Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2006

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Executive Summary

Stock

This assessment reports the status of the coastal Pacific hake (*Merluccius productus*) resource off the west coast of the United States and Canada. The coastal stock of Pacific hake is currently the most abundant groundfish population in the California Current system. Smaller populations of hake occur in the major inlets of the north Pacific Ocean, including the Strait of Georgia, Puget Sound, and the Gulf of California. However, the coastal stock is distinguished from the inshore populations by larger body size, seasonal migratory behavior, and a pattern of low median recruitment punctuated by extremely large year classes. The population is modeled as a single stock, but the United States and Canadian fishing fleets are treated separately in order to capture some of the spatial variability in Pacific hake distribution.

Catches

Fishery landings from 1966 to 2005 have averaged 214 thousand mt, with a low of 90 thousand mt in 1980 and a peak harvest of 362 thousand mt in 1994. Recent landings have been above the long term average, at 335 thousand mt in 2004, and 360 thousand mt in 2005. Catches in both of these years were predominately comprised by the large 1999 year class. The United States has averaged 159 thousand mt, or 74.6% of the total landings over the time series, with Canadian catch averaging 54 thousand mt. The 2004 and 2005 landings had similar distributions, with 62.9 and 72.1%, respectively, harvested by the United States fishery. The current model assumes no discarding mortality of pacific hake.

Table a. Recent commercial fishery landings (1000s mt).

Year	US at-sea	US shore based	US tribal	US total	Canadian foreign and JV	Canadian shore based	Canadian total	Total
1996	113	85	15	213	67	26	93	306
1997	121	87	25	233	43	49	92	325
1998	120	88	25	233	40	48	88	321
1999	115	83	26	225	17	70	87	312
2000	116	86	7	208	16	6	22	231
2001	102	73	7	182	22	32	54	236
2002	63	46	23	132	0	51	51	183
2003	67	55	21	143	0	62	62	206
2004	90	96	24	210	59	65	124	335
2005	150	86	24	260	15	85	100	360

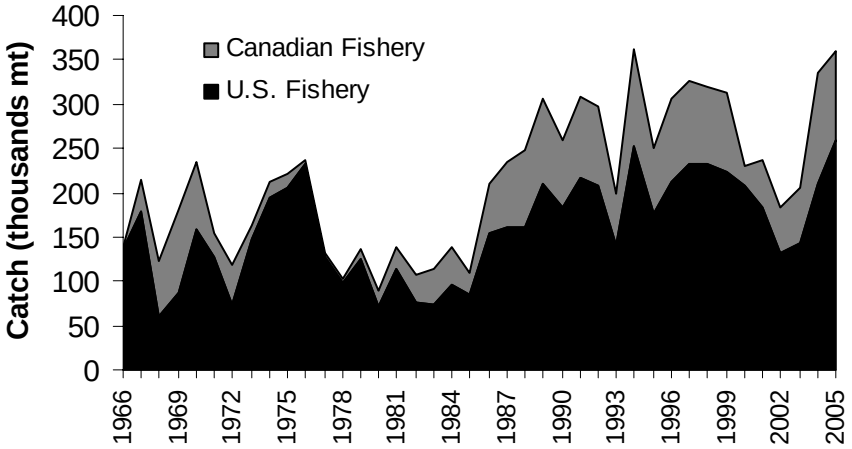


Figure a. Pacific whiting landings (1000s mt) by nation, 1966-2005.

Data and assessment

Age-structured assessment models of various forms have been used to assess Pacific hake since the early 1980's, using total fishery catches, fishery age compositions and abundance indices. In 1989, the hake population was modeled using a statistical catch-at-age model (Stock Synthesis) that utilizes fishery catch-at-age data and survey estimates of population biomass and age-composition data (Dorn and Methot, 1991). The model was then converted to AD Model Builder (ADMB) in 1999 by Dorn (1999), using the same basic population dynamics equations. This allowed the assessment to take advantage of ADMB's post-convergence routines to calculate standard errors (or likelihood profiles) for any quantity of interest. Since 2001, Helser et al. (2001, 2003, 2004) have used the same ADMB modeling platform to assess the hake stock and examine important assessment modifications and assumptions, including the time varying nature of the acoustic survey selectivity and catchability. The acoustic survey catchability coefficient (q) has been, and continues to be, one of the major sources of uncertainty in the model. Due to the lengthened acoustic survey biomass trends the assessment model was able to freely estimate the acoustic survey q. These estimates were substantially below the assumed value of q=1.0 from earlier assessments. The 2003 and 2004 assessment presented uncertainty in the final model result as a range of biomass. The lower end of the biomass range was based upon the conventional assumption that the acoustic survey q was equal to 1.0, while the higher end of the range represented a q=0.6 assumption.

This year's assessment used the Stock Synthesis modeling framework (SS2 Version 1.21, December, 2006) which was written by Dr. Richard Methot (Northwest Fisheries Science Center) in AD Model Builder. Conversion of the previous hake model into SS2 was guided by three principles: 1) the incorporation of less derived data, 2) explicitly model the underlying hake growth dynamics, and 3) achieve parsimony[1] in terms on model complexity. "Incorporating less derived data" entailed fitting observed data in their most elemental form. For instance, no pre-processing to convert length data to age compositional data was performed. Also, incorporating conditional age-at-length data, through age-length keys for each fishery and survey, allowed

[1] Parsimony is defined as a balance between the number of parameters needed to represent a complex state of nature and data quality/quantity to support accurate and precise estimation of those parameters.

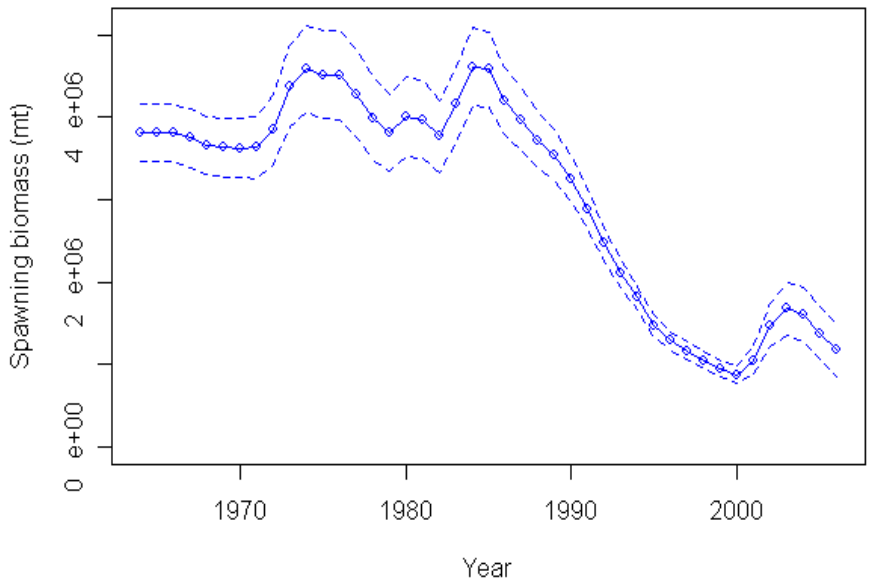
explicit estimation of expected growth, dispersion about that expectation, and its temporal variability, all conditioned on selectivity. As in the previous year's assessment, two models are presented to bracket the range of uncertainty in the acoustic survey catchability coefficient, *q*. The base model with steepness fixed at *h*=0.75 and *q*=1.0 represents the endpoint of the lower range while the alternative model which places a prior on *q* (effective *q*=0.7) represents the upper endpoint of the range. As such, model estimates presented below report a range of values representing these endpoints.

Stock biomass

Pacific hake spawning biomass declined rapidly after 1984 (4.6-5.1million mt) to the lowest point in the time series in 2000 (0.88-1.21 million mt). This long period of decline was followed by a brief increase to 1.68-2.13 million mt in 2003 as the 1999 year class matured. In 2006 (beginning of year), spawning biomass is estimated to be 1.18-1.60 million mt and approximately 30.9%-38.0% of the unfished level. Estimates of uncertainty in level of depletion range from 24.7%-36.9% and 29.7%-45.0% of unfished biomass for the base and alternative models, respectively, based on asymptotic confidence intervals.

Table b. Recent trend in Pacific hake spawning biomass and depletion level from the base and alternative SS2 models.

	Base Model				Alternative Model			
Year	Spawning biomass millions mt	~ 95% Interval	Relative Depletion	~ 95% Interval	Spawning biomass millions mt	~ 95% Interval	Relative Depletion	~ 95% Interval
1997	1.169	1.063 - 1.273	30.6%	-	1.314	1.146 - 1.482	30.66%	-
1998	1.056	0.954 - 1.157	27.7%	-	1.202	1.037 - 1.368	28.05%	-
1999	0.952	0.849 - 1.054	25.0%	-	1.102	0.934 - 1.271	25.72%	-
2000	0.880	0.767 - 0.990	23.1%	-	1.044	0.860 - 1.227	24.35%	-
2001	1.054	0.891 - 1.213	27.6%	-	1.288	1.025 - 1.551	30.04%	-
2002	1.485	1.217 - 1.746	38.9%	-	1.857	1.437 - 2.277	43.32%	-
2003	1.684	1.358 - 2.003	44.2%	-	2.132	1.624 - 2.641	49.74%	-
2004	1.617	1.280 - 1.945	42.4%	-	2.075	1.552 - 2.598	48.40%	-
2005	1.386	1.060 - 1.703	36.3%	30.4% - 42.1%	1.826	1.322 - 2.330	42.59%	35.2% - 50.1%
2006	1.178	0.857 - 1.491	30.9%	24.7% - 36.9%	1.601	1.109 - 2.093	38.00%	29.7% - 45.0%



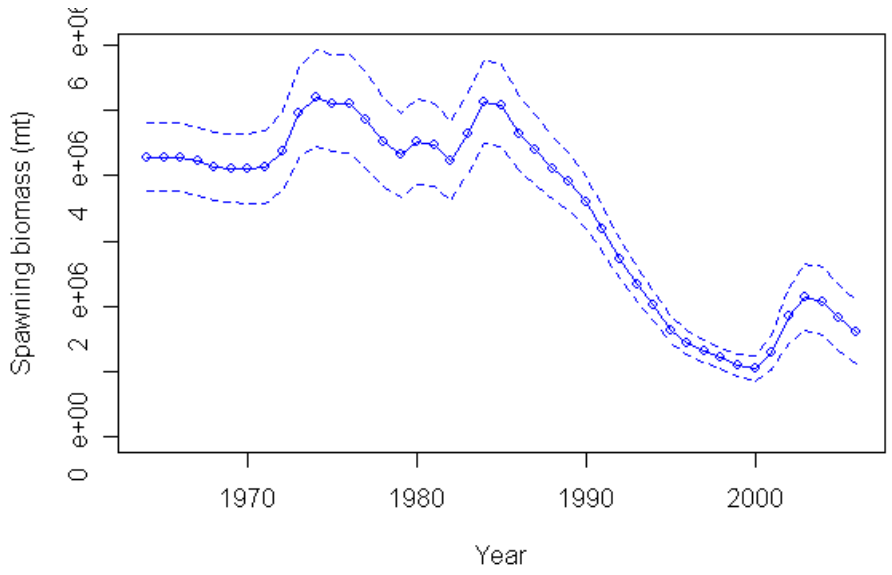


Figure b. Estimated spawning biomass time-series with approximate asymptotic 95% confidence intervals for the base (upper plot) and alternative (lower plot) models.

Recruitment

Estimates of Pacific hake recruitment indicate very large year classes in 1980 and 1984, with secondary recruitment events in 1970, 1973 and 1977, earlier in the time series. The recent 1999 year class was the single most dominate cohort since the late 1980s and has in large part support fishery catches during the last few years. Uncertainty in recruitment can be substantial as shown by asymptotic 95% confidence intervals. Recruitment to age 0 before 1967 is assumed to be equal to the long-term mean recruitment. Age-0 recruitment in 2003 is very uncertain, but predicted to be below the mean, despite some evidence to the contrary in the 2005 acoustic survey.

Table c. Recent estimated trend in Pacific hake recruitment.

	Base Model		Alternative Model	
Year	Recruitment (billions)	~ 95% Interval	Recruitment (billions)	~ 95% Interval
1997	1.933	1.671 - 2.227	2.275	1.893 - 2.735
1998	2.814	2.365 - 3.328	3.435	2.774 - 4.253
1999	13.789	11.337 - 16.692	17.323	13.667 - 21.956
2000	0.990	0.770 - 1.264	1.267	0.953 - 1.684
2001	1.372	1.048 - 1.783	1.787	1.322 - 2.416
2002	0.234	0.147 - 0.371	0.312	0.192 - 0.505
2003	2.338	1.502 - 3.618	3.137	1.978 - 4.976
2004	1.446	0.417 - 5.004	1.663	0.467 - 5.924
2005	0.279	0.069 - 1.131	0.323	0.079 - 1.315
2006	2.192	0.366 - 13.103	2.565	0.428 - 15.370

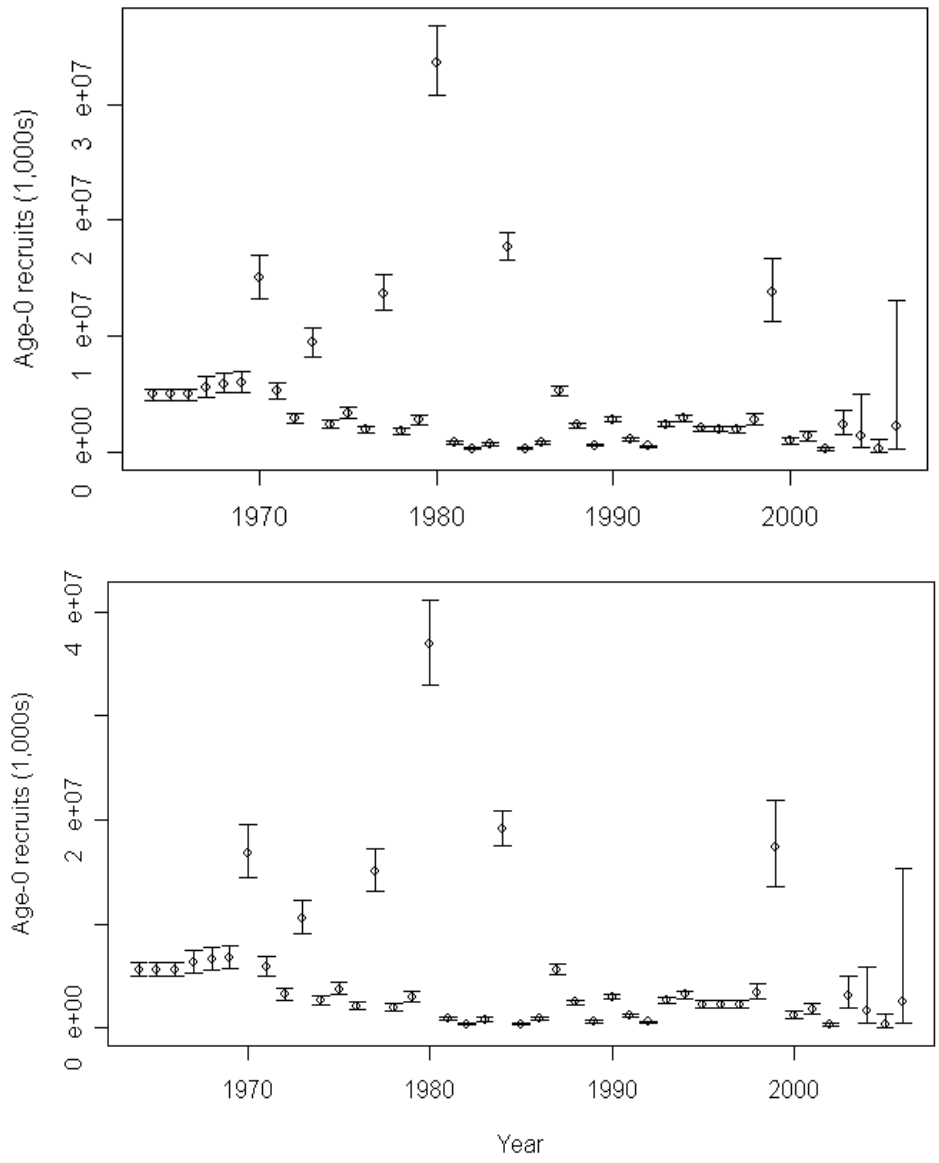


Figure c. Estimated recruitment time-series with approximate asymptotic 95% confidence intervals for the base (upper plot) and alternative (lower plot) models.

Reference points

Two types of reference points are reported in this assessment: those based on the assumed population parameters at the beginning of the modeled time period and those based on the most recent time period in a 'forward projection' mode of calculation. This distinction is important since temporal variability in growth and other parameters can result in different biological reference point calculations across alternative chronological periods. All strictly biological reference points (e.g., unexploited spawning biomass) are calculated based on the unexploited conditions at the start of the model, whereas management quantities (MSY, SB_{msy}, etc.) are based on the current growth and maturity schedules and are marked throughout this document with an asterisk (*).

