3	0	0	0	0	18	19	34	50	76	41	41	41	43	20	57	28	32	63	69	85	67	115	138	308	279	329
2004	surv.	0	0	0	0	0	0	0	0	0	0	9	0	2	6	10	4	25	24	15	15	11	3	1	3	0	0	0	6	1	11	17	32
2006	surv.	0	0	0	0	0	0	0	0	0	11	22	27	87	156	144	135	46	44	37	33	49	26	9	4	2	5	0	2	14	2	10	9
2010	surv.	0	0	0	0	0	0	0	0	0	0	14	35	28	33	37	64	40	23	7	4	0	7	2	4	5	26	45	63	61	70	68	68

Table 2.2.1.5 (page 2 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
1982	fish.	2	3	4	5	5	8	6	5	6	9	9	9	10	9	9	11	11	11	11	11	11	12	12	12	11	12	12
1983	fish.	3	5	4	3	6	4	4	4	6	8	7	8	8	8	8	8	8	8	8	7	8	8	7	9	7	7	9
1984	fish.	1	2	2	1	3	3	3	3	6	5	5	5	6	7	7	9	9	9	10	9	10	10	12	11	10	9	10
1991	fish.	5	5	4	3	5	6	6	6	8	7	9	10	12	12	11	13	11	13	16	14	16	17	17	17	16	16	18
1992	fish.	6	7	6	11	13	13	15	15	15	15	16	16	17	16	17	16	16	16	16	16	16	16	16	16	16	17	16
1993	fish.	4	4	4	5	3	7	6	6	6	8	9	9	8	9	10	9	9	10	10	10	10	10	10	10	9	10	8
1994	fish.	5	3	3	4	6	7	8	8	8	9	9	9	8	9	9	9	11	10	11	11	10	11	10	11	10	11	10
1995	fish.	2	5	4	4	3	5	7	7	6	10	12	12	13	15	15	14	16	19	17	17	20	19	19	18	20	20	21
1996	fish.	3	5	5	5	9	9	10	12	12	15	15	18	18	20	19	19	21	20	20	21	20	20	20	20	19	20	21
1997	fish.	4	3	4	3	4	5	5	3	4	5	5	7	7	7	8	8	8	8	5	8	9	9	10	9	10	10	10
1998	fish.	10	9	8	9	10	10	12	10	11	11	11	14	13	14	15	14	16	17	15	15	16	16	17	17	17	17	17
1999	fish.	6	6	6	7	10	8	15	14	14	16	15	18	19	17	18	19	20	19	21	20	19	20	19	19	20	20	20
2000	fish.	5	9	12	14	13	13	17	18	19	19	22	21	22	21	22	21	22	22	23	23	22	24	23	23	24	22	25
2001	fish.	8	8	11	12	11	12	13	13	12	13	16	12	13	13	15	16	16	17	15	18	18	17	18	19	19	20	21
2002	fish.	8	11	11	9	10	10	9	11	11	11	10	10	12	10	11	13	12	12	11	15	14	16	14	12	12	13	15
2003	fish.	2	3	5	3	4	7	8	9	10	8	11	11	10	10	10	12	12	13	13	16	16	17	18	17	18	17	17
2004	fish.	6	5	6	7	6	7	7	8	8	9	8	10	11	9	12	11	12	14	11	14	13	13	14	14	14	15	14
2005	fish.	3	3	4	5	7	6	7	7	10	10	10	8	11	12	12	11	13	15	14	14	15	16	14	16	16	15	15
2006	fish.	4	0	2	3	6	5	7	6	7	11	9	11	10	11	11	14	12	12	14	13	13	13	15	13	16	15	14
2007	fish.	6	7	6	7	8	7	8	9	10	12	11	10	13	13	15	13	16	15	14	15	15	16	15	17	18	18	18
2008	fish.	6	6	7	9	12	12	15	12	15	16	15	16	17	19	18	17	17	22	16	20	19	20	19	19	20	21	19
2009	fish.	8	9	7	7	10	8	9	9	9	11	8	9	13	12	11	12	12	14	14	13	14	17	18	14	16	19	18
2010	fish.	7	7	11	9	12	12	11	12	13	12	11	12	15	15	15	15	16	15	14	17	16	18	15	14	16	17	17
2011	fish.	0	0	0	1	1	1	2	4	4	6	5	5	8	8	9	8	9	8	10	10	10	9	10	11	11	11	11
2012	fish.	1	1	2	0	4	2	1	2	1	3	2	3	4	5	2	4	5	4	5	6	6	5	6	7	6	6	7
1980	surv.	197	238	293	452	385	461	477	594	1094	977	1388	1857	1582	1881	1705	1215	1065	810	570	616	572	498	366	282	366	481	360
1983	surv.	168	200	189	175	296	515	301	460	417	362	415	462	572	515	596	719	849	694	726	613	497	561	660	767	707	586	735
1986	surv.	949	760	709	539	577	577	525	537	573	541	672	492	517	473	500	422	525	372	359	476	327	334	350	288	337	317	356
1991	surv.	626	534	502	341	324	215	216	123	179	119	147	157	158	155	126	167	142	138	157	141	216	215	180	256	248	238	261
1994	surv.	121	111	125	94	76	107	148	118	160	172	225	228	242	212	249	186	188	188	200	182	180	259	220	211	231	239	245
1997	surv.	204	215	237	224	134	108	109	113	88	66	99	111	118	135	192	161	177	181	227	242	238	289	382	290	405	379	280
2000	surv.	84	45	39	9	65	52	47	132	207	264	201	253	231	265	262	310	271	284	263	245	290	254	353	374	346	387	329
2002	surv.	448	453	387	325	290	223	207	234	213	229	241	293	305	335	270	231	288	293	338	235	318	242	250	201	208	157	138
2004	surv.	52	64	54	71	58	83	75	76	58	89	117	134	168	171	206	171	171	198	153	188	199	198	197	166	257	205	173
2006	surv.	18	27	24	57	38	74	40	43	58	67	92	116	122	161	169	175	195	149	158	116	117	132	73	111	96	91	122
2010	surv.	88	49	71	68	60	81	93	110	171	221	237	278	299	301	277	315	346	358	352	313	299	312	264	220	280	252	199