Unexploited equilibrium Pacific hake spawning biomass (B_{zero}) from the base model was estimated to be 3.81 million mt (~ 95% confidence interval: 3.46 – 4.16 million mt), with a mean expected recruitment of 4.97 billion age-0 hake. Under the alternative model, spawning biomass (B_{zero}) from the base model was estimated to be 4.29 million mt (~ 95% confidence interval: 3.76 – 4.81 million mt), with a mean expected recruitment of 5.59 billion age-0 hake. Associated management reference points for target and critical biomass levels for the base model are 1.52 million mt (B40%) and 0.95 million mt (B25%), respectively. Under the alternative model, B40% and B25% are estimated to be 1.71 and 1.07 million mt, respectively. The MSY-proxy harvest amount (F40%) under the base model was estimated to be 573,945* mt (~ 95% confidence interval: 521,122-619,501), and 645,240* mt (~ 95% confidence interval: 566,830-712,848) under the alternative model. The spawning stock biomass that produces the MSY-proxy catch amount under the base model was estimated to be 1.06 million* mt (confidence interval is 0.96-1.14* million mt), and 1.19 million* mt (confidence interval is 1.04 -1.31* million mt) under the alternative model, given current life history parameters.

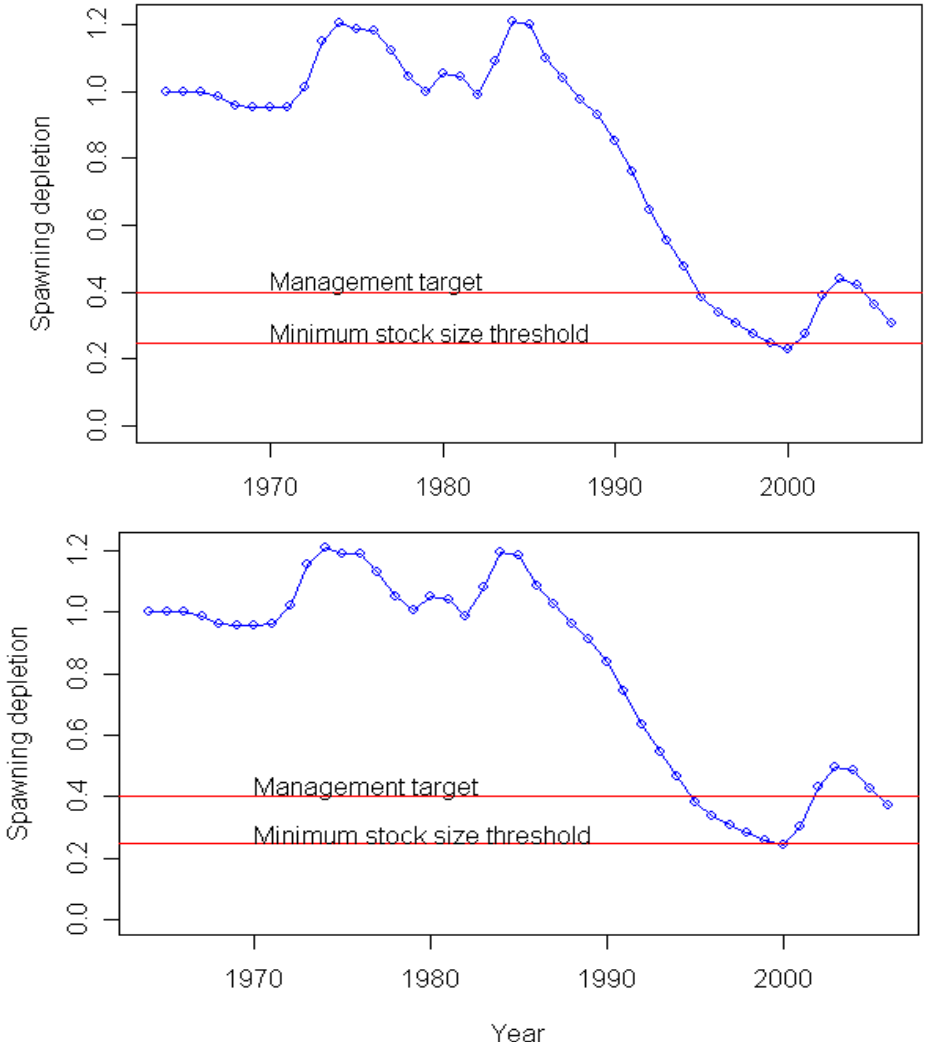


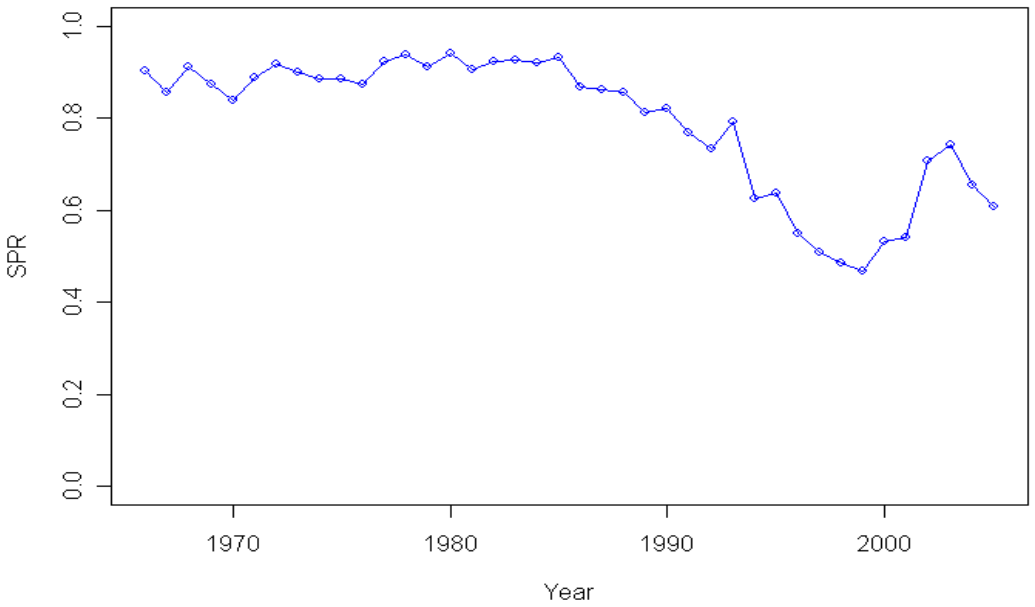
Figure d. Time series of estimated depletion, 1966-2006, for the base (upper plot) and alternative (lower plot) models.

Exploitation status

The estimated spawning potential ratio (SPR) for Pacific hake has been above the proxy target of 40% for the history of this fishery. In terms of its exploitation status, Pacific hake are presently below the target biomass level (40% unfished biomass) and above the target SPR rate (40%). The full exploitation history is portrayed graphically below which plots for each year the calculated SPR and spawning biomass level (B) relative to their corresponding targets, F40% and B40%, respectively.

Table d. Recent trend in spawning potential ratio (SPR).

	Base Model		alternative Model	
Year	Estimated SPR	~ 95% Interval	Estimated SPR	~ 95% Interval
1997	0.513	-	0.539	-
1998	0.491	-	0.521	-
1999	0.473	-	0.509	-
2000	0.540	-	0.584	-
2001	0.550	-	0.601	-
2002	0.716	-	0.762	-
2003	0.749	-	0.793	-
2004	0.664	-	0.721	-
2005	0.619	-	0.686	-



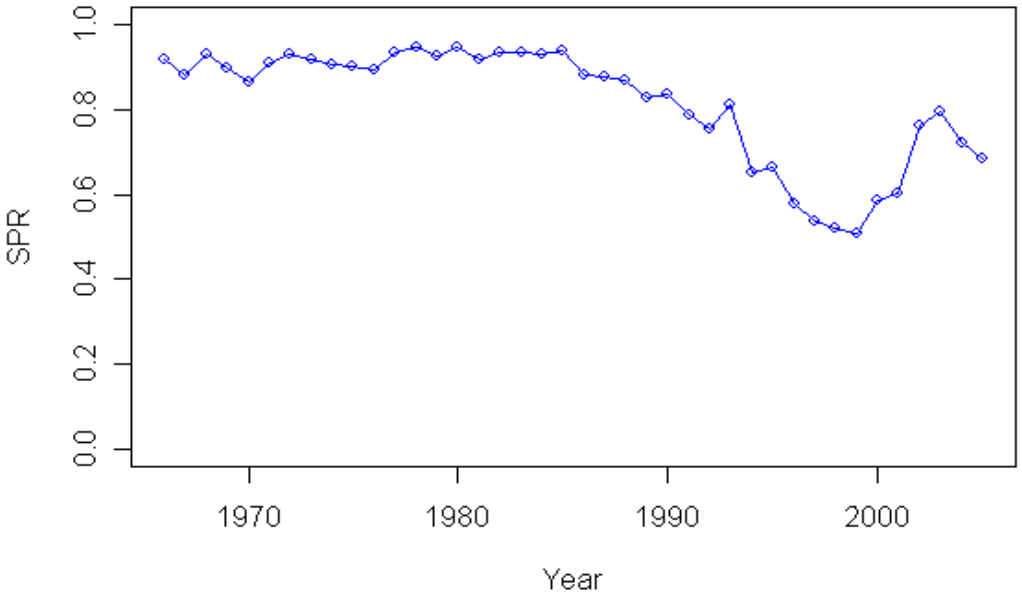
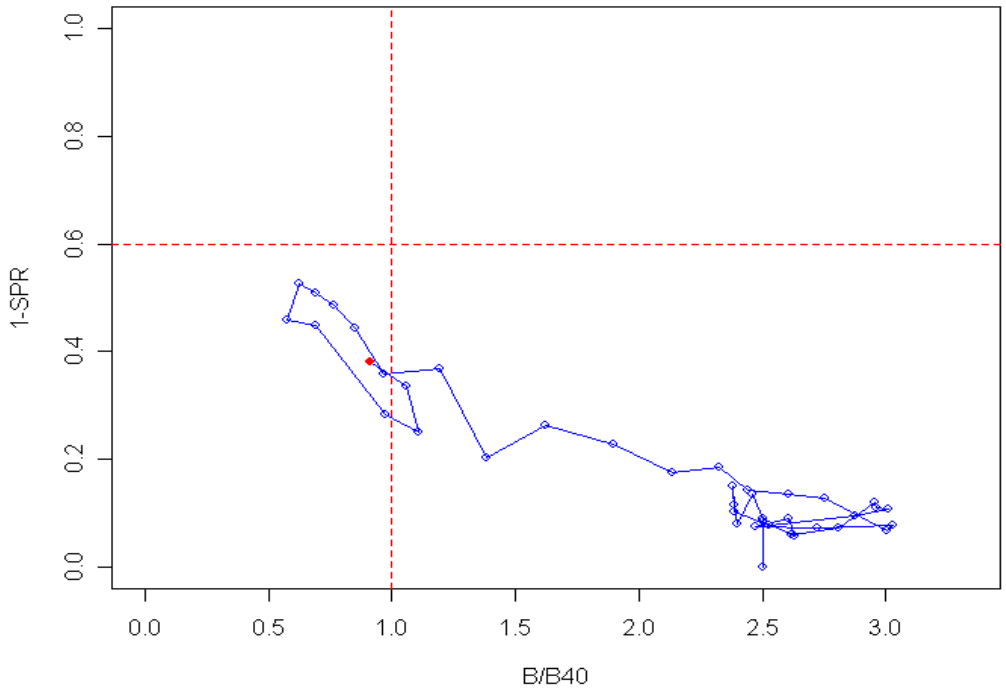


Figure e. Time series of estimated spawning potential ratio from base (upper plot) and alternative (lower plot) models.



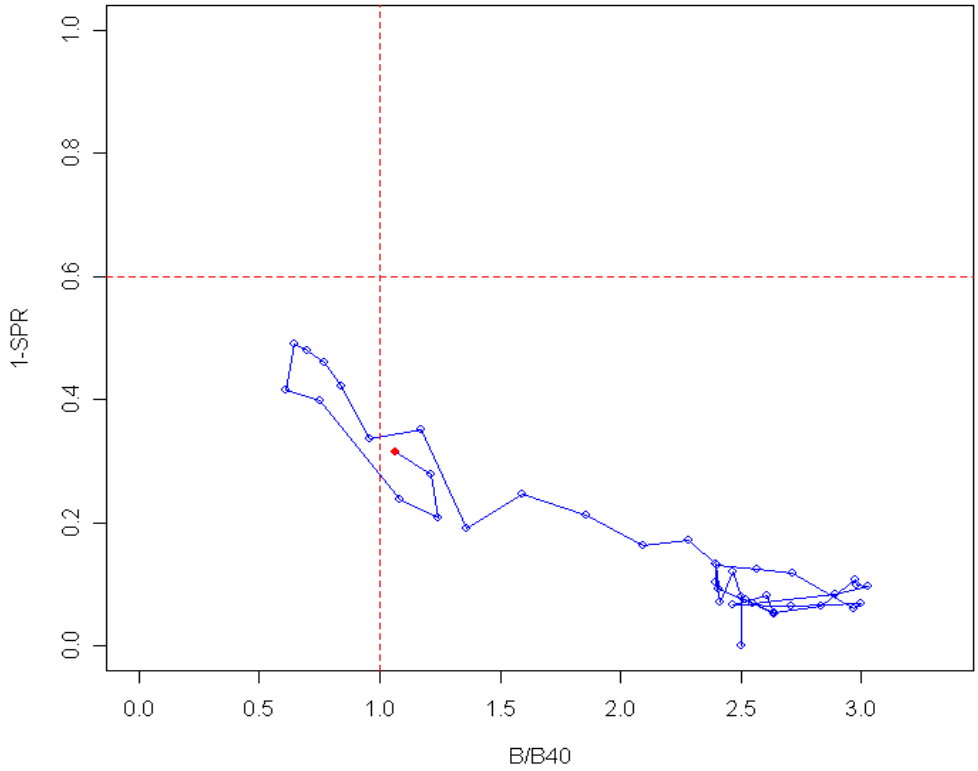


Figure f. Temporal pattern of estimated spawning potential ratio relative to the proxy target of 40% vs estimated spawning biomass relative to the proxy 40% level for base (upper plot) and alternative (lower plot) models.

Management performance

Since implementation of the Magnuson Fisheries Conservation and Management Act in the U.S. and the declaration of a 200 mile fishery conservation zone in Canada in the late 1970's, annual quotas have been the primary management tool used to limit the catch of Pacific hake in both zones by foreign and domestic fisheries. The scientists from both countries have collaborated through the Technical Subcommittee of the Canada-US Groundfish Committee (TSC), and there has been informal agreement on the adoption of an annual fishing policy. During the 1990s, however, disagreement between the U.S. and Canada on the division of the acceptable biological catch (ABC) between the two countries led to quota overruns; 1991-1992 quotas summed to 128% of the ABC and quota overruns have averaged 114% from 1991-1999. Since 2000, total catches have been below coastwide ABCs. A recent treaty between the United States and Canada (2003), which awaits final signature, establishes U.S. and Canadian shares of the coastwide allowable biological catch at 73.88% and 26.12%, respectively.

Table e. Recent trend in Pacific hake management performance.

Year	Total landings (mt)	ABC
1996	306,100	265,000
1997	325,215	290,000
1998	320,619	290,000
1999	311,855	290,000
2000	230,819	290,000
2001	235,962	238,000
2002	182,883	208,000
2003	205,582	235,000
2004	334,721	514,441
2005	360,306	

Unresolved problems and major uncertainties

The acoustic survey catchability, *q*, remains uncertain. This is largely driven by an inconsistency in the acoustic survey biomass time series and age compositions; age composition data suggest a large build up of stock biomass in the mid 1980s while the acoustic survey biomass time series is relatively flat since 1977.

Forecasts

Forecasts were generated assuming the maximum potential catch would be removed under 40:10 control rule for both the base and alternative models. Projections were based on the relative F contribution of 74.88% and 26.12% coast wide national allocation to the U.S. and Canada, respectively. For base case model, the 2006 coastwide ABC is estimated to be 661,681 mt with an OY of 593,750 mt. Under the alternative model, the 2006 coastwide ABC is estimated to be 904,944 mt with an OY of 883,490 mt. Spawning stock biomass is projected to decline with a corresponding relative depletion of 22.7% and 26.4% for the base and alternative models, respectively in 2007.

Table f. Three year projection of potential Pacific hake landings, spawning biomass and depletion for the base and alternative models under the 40:10 rule.

		Spawning biomass millions mt			Depletion percent unfished biomass		
Year	Expected coastwide catch (mt)	Mean	5%	95%	Mean	5%	95%
Base model, h=0.75, q=1.0							
2006	593,750	1.174	0.857	1.491	30.8%	24.7%	36.9%
2007	358,420	0.864	0.636	1.092	22.7%	18.1%	27.2%
2008	213,220	0.679	0.485	0.873	17.8%	13.5%	22.1%
2009	183,620	0.657	0.337	0.976	17.2%	9.2%	25.3%
Alt. model, h=0.75, q prior							
2006	883,490	1.601	1.109	2.093	38.0%	29.7%	45.0%
2007	522,510	1.130	0.795	1.464	26.4%	21.0%	31.7%
2008	302,300	0.851	0.588	1.113	19.8%	15.1%	24.5%
2009	240,700	0.792	0.404	1.179	18.5%	10.0%	26.9%

Decision table

A decision table was constructed to represent the uncertainty on the acoustic survey catchability coefficient, *q*. The base model with a *q*=1.0 represents the lower range while the alternative model which places a prior on *q* (effective *q*=0.7) represents the upper range. Below the decision table shows the consequences of management action given a state of nature. States of nature include the base model (*h*=0.75, *q*=1.0) and the alternative model (*h*=0.75, *q* prior). The management actions include the OY from each state of nature and two constant coastwide catch scenarios.

Table g. Decision table for two states of nature (base and alternative models) and four different harvest strategies given the state of nature.

			State of Nature	
Relative probability			**0.50**	**0.50**
Model			h = 0.75, q = 1.0	h = 0.75, q prior
Management action	Total coast-wide Catch (mt)	Year	Relative depletion (2.5%-97.5% interval)	
OY Model h=0.75, q=1.0	593,746	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
	358,416	2007	0.227 (0.181-0.272)	0.310 (0.219-0.401)
	213,223	2008	0.178 (0.135-0.221)	0.263 (0.164-0.363)
	183,620	2009	0.172 (0.092-0.253)	0.254 (0.127-0.380)
OY Model h=0.75, q prior	883,490	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
	522,511	2007	0.202 (0.125-0.279)	0.268 (0.215-0.322)
	302,298	2008	0.144 (0.056-0.232)	0.202 (0.155-0.249)
	240,702	2009	0.136 (0.020-0.252)	0.188 (0.104-0.273)
Total coast-wide	200,000	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
catch = 200,000 mt	200,000	2007	0.282 (0.209-0.354)	0.351 (0.264-0.438)
	200,000	2008	0.250 (0.167-0.333)	0.315 (0.219-0.411)
	200,000	2009	0.239 (0.125-0.352)	0.299 (0.175-0.423)
Total coast-wide	400,000	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
catch = 400,000 mt	400,000	2007	0.258 (0.184-0.332)	0.330 (0.241-0.419)
	400,000	2008	0.207 (0.122-0.292)	0.276 (0.177-0.375)
	400,000	2009	0.178 (0.063-0.294)	0.245 (0.118-0.372)

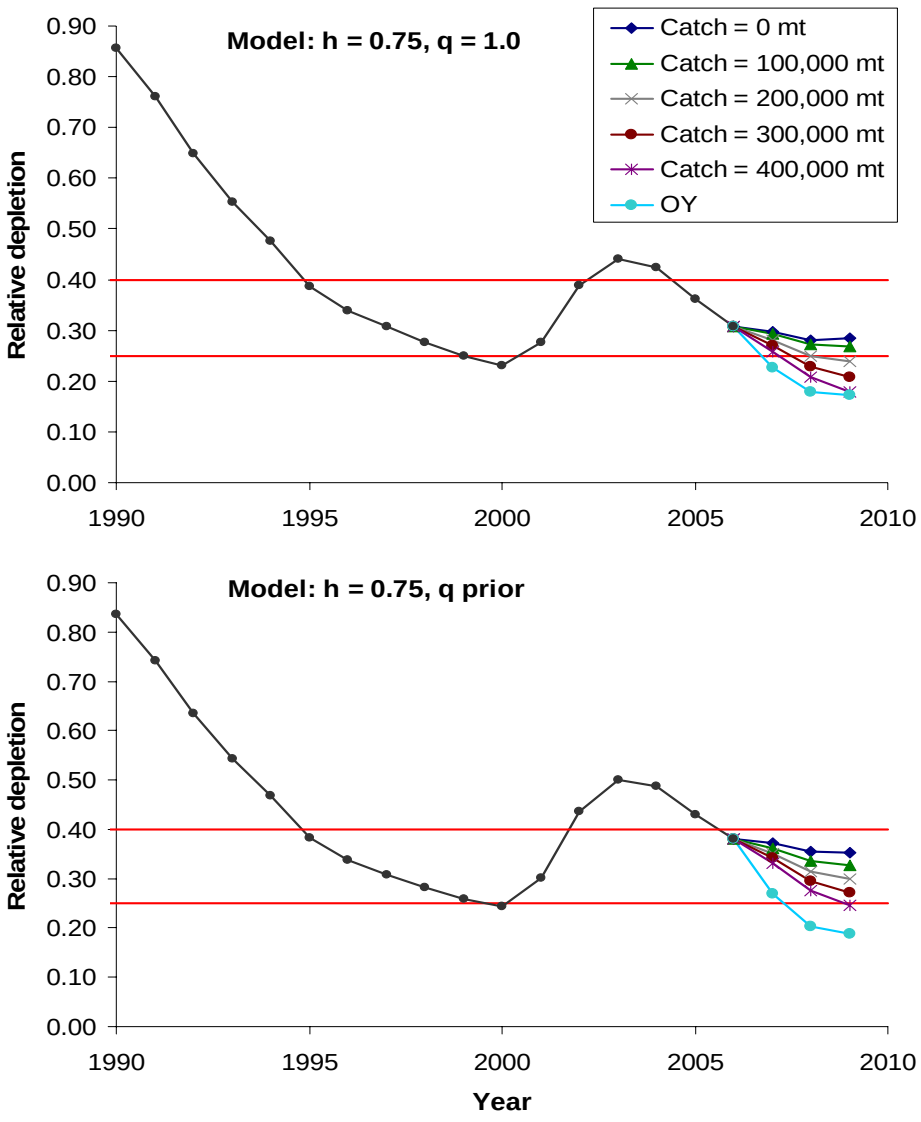


Figure g. Projections through 2009 for the base case (upper plot) and alternative (lower plot) models under various total coast-wide catch scenarios.

Research and data needs

1) The quantity and quality of biological data prior to 1988 from the Canadian fishery should be evaluated for use in developing length and conditional age at length compositions.
2) Evaluate whether modeling the distinct at-sea and shore based fisheries in the U.S. and Canada explain some lack of fit in the compositional data.
3) Compare spatial distributions of hake across all years and between bottom trawl and acoustic surveys to estimate changes in catchability/availability across years. The two primary issues are related to the changing spatial distribution of the survey as well as the environmental factors that may be responsible for changes in the spatial distribution of hake and their influences on survey catchability and selectivity.

4) Initiate analysis of the acoustic survey data to determine variance estimates for application in the assessment model. The analysis would provide a first cut to define the appropriate CV for the weighting of the acoustic data.
5) Develop an informed prior for the acoustic q. This could be done either with empirical experiments (particularly in off-years for the survey) or in a workshop format with technical experts. There is also the potential to explore putting the target strength estimation in the model directly. This prior should be used in the model when estimating the q parameter.
6) Review the acoustic data to assess whether there are spatial trends in the acoustic survey indices that are not being captured by the model. The analysis should include investigation of the migration (expansion/contraction) of the stock in relation to variation in environmental factors. This would account for potential lack of availability of older animals and how it affects the selectivity function.
7) Investigate aspects of the life history characteristics for Pacific hake and their possible effects on the interrelationship of growth rates and maturity at age. This should include additional data collection of maturity states and fecundity, as current information is limited.

Table h. Summary of recent trends in Pacific hake exploitation and stock levels; all values reported at the beginning of the year.

Base Model	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Landings (1000s mt)	306.1	325.2	320.6	311.9	230.8	236.0	182.9	205.6	334.7	360.3	NA
ABC (1000s mt)	265	290	290	290	290	238	208	235	514.441	265	
OY (1000s mt)											
SPR*	0.579	0.539	0.521	0.509	0.584	0.601	0.762	0.793	0.721	0.686	NA
Total biomass (millions mt)	2.601	2.437	2.184	1.958	1.761	1.813	3.657	3.534	3.274	2.640	2.328
Spawning biomass (millions mt)	1.293	1.169	1.056	0.952	0.880	1.054	1.485	1.684	1.617	1.386	1.178
~95% interval	1.180-1.405	1.063-1.273	0.954-1.157	0.849-1.054	0.767-0.990	0.891-1.213	1.217-1.746	1.358-2.003	1.280-1.945	1.060-1.703	0.857-1.491
Recruitment (billions)	1.988	1.933	2.814	13.789	0.990	1.372	0.234	2.338	1.446	0.279	2.192
~95% interval	1.711-2.167	1.617-2.152	2.271-3.199	10.770-15.912	0.722-1.199	0.972-1.681	0.124-0.343	1.238-3.233	4.165-4.988	4.165-4.988	4.165-4.988
Depletion	33.9%	30.6%	27.7%	25.0%	23.1%	27.6%	38.9%	44.2%	42.4%	36.3%	30.9%
~95% interval	NA	NA	NA	NA	NA	NA	NA	NA	NA	30.4%-42.1%	24.7%-36.9%

Alternative Model	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Landings (1000s mt)	306.1	325.2	320.6	311.9	230.8	236.0	182.9	205.6	334.7	360.3	NA
ABC (1000s mt)	265	290	290	290	290	238	208	235	514.441	265	
OY (1000s mt)											
SPR*	0.579	0.539	0.521	0.509	0.584	0.601	0.762	0.793	0.721	0.686	
Total biomass (millions mt)	2.979	2.812	2.556	2.340	2.166	2.295	4.801	4.699	4.427	3.680	3.389
Spawning biomass (millions mt)	1.443	1.314	1.202	1.102	1.044	1.288	1.857	2.132	2.075	1.826	1.601
~95% interval	1.266-1.620	1.146-1.482	1.037-1.368	0.934-1.271	0.860-1.227	1.025-1.551	1.437-2.277	1.624-2.641	1.552-2.598	1.322-2.330	1.109-2.093
Recruitment (billions)	2.275	2.275	3.435	17.323	1.267	1.787	0.312	3.137	1.663	0.323	2.565
~95% interval	1.945-2.661	1.893-2.735	2.774-4.253	13.677-21.956	0.953-1.684	1.322-2.416	0.192-0.505	1.978-4.976	0.467-5.924	0.079-1.315	0.428-15.370
Depletion	33.7%	30.7%	28.0%	25.7%	24.3%	30.0%	43.3%	49.7%	48.4%	42.6%	38.0%
~95% interval	NA	NA	NA	NA	NA	NA	NA	NA	NA	35.2%-50.1%	29.7%-45.1%

Table i. Summary of Pacific hake reference points.

Base Model

Quantity	Estimate	~95% Confidence interval
Unfished spawning stock biomass (SB_0, millions mt)	3.810	3.461 - 4.160
Unfished total biomass (B_0, millions mt)	9.200	NA
Unfished age 3+ biomass (millions mt)	7.832	NA
Unfished recruitment (R_0, billions)	4.974	4.536 – 5.447
Spawning stock biomass at MSY (SB_{msy})*	1.06	0.96 – 1.14
Basis for SB_{msy}	$F_{40\%}$ proxy	NA
SPR_{msy}*	40.0%	33.2%-46.7%
Basis for SPR_{msy}	$F_{40\%}$ proxy	NA
Exploitation rate corresponding to SPR_{msy}*	24.6%	NA
MSY* (mt)	573,945	521,122 – 619,501

Alternative Model

Quantity	Estimate	~95% Confidence interval
Unfished spawning stock biomass (SB_0, millions mt)	4.287	3.764 – 4.810
Unfished total biomass (B_0, millions mt)	10.333	NA
Unfished age 3+ biomass (millions mt)	8.804	NA
Unfished recruitment (R_0, billions)	5.593	4.955 - 6.313
Spawning stock biomass at MSY (SB_{msy})*	1.191	1.041 - 1.310
Basis for SB_{msy}	$F_{40\%}$ proxy	NA
SPR_{msy}*	40.0%	33.2%-46.7%
Basis for SPR_{msy}	$F_{40\%}$ proxy	NA
Exploitation rate corresponding to SPR_{msy}*	24.6%	NA
MSY* (mt)	645,240	566,830 - 712,848

INTRODUCTION

This assessment was undertaken in the spirit and intent of the "Agreement between the Government of the United States and the Government of Canada on Pacific Hake/Whiting", signed at Seattle, Washington, on November 21, 2003. Under this agreement, pending ratification as part of the reauthorization of the Magnuson-Stevens Act by Congress, Pacific hake (a.k.a. Pacific whiting) stock assessments are to be prepared by the Hake Technical Working Group comprised of U.S. and Canadian scientists and reviewed by a Scientific Review Group (SRG), with memberships as appointed by both parties to the agreement. While these entities have not been formally established, the current assessment was cooperatively prepared and reviewed as outlined in this agreement. As background, separate Canadian and U.S. assessments were submitted to each nation's assessment review process prior to 1997. In the past, this practice has resulted in differing yield options being forwarded to each country's managers for this single, yet shared trans-boundary fish stock. Multiple interpretations of Pacific hake status made it difficult to coordinate overall management policy. To address this problem, the working group agreed in 1997 to present scientific advice in a single collaborative assessment, while that agreement was officially formalized in 2003. To further advance the coordination of scientific advice on Pacific hake, this report was submitted to a joint Canada-U.S. SRG for technical review in fulfillment of the agreement and to satisfy management responsibilities of both the U.S. Pacific Fisheries Management Council (PFMC) and the Canadian Pacific Stock Assessment Review Committee (PSARC). The Review Group meeting was held in Seattle, WA at the Northwest Fisheries Science Center, during Feb 6-10, 2006. While this report forms the basis for scientific advice to managers, final advice on appropriate yield is deferred to Canadian DFO managers by the PSARC Groundfish Sub-committee and the PSARC Steering Committee and to the U.S. Pacific Fisheries Management Council by the Groundfish Management Team.

Stock Structure and Life History

Pacific hake (*Merluccius productus*), also referred to as Pacific whiting, is a codlike species distributed along the west coast of North America generally ranging from 25^0 N. to 51^0 N. latitude. It is among about 11 other species of hakes from the genus, *Merluccidae*, which are distributed worldwide in both hemispheres of the Atlantic and Pacific Oceans and collectively constitute nearly two million mt of catch annually (Alheit and Pitcher 1995). The coastal stock of Pacific hake is currently the most abundant groundfish population in the California Current system. Smaller populations of this species occur in the major inlets of the North Pacific Ocean, including the Strait of Georgia, Puget Sound, and the Gulf of California. Electrophoretic studies indicate that Strait of Georgia and the Puget Sound populations are genetically distinct from the coastal population (Utter 1971). Genetic differences have also been found between the coastal population and hake off the west coast of Baja California (Vrooman and Paloma 1977). The coastal stock is distinguished from the inshore populations by larger body size, seasonal migratory behavior, and a pattern of low median recruitment punctuated by extremely large year classes.

The coastal stock of Pacific hake typically ranges from the waters off southern California to Queen Charlotte Sound. Distributions of eggs, larvae, and infrequent observations of spawning aggregations indicate that Pacific hake spawning occurs off south-central California during January-March. Due to the difficulty of locating major offshore spawning concentrations, details of spawning behavior of hake remains poorly understood (Saunders and McFarlane 1997). In spring, adult Pacific hake migrate onshore and to the north to feed along the continental shelf and slope from northern California to Vancouver Island. In summer, Pacific hake form extensive midwater aggregations in association with the continental shelf break, with highest densities located over bottom depths of 200-300 m (Dorn et al. 1994). Pacific hake feed on euphausiids, pandalid shrimp, and pelagic schooling fish (such as eulachon and Pacific herring) (Livingston and Bailey 1985). Larger Pacific hake become increasingly piscivorous, and Pacific herring are commonly a large component of hake diet off Vancouver Island. Although Pacific hake are cannibalistic, the geographic separation of juveniles and adults usually prevents cannibalism from being an important factor in their population dynamics (Buckley and Livingston 1997).

Older (age 5+), larger, and predominantly female hake exhibit greatest northern migration each season. During El Niño events, a larger proportion of the stock migrates into Canadian waters, apparently due to intensified northward transport during the period of active migration (Dorn 1995). Range extensions to the north also occur during El Niño conditions, as evidenced by reports of hake from southeast Alaska during these warm water years. Throughout the warm period experienced in 1990s, there have been changes in typical patterns of hake distribution: Spawning activity has been recorded north of California, and frequent reports of unusual numbers of juveniles from Oregon to British Columbia suggest that juvenile settlement patterns have also shifted northwards in the late 1990s. Because of this shift, juveniles may be subjected to increased predation from cannibalism and to increased vulnerability to fishing mortality. Subsequently, La Nina conditions apparently caused a southward shift in the center of the stock's distribution and a smaller portion of the population was found in Canadian waters in the 2001 survey.