Table 2.2.1.5 (page 3 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
1982	fish.	12	11	11	11	11	11	11	11	12	11	10	12	10	11	10	11	8	9	9	9	11	8	10	9	8	8	7	9	7
1983	fish.	8	8	7	8	6	7	9	8	7	7	7	7	8	7	7	6	7	7	8	5	5	4	6	4	4	7	6	4	7
1984	fish.	11	11	11	12	11	11	12	11	11	12	12	10	12	10	10	11	10	11	9	11	9	10	9	8	9	8	8	8	9
1991	fish.	18	18	19	17	19	19	19	20	19	18	20	19	20	20	19	20	18	20	18	19	19	19	18	19	20	18	18	17	16
1992	fish.	16	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16	16	16	17	17	17	17	17	17	17
1993	fish.	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10	9	10	10	10	10	10	10	10	10	10	9	9	9	10
1994	fish.	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	10	10	10	10	10	10	11	10	10	10	11
1995	fish.	21	19	20	20	21	20	21	20	19	20	21	20	20	20	17	20	19	20	19	19	19	19	20	19	19	20	19	19	19
1996	fish.	20	21	22	20	20	22	21	22	20	21	22	22	22	22	22	21	21	22	22	21	21	22	22	21	21	19	21	20	21
1997	fish.	10	10	10	10	10	9	9	10	10	9	9	10	10	10	10	9	9	9	9	8	9	9	9	10	10	10	9	8	10
1998	fish.	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16	17	17
1999	fish.	19	20	20	19	19	19	19	19	19	21	21	20	20	19	20	20	19	20	19	17	19	18	20	20	17	18	18	18	17
2000	fish.	25	24	25	25	24	25	24	24	24	24	25	21	22	21	23	21	23	22	21	22	19	23	20	21	20	24	18	23	21
2001	fish.	21	22	21	20	22	23	21	22	20	22	21	22	23	22	23	19	22	21	19	21	21	19	17	18	17	15	16	14	16
2002	fish.	14	14	16	15	18	16	15	16	14	17	16	16	17	16	15	15	13	13	15	17	15	14	14	15	12	12	12	11	11
2003	fish.	18	18	15	18	17	12	17	14	14	15	15	13	15	14	15	13	12	13	11	9	12	10	14	12	10	10	12	10	11
2004	fish.	18	17	16	17	16	15	15	16	16	17	13	17	15	15	15	13	13	15	16	14	13	14	15	15	14	11	13	13	13
2005	fish.	16	16	15	16	16	15	16	14	15	13	16	14	15	15	15	14	16	14	15	16	12	13	14	14	14	13	10	15	13
2006	fish.	14	16	14	18	16	16	16	14	15	16	14	15	13	15	17	12	15	13	15	12	14	14	15	16	14	14	14	13	13
2007	fish.	17	18	17	17	16	18	17	18	17	16	17	16	16	17	16	16	15	15	16	16	16	16	13	14	16	15	16	16	17
2008	fish.	23	20	21	21	23	24	23	20	24	21	21	23	24	21	18	23	22	24	21	21	18	18	20	21	20	20	18	19	20
2009	fish.	16	18	18	18	18	18	18	18	19	15	16	15	15	15	14	14	15	13	16	11	13	14	16	15	14	15	14	14	15
2010	fish.	21	20	20	18	16	17	22	20	21	21	23	21	24	21	21	21	19	22	22	17	21	20	18	18	19	19	20	19	16
2011	fish.	11	10	11	9	10	9	9	10	10	9	7	9	10	8	6	8	8	7	8	9	7	7	7	6	6	6	6	5	6
2012	fish.	8	8	7	7	6	8	8	7	7	6	7	7	6	7	7	8	7	7	7	7	8	8	7	7	7	7	8	6	7
1980	surv.	387	588	320	419	576	443	568	436	451	283	386	355	216	230	164	176	362	352	379	250	208	271	102	42	115	190	148	103	166
1983	surv.	961	576	772	498	535	725	598	623	539	482	582	482	473	511	498	510	505	317	495	294	255	187	275	201	83	76	92	225	53
1986	surv.	515	427	448	472	511	533	569	437	364	487	586	402	365	363	194	248	247	158	139	142	110	65	74	70	60	53	52	80	21
1991	surv.	297	191	263	340	335	335	273	292	253	285	249	250	207	189	229	240	169	172	158	131	127	136	96	115	102	47	66	61	87
1994	surv.	302	297	301	258	293	280	313	270	284	302	265	329	192	206	215	188	131	181	116	170	149	127	184	130	148	109	127	219	158
1997	surv.	359	323	277	228	285	302	241	190	131	180	139	128	140	123	84	62	78	82	74	79	53	58	50	54	59	52	43	50	75
2000	surv.	321	315	308	333	235	228	209	164	180	150	172	143	165	174	120	94	98	86	58	54	71	43	56	39	50	43	29	25	34
2002	surv.	147	153	122	135	119	130	121	112	125	124	115	148	168	160	151	118	130	156	162	159	165	122	141	115	121	96	45	91	90
2004	surv.	199	226	229	241	230	199	178	185	202	208	142	170	163	163	140	147	121	96	149	117	119	97	99	118	90	35	58	61	42
2006	surv.	113	90	98	130	64	100	89	101	73	107	106	88	84	99	80	83	91	102	105	101	63	116	69	62	89	80	82	100	59
2010	surv.	160	168	180	231	245	227	163	135	130	126	119	92	116	87	61	72	60	35	66	42	54	35	13	42	30	29	35	23	25