Fisheries

The fishery for the coastal population of Pacific hake occurs primarily during April-November along the coasts of northern California, Oregon, Washington, and British Columbia. The fishery is conducted almost exclusively with midwater trawls. Most fishing activity occurs over bottom depths of 100-500 m, but offshore extensions of fishing activity have occurred. The history of the coastal hake fishery is characterized by rapid changes brought about by the development of foreign fisheries in 1966, joint-venture fisheries in the early 1980's, and domestic fisheries in 1990's (Fig. 1).

Large-scale harvesting of Pacific hake in the U.S. zone began in 1966 when factory trawlers from the former Soviet Union began targeting Pacific hake. During the mid 1970's, factory trawlers from Poland, Federal Republic of Germany, the former German Democratic Republic and Bulgaria also participated in the fishery. During 1966-1979, the catch in U.S.

waters averaged 137,000 t per year (Table 1). A joint-venture fishery was initiated in 1978 between two U.S. trawlers and Soviet factory trawlers acting as mother ships (the practice where the catch from several boats is brought back to the larger, slower ship for processing and storage until the return to land). By 1982, the joint-venture catch surpassed the foreign catch. In the late 1980's, joint-ventures involved fishing companies from Poland, Japan, former Soviet Union, Republic of Korea and the People's Republic of China. In 1989, the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota, and no foreign fishing was allowed. In contrast, Canada allocates a portion of the Pacific hake catch to joint-venture operations once shore-side capacity is filled.

Historically, the foreign and joint-venture fisheries produced fillets and headed and gutted products. In 1989, Japanese mother ships began producing surimi from Pacific hake, using a newly developed process to inhibit myxozoan-induced proteolysis. In 1990, domestic catcher-processors and mother ships entered the Pacific hake fishery in the U.S. zone. Previously, these vessels had engaged primarily in Alaskan pollock fisheries. The development of surimi production techniques for walleye pollock was expanded to include Pacific hake as a viable alternative. In 1991, the joint-venture fishery for Pacific hake ended because of the increased level of participation by domestic catcher-processors and mother ships, and the growth of shore-based processing capacity. Shore-based processors of Pacific hake had been constrained historically by a limited domestic market for Pacific hake fillets and headed and gutted products. The construction of surimi plants in Newport and Astoria, Oregon led to a rapid expansion of shore-based landings in the U.S. fishery in the early 1990's.

The sectors involved in the Pacific hake fishery in Canada exhibits a similar pattern, although phasing out of the foreign and joint-venture fisheries has lagged a few years relative to the U.S. Since 1968, more Pacific hake have been landed than any other species in the groundfish fishery on Canada's west coast (Table 1). Prior to 1977, the fishing vessels from the former Soviet Union caught the majority of Pacific hake in the Canadian zone, with Poland and Japan accounting for much smaller landings. Since declaration of the 200-mile extended fishing zone in 1977, the Canadian fishery has been divided into shore-based, joint-venture, and foreign fisheries. In 1990, the foreign fishery was phased out, but the demand of Canadian shore-based processors remains below the available yield, thus the joint-venture fishery will continued through 2002. Poland is the only country that participated in the 1998 joint-venture fishery. The majority of the shore-based landings of the coastal hake stock is processed into surimi, fillets, or mince by processing plants at Ucluelet, Port Alberni, and Delta, British Columbia. Small deliveries were made in 1998 to plants in Washington and Oregon. Although significant aggregations of hake are found as far north as Queen Charlotte Sound, in most years the fishery has been concentrated below 49° N latitude off the south coast of Vancouver Island, where there are sufficient quantities of fish in proximity to processing plants.

Management of Pacific hake

Since implementation of the Magnuson-Stevens Fishery Conservation and Management Act in the U.S. and the declaration of a 200-mile fishery conservation zone in Canada in the late

1970's, annual harvest quotas have been the primary management tool used to limit the catch of Pacific hake. Scientists from both countries have historically collaborated through the Technical Subcommittee of the Canada-US Groundfish Committee (TSC), and there have been informal agreements on the adoption of annual fishing policies. During the 1990s, however, disagreements between the U.S. and Canada on the allotment of the acceptable biological catch (ABC) between U.S. and Canadian fisheries lead to quota overruns; 1991-1992 quotas summed to 128% of the ABC, while in 1993-1999 the combined quotas were 107% of the ABC on average. The 2002 and 2003 fishing year were somewhat different from years past in that the ABC of Pacific hake was utilized at an average of 87%. In the signed Pacific hake agreement between the United States and Canada 73.88% and 26.12%, respectively, of the coastwide allowable biological catch is to be allocated between the two countries. Furthermore, the agreement establishes a Joint Technical Committee to exchange data and conduct stock assessments, which will be reviewed by a Scientific Review Group. This document represents the efforts of the aborning joint US-Canada Technical Committee.

United States

Prior to 1989, catches in the U.S. zone were substantially below the harvest guideline, but since 1989 the entire harvest guideline has been caught with the exceptions in 2000, 2001 and 2003, in which 90%, 96% and 96% of the quota were taken, respectively. The total U.S. catch has not significantly exceeded the harvest guideline for the U.S. zone (Table 2), indicating that in-season management procedures have been effective.

In the U.S. zone, participants in the directed fishery are required to use pelagic trawls with a codend mesh that is at least 7.5 cm (3 inches). Regulations also restrict the area and season of fishing to reduce the bycatch of Chinook salmon, and several depleted rockfish stocks. More recently, yields in the U.S. zone have been restricted to level below optimum yields due to widow rockfish bycatch in the Pacific hake fishery. At-sea processing and night fishing (midnight to one hour after official sunrise) are prohibited south of 42° N latitude. Fishing is prohibited in the Klamath and Columbia River Conservation zones, and a trip limit of 10,000 pounds is established for Pacific hake caught inside the 100-fathom contour in the Eureka INPFC area. During 1992-95, the U.S. fishery opened on April 15, however in 1996 the opening date was advanced to May 15. Shore-based fishing is allowed after April 1 south of 42° N. latitude., but is limited to 5% of the shore-based allocation being taken prior to the opening of the main shore-based fishery. The main shore-based fishery opens on June 15. Prior to 1997, at-sea processing was prohibited by regulation when 60 percent of the harvest guideline was reached. The current allocation agreement, effective since 1997, divides the U.S. non-tribal harvest guideline between factory trawlers (34%), vessels delivering to at-sea processors (24%), and vessels delivering to shore-based processing plants (42%).

Shortly after the 1997 allocation agreement was approved by the PFMC, fishing companies with factory trawler permits established the Pacific Whiting Conservation Cooperative (PWCC). The primary role of the PWCC is to allocate the factor trawler quota between its members. Anticipated benefits of the PWCC include more efficient allocation of

resources by fishing companies, improvements in processing efficiency and product quality, and a reduction in waste and bycatch rates relative to the former "derby" fishery in which all vessels competed for a fleet-wide quota. The PWCC also initiated recruitment research to support hake stock assessment. As part of this effort, PWCC sponsored a juvenile recruit survey in summer of 1998 and 2001, which since 2002 is presently ongoing in collaboration and support by NMFS.

Canada

The Canadian Department of Fisheries and Oceans (DFO) is responsible for managing the Canadian hake fishery. Prior to 1987, the quota was not reached due to low demand for hake. In subsequent years the quota has been fully subscribed, and total catch has been successfully restricted to ±5% of the quota (Table 2).

Domestic requirements are given priority in allocating yield between domestic and joint-venture fisheries. During the season, progress towards the domestic allocation is monitored and any anticipated surplus is re-allocated to the joint-venture fishery. The Hake Consortium of British Columbia coordinates the day-to-day fleet operations within the joint-venture fishery. Through 1996, the Consortium split the available yield equally among participants or pools of participants. In 1997, an Individual Vessel Quota (IVQ) system was implemented for the British Columbia trawl fleet. IVQs of Pacific hake were allotted to license holders based on a combination of vessel size and landing history. Vessels are permitted to deliver Joint-venture hake quota to domestic shore-side processors. However, vessels are not permitted to deliver domestic allocation to Joint-venture/processor operations at sea. There is no direct allocation to individual shoreside processors. License holders declare the proportion of their hake quota that will be landed in the domestic market, and shoreside processors must secure catch from vessel license holders.

Overview of Recent Fishery and Management

United States

The coastwide acceptable biological catch (ABC) for 2004 was estimated to be 514,441 mt based on the F_{msy} proxy harvest rate of F40% applied to the model in which acoustic survey catchability (q) was assumed to be 1.0 (Helser et al. 2004). This was the largest ABC in recent years and reflected substantial increases in biomass (above 40% unfished biomass) due to the presence of the strong 1999 year-class. The final commercial US optimum yield (OY) was set at 250,000 mt due to constraints imposed by bycatch of canary and widow rockfish in the hake fishery. The Makah tribe was allocated 32,500 mt in 2004. For the 2005 fish season, the coastwide OY was estimated to be 364,197 mt, with 269,069 mt apportioned to the U.S. fishery. The 2005 OY was nearly 100% utilized.

The at-sea sector's distribution of catch in 2004 ranged slightly stronger northward with roughly 50% of the catch occurring north and south of Newport, Oregon (Fig. 2). The total at sea sector harvested approximately 43% (90,200 mt) of the total U.S. catch of 210,400 mt. In

2005, at sea catches extended from south of Cape Blanco to Cape Flattery, with nearly even distribution north and south of Newport.

The shore-based sector harvested 46% (96,200 mt) of the total U.S. catch of 210,400 mt in 2004. As in previous years, the dominate ports were Newport (38,800 mt) followed by Westport (30,000 mt) and Astoria (16,000 mt). The 2005 shore-based fishery began on June 15 and ended on August 18, and utilized approximately 94% of the commercial optimum yield of 97,469 mt.

Since 1996, the Makah Indian Tribe has conducted a separate fishing in its" usual and accustomed fishing area." During the 2004 and 2005 fishing season, the distribution of Pacific hake provided favorable conditions to support the fishery in the Makah tribal fishing area;, where the Makahs harvested approximately 74% (24,000 mt) of the Tribal allocation and 11% of total US catch in 2004. The 2005 Makah fishery, which began on May 1 and ended on August 15, utilized 28,325 mt, (approximately 81% of the 35,000 mt allocation).

Canada

DFO managers allow a 15% discrepancy between the quota and total catch. The quota may be exceeded by up to 15% in any given year, which is then deducted from the quota for the subsequent year. Conversely, if less than the quota is taken, up to 15% can be carried over into the next year. For instance, the overage in 1998 (Table 2) is due to carry-over from 1997 when 9% of the quota was not taken. During 1999-2001 the PSARC groundfish subcommittee recommended to DFO managers yields based on F40% (40-10) option and Canadian managers adopted allowable catches prescribed at 30% of the coastwide ABC (Table 14; Dorn et al. 1999).

The all-nation catch in Canadian waters was 53,585 mt in 2001, up from only 22,401 mt in 2000 (Table 1). In 2000, the shore-based landings in the Canadian zone hit a record low since 1990 due to a decrease in availability. Catches in 2001 increased substantially over those of 2000 for both the Joint Venture and shore-based sectors over catches in 2000, but were still below recommended TAC. Total Canadian catches in 2002 and 2003 were 50,769 mt and 62,090 mt, respectively, and were harvested exclusively by the shore-side sector; constituting nearly 87% of the total allocation of that country. In 2004, the allowable catch in Canada was 26.14% of the coastwide ABC, approximately 134,000 mt. Catches were nearly split equally between the shore-based and joint venture sectors, totaling 124,000 mt. Canadian Pacific hake catches were fully utilized in the 2005 fishing season with 85,284 mt and 15,178 mt taken by the Domestic and Joint Venture fisheries, respectively.

ASSESSMENT

Modeling Approaches

Age-structured assessment models have been used to assess Pacific hake since the early 1980's. Modeling approaches have evolved as new analytical techniques have been developed.

Initially, a cohort analysis tuned to fishery CPUE was used (Francis et al. 1982). Later, the cohort analysis was tuned to NMFS triennial acoustic survey estimates of absolute abundance at age (Hollowed et al. 1988a). Since 1989, a stock synthesis model that utilizes fishery catch-at-age data and acoustic survey estimates of population biomass and age composition has been the primary assessment method (Dorn and Methot, 1991). Dorn et al. (1999) converted the age-structured stock synthesis Pacific hake model to an age-structured model using AD model builder (Fournier 1996). AD model builder's post-convergence routines permit calculation of standard errors (or likelihood profiles) for any quantity of interest, allowing for a unified approach to the treatment of uncertainty in estimation and forward projection. Since 2001, Helser et al. (2001, 2003, 2004) have used the same ADMB modeling platform to assess the hake stock and examine important modifications and assumptions, including the time varying nature of the acoustic survey selectivity and catchability. The acoustic survey catchability coefficient (q) has been, and continues to be, one of the major sources of uncertainty in the model. Due to the lengthened acoustic survey biomass trends the assessment model was able to freely estimate the acoustic survey q. These estimates were substantially below the assumed value of q=1.0 from earlier assessments. The 2003 and 2004 assessment presented uncertainty in the final model result as a range of biomass. The lower end of the biomass range was based upon the conventional assumption that the acoustic survey q was equal to 1.0, while the higher end of the range represented a q=0.6 assumption.

This year's assessment used the Stock Synthesis modeling framework (SS2 Version 1.21, December, 2006) which was written by Dr. Richard Methot (Northwest Fisheries Science Center) in AD Model Builder. Conversion of the previous hake model into SS2 was guided by three principles: 1) the incorporation of less derived data, 2) explicitly model the underlying hake growth dynamics, and 3) achieve parsimony[2] in terms on model complexity. "Incorporating less derived data" entailed fitting observed data in their most elemental form. For instance, no pre-processing to convert length data to age compositional data was performed. Also, incorporating conditional age-at-length data, through age-length keys for each fishery and survey, allowed explicit estimation of expected growth, dispersion about that expectation, and its temporal variability, all conditioned on selectivity. Our final goal was to achieve parsimony of model complexity without loss of performance in maximum likelihood estimation. We assess this goal through a combination of diagnostics, convergence criteria and comparative analysis with MCMC integration.

Data Sources

The data used in the stock assessment model included:

- Total catch from the U.S. and Canadian fisheries (1966-2005).

[2] Parsimony is a balance between the number of parameters needed to represent a complex state of nature and data quality/quantity to support accurate and precise estimation of those parameters.

- Length compositions from the U.S. fishery (1975-2005) and Canadian fishery (1988-2005).

- Age compositions from the U.S. fishery (1973-1974) and Canadian fishery (1977-1987). These are the traditional age compositional data generated by applying fishery length compositions to an age-length key. Use of this approached was necessary to fill in gaps for those years in which biological samples could not be re-acquired from standard procedures.

- Conditional age-at-length compositions from the U.S. fishery (1975-2005) and Canadian fishery (1988-2005).

- Biomass indices, length compositions and conditional age-at-length composition data from the Joint US-Canadian acoustic/midwater trawl surveys (1977, 1980, 1983, 1986, 1989, 1992, 1995, 1998, 2001, 2003, and 2005). Note: the 1986 acoustic survey biomass index was omitted due to transducer and calibration problems.

- Indices of young-of-the-year abundance from the Santa Cruz Laboratory larval rockfish surveys (1986-2005). In this, as in the previous 2001 and 2003 assessment, the Santa Cruz Laboratory indices of young-of-the-year abundance were used as an age-2 tuning index for stock reconstruction and for future projections (two years out from the terminal year in the assessment, i.e. 2003 and 2004).

As in the previous hake model, the U.S. and Canadian fisheries were modeled separately. The model also used biological parameters to estimate spawning and population biomass to obtain predictions of fishery and survey biomass from the parameters estimated by the model. These parameters were:

- Proportion mature at length (not estimated in model).

- Population allometric growth relationship, as estimated from the acoustic survey (not estimated in model).

- Initial estimates of growth including CVs of length at age for the youngest and oldest fish (estimated in model).

- Natural mortality (*M*, not estimated in model).

Total catch

Table 1 lists the catch of Pacific hake for 1966-2005 by nation and fishery. Catches in U.S. waters for 1966-1980 are from Bailey et al. (1982). Prior to 1977, the at-sea catch was

reported by foreign nationals without independent verification by observers. Bailey et al. (1982) suggest that the catch from 1968 to 1976 may have been under-reported because the apparent catch per vessel-day for the foreign feet increased after observers were placed on foreign vessels in the late 1970's. For 1981-2005, the shore-based landings are from Pacific Fishery Information Network (PacFIN). Foreign and joint-venture catches for 1981-1990, and domestic at-sea catches for 1991-2005 are estimated by the North Pacific Groundfish Observer Program (NPGOP).

At-sea discards are included in the foreign, joint-venture, at-sea domestic catches in the U.S. zone. Discards have not been estimated for the shore-based fishery. The majority of vessels in the U.S. shore-based fishery operate under experimental fishing permits that require them to retain all catch and bycatch for sampling by plant observers. Canadian joint-venture catches are monitored by at-sea observers, which are placed on all processing vessels. Observers use volume/density methods to estimate total catch. Domestic Canadian landings are recorded by dockside monitors using total catch weights provided by processing plants. Catch data from Canadian JV and domestic fisheries were provided by Greg Workman (DFO, Pacific Biological Station, Nanaimo, B.C.).

Fishery-dependent Data

Since the SS2 model uses length compositions and conditional age-at-length compositions, a complete reconstruction of these data inputs was required. Biological information from the U.S. at-sea commercial Pacific hake fishery was extracted from the NORPAC database management system maintained at the Alaska Fisheries Science Center. A query of length, weight and age information yielded biological samples from the Foreign and Joint Venture fisheries from 1975-1990, and from the domestic at sea fishery from 1991-2005. Specifically these data included sex-specific length and age data collected at the haul level by observers, where random samples of fish lengths from a known sampled haul weight and otoliths are then collected on a length-stratified basis. Detailed sampling information including the numbers of hauls sampled, lengths collected, and otoliths aged in the Foreign, JV and domestic at-sea fisheries are presented in Table 2.

Biological samples from the U.S. shore-based fishery were collected by port samplers from ports with substantial landings of Pacific hake: primarily Newport, Astoria, Crescent City, and Westport, from 1991-2005. Port samplers routinely take one sample per offload or trip in the port consisting of 100 randomly selected fish for individual length and weight, and 20 random samples per offload for otolith extraction and subsequent aging. It should be noted that the sampling unit here is the trip rather than the haul as in the case of the at-sea fishery. Since detailed haul-level information is not recorded on trip landings documentation in the shore-based fishery, and hauls sampled in the at-sea fishery can not be aggregated to a comparable trip level, there is no least common denominator for aggregating at-sea and shore-based fishery samples. As a result, samples sizes were simply summed over hauls and trips for U.S. fishery length- and age-compositions, however each fishery was weighted according to the proportion of its catch.

The Canadian domestic shore-based fishery is subject to 10% observer coverage. On observed trips, an otolith sample is taken from the first haul of the trip with associated length information, followed by length samples on subsequent hauls. For unobserved trips, port samplers obtain biological data from the landed catch. Observed domestic haul-level information is then aggregated to the trip level to be consistent with the unobserved trips that are sampled in ports. Sampled weight of the catch from which biological information is collected must be inferred from year-specific length-weight relationships. Canadian domestic fishery biological samples were only available from 1996-2005, and detailed sampling information is presented in Table 3.

For the Canadian at-sea Joint Venture fishery, an observer aboard the factory ship records the codend weight for each codend transferred from companion catcher boats. However, length samples are only collected every second day of fishing operations, and an otolith sample is only collected once a week. Length and age samples are taken randomly from a given codend. Since sample weight from which biological information is taken is not recorded, sample weight must be inferred from a weight-length relationship applied to all lengths taken and summed over haul. Length and age information was only available from the Joint Venture fishery from 1988-2005. As in the case with the U.S. at-sea fishery, the basic sampling unit in the Canadian Joint Venture fishery is assumed to be a haul. Detailed sampling information for the Canadian Joint Venture fishery is also presented in Table 3.

The length and age data were analyzed based on the sampling protocols used to collect them, and expanded to estimate the corresponding statistic from entire landed catch by fishery and each year that sampling occurred. In general, the analytic steps can be summarized as follows:

1) Count lengths (or ages) in each size (or age) bin (1 cm/year) for each haul in the at-sea fishery and for each trip in the shore-based fishery, generating “raw” frequency data.
2) Expand the raw frequencies from the haul or trip level to account for the catch weight sampled in each trip.
3) Expand the summed frequencies by fishery sector to account for the total landings.
4) Calculate sample sizes (number of samples and number of fish within sample) and normalize to proportions that sum to unity within each year.

To complete step (2), it was necessary to derive a multiplicative expansion factor for the observed raw length frequencies of the sample. This expansion factor was calculated for each sample corresponding to the ratio of the total catch weight in a haul or trip divided by the total sampled weight from which biological samples were taken within the haul or trip. In some cases, where there was not an estimated sample weight (more common in the Canadian domestic shore-based trips), a predicted weight of the sample was computed by applying a year-specific length-weight relationship to each length in the sample, then summing these weights. Anomalies that could emerge where very small numbers of fish lengths were collected from very large landings were avoided by constraining expansion factors to not exceed the 95^{th} percentile of all

expansion factors calculated for each year and fishery. The expanded lengths (N at each length times the expansion factor for the sample) were then summed within each fishery sector, and then weighted a second time by the relative proportion of catches by fishery within each year and nation. Finally, the year-specific length frequencies were summed over fishery sector and normalized so that the sum of all lengths in a single year and nation was equal to unity.

Tables 4 and 5 provide a detailed sampling summary, by fishery and nation, including the number of unique samples (hauls in the JV fishery and trips in the domestic fishery) by year and other sampling metrics of the relative efficiency of sample effort. Ultimately, the total sample size (# samples) by year is the multinomial sample size included in the stock assessment model. In both the U.S. and Canada, at-sea biological samples are collected at the haul level while shore-based samples are collected at the trip level. Tables 4 and 5 provide comparisons of sampling levels relative to the total sector catches in each country. In recent U.S. fisheries, between 9% and 16% of all shore-based catch has been sampled, compared to 40% to 60% of the at-sea catch. In both cases, fraction sampled has increased over time. Between 2000 and 2005, a sample was taken, on average, once per 575 mt of hake caught in the shore-based fishery, compared to once per 45 mt of catch in the at-sea fishery. Sample sizes for conditional age at length compositions for the U.S. and Canadian fisheries are given in Tables 6 and 7, respectively.

U.S. fishery length compositions representing fish caught in both the at-sea and shore-based fisheries are shown in Figures 3 and 4. It should be noted that there are some differences in the length compositions between the at sea and shore-based domestic fisheries, suggesting that future attempts should be made to model them separately. In general, the composite U.S. fishery length compositions confirm the well known pattern of year class strengths, including the dominant 1980 and 1984 and secondary 1970, 1977 and 1999 year classes moving through the size structure (Figure 4). These relationships suggest that the sizes of hake which are vulnerable to the U.S. fishery have changed over time, possibly due to growth, selectivity or both. This is particularly evident as larger fish before 1990 and a shift to smaller fish between 1995 and 2000. These features will be explored within the population dynamics model.

As with the U.S. fleet sectors, differences in length compositions between the Canadian Joint-venture and domestic fleets among some years warrant exploration of fitting the fisheries separately. This however was not done in this assessment due to time limitations. The composite Canadian fishery length compositions (Figures 5 and 6) indicate that the Canadian fleets exploit larger and presumably older hake. A particularly interesting feature of these length compositions is that the Canadian fleet prosecuted a seemingly fast growing 1994 year class of hake in 1995 (age 1), 1996 (age 2) and subsequent years. It is unclear whether this is due to size- vs. age-based selectivity, however, it is well known that larger (and older) hake migrate further northward annually (Dorn, 1995). As in the U.S. fishery, Canadian length compositions show some temporal pattern in the range of fish exploited by the fishery (Figure 6).

U.S. and Canadian fishery conditional age-at-length compositions constitute the bulk of data in this assessment and provide information on recruitment strength, growth and growth

variability. These data are shown graphically for the U.S. fishery from 1975-2005 and from 1988-2005 for the Canadian hake fishery in Figures 7 and 8, respectively. Since age-composition data used in the old hake assessment extended further back in time than the conditional age-at-length data generated here, the older data were also included in the assessment model to augment information on recruitment earlier in the time series and are shown in Figure 9.

Acoustic Survey (Biomass, length and age composition)

Integrated acoustic and trawl surveys, used to assess the distribution, abundance and biology of coastal Pacific hake, *Merluccius productus*, along the west coasts of the United States and Canada. The Pacific Biological Station (PBS) of the Canadian Department of Fisheries and Oceans (DFO) has conducted annual surveys along the Canadian west coast since 1990. From 1977-2001, surveys in U.S. waters were conducted triennially by Alaska Fisheries Science Center (AFSC). The triennial surveys in 1995, 1998, and 2001 were carried out jointly by AFSC and PBS. Following 2001, the responsibility for the US portion of the survey was transferred to the Fishery Resource Analysis and Monitoring (FRAM) Division of NOAA's Northwest Fisheries Science Center (NWFSC). Following the transfer, the survey was scheduled on a bi-annual basis, with joint acoustic surveys conducted by FRAM and PBS in 2003 and 2005.

The 2005 survey was conducted jointly by US and Canadian science teams aboard the NOAA vessel *Miller Freeman* from 20 June to 19 August, spanning the continental slope and shelf areas the length of the West Coast from south of Monterey California (35.7º N) to the Dixon Entrance area (54.8º N). A total of 106 line transects, generally oriented east-west and spaced at 10 or 20 nm intervals, were completed (Figure 10). During the 2005 acoustic survey, aggregations of coastal Pacific hake were detected as far south as 37º N (Monterey Bay) and extending nearly continuously to the furthest northerly area surveyed at Dixon Entrance. Areas of prominent concentrations of hake included the waters off Point Arena (ca. 39º N) and north of Cape Mendocino, California (ca. 41º N), in the area south of Heceta Bank, Oregon (ca. 44º N), the waters spanning the US-Canadian border off Cape Flattery and La Perouse Bank (ca. 48.5E N), and locally within Queen Charlotte Sound (ca. 51º N). Mid-water and bottom trawls, deployed to verify size and species composition and collect biological information (i.e., age composition, sex), found that smaller individuals - age-2 fish - were prevalent in the southern portion of their range, but the coastal Pacific hake stock continued to be dominated by representatives of the 1999 year-class (age 6) throughout most of their range, except for the occurrence of numbers of larger Pacific hake in the north.

As with the fishery data, acoustic survey length and conditional age compositions were used to reconstruct the age structure of the hake population. In general, biological samples taken by midwater trawls were post-stratified based on geographic proximity and similarity in size composition. Each sample was given equal weight without regard to the total catch weight. The composite length frequency was then used for characterizing the hake distribution along each particular transect and were the basis for predicting the expected backscattering cross section for Pacific hake based on the fish size-target strength relationship TS_{db} = 20logL-68 (Traynor

1996.). Estimates of numbers (or biomass) of hake at length (or age) for individual cells were summed for each transect to derive a coast-wide estimate. Details of this procedure can be found in Fleischer et al. (2005).

Acoustic survey sampling information including the number of hauls, numbers of length taken and hake aged are provided in Tables 8 and 9. The 2005 acoustic survey size composition shows a dominate peak at 45 cm indicating the persistence of the 1999 year class in the population (Figure 11). A secondary peak around 33 cm suggests the potential of a 2003 year class. Model structure in the size compositions of the previous acoustic surveys also confirm the dominant 1980 and 1984 year classes present in the mid-1980s to early 1990s. Proportions at size are given in Figure 12 and conditional age-at-length proportions are shown in Figure 13.

Based on the estimates from the acoustic survey, Pacific hake biomass has declined by 32% from 1.8 million mt in 2003 to 1.26 million mt in 2005 (Table 10). In general, acoustic survey estimates of biomass indicate that the hake population has varied with little trend since the first survey in 1977 to the most recent in 2005 survey (Figure 14). Error bars shown around point estimates of biomass are not estimated but rather assumed based on reliability of the survey in a given year and are used as input in SS2 (CV=0.5 1977-1989, CV=0.25 1992-2005). It should be noted that while shown in this plot the 1986 acoustic survey biomass estimate is not used in the assessment due to transducer calibration problems during survey operations that year (The decision to omit this data point was made during the 2003 STAR panel review).

Aging Error

Since aging Pacific hake was transferred to the Northwest Fisheries Science Center in 2001, an effort was made to cross-calibrate age reader agreement. Cross-calibration was performed on a total of 197 otoliths from the 2003 acoustic survey between the Northwest Fisheries Science Center (NWFSC) and Department of Fisheries and Oceans (DFO). Overall agreement between NWFSC/DFO was 50%, and for ages assigned that were aged within one and two years, the agreement was 86% and 96%, respectively. As would be expected, agreement between the three labs was better for younger fish than for older fish. These cross-calibration results were somewhat better than 2001 comparisons between NWFSC/DFO, but poorer than 1998 comparisons between AFSC (Alaska Fishery Science Center) and DFO. It should be noted, however, that agreement between two age readers at NWFSC was closer to 87%, with 98% agreement within one year of age. Agreement for ages 3-4 and ages 5-7 was 82% and 40%, respectively, for NWFSC between reader comparisons, with similar results for NWFSC/DFO comparisons. Also, when ages did not agree between the three labs, the NWFSC tended to assign older ages than DFO. Additional comparisons are needed to further calibrate ageing criteria between agencies. For the present model, aging error has not been included.

Pre-recruit surveys

The Santa Cruz Laboratory (SCL) of NOAA's Southwest Fisheries Science Center has conducted annual surveys since 1983 to estimate the relative abundance of pelagic juvenile

rockfish off central California. Although not specifically designed to sample juvenile hake, young-of-the-year hake appear frequently in the midwater trawl catches. In this assessment, as in the previous assessments, this survey is used to produce a tuning index for recruitment to age-2 (Table 11, Figure 15). This index was created using a generalized linear model (GLM) fit to the log-transformed CPUEs (Ralston et al. 1998; Sakuma and Ralston 1996). Specifically, the year effect from the GLM was back-transformed to obtain an index of abundance. Only the Monterey outside stratum was used because of its higher correlation with hake recruitment. Also, Dorn et al. (1999) showed that the juvenile index was significantly correlated to the predicted recruitment two years later in the stock assessment model. The index in 1999 suggested that age-2 recruitment in 2001 may be above average, which has largely been confirmed by other data sources, such as numbers at age in the fishery catches and acoustic surveys. The 2003 juvenile index, representing recruitment in 2005, is among the lowest observed since 1986. As will be discussed below, the Pacific Whiting Conservation Cooperative (PWCC)/NWFSC recruit survey shows a marked contrast to the 2003 survey index. The two most recent index values, in 2004 and 2005, suggest an above average year class in 2006 and very low year class in 2007. The general magnitude of these forecast indexes are consistent with those from the PWCC/NWFSC pre-recruit survey. The Santa Cruz series average CV, estimated from the GLM, was calculated to be approximately 0.50. Relative accuracy of the Santa Cruz and PWCC/NWFSC pre-recruit surveys will be evaluated in future work. It should be noted that comparative analyses with SS2 and the previous hake model lagged the index forward two years and was used to index recruitment to age-2. Subsequent formulation of the base case model in SS2 used the log-abundance to index age-0 recruitment during the year in which the survey occurred.

The PWCC and NWFSC, in cooperation with the SCL, have been conducting an expanded survey of juvenile hake and rockfish relative abundance and distribution to include Oregon and California since 1999. This survey is an expansion of the SCL juvenile survey, which is conducted between Monterrey Bay and Pt. Reyes, California. Prior to 2001, results between the PWCC/NWFSC survey and the SCL survey were not comparable because of trawl gear differences. Since 2001, the gear has been comparable and side-by-side comparisons were made between the contracted vessel *Excalibur* and the NOAA vessel *David Starr Jordan.*

The cooperative PWCC/NWFSC pre-recruit survey uses a modified anchovy midwater trawl with an 86' headrope and ½" codend with a 1/4” liner was used to obtain samples of juvenile hake and rockfish. Trawling was done at night with the head rope at 30 m at a speed of 2.7 kt. Some trawls were made prior to dusk to compare day/night differences in catch. Trawl tows of 15 minutes duration at target depth were conducted along transects located at 30 nm intervals along the coast. Stations were located along each transect from 50m bottom depth seaward to 700 m with hauls taken over bottom depths of 50, 100, 200, 300, and 500 meters at each transect.

The PWCC/NWFSC Pacific hake pre-recruit survey results show an inconsistent trend in some years compared to the Santa Cruz survey over the same time period. The PWCC/ NWFSC survey indicates 2001 and 2002 abundance to be about the same magnitude , but 2003 to be

significantly higher. The SCL survey, on the other hand, suggests that the 2003 index to be the least abundant year class of the series, while the index for 2004 (after an extension of the range surveyed by SCL this year) is more consistent between the two surveys. However, until the effects on catch rate of the differences in geographic ranges of each survey can be established and a longer time series collected, it is difficult to interpret the implications for future abundance levels of a particular year class. As the year classes in question age and become selected by the fishery, their relative sizes will be established. The expansion of the hake recruitment index beyond the traditional SCL survey area raises questions about the inter-annual consistency of juvenile hake distribution. The results of the 2003, and particularly 2004 PWCC/ NWFSC survey shows a northward shift in the distribution of juveniles with peak numbers of age-0 found north of the Monterey index area in recent years. However, it is possible that the age-0 hake follow a set transport pattern, but vary temporally. If there is a temporal component there may be some evidence in age-0 daily growth or an environmental signal. With additional data, it may be possible to model and predict the distribution of young-of-the-year hake and improve the deployment of survey efforts.