Table 2.2.1.5 (page 4 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1982	fish.	3	5	6	5	1	4	4	3	0	4	2	2	2	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1983	fish.	3	4	6	4	3	3	2	4	4	3	2	2	1	3	0	1	0	1	0	1	0	0	0	0	0	1	0	0	1
1984	fish.	8	9	6	8	5	3	7	4	5	5	3	3	5	4	4	4	1	1	1	0	0	0	1	0	0	0	0	0	0
1991	fish.	18	17	16	16	13	13	14	10	10	10	9	10	8	6	6	3	2	1	1	0	0	1	1	1	0	0	0	0	0
1992	fish.	17	17	17	17	17	17	16	17	17	15	15	14	16	13	15	12	11	9	10	11	10	5	4	3	3	0	2	1	1
1993	fish.	9	10	10	9	10	9	9	9	9	9	9	9	9	9	8	9	8	7	8	7	6	5	3	2	3	2	1	0	1
1994	fish.	10	11	10	10	10	9	9	10	10	8	11	10	7	9	7	5	6	6	7	4	5	4	3	4	3	2	1	1	1
1995	fish.	19	19	20	19	19	20	19	17	19	17	18	16	16	16	15	12	13	11	11	9	6	8	4	6	3	3	0	1	2
1996	fish.	20	20	21	19	20	20	18	19	19	17	17	17	17	19	18	16	16	12	12	12	7	8	9	3	3	4	1	0	5
1997	fish.	9	10	10	10	9	10	9	9	9	10	8	10	10	9	9	8	8	8	8	8	8	6	9	8	6	2	2	2	5
1998	fish.	17	17	17	16	17	17	17	17	16	17	17	17	17	16	15	16	16	15	13	11	12	10	10	7	6	4	3	4	14
1999	fish.	18	14	15	17	15	17	15	17	15	17	15	15	14	14	13	15	13	12	12	10	10	8	10	6	2	5	2	4	11
2000	fish.	22	19	22	18	20	20	19	20	19	20	18	20	19	19	21	19	18	18	19	15	13	13	11	9	9	5	2	2	12
2001	fish.	16	16	16	16	16	14	17	16	17	15	13	15	15	16	17	15	13	13	13	12	11	11	11	10	8	8	7	8	12
2002	fish.	12	11	12	12	11	11	11	10	12	10	10	11	12	8	8	6	8	6	7	6	7	5	2	1	3	1	1	1	0
2003	fish.	9	9	11	10	9	8	7	9	9	7	6	5	7	5	5	4	6	3	4	3	5	2	2	1	2	0	2	2	2
2004	fish.	12	12	11	13	13	11	12	12	11	12	10	11	12	12	11	11	10	8	9	5	6	4	5	4	4	1	3	2	2
2005	fish.	12	12	13	12	12	12	11	11	11	10	10	10	9	11	9	8	8	7	5	5	4	3	4	2	2	2	1	1	6
2006	fish.	13	12	11	12	13	12	13	13	11	13	12	10	10	12	9	9	10	9	7	7	5	5	4	5	1	1	3	2	5
2007	fish.	15	14	14	15	15	13	14	16	12	14	13	14	12	12	12	13	12	10	6	6	10	8	5	5	4	3	2	1	0
2008	fish.	21	18	21	20	20	18	18	19	19	19	19	19	19	18	17	15	17	16	14	15	14	12	8	7	7	4	5	4	24
2009	fish.	16	16	15	17	14	13	17	14	16	13	14	12	12	13	13	14	13	12	13	11	9	10	10	7	4	2	0	1	1
2010	fish.	16	19	18	16	18	19	17	22	18	17	17	19	15	16	18	16	15	15	14	12	13	9	8	9	8	7	3	1	9
2011	fish.	6	6	6	5	7	6	5	7	5	6	5	6	6	5	5	6	4	3	4	4	3	3	2	4	2	1	1	2	4
2012	fish.	6	7	7	7	6	6	5	6	6	7	6	5	7	7	5	5	5	5	2	2	3	2	1	1	1	1	1	2	4
1980	surv.	30	95	58	55	22	48	18	31	15	15	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	surv.	17	56	36	36	36	47	9	6	54	4	1	5	3	7	4	13	0	3	0	0	0	0	0	0	0	0	0	0	0
1986	surv.	22	29	31	26	16	25	23	14	23	2	3	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1991	surv.	62	43	23	28	13	24	8	25	8	4	10	0	6	7	3	13	1	1	0	0	0	0	0	3	0	0	0	0	0
1994	surv.	159	130	97	103	119	76	58	76	22	33	20	28	20	10	14	5	0	5	3	0	0	5	5	0	0	0	0	0	0
1997	surv.	61	24	61	18	46	30	42	48	26	27	55	18	7	21	17	2	7	6	6	0	3	3	0	0	0	0	0	0	0
2000	surv.	26	12	27	20	17	12	19	16	9	3	8	11	6	8	11	2	22	3	3	3	0	0	0	1	0	0	0	0	0
2002	surv.	31	61	50	34	28	23	24	14	14	11	17	37	2	19	7	7	6	0	4	0	9	0	0	3	0	0	0	0	0
2004	surv.	54	51	38	35	24	31	21	37	21	13	18	15	12	12	4	5	7	2	0	2	0	0	0	0	0	0	0	0	0
2006	surv.	34	36	28	59	40	32	22	31	30	11	20	10	35	6	9	13	17	7	0	3	7	5	2	0	2	0	0	0	0
2010	surv.	23	18	28	15	16	22	12	31	23	41	12	13	7	17	8	12	12	8	6	11	2	1	0	2	0	0	0	0	0

Table 2.2.1.6. Survey biomass (t) by area with coefficients of variation (CV), 1980-2010.

Survey biomass (t)

Year	S. Bering Sea	Eastern	Central	Western	All areas
1980	66,324	33,883	37,934	10,132	148,272
1983	28,246	51,742	66,153	69,613	215,755
1986	22,445	50,015	134,235	48,377	255,072
1991	8,286	64,926	42,323	75,514	191,049
1994	31,084	78,081	51,538	23,365	184,068
1997	10,742	28,239	30,252	14,183	83,416
2000	9,157	47,117	36,456	43,298	136,028
2002	9,601	25,241	24,327	23,802	82,970
2004	31,964	51,851	20,709	9,637	114,161
2006	7,410	43,349	22,033	19,734	92,526
2010	12,608	23,184	11,100	21,269	68,161

Coefficient of variation

Year	S. Bering Sea	Eastern	Central	Western	All areas
1980	0.344	0.215	0.464	0.175	0.201
1983	0.329	0.192	0.069	0.395	0.144
1986	0.295	0.125	0.478	0.314	0.261
1991	0.285	0.370	0.119	0.092	0.134
1994	0.375	0.301	0.390	0.286	0.183
1997	0.354	0.230	0.208	0.263	0.126
2000	0.220	0.222	0.270	0.429	0.173
2002	0.199	0.329	0.266	0.243	0.147
2004	0.355	0.304	0.208	0.169	0.175
2006	0.206	0.545	0.188	0.230	0.264
2010	0.231	0.230	0.258	0.410	0.161

Table 2.2.1.7. Parameters other than recruitment *dev*s, growth *dev*s (Model 2 only), and fishing mortality rates estimated by Models 1 and 2, with standard deviations.

	Model 1		Model 2	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	17.988	0.155	20.246	0.532
Asymptotic length (cm)	117.274	2.150	125.056	3.597
Brody growth coefficient	0.186	0.005	0.163	0.007
SD of length at age 1 (cm)	2.820	0.105	2.174	0.072
SD of length at age 20 (cm)	11.294	0.455	12.719	0.471
ln(mean post-1976 recruitment)	10.953	0.050	10.768	0.051
ln(pre-1977 recruitment offset)	-0.638	0.146	-0.124	0.177
Initial age 3 ln(abundance) dev	-0.044	0.377	0.042	0.411
Initial age 2 ln(abundance) dev	0.718	0.175	-0.130	0.465
Initial age 1 ln(abundance) dev	-0.843	0.316	-0.008	0.323
Initial fishing mortality	0.009	0.002	0.010	0.003
Fishery beginning_of_peak_region	109.221	8.374	105.764	6.903
Fishery ascending_width	7.611	0.182	7.464	0.163
Survey beginning_of_peak_region	3.495	0.098	3.525	0.119
Survey width_of_peak_region	-9.538	12.118	-1.416	1.068
Survey ascending_width	0.718	0.164	0.791	0.184
Survey descending_width	2.557	0.121	-1.559	10.458
Survey initial_selectivity	-7.342	0.368	-6.952	0.370
Survey final_selectivity	-9.783	6.222	-9.806	5.624
Survey ascending_width dev_1980	-0.113	0.017	-0.102	0.020
Survey ascending_width dev_1983	-0.090	0.015	-0.094	0.017
Survey ascending_width dev_1986	0.014	0.025	0.024	0.030
Survey ascending_width dev_1991	0.082	0.027	0.075	0.030
Survey ascending_width dev_1994	0.166	0.029	0.174	0.033
Survey ascending_width dev_1997	0.004	0.015	0.020	0.016
Survey ascending_width dev_2000	-0.008	0.016	-0.012	0.017
Survey ascending_width dev_2002	0.039	0.018	0.025	0.018
Survey ascending_width dev_2004	-0.048	0.018	-0.041	0.017
Survey ascending_width dev_2006	0.053	0.020	0.056	0.022

Table 2.2.1.8. Recruitment *dev*s estimated my Models 1 and 2, with standard deviations.