Biological Parameters

Growth

There is a considerable amount of variability in the length-at-age data collected during the acoustic surveys since 1977. The process governing variation in growth may include effects from size-selective fishing, changes in size selectivity over time, and variation in growth rates over time. In order to explore alternative specifications for hake growth within SS2, we fit alternative growth models to the length-at-age data collected in the acoustic surveys (assuming size-selectivity in the acoustic surveys has been constant over time). The first of these models is a simple time-varying growth model, where the growth coefficient (k) is allowed to vary over time. This assumes that all extant cohorts are subject to time varying changes in the metabolic rates (presumably associated with changes in available food). This is the version of the growth model that is presently implemented in Stock Synthesis 2 (SS2). The second growth model assumes that growth is density-dependent. That is, the density of each cohort determines the overall growth rate and each cohort has its own asymptotic length. The third model is similar to the second model; however, in this case we assume the growth coefficient (k) is cohort specific. Details of this analysis are given in Appendix A.

Temporal variability in hake growth is shown in Figure 16 in terms of the observed lengths at age from the acoustic survey from 1977-2005. Of the 3 alternative growth models, the model with cohort specific l_2 values explains more of the variation in the length-age data versus the time varying k model and cohort k model (Figure 17). In particular, cohort based L2 begins relatively high (> 55 cm) prior to 1980 (Figure 22) and then appears to decline rapidly as the very large 1980 and 1984 year class grow. Expected size at age, based on the cohort based L2, parameter are above the expected size for the other models in the 1977, 1980, and 1983 survey data (Figure 16). Likewise, cohort based k declines rapidly between the mid 1970s and middle 1980s (Figure 17). Is should be noted that these cohort based models do not assume the

cumulative affects of size-selective fisheries. To properly represent the cumulative affects of size-selective fisheries in this approach, the cohort based growth model should be integrated into the assessment model itself. This would provide a fruitful area of research for improving SS2. In this case it would not be necessary to use the conditional MLE for the numbers at age; this information could be provided from the stock assessment model itself. Since this feature is not currently implemented in SS2, blocks were created aggregating various years in which it was anticipated the cohort affects on growth would be manifested (See *Model Selection and Evaluation* below).

Size/Age at Maturity

Fraction mature by size was estimated using data from Dorn and Saunders (1997) with a logistic regression. These data consisted of 782 individual ovary collections based on visual maturity determinations by observers. The highest variability in the percentage of each length bin that was mature within an age group occurred at ages 3 and 4, with virtually all age-one fish immature and age 4+ hake mature. Within ages 3 and 4, the proportion of mature hake increased with larger sizes such that only 25% were mature at 31 cm while 100% were mature at 41 cm. Maturity in hake probably varies both as a function of length and age, however, for the purposes of parameterizing SS2 the logistic regression model was fit as a function of length. Maturity proportions by length are shown in Figure 18. Less then 10% of the fish smaller than 32 cm are mature, while 100% maturity is achieved by 45 cm.

Natural mortality

The natural mortality currently used for Pacific hake stock assessment and population modeling is 0.23. This estimate was obtained by tracking the decline in abundance of a year class from one triennial acoustic survey to the next (Dorn et. al 1994). Pacific hake longevity data, natural mortality rates reported for Merluciids in general, and previously published estimates of Pacific hake natural mortality indicate that natural morality rates in the range 0.20-0.30 could be considered plausible for Pacific hake (Dorn 1996).

Model description

This assessment used the Stock Synthesis modeling framework written by Dr. Richard Methot at the NWFSC (SS2 Version 1.21). The Stock Synthesis application provides a general framework for the modeling fish stocks because the complexity of the population dynamics can be made commensurate with the data quantity and quality. In this regard, both complex and simple models were explored. The Pacific hake population is assumed to be a single coastwide stock along the Pacific coast of the United States and Canada. As in the previous model, sexes are combined in the current model in representing the underlying dynamics and in all data sources where this was possible: growth and fishery and survey size/age compositions. The accumulator age for the internal dynamics of the population was set at 15 years, well beyond the expectation of asymptotic growth. The length structure ranged from 20 cm to 70 cm. The years explicitly modeled were 1966-2005 (last year of available data). Initial population conditions

were assumed to be in equilibrium prior to the first year of the model. No initial fishing mortality was estimated and the spawning biomass was assumed equal to Bzero in 1966, preceding the advent of the distant water fleets during the mid-to-late 1960s. The level of hake removals prior to 1966 is unknown, but there were no directed commercial fisheries for hake until the arrival of foreign fleets in the mid to late 1960s.

The following narrative of the model structure is accompanied by the detailed parameter specifications and assumptions found in Table 12. The assessment model includes two national fisheries: US and Canadian trawl fisheries. Arguably, the U.S. at-sea and shore-based fisheries, as well as the Canadian JV and domestic fisheries could be modeled separately for reasons mentioned above. However, in this assessment each nation's fleets are combined and implicitly assumed to have the same selectivity patterns. The selectivity curves for the acoustic survey and the U.S. and Canadian fisheries are assumed to be dome-shaped and modeled as a function of age using the double logistic function (option 19 in SS2). Considerable discussion continues to be centered on asymptotic vs. dome-shaped selectivity for the acoustic survey: dome-shaped selectivity implies a greater proportion of older hake in the population than that observed in the survey. While this topic warrants more detailed analysis, preliminary work comparing the numbers at age in both the acoustic and bottom trawl surveys indicate empirical evidence in support of an acoustic survey selectivity that is dome-shaped (Figure 19). As will be discussed in greater detail below, a time-varying selectivity option for the U.S. and Canadian fisheries, in which the parameters are treated as a random walk process, was initially implemented as a means to provide a direct comparison between the previous hake model and SS2. While some of the fundamental underlying assumptions differed between these two modeling platforms, the specification of selectivity, survey catchability, recruitment deviations and growth parameters were tuned in as close as possible in order to confirm results of the basic population dynamic equations. The model specification in SS2 was then simplified in terms of reducing model complexity to achieve parsimony with the data. This reduced model is considered the base model.

For the base case model, as well as the previous model, instantaneous natural mortality (M) is assumed to be age- and time-independent and equal to 0.23 y^{-1}. The stock-recruitment function was a Beverton-Holt parameterization, with the log of mean unexploited recruitment estimated. When freely estimated, the steepness parameter was close to the upper limit of 1.0, thus implying that recruitment is independent of the level of spawning biomass. However, for this assessment steepness was assumed to be h=0.75 based on several meta-analyses of marine fish stocks (Myers et al. 1999, Myers et al. 2002). Year-specific recruitment deviations were estimated from 1967-2003. This structure was based upon inspection of year-specific standard deviations relative to the input value of $sigma_R$.

The constraint and bias correction standard deviation, $sigma_R$, is treated as a fixed quantity in SS2. Typically, the value is derived through an iterative process of adjusting the input value corresponding to the minimal difference between the root means square error (RMSE) of the predicted recruitment deviations and the input value. This ensures that the approximate bias-correction term would be appropriately and internally consistent for predicted

recruitments estimated in the model and projected forward in time. Initial models runs began with the value used in the previous hake model, $sigma_R$ = 1.17, but were iterated to 1.13. In addition, input sample sizes were iterated by examining the relationship between effective sample size estimated in the model and the observed input sample sizes.

Maturity of Pacific hake is assumed to have a logistic functional form, increasing sigmoidally to an asymptote as a function of size (Figure 20). Fecundity (spawning output) is assumed to be a function only of mass and equivalent in form to the maturity-at-length relationship. Individual growth is modeled for combined sexes and based on the von Bertalanffy growth function. All von Bertalanffy growth parameters, including the growth coefficient k, length at minimum age, length at maximum age (15 years old), CVs of size at age, as well as time blocks describing changes in some parameters, were estimated within the model. The explicit temporal parameterization is shown in Table 12.

Multinomial sample sizes for the length composition and conditional age at length data used in this assessment are based on the number of hauls or trips sampled for the commercial at sea and shore-based fisheries, respectively, and the number of tows in the research surveys. Sample sizes for conditional age-at-length data were taken from the number of fish aged. Standard deviations from the survey indices were not adjusted, as the RMSE from preliminary model runs were consistent with the mean of the input standard deviations. The base case model employs equal emphasis factors (lambdas=1.0) for each likelihood component, however, sensitivity analyses are performed.

Modeling Results

Comparative Models

As previously mentioned our first goal was to perform a comparative population assessment between the previous hake model and SS2. This exercise required reconstruction of the entire time series of data inputs for SS2 and configuring the model so that assumptions in SS2 were as close as possible to the previous hake model. It is important to point out that the structure of the data inputs for SS2 was quite different from the previous hake model, and used length-frequency compositions and conditional age-at-length compositions from the U.S. and Canadian fisheries, as well as the acoustic survey. Time series of biomass indices remained the same, including the same error assumptions as Model 2b (CVs=0.20 1977-1989, CVs=0.10 1992-2005) in the previous hake model (Helser et al. 2004). However, multinomial sample sizes were input consistent with the year in which samples were taken, unlike the old hake model which used a single sample size over all years of a given data source. Those years for which fishery data could not be acquired from standard U.S. and Canadian sources, (1972-1973 in the U.S. and 1977-1987 in the Canadian fishery), the traditional age-composition data and associated sample sizes were used. In terms of model specification, time-varying fishery selectivity was modeled as a random walk process constrained by standard deviation of 0.2 using the double logistic curve. As in the previous model, maturity was specified as a function of age and natural mortality (M) was assumed to be equal over ages and time invariant at 0.23 y^{-1}. Growth in SS2

was treated as time varying, by assuming a random walk process in the growth parameter k (constrained by standard deviation of 0.1), and with all other growth parameters freely estimated as base parameters. This aspect of time-varying growth was employed to mimic temporal changes in the observed fishery weights at age, which were treated as deterministic inputs in the old hake model.

Despite some differences in acoustic survey biomass and selectivity patterns, SS2 and the previous hake model produced very similar biomass trajectories and management reference points (Figure 21). Age 3+ biomass and female spawning biomass trajectories between assessment models were consistent over time, but in general SS2 estimates of biomass were slightly higher than those from the previous hake model, particularly for the years 1970-1990 (Figure 21). This result appears to be primarily driven by global scaling parameters, such as logRzero and the magnitude of year-class strengths, which were estimated to be higher in the SS2 model. These scale parameters in turn are most likely due to slight differences in acoustic survey biomass trends (Figure 22) and fishery and acoustic survey selectivities (Figure 23). Despite these differences the relative depletion level of the Pacific hake stock over time and in the final year (beginning of 2006) were similar. Current depletion was estimated to be 27% of the unfished level using SS2 compared to 29% using the previous hake model, respectively (Figure 21). Based on this evaluation, we concluded that SS2 was capable of reproducing the most important results from the previous model, when similarly configured. Consequently, further model explorations were performed in SS2.

Model selection and evaluation

An effort was made to explore many levels of model complexity in order to achieve a model that was parsimonious in the number of estimated parameters, but also retained a realistic level of complexity in representing the underlying population dynamics. Many preliminary models were fit to the data and evaluated based on residual patterns, plausibility of estimated model parameters and convergence criteria. However, only a subset of these models was retained for sensitivity analysis (see below), and the base case model reflects the best aspects from each these exploratory analyses.

Based on past and current experience with modeling hake dynamics, a complex modeling structure was used as the starting point for explorations of more parsimonious alternatives. Factors that were important in this decision included: 1) a persistent structure of recruitment deviations, most notably the 1980 and 1984 cohorts, have a large impact on the scale parameter logRzero, 2) hake growth has varied substantially over time either through density-dependent and or environmental factors, and 3) fishery selectivity has varied temporally in response to the presence of one or two dominant year classes in the exploitable population. Based on this knowledge our approach was to reduce the total number of parameters, but maintain the underlying dynamic, temporal structure of the hake population.

The wealth of conditional age-at-length data from the commercial fleets and acoustic survey provided a great deal of flexibility in modeling potential changes in growth curves over

time. The comparative analysis used a 'random walk' approach to growth, but it was felt that this approach might be over-parameterized since empirical examination of the growth parameters outside the model suggested a pattern of discrete changes between multi-year periods. Preserving some degree of temporal variability was clearly warranted, since specifying growth as time-invariant resulted in a decline of roughly 8,000 likelihood units in the objective function, relative to the random-walk structure. Through an iterative process of gradually increasing the size of adjacent-year blocks and examining residuals, a block structure was developed that sacrificed little in the value of the objective function and seemed consistent with empirical observations. Two blocks were used for the L2 parameter, 1966-1983 and 1984-2005, which allowed the model to account for the larger asymptotic fish size and the generally prevalence of larger observed during the early period. Three blocks were used to partition the growth parameter k: 1966-1980, 1981-1986, and 1987-2005. The middle period was intended to allow the model accommodate the slightly smaller body size of age 4-6 year old fish during those years. The temporal structure of hake growth in terms of the expected size at age is (Figure 24) characterized as an early period from 1966 to the early 1980s where expected maximum size (i.e., L2) is high relative to the subsequent period from the mid 1980s to 2005, and a decline in growth rates (i.e., smaller expected size at age for ages 4-6) during the early-to-mid 1980s. In the most recent block, 1987-2005, growth returns to near baseline rates but the expected maximum size is lower.

As with growth, we employed the same approach and developed a block structure that seemed consistent with the empirical data. In particular, both the U.S. and Canadian fisheries consisted of four discrete temporal blocks. For the U.S. fishery, separate selectivity functions were estimated for the periods: 1966-1983, 19884-1992, 1993-2000, and 2001-2005. Selectivity functions for the Canadian fishery were estimated for the periods: 1966-1994, 1995-2000, 2001-2002, and 2003-2005. The acoustic survey selectivity was estimated freely but was time invariant. The estimated selectivity curves are shown in Figure 25 with parameter estimates and asymptotic standard deviations in Table 13. The shapes of the curves for both the U.S. and Canadian fisheries appear to be quite reasonable, even with the apparent temporal shifts in the curves. The U.S. fishery selectivity curves show substantial temporal variation in both the ascending and descending limbs. As might be expected, U.S. fishery selectivity increased on the younger aged fish (ages 3 and 4) as the dominant 1980 and 1984 year classes become vulnerable to exploitation during the mid 1980s to early 1990s. As these cohorts grew into the older age structure and persisted in the fishable stock U.S. fishery selectivity increased on the older ages as seen as an increase in the descending curve in 1993-2005. Canadian fishery selectivity curves also show variability through time (it should be noted that Canadian fishery selectivity curves on older fish were assumed to be the same through). As is the case with the U.S., changes in ascending-limb selectivity appear to be associated with availability of a specific year class and its exploitation by the Canadian fleets, which can be observed in the exploitation of the 1994 year class during1995-2000.

Model fits to size-composition data are shown as predicted length frequency distributions, Pearson residual plots, and effective vs. observed sample sizes and illustrated separately for the U.S. fishery (Figures 26-28), Canadian fishery (Figures 29-31) and acoustic

survey (Figures 32-34). In general, model fits to the U.S. fishery length-frequency distributions show reasonable predictions given the observed data (Figure 26). Predictions seem be consistent with the observed length compositions in terms of hitting the modes of the distribution and range of sizes exploited. Comparison of observed and calculated effective sample sizes for U.S. fishery length frequencies show no clear relationship, but generally indicate that model fits are as good as expected given the input sample sizes and length frequency data (Figure 27). It should be noted that the input samples sizes shown in Figure 31 for the U.S. length and length-at-age compositions have already been iteratively tuned to 0.3 and 0.5, respectively, of their original input sizes. Some lack of fit does appear to be evident in the U.S. fishery length compositions, but this is generally restricted to the largest sizes, especially in the earlier years (Figure 28).

The model fit the Canadian fishery length composition data slightly less well than the U.S. fishery, but this may not be surprising given the fewer years of data (Figure 29). Predicted length distributions were on the mode for most years with the exception of 2000, 2001, and 2002 suggesting a pool of larger hake was exploited during those years than predicted by the model. The model was also not able to accommodate well the catches of smaller hake in 1995-1998. This suggests that hake spawned in Canadian waters in 1994 and were exploited by the Canadian fleet as young fish. This pattern has not been observed in the Canadian fishery during any other period. Despite the lack of fit created by these anomalies, overall the model fit these data as well as expected given the observed data and input sample sizes (Figure 30). Canadian size or age composition data did not require iterative re-scaling of input sample sizes. Pearson residuals of length compositions data also illustrate the apparent lack of fit in the mid-1990s and early 2000s (Figure 31).

Predicted lengths for the acoustic survey were also generally on the modes with the observed size compositions. But in a number of years (1980, 1995, and 2005) the model was unable to effectively reproduce the observed bi-modal structure (Figure 32). Comparison of effective vs. input sample sizes suggest that the model fit these data as well as expected, given the observed data and input sample sizes (Figure 33). Figure 34 illustrates model lack of fit, consistent with the model's inability to reproduce the bi-model structure of the observed size compositions.

Given the assumption of age-based selectivity for the fisheries and the volume of conditional age-at-length data, the model generally fits the age data better than the length-composition data. Plots of effective vs. input sample sizes indicate that the model fit the data as well as expected, given the data and sample sizes (Figure 27, Figure 30, and Figure 33). As with the U.S. fishery length compositions, the U.S. fishery age-composition sample sizes were iterated to 50% of the original input sample sizes. The Canadian and acoustic survey conditional age-at-length compositions were unmodified. Model fits to the conditional age-at-length data are illustrated for 1988 (Figures 35-36) and 2005 (Figure 38-40). Plots of Pearson residuals by fishery for 1988 and 2005 are provided in Figures 37 and 41, respectively. These years were chosen to show the structure of the conditional age-at-length data when several dominant year classes were present. In 1988, the large 1980 (age 8) and 1984 (age 4) cohorts are evident in the size bins between 39 and 50 cm in both the U.S. and Canadian fisheries. The 1977 year class is

also present as age 11 fish in size bins greater than 50 cm. Model fits to the conditional age-at-length compositions are generally in agreement with the observed data in both the U.S. (Figure 35) and Canadian fisheries (Figure 36). The discrepancy of model fits to the observed data at length bins greater than 59 cm reflects relatively small sample sizes and cannot be differentiated from noise. Pearson residuals for the U.S. and Canadian conditional age-at-length data for 1988 show no severe patterns of lack of fit (Figure 37). The 1999 year class was the dominant year class in the 2005 U.S. fishery, Canadian fishery and acoustic survey conditional age-at-length compositions, and the model fit approximately this well (Figure 38-40). The acoustic survey age-compositions also show the presence of the 2003 year class as age-2 fish in the 28-38 cm length bins (Figure 40). Again, the model appears to fit the conditional age-at-length data reasonably well (Figure 41). The full suite of standardized Pearson residuals for all fisheries and survey conditional age-at-length data in each year are shown in detail in Figure 42.

The model's fit to the acoustic survey biomass time series seems reasonable given the error structure assumed for the index (Figure 43). For biomass points since 1992, which are assumed to have less error than pre-1992 data, the predicted biomasses are within asymptotic 95% confidence intervals for all years except 2001. Given the assumed error on the Santa Cruz juvenile hake recruitment index, the model fits the observed data quite well (Figure 44). As plotted in log-space the index appears rather flat and the model fits the slight departures from the mean, as in the case of the 1999 year class (in 2001). Despite being the lowest index on record, the 2003 (age 2 in 2005) prediction of recruitment is greater (although below average) than indicated by the observed data owing to the relatively large CV on the recruit index time series and sigma$R$.

Assessment Model Results

During the STAR panel review, Feb. 6-10, discussion focused on the uncertainty in acoustic survey q as the dominant axis of uncertainty. This parameter essentially globally scales population biomass higher if q is lower and lower if q is higher. As in the previous year's assessment, two models are presented to bracket the range of uncertainty in the acoustic survey catchability coefficient, q. The base model with steepness fixed at h=0.75 and q=1.0 represents the endpoint of the lower range while the alternative model which places a prior on q (effective q=0.7) represents the upper endpoint of the range. As such, model estimates presented below report a range of values representing these endpoints.

The predicted time series of hake recruitments, as well as recruitment uncertainty, recruitment deviations from the S-R curve, and yearly estimates of variability are shown in Figure 45. The model predicted very large year classes in 1980 and 1984, with secondary recruitment events in 1970, 1973 and 1977. The 1999 year class was the single most dominate cohort since the late 1980s. Uncertainty in recruitment can be substantial as shown by asymptotic 95% confidence intervals (Figure 45). Based on the assumption of log-normal error about the mean log recruitment, uncertainty increases with the magnitude of recruitment. Recruitment to age 0 before 1967 is assumed to be equal to mean recruitment, while recruitment from 1967 to 2005 is estimated from the data. Age-0 recruitment in 2003 is predicted to be

uncertain and below mean recruitment, despite some evidence to the contrary in the 2005 acoustic survey. Except for the actual magnitude of estimated recruitments, the patterns in recruitment deviations and uncertainty are qualitatively the same under both the base and alternative models.

Summary of Pacific hake population time trends in 3+ biomass, recruitment, spawning biomass, relative depletion, spawning potential ratio (SPR) and fishery performance are shown in Figures 46-48 for the base model and in Figures 49-51 under the alternative model. Summary Pacific hake biomass (age 3+) under unfished conditions (< 1966) was estimated to be 7.8 millions mt (Table 14a). Summary biomass increased briefly during the mid-1970s, as the 1970 and 1973 year classes recruited, then declined briefly until 1980 (Figure 46, Table 14a). Summary biomass increased again to the highest level in the time series in 1983 as the very large 1980 and 1984 classes entered the population (Figure 46, Table 14a). The hake population then experienced a long period of decline as fishing increased and few large recruitment events occurred between 1985 and 2001. Summary biomass increased slightly in 2002 due to recruitment of the 1999 year class, but has subsequently declined as the U.S. and Canadian fisheries prosecute this dominate cohort in the exploitable biomass. Trends in summary biomass and recruitment under the alternative model are nearly identical but larger in magnitude (Figure 49, Table 14b).

Pacific hake spawning biomass trend is similar to that for summary biomass (Figure 47 and 50, Table 14a and 14b). Under both the base and alternative models, spawning biomass declined rapidly after peaking in 1984 (4.6 and 5.1 million mt, respectively) to the lowest point in the time series in 2000 (0.88 and 1.0 million mt), followed subsequently by a brief increase to 1.68 and 2.1 million mt, respectively, in 2003. In 2006, spawning biomass is estimated to be 1.18 million mt, and is at 30.8 % (~95% CI range from 24.7% to 36.9%; Figure 47, Table 14a) of the unfished level (Figure 49; Table 14a) under the base model. Under the alternative model, spawning biomass is 1.6 million mt with an associated relative depletion of 38.0% (~95% CI range from 29.7% to 45.0%, Figure 50, Table 14b). Approximate asymptotic intervals about the MLE for spawning biomass and recruitment for the entire times series are given in Tables 15a and 15b for the base and alternative models, respectively.

Reference points (biomass and exploitation rate)

Because of temporal changes in growth, there are two types of reference points reported in this assessment: those based on the assumed population parameters at the beginning of the modeled time period and those based on the most recent time period in a 'forward projection' mode of calculation. All strictly biological reference points (e.g., unexploited spawning biomass) are calculated based on the unexploited conditions at the start of the model, whereas management quantities (MSY, SB_{msy}, etc.) are based on the current growth and maturity schedules and are marked throughout this document with an asterisk (*).

Given the current life history parameters and long term exploitation patterns, the fishing mortality that reduces the spawning potential of the stock to 40% of the unfished level is referred

to as F40%, which is the default Pacific Fishery Management Council proxy for F_{MSY} for Pacific hake. Similarly, the proxy for B_{MSY} is spawning biomass corresponding to 40% of the unfished stock size (B40%). Unexploited equilibrium Pacific hake spawning biomass (B_{zero}) from the base model was estimated to be 3.81 million mt (~ 95% confidence interval: 3.46 – 4.16 million mt), with a mean expected recruitment of 4.97 billion age-0 hake. Under the alternative model, spawning biomass (B_{zero}) from the base model was estimated to be 4.29 million mt (~ 95% confidence interval: 3.76 – 4.81 million mt), with a mean expected recruitment of 5.59 billion age-0 hake. Associated management reference points for target and critical biomass levels for the base model are 1.52 million mt (B40%) and 0.95 million mt (B25%), respectively. Under the alternative model, B40% and B25% are estimated to be 1.71 and 1.07 million mt, respectively. The MSY-proxy harvest amount (F40%) under the base model was estimated to be 573,945* mt (~ 95% confidence interval: 521,122-619,501), and 645,240* mt (~ 95% confidence interval: 566,830-712,848) under the alternative model. The spawning stock biomass that produces the MSY-proxy catch amount under the base model was estimated to be 1.06 million* mt (confidence interval is 0.96-1.14* million mt), and 1.19 million* mt (confidence interval is 1.04 - 1.31* million mt) under the alternative model, given current life history parameters.

The full exploitation history under the base and alternative models is portrayed graphically in Figures 48 and 51, respectively, which plot for each year the calculated spawning potential ratio (1-SPR) and spawning biomass level (B) relative to their corresponding targets, F40% and B40%, respectively. As seen from Figures 48 and 51estimated spawning potential ratio for Pacific hake has generally been above both the 40% proxy target MSY and B_{MSY} level for several decades. During the last decade both target reference points have gradually declined as stock biomass decreased under moderately high removals. While SPR has been above proxy target of 40% for Pacific hake, the biomass relative to the B40 reference target dropped briefly below the target in recent years.

Harvest projections

Forecasts were generated assuming the maximum potential catch would be removed under the 40:10 harvest control rule. Projections were based on the relative F contribution from the U.S. and Canadian fishery commensurate with the 74.88% and 26.12% coast wide national allocation to the U.S. and Canada, respectively, as specified in the Treaty. Table 16 presents 3-year projections using the base case and alternative models. Spawning biomass is expected to continue to decline in 2007 to 864 thousand mt (~95% CI 0.64 - 1.1 million mt) with a corresponding depletion level of 22.7% (~95% CI 18.1% - 27.2%) of unfished biomass for the base model. Under the alternative model, spawning biomass in 2007 is 1.1 million mt (~95% CI 0.79 - 1.46 million mt) with a corresponding relative depletion of 26.2% (~95% CI 21.0% - 31.7%).

Uncertainty and reliability

A retrospective analysis of the base model was performed to evaluate any pathological behavior or pattern of bias in the model results. This analysis was performed by systematically

removing the terminal years' data sequentially for six years and re-running the model. This analysis revealed no systematic bias in model results based on an evaluation of trends in relative depletion or recruitment (Figure 52).

Uncertainty in current stock size and other state variables were explored using a Markov Chain Monte Carlo (MCMC) simulation in AD model builder. Although MCMC has been used mostly in Bayesian applications, it can also be used to obtain likelihood-based confidence regions (Punt and Hilborn 1997). It has the advantage of producing the true marginal likelihood (or marginal distributions) of the parameter, rather than the conditional mode, as with the likelihood profile. We ran the MCMC routine in ADMB drawing 1,000,000 samples in which one in every 1000^{th} sample was saved to reduce autocorrelation in the chain sequence. Results of the MCMC simulation were evaluated for nonconvergence to the target posterior distribution as prescribed in Gelman et al. (2004). The final samples from the MCMC were used to develop the probability distributions of the marginal posterior of management quantities and were compared to MLE asymptotic estimates of uncertainty.

We also preformed a parametric bootstrap of the observed data to assess model reliability to the data and assumptions. Within the SS2 model framework, new data sets were generated directly from expected values of population parameters obtained during maximum likelihood estimation. Observation error about the expected values is included via a parametric bootstrap, based on the appropriate likelihood and the level of error assumed for each data source. All data components in this application were assumed to have observation errors distributed as either lognormal (indices) or multinomial (length- and age-frequencies) distributions. Therefore, the input standard errors and sample sizes are retained in the simulated data sets; the resulting simulated data set has identical dimensions as the original, but new 'observations'. Using this method, 75 simulated data sets were generated from the assessment model and evaluation of simulation results is performed through comparison of the set of simulated parameter value against the MLE and the true value.

Convergence diagnostics of selected parameters from the MCMC simulation provided no evidence for lack of convergence in the base model, in either the primary estimated parameters (Figure 53) or derived quantities such as spawning stock biomass and recruitment (Figure 54). In nearly all cases, parameter autocorrelation was less than +/- 0.15. Furthermore, most of the primary parameters or derived variables have a Geweke statistic of less than +/- 1.96 indicating stationarity of the parameter mean. Finally, parameters passed the Heidelberger-Welch statistic test. If this test is passed, the retained sample is deemed to estimate the posterior mean with acceptable precision, while failure implies that a longer MCMC run is needed to increase the accuracy of the posterior estimates for the given variable. Based on the above diagnostic tests the retained MCMC sample appears acceptable for use in characterizing the uncertainty (distribution) of state variables.

There was very good agreement between distributions from MCMC integration and asymptotic variance estimates from the Hessian estimated using maximum likelihood in SS2 (Figure 55-56). Maximum likelihood estimates of the expected value of unfished spawning biomass (SBzero) and unfished recruitment (Rzero) were in very close agreement with the

median of the marginal posterior distribution of those quantities obtained from MCMC (Figure 55). Likewise, the median of unfished biomass and recruitment from SS2 fit to 75 parametric bootstraps of the data were also close to expected values from MLE (Figure 55). Dispersion about the expected value was also in close agreement between MLE, MCMC and parametric bootstrap. Similar results were found for other state variables such as 2006 spawning biomass and depletion (Figure 56). In general, these results confirm convergence of MLE and reliability of the model and data assumptions.

Additional Analyses Requested by the STAR Panel

A number of additional analyses were requested during the course of the STAR panel. These requests were intended to be either 1) exploratory in nature and to assist the panel in better understanding the assessment or 2) to provide a more complete explanation of the assessment results in the final presentation. The exploratory requests are summarized here (as well as in the STAR panel report itself), while the second kind of requests have been integrated into the document and executive summary as appropriate.

STAR panel requests (in italics) are reported in the order they were made during the panel:

1) *Use the biomass at age and the survey selectivity curve to assess what proportion of the spawning biomass is less vulnerable with respect to the acoustic survey. Rationale: there are concerns regarding the inability of the survey to "see" the entire biomass.*

The spawning biomass greater than or equal to age 9 that was selected by the acoustic survey (the product of: spawning biomass at age, selectivity at age and maturity at age) was calculated from the base case model output. This value was then subtracted from the total spawning biomass greater than or equal to age 9 to obtain the absolute level of poorly selected spawning biomass. This quantity and the ratio of poorly selected age 9+ spawning biomass to total spawning biomass are shown in Figure 57. The fraction of poorly selected spawning biomass was 10-15% throughout the early part of the time series, and increased to 30% during the late 1990s. This increase is attributable to the persistence and relative abundance of the 1980 and 1984 year classes at older ages. The ratio of 'poorly selected' to total spawning biomass subsequently dropped to less than 10%, as the population became dominated by younger fish.

2) *Run the model using asymptotic selectivity for the acoustic survey, both with age of full selectivity free and with a prior on the ascending slope of the selectivity curve that would approximate full selectivity at age 5. Rationale is same as above.*

Both of these sensitivity runs produced a substantial degradation of the model fit to the age composition data. The total negative log-likelihood for the sensitivity without a prior was increased by almost 500 units (Table 17), with the prior on the ascending limb further degrading the fit. Assuming asymptotic selectivity reduced the spawning biomass dramatically over the entire time-series (Figure 58), but the relative trend was most noticeably different during only the most recent years and resulted in a current depletion below 10% of unexploited equilibrium

conditions. This change in scaling also resulted in much larger estimated exploitation rates throughout the time-series, again most pronounced in the most recent years (Figure 60). The SSB time series with the age of full selectivity moved forward to roughly age 5 produced little change to the above results.

3) *Explore the results when pre-1992 acoustic survey data points (both biomass and age/size comps) are removed from the model. Rationale: The higher CVs used in the early acoustic survey data lead the Panel to question what impact those data are having in the model. Similarly, the observation that full selectivity is not reached until age 9, whereas 9 year old fish rarely comprise a major fraction of the catch at age, lead to questions regarding the true shape of the acoustic survey selectivity curve.*

When the pre-1992 acoustic survey data were removed from the assessment model, the estimated selectivity of acoustic survey tended to shift toward older age classes, and the 2006 spawning biomass is estimated to be close to $SB_{40\%}$; no other major changes were observed.

4) *Down-weight the input sample sizes to the 2001-2002 Canadian age-composition data (as well as conditional length at age) to assess what the impact is to the model. Rationale: This will allow the STAT and STAR to evaluate what the consequences of these patterns may be to the model (particularly the strength of the 1999 year class).*

The input sample sizes were set to 1 for all length-frequency and conditional age-at-length-frequency data during these two years. In addition, the selectivity block for 2001-2002 was merged with that for 2003-2005. Very little change was observed in model predicted size and age distributions during these years, or other estimated quantities. It was concluded that it made little difference if these data were included or excluded from the base case and so they were retained with original weighting for all subsequent analyses in the absence of a clear rationale for removal.

5) *Following up on request #2 to use asymptotic selectivity for acoustic survey, repeat this run, but (1) allow q to be estimated in one of the asymptotic selectivity runs, (2) allow M to be estimated with a uninformative prior, if feasible.*

When estimated freely, acoustic survey catchability (q) fell to unrealistically low values, indicating some sort of informative prior would be necessary in this assessment. When natural mortality (M) was estimated using the model in which acoustic selectivity was forced to be asymptotic the maximum likelihood value was 0.33. Natural mortality in this run was constrained by a very uninformative prior with a mean of 0.23 and a standard deviation of 0.8. The fit to the age and length frequency distributions was degraded by over 300 units of log-likelihood, but was somewhat better than the model with asymptotic acoustic selectivity and M fixed at 0.23 (Table 17). This sensitivity run predicted fewer older fish, and forces fishery selectivity curves into unusual and unrealistic configurations, although the relative trend in spawning biomass is similar to other sensitivities (Figures 58, 59).