	Model 1		Model 2	
Year	Estimate	St. Dev.	Estimate	St. Dev.
1977	0.915	0.113	1.333	0.131
1978	0.169	0.213	0.175	0.284
1979	0.449	0.117	0.543	0.146
1980	0.169	0.125	-0.056	0.224
1981	1.514	0.142	1.396	0.175
1982	0.005	0.257	-0.523	0.431
1983	1.020	0.117	0.800	0.141
1984	1.500	0.152	1.199	0.211
1985	-1.536	0.448	-0.921	0.483
1986	1.543	0.138	0.120	0.928
1987	0.562	0.196	1.017	0.173
1988	-0.074	0.167	-0.088	0.155
1989	1.270	0.083	1.103	0.096
1990	-0.764	0.243	-0.819	0.281
1991	0.045	0.106	-0.163	0.123
1992	-1.016	0.146	-1.064	0.156
1993	0.870	0.086	0.710	0.092
1994	-0.920	0.197	-0.856	0.254
1995	0.242	0.117	-0.132	0.121
1996	0.897	0.097	0.697	0.102
1997	0.095	0.110	0.048	0.129
1998	-0.500	0.153	-0.767	0.174
1999	0.394	0.087	0.261	0.095
2000	0.291	0.089	0.384	0.089
2001	-0.537	0.129	-0.332	0.140
2002	-0.567	0.175	-0.351	0.154
2003	-0.346	0.121	-0.079	0.113
2004	-1.857	0.241	-1.286	0.219
2005	-0.237	0.139	-0.109	0.167
2006	-0.432	0.148	-0.200	0.177
2007	-0.410	0.124	0.002	0.142
2008	-1.402	0.208	-1.024	0.210
2009	-0.803	0.336	-0.604	0.349
2010	-0.548	0.471	-0.415	0.479

Table 2.2.1.9. Growth parameter *dev*s for mid-year length at age 1 (*L1*) and asymptotic length (*Linf*) estimated by Model 2.

	L1 dev s		*Linf dev* s	
Year	Estimate	St. Dev.	Estimate	St. Dev.
1977	0.008	0.086	-0.144	0.048
1978	0.022	0.075	0.178	0.050
1979	0.008	0.078	-0.045	0.058
1980	0.000	0.079	-0.037	0.071
1981	-0.090	0.068	-0.109	0.066
1982	0.013	0.101	-0.124	0.061
1983	-0.026	0.068	-0.132	0.067
1984	0.045	0.069	0.050	0.065
1985	0.235	0.042	-0.053	0.053
1986	0.073	0.124	-0.051	0.070
1987	0.191	0.115	-0.175	0.084
1988	-0.001	0.088	-0.113	0.121
1989	-0.010	0.069	0.088	0.068
1990	0.016	0.037	-0.004	0.064
1991	-0.014	0.078	-0.032	0.066
1992	0.018	0.071	-0.039	0.067
1993	-0.191	0.027	-0.004	0.056
1994	-0.017	0.087	-0.035	0.068
1995	0.021	0.075	0.079	0.054
1996	0.121	0.028	0.050	0.066
1997	0.010	0.073	0.068	0.066
1998	-0.049	0.076	-0.026	0.041
1999	-0.153	0.036	-0.010	0.056
2000	-0.106	0.073	-0.044	0.064
2001	-0.042	0.035	0.104	0.037
2002	0.023	0.075	0.098	0.055
2003	0.017	0.044	0.055	0.046
2004	0.061	0.083	0.140	0.059
2005	-0.071	0.031	0.060	0.045
2006	0.005	0.085	0.091	0.068
2007	0.023	0.081	0.097	0.063
2008	-0.018	0.074	0.033	0.069
2009	-0.106	0.038	0.035	0.058
2010	-0.014	0.099	-0.032	0.069

Table 2.2.1.10. Fishing mortality rates as estimated by Models 1 and 2.

	Fishing mortality rate	
Year	Model 1	Model 2
1977	0.029	0.034
1978	0.029	0.028
1979	0.050	0.041
1980	0.050	0.040
1981	0.059	0.050
1982	0.059	0.056
1983	0.052	0.057
1984	0.043	0.049
1985	0.032	0.037
1986	0.027	0.034
1987	0.045	0.066
1988	0.016	0.027
1989	0.013	0.021
1990	0.019	0.030
1991	0.024	0.038
1992	0.108	0.175
1993	0.091	0.152
1994	0.062	0.104

	Fishing mortality rate	
Year	Model 1	Model 2
1995	0.051	0.083
1996	0.110	0.167
1997	0.100	0.146
1998	0.157	0.231
1999	0.143	0.221
2000	0.220	0.366
2001	0.206	0.348
2002	0.199	0.313
2003	0.223	0.336
2004	0.216	0.295
2005	0.183	0.222
2006	0.180	0.200
2007	0.309	0.309
2008	0.337	0.316
2009	0.421	0.378
2010	0.493	0.434
2011	0.226	0.197

Table 2.2.1.11. Fit to survey abundance (1000s of fish, "Observed") obtained by Models 1 and 2. "Expected" shows estimate for each model. "Residual" shows ln(observed/expected). The bottom row under "Residual" shows the mean for each column. Ideally, this value should be close to zero. A positive mean implies that the model tends to be biased low. Squared standardized residuals ("Squared std. res.") shows $(\ln(\text{observed/expected})/\sigma)^2$. The bottom row under "Squared std. res." shows the root mean squared error. Ideally, this value should be close to unity.

			Expected		Residual		Squared std. res.	
Year	Observed	Sigma	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
1980	57,036	0.156	41,040	54,403	0.329	0.047	4.452	0.092
1983	70,402	0.131	56,583	54,408	0.219	0.258	2.804	3.900
1986	109,969	0.226	127,501	90,234	-0.148	0.198	0.429	0.767
1991	70,557	0.214	127,044	87,004	-0.588	-0.210	7.574	0.961
1994	62,333	0.266	86,432	63,933	-0.327	-0.025	1.510	0.009
1997	28,724	0.137	53,822	39,668	-0.628	-0.323	21.071	5.569
2000	47,231	0.207	58,291	39,930	-0.210	0.168	1.030	0.656
2002	30,560	0.139	58,786	42,106	-0.654	-0.320	22.152	5.316
2004	29,224	0.132	36,878	30,542	-0.233	-0.044	3.096	0.111
2006	24,649	0.153	31,430	32,000	-0.243	-0.261	2.523	2.910
2010	24,617	0.121	21,988	25,341	0.113	-0.029	0.875	0.058
					-0.216	-0.049	2.477	1.360

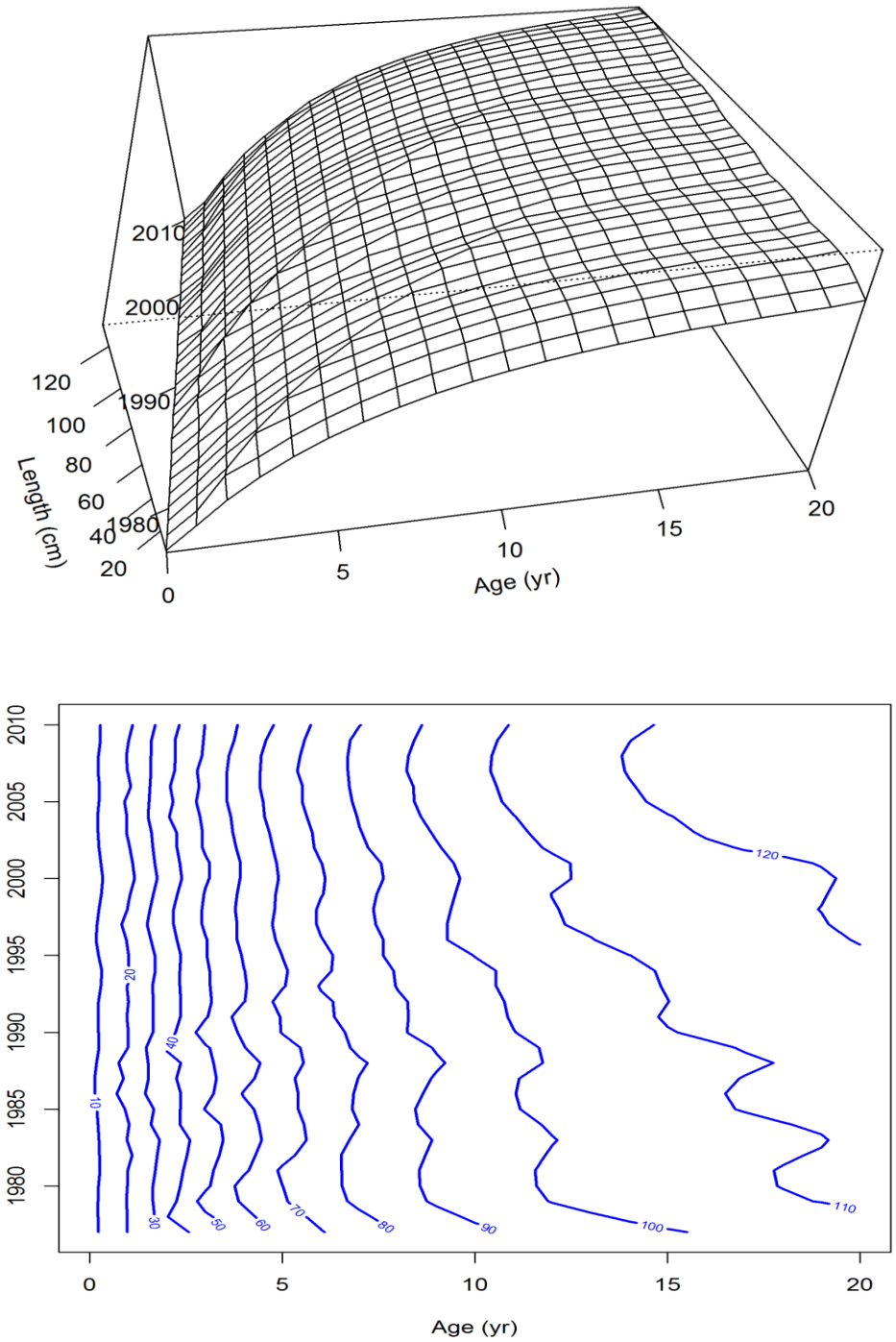

Figure 2.2.1.1. Time-varying length at age as estimated by Model 2, shown as a surface plot (upper panel) and as a contour plot (lower panel).

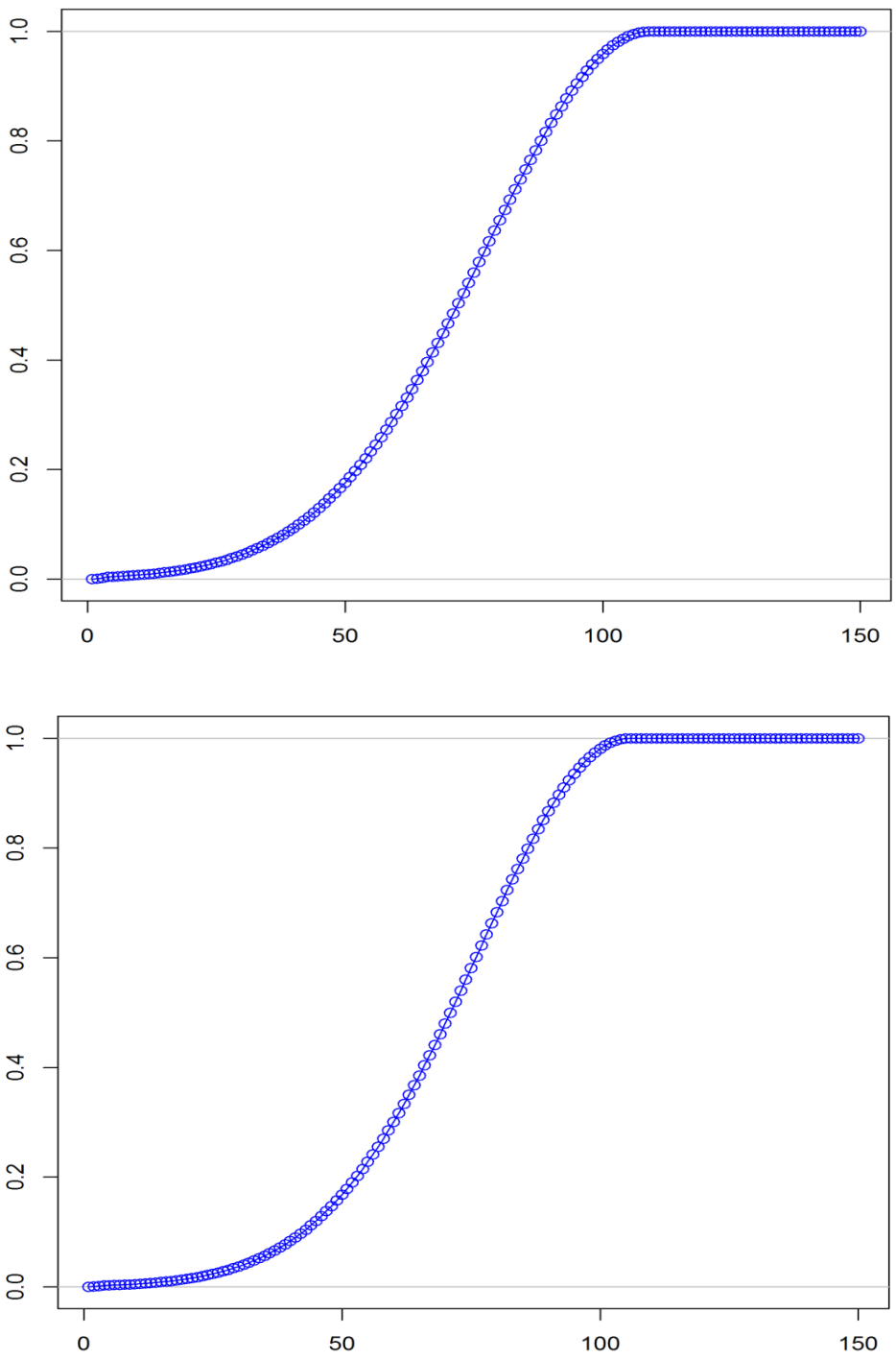

Figure 2.2.1.2. Fishery selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel).

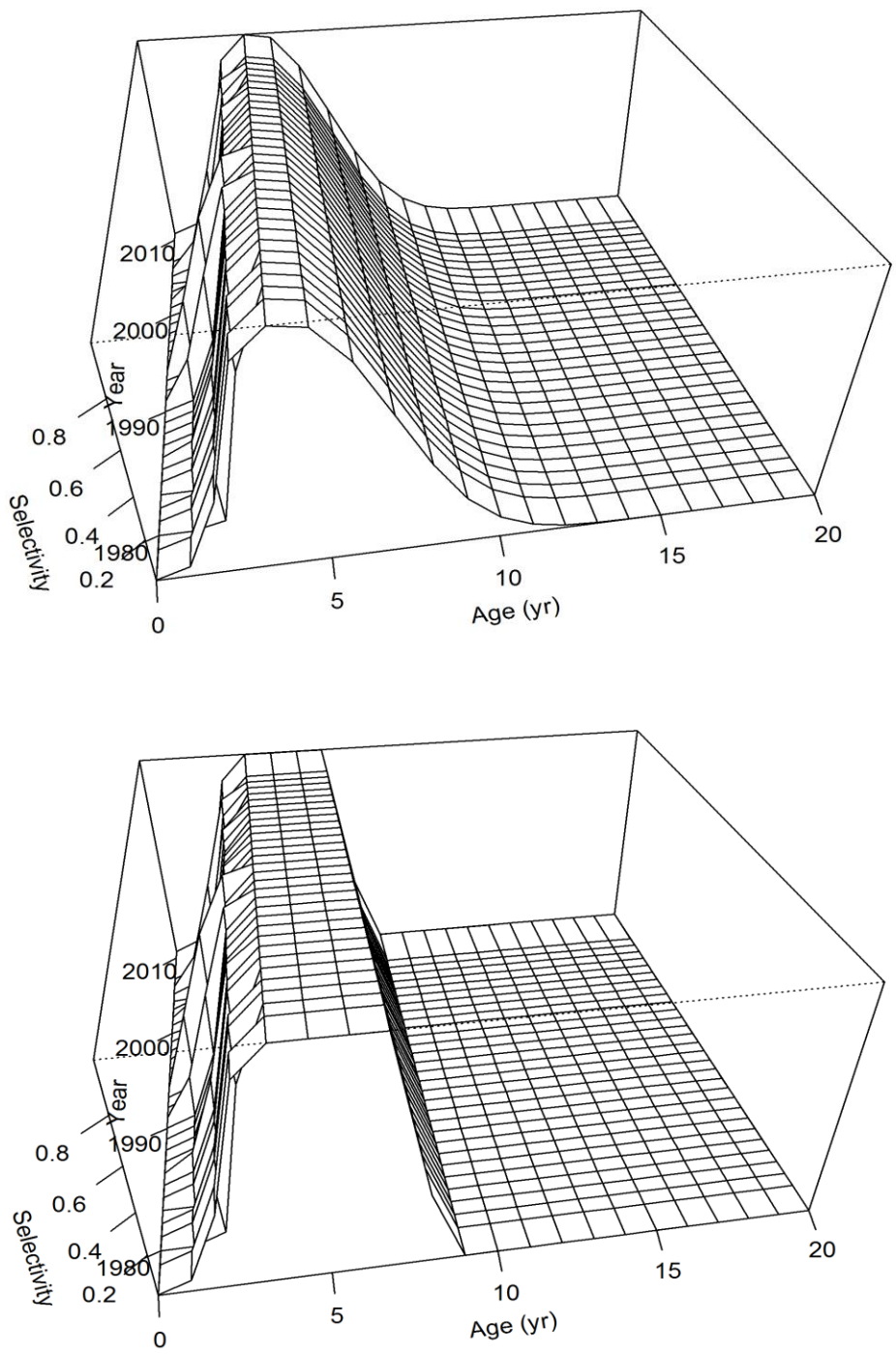

Figure 2.2.1.3a. Time-varying survey selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel), shown as surface plots.

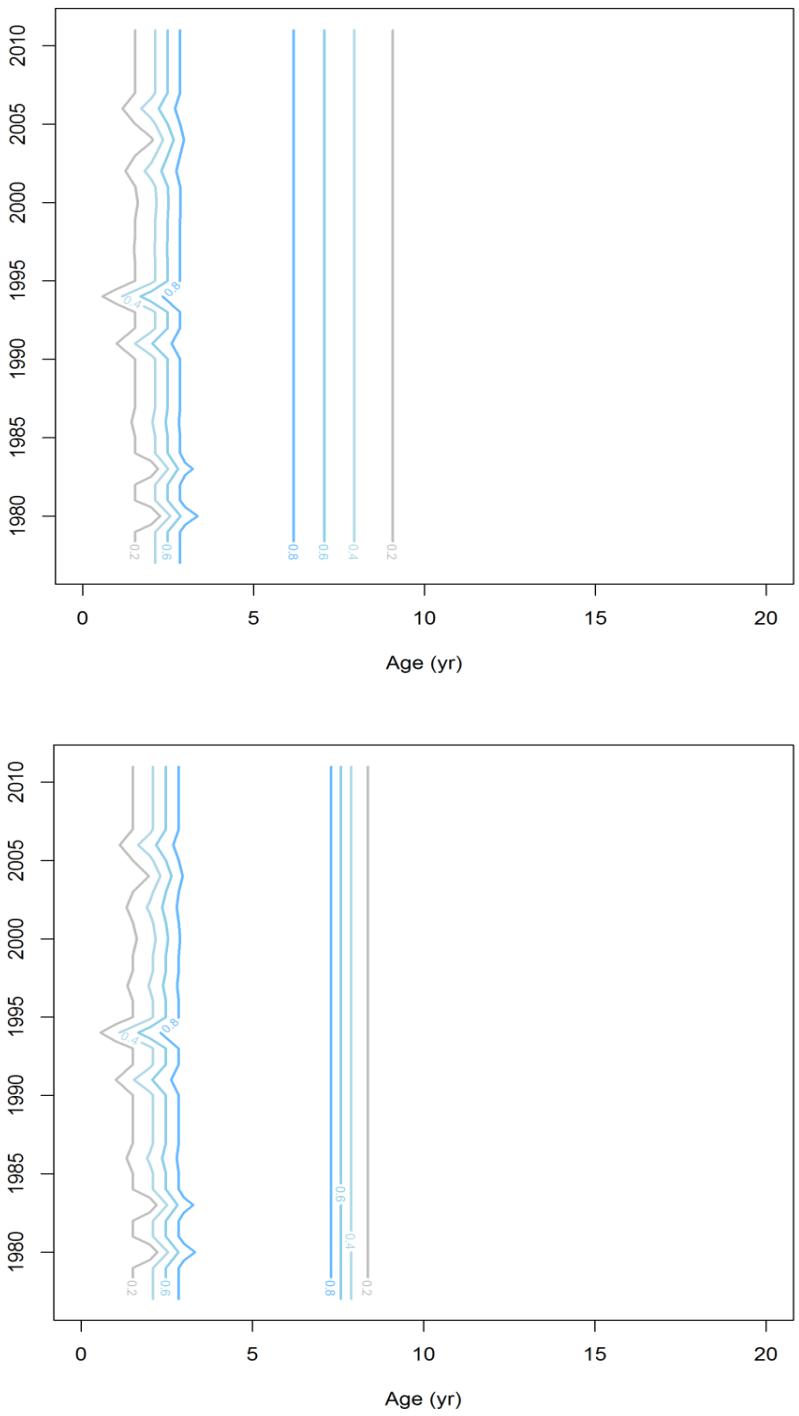

Figure 2.2.1.3b. Time-varying survey selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel), shown as contour plots.

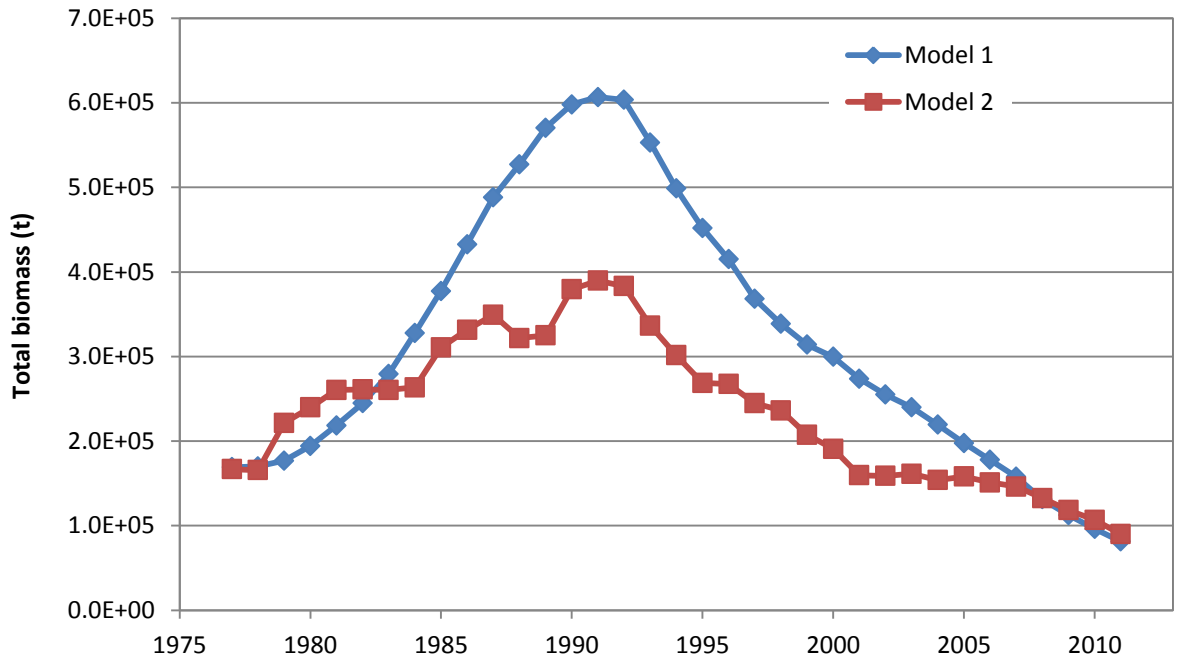

Figure 2.2.1.4. Time series of total (age 0+) biomass (t) as estimated by Models 1 and 2.

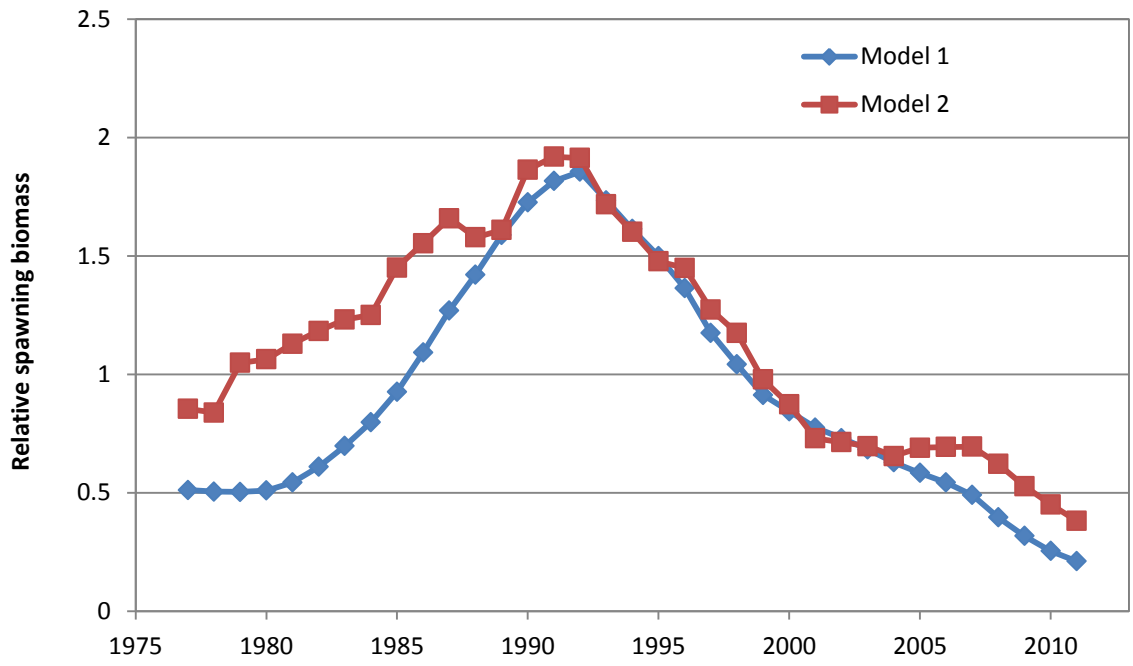

Figure 2.2.1.5. Time series of spawning biomass relative to $B_{100\%}$ as estimated by Models 1 and 2.

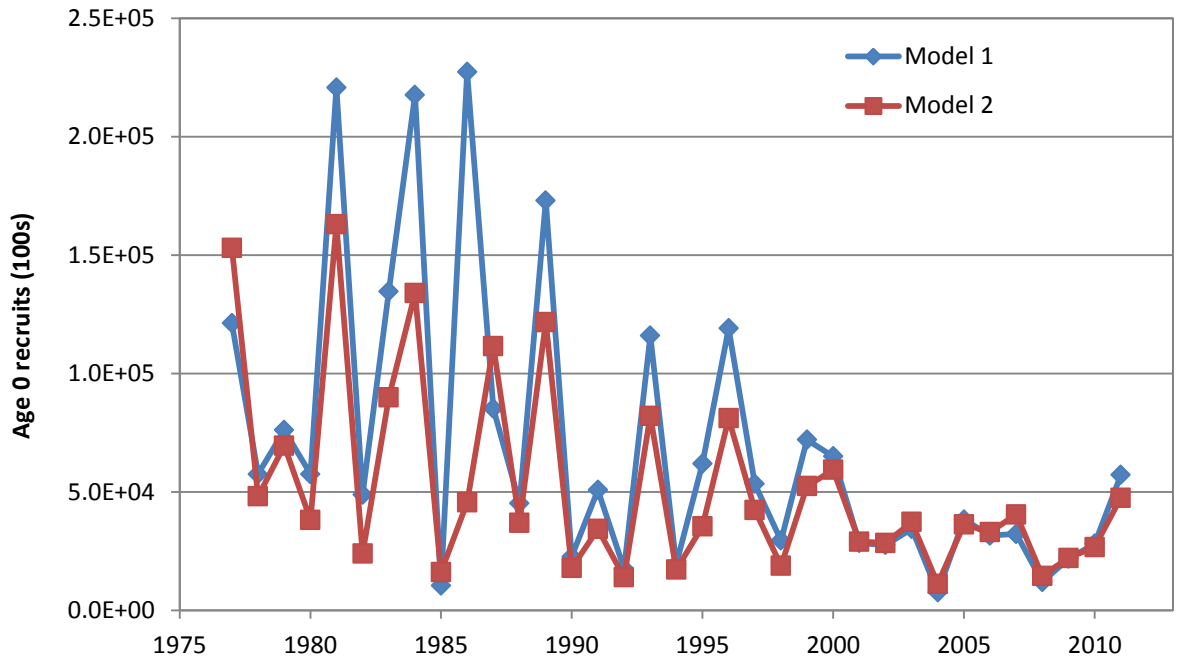

Figure 2.2.1.6. Time series of age 0 recruits (1000s) as estimated by Models 1 and 2.

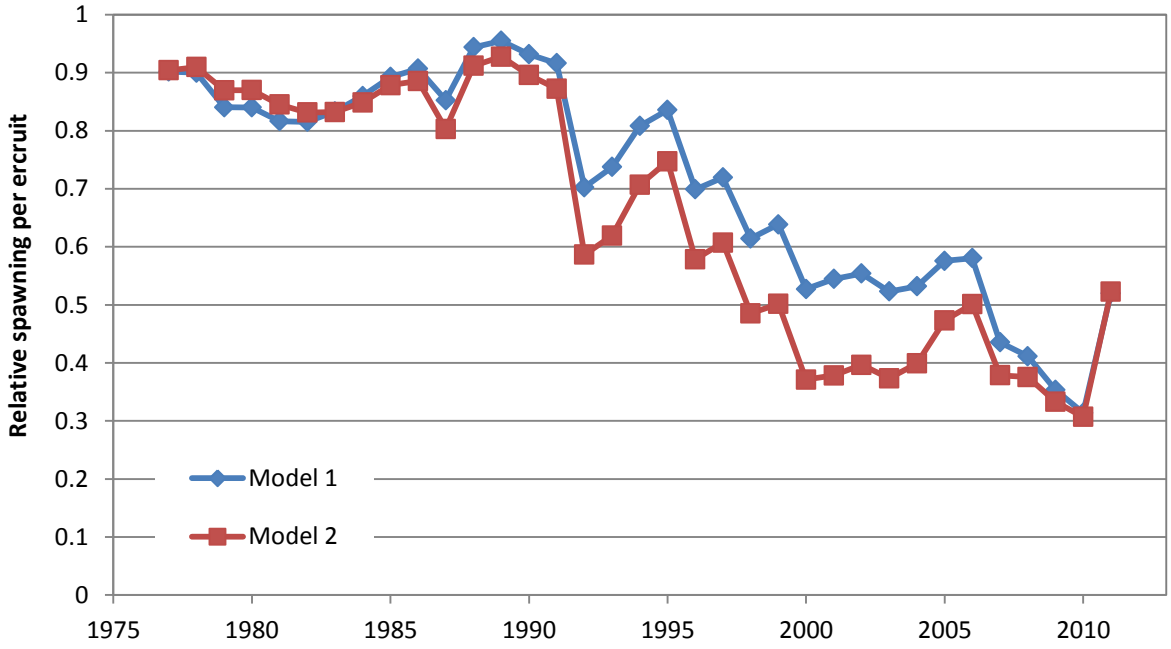

Figure 2.2.1.7. Time series of relative spawning per recruit (RSPR) corresponding to fishing mortality rates as estimated by Models 1 and 2 (higher fishing mortality corresponds to lower RSPR).

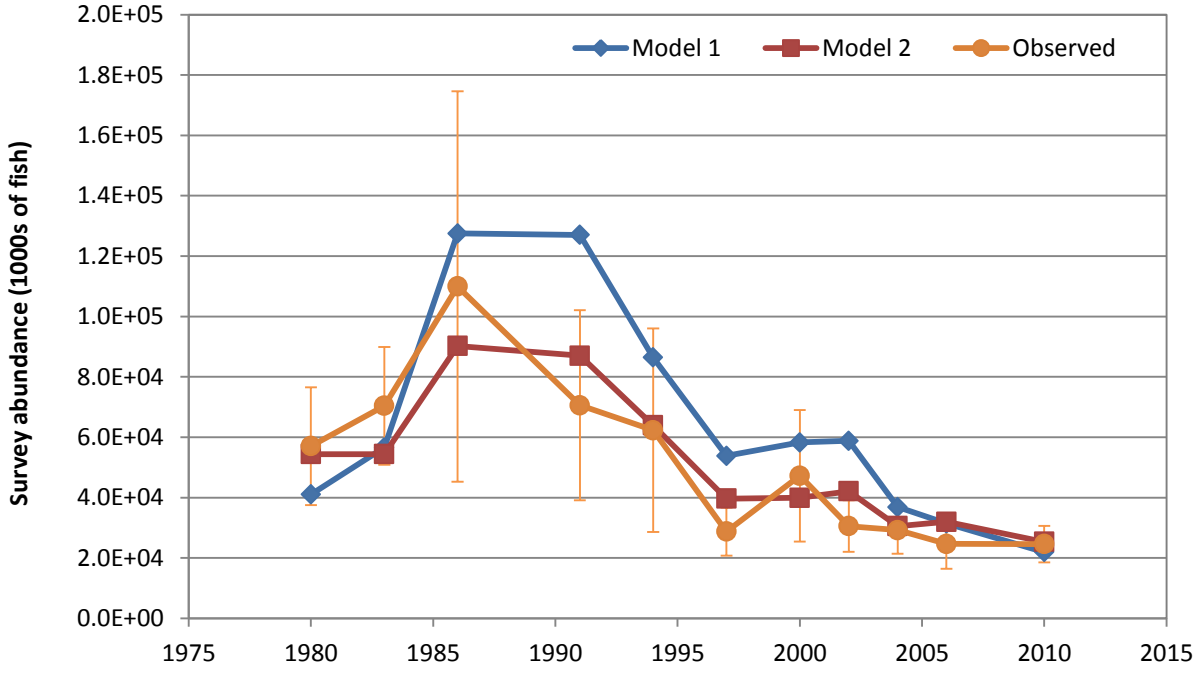

Figure 2.2.1.8. Estimates of survey abundance (1000s of fish) obtained by Models 1 and 2, with point estimates and 95% confidence intervals from the survey ("Observed").