6) *With respect to the catchability coefficient (q), run the model with an informative prior on q (mean of 1 and a standard deviation of 0.1), both with the entire acoustic biomass time series as well as without the pre-1992 data. Rationale: Fixing q at 1 underestimates the true uncertainty in the model.*

Because the acoustic survey catchability (q) is estimated in log-space the requested prior was converted to have a mean of 0 with a standard deviation of 0.112. This prior resulted in a maximum likelihood estimate of 0.69. This is consistent with the general tendency of this model to estimate a lower q, and reflects an estimate that is very nearly bounded by the small prior density at values appreciably lower than 0.69. The overall improvement in fit was small (8 units of log-likelihood), suggesting that there is little information in the data to inform an estimate of q (Table 17). The greatest changes in model output was an upward scaling of total biomass, a slightly greater estimate of the 1999 year class, both of which resulted in the estimated relative depletion level increasing from 0.34 (with q = 1.0) to 0.41 in 2006 (Table 17). The projected 2006 OY from this model was substantially increased to 942,000 mt, nearly double that of the model assuming q = 1.0.

When the pre-1992 acoustic survey data was excluded, catchability was estimated to be 0.76. This result implies that survey catchability may have been lower (or selectivity may have differed) during the pre-1992 survey years. This sensitivity produced an upward revision of the estimated size of the 1999 year class that then translated into a larger current biomass both on an absolute and relative scale (Table 17, Figures 58, 59). Although there was considerable discussion regarding the inclusion of these early data, it was recognized that they provide the only contrast in the survey time-series and would be retained pending a more detailed reanalysis of specific application of a threshold value for the entire survey series.

7) *Run the model with a steepness value (h) of 0.75. Rationale: There is some resistance to the idea that recruitment is entirely independent of SSB. In a meta-analysis of steepness values for thirteen assessed Merluciid stocks, Dorn (1999) had earlier estimated a posterior mode of approximately 0.6, with a wide posterior distribution that was indicative of a great deal of uncertainty. The STAR Panel suggests that a reasonable expectation for steepness might be 0.75, based on theoretical considerations as well as Myers et al. 2002.*

The resulting time-series' of biomass and relative depletion were very similar to the h = 1.0 model, indicating the strong influence of informative age frequency data to estimate recruitments. The projected recruitments (much more heavily influenced by the central tendency of the stock-recruitment relationship and the variability about this relationship) did show a response to the reduction in steepness. Catch projections for 2006 were nearly identical, but projections for future catches declined somewhat more rapidly than the base model reflecting a reduced expectation of recruitment at predicted stock levels. There was little change in the objective function and associated model fit to the data included. There was general agreement that the lower steepness value may represent a more realistic expectation for h.

8) *Provide the relative contributions to changes in likelihood in the model runs in request # 2 (asymptotic versus dome-shaped selectivity, and a freely estimated M). Rationale: the Panel was interested in what factors actually contributed to the relative changes in likelihood.*

By forcing asymptotic acoustic survey selectivity, the reduction in total biomass caused both the U.S. and Canadian fishery selectivity curves to become much more asymptotic as well. There was a slight improvement in fit to the Canadian age composition data, but a substantial degradation in the objective function resulting from the poor fit to the U.S. fishery and acoustic survey data (Table 17). These results suggested that a sensitivity where at least one data series had asymptotic selectivity should consider the Canadian fishery; and that this could be explored in future assessments.

9) *Evaluate the relative proportion of older hake in the triennial shelf survey versus the acoustic survey over time. Rationale: There are questions lingering regarding where the older fish (i.e. those not seen in the acoustic survey) might be. If feasible, explore doing this with the Canadian catch-at-age data as well.*

A preliminary comparison was made between the acoustic and historic shelf groundfish survey age composition data from 1977-2001 to evaluate whether there was empirical evidence for dome-shaped selectivity. This analysis provided preliminary evidence in support of dome-shaped acoustic survey selectivity (Figure 19). A more methodical analysis, however, is needed to fully address this issue.

10) *Provide graphs of the time series from beginning of the modeled time period to 2009 that includes catch, spawning biomass, depletion, and exploitation rate (relative to vulnerable biomass). Present the time series to 2005 and the forecasts with a different set of symbols. Do these for the STAT base model with steepness set at 0.75.*

These figures were provided to the STAR panel and are included in their report. They resulted in a discussion of the 40:10 harvest policy creating the projected OY catch levels for 2006 and future years. The concern was raised that this policy would lead to a decline in spawning biomass to the lowest level of the time series by 2009, during which time the largest total coast-wide catch could be removed in 2006.

11) *The STAR Panel requests that the base model be run with steepness fixed at 0.75 and acoustic survey catchability (q) estimated with a mean of 1 and a standard deviation of 0.1 in the equivalent log domain. Rationale: The STAR Panel would like to evaluate the STAT base model with steepness fixed at 0.75, with q estimated.*

The results of the $h = 0.75$ model, as described above, were similar to the $h = 1.0$ model for the time-series but resulted in slightly lower OY projections. The model with $h = 0.75$ and catchability estimated with an informative prior scaled the biomass up considerable, while showing little change to the objective function (Table 17). These two models were considered to be plausible alternatives that bracketed the range of uncertainty in acoustic survey catchability.

12) *The STAR would like to see projections of the base model with a range of catches (0 to 400,000 tons in 100,000 ton increments) to evaluate the relative impact of harvest on the biomass trajectory. Rationale: Given that the strict application of the 40:10 harvest rule in this run will result in stock biomass falling below the 25% depletion level, the STAR Panel would like to explore the relative impact of fishing on future stock biomass.*

With total coast-wide catch set to 0 in 2006 onward, the spawning biomass continues to decline (Figure 61). For total catches in excess of 100,000 mt through 2008, the stock is predicted to drop below the $SB_{25\%}$ overfished threshold. It was agreed that this figure was an informative addition to the decision table which should also include some constant catch scenarios for comparison with OY catches generated via the 40:10 harvest policy.

13) *The STAR Panel would like to see the same graphic as in request #12 with the q estimated scenario (as in request #11). Rationale: Same as request # 12.*

This graphic is combined with the request above and reported in the lower panel of Figure 61. For the alternate model with q estimated using an informative prior the same pattern of decline in spawning biomass is observed through 2009, even in the absence of fishing. However, this model shows much less sensitivity to the constant catch scenarios, with only the 400,000 mt level resulting in a relative depletion less than 25% in 2009.

14) *The STAR Panel would like to see a draft decision table, based on the two scenarios presented as preliminary base and alternative models in request # 11 (the STAT base model with steepness fixed at 0.75 and acoustic survey catchability (q) estimated with an informative prior with mean of 1 and a standard deviation of 0.1 in the equivalent log domain). Rationale: The STAR Panel considers these two models to be the two most important alternative states of nature for the final document. The decision table will include the following management actions: OY from model 1, OY from model 2, and 200,000 and 400,000 mt total coast-wide catch for 2006-2008.*

The STAT Team produced a final decision table based on this request (Table 18).

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Table 1. Annual catches of Pacific hake (1,000 t) in U.S. and Canadian management zones by foreign, joint venture (JV), domestic at-sea, domestic shore-based, and tribal fisheries, 1966-2005.

	U.S.						Canada				U.S. and
			Domestic								Canada
Year	Foreign	JV	At-sea	Shore	Tribal	Total	Foreign	JV	Shore	Total [1]	total
1966	137.000	0.000	0.000	0.000	0.000	137.000	0.700	0.000	0.000	0.700	137.700
1967	168.699	0.000	0.000	8.963	0.000	177.662	36.713	0.000	0.000	36.713	214.375
1968	60.660	0.000	0.000	0.159	0.000	60.819	61.361	0.000	0.000	61.361	122.180
1969	86.187	0.000	0.000	0.093	0.000	86.280	93.851	0.000	0.000	93.851	180.131
1970	159.509	0.000	0.000	0.066	0.000	159.575	75.009	0.000	0.000	75.009	234.584
1971	126.485	0.000	0.000	1.428	0.000	127.913	26.699	0.000	0.000	26.699	154.612
1972	74.093	0.000	0.000	0.040	0.000	74.133	43.413	0.000	0.000	43.413	117.546
1973	147.441	0.000	0.000	0.072	0.000	147.513	15.125	0.000	0.001	15.126	162.639
1974	194.108	0.000	0.000	0.001	0.000	194.109	17.146	0.000	0.004	17.150	211.259
1975	205.654	0.000	0.000	0.002	0.000	205.656	15.704	0.000	0.000	15.704	221.360
1976	231.331	0.000	0.000	0.218	0.000	231.549	5.972	0.000	0.000	5.972	237.521
1977	127.013	0.000	0.000	0.489	0.000	127.502	5.191	0.000	0.000	5.191	132.693
1978	96.827	0.856	0.000	0.689	0.000	98.372	3.453	1.814	0.000	5.267	103.639
1979	114.909	8.834	0.000	0.937	0.000	124.680	7.900	4.233	0.302	12.435	137.115
1980	44.023	27.537	0.000	0.792	0.000	72.352	5.273	12.214	0.097	17.584	89.936
1981	70.365	43.556	0.000	0.839	0.000	114.760	3.919	17.159	3.283	24.361	139.121
1982	7.089	67.464	0.000	1.024	0.000	75.577	12.479	19.676	0.002	32.157	107.734
1983	0.000	72.100	0.000	1.050	0.000	73.150	13.117	27.657	0.000	40.774	113.924
1984	14.722	78.889	0.000	2.721	0.000	96.332	13.203	28.906	0.000	42.109	138.441
1985	49.853	31.692	0.000	3.894	0.000	85.439	10.533	13.237	1.192	24.962	110.401
1986	69.861	81.640	0.000	3.463	0.000	154.964	23.743	30.136	1.774	55.653	210.617
1987	49.656	105.997	0.000	4.795	0.000	160.448	21.453	48.076	4.170	73.699	234.147
1988	18.041	135.781	0.000	6.876	0.000	160.698	38.084	49.243	0.830	88.157	248.855
1989	0.000	203.578	0.000	7.418	0.000	210.996	29.753	62.618	2.563	94.934	305.930
1990	0.000	170.972	4.713	8.115	0.000	183.800	3.814	68.313	4.022	76.149	259.949
1991	0.000	0.000	196.905	20.600	0.000	217.505	5.605	68.133	16.178	89.916	307.421
1992	0.000	0.000	152.449	56.127	0.000	208.576	0.000	68.779	20.048	88.827	297.403
1993	0.000	0.000	99.103	42.119	0.000	141.222	0.000	46.422	12.355	58.777	199.999
1994	0.000	0.000	179.073	73.656	0.000	252.729	0.000	85.162	23.782	108.944	361.673
1995	0.000	0.000	102.624	74.965	0.000	177.589	0.000	26.191	46.193	72.384	249.973
1996	0.000	0.000	112.776	85.127	14.999	212.902	0.000	66.779	26.395	93.174	306.076
1997	0.000	0.000	121.173	87.410	24.840	233.423	0.000	42.565	49.227	91.792	325.215
1998	0.000	0.000	120.452	87.856	24.509	232.817	0.000	39.728	48.074	87.802	320.619
1999	0.000	0.000	115.259	83.419	25.844	224.522	0.000	17.201	70.132	87.333	311.855
2000	0.000	0.000	116.090	85.828	6.500	208.418	0.960	15.059	6.382	22.401	230.819
2001	0.000	0.000	102.129	73.474	6.774	182.377	0.000	21.650	31.935	53.585	235.962
2002	0.000	0.000	63.258	45.708	23.148	132.114	0.000	0.000	50.769	50.769	182.883
2003	0.000	0.000	67.473	55.335	20.684	143.492	0.000	0.000	62.090	62.090	205.582
2004	0.000	0.000	90.258	96.229	23.997	210.484	0.000	58.892	65.345	124.237	334.721
2005	0.000	0.000	150.400	85.914	23.53	259.844	0.000	15.178	85.284	100.462	360.306
Average 1966-2005						159.482				54.441	213.923

[1] Canadian fishery total catch revised 1996-2001.

Table 2. U.S. fishery sampling information by sector showing the number of hauls (or trips), number of lengths and number of ages taken by year. Samples sizes shown are the number of hauls or trips where length samples were taken.

U.S. At-sea fishery length samples				U.S. Shore-based fishery			
Year	No. Hauls	No. Lengths	No. Aged	Year	No. Trips	No. Lengths	No. Aged
1973	-	-	-	1973	-	-	-
1974	-	-	-	1974	-	-	-
1975	13	486	332	1975	-	-	-
1976	249	48,433	4,077	1976	-	-	-
1977	1,071	140,338	7,693	1977	-	-	-
1978	1,135	122,531	5,926	1978	-	-	-
1979	1,539	170,951	3,132	1979	-	-	-
1980	811	101,528	4,442	1980	-	-	-
1981	1,093	135,333	4,273	1981	-	-	-
1982	1,142	169,525	4,601	1982	-	-	-
1983	1,069	163,992	3,219	1983	-	-	-
1984	2,035	237,004	3,300	1984	-	-	-
1985	2,061	259,583	2,450	1985	-	-	-
1986	3,878	467,932	3,136	1986	-	-	-
1987	3,406	428,732	3,185	1987	-	-	-
1988	3,035	412,277	3,214	1988	-	-	-
1989	2,581	354,890	3,041	1989	-	-	-
1990	2,039	260,998	3,112	1990	-	-	-
1991	800	94,685	1,333	1991	17	1,273	934
1992	787	72,294	2,175	1992	49	3,152	1,062
1993	406	31,887	1,196	1993	36	1,919	845
1994	569	41,143	1,775	1994	80	4,939	1,457
1995	413	29,035	690	1995	57	3,388	1,441
1996	510	32,133	1,333	1996	47	3,330	1,123
1997	614	47,863	1,147	1997	67	4,272	1,759
1998	740	47,511	1,158	1998	63	3,979	2,021
1999	2,176	49,192	1,047	1999	92	4,280	1,452
2000	2,118	48,153	1,257	2000	81	2,490	1,314
2001	2,133	48,426	2,111	2001	106	4,290	1,983
2002	1,727	39,485	1,695	2002	94	3,890	1,582
2003	1,814	37,772	1,761	2003	101	3,866	1,561
2004	2,668	57,014	1,875	2004	129	7,170	1,440
2005	2,956	62,944	2,451	2005	108	6,166	1160

Table 3. Canadian fishery sampling information by sector showing the number of hauls (or trips), number of lengths and number of ages taken by year. Samples sizes shown are the number of hauls or trips where length samples were taken.

	Canadian JV fishery samples				Canadian shore-based fishery samples		
Year	No. Hauls	No. Lengths	No. Aged	Year	No. Trips	No. Lengths	No. Aged
1988	231	75,767	1,557	1988	-	-	-
1989	261	56,202	1,353	1989	-	-	-
1990	171	33,312	1,024	1990	-	-	-
1991	632	97,205	1,057	1991	-	-	-
1992	429	60,391	1,786	1992	-	-	-
1993	500	70,522	1,228	1993	-	-	-
1994	875	122,871	2,196	1994	-	-	-
1995	183	20,552	1,747	1995	-	-	-
1996	813	99,228	1,526	1996	463	116	-
1997	414	16,957	1,430	1997	1,011	41,782	50
1998	468	45,117	1,113	1998	897	28,173	454
1999	66	8,663	812	1999	1,332	40,964	1,318
2000	375	45,946	1,536	2000	131	1,001	50
2001	284	26,817	1,424	2001	689	14,320	-
2002	-	-	-	2002	1,033	12,132	1,337
2003	-	-	-	2003	1,183	8,296	1,065
2004	595	60,025	1,102	2004	976	3,900	1,201
2005	58	5,206	292	2005	130	2,416	327

Table 4. U.S. fishery sampling summary by sector showing number of samples, total sampled weight, total fishery weight, and sampling intensity given as the percent of total catch weight sampled and catch weight per sample taken.

	Foreign-JV fishery sampling					U.S. Shore-based fishery sampling				
Year	No. Hauls	Sampled weight (mt)	Total fishery landings (mt)	% total weight Sampled	Weight (mt) per sample	No. Trips	Sampled weight (mt)	Total fishery landings (mt)	% total weight Sampled	Weight (mt) per sample
1975	13	47	205,654	0.0%	15,820	-	-	-	-	-
1976	249	4,165	231,331	1.8%	929	-	-	-	-	-
1977	1,071	4,239	127,013	3.3%	119	-	-	-	-	-
1978	1,135	4,769	97,683	4.9%	86	-	-	-	-	-
1979	1,539	6,797	123,743	5.5%	80	-	-	-	-	-
1980	811	10,074	71,560	14.1%	88	-	-	-	-	-
1981	1,093	9,846	113,921	8.6%	104	-	-	-	-	-
1982	1,142	23,956	74,553	32.1%	65	-	-	-	-	-
1983	1,069	27,110	72,100	37.6%	67	-	-	-	-	-
1984	2,035	13,603	93,611	14.5%	46	-	-	-	-	-
1985	2,061	11,842	81,545	14.5%	40	-	-	-	-	-
1986	3,878	24,602	151,501	16.2%	39	-	-	-	-	-
1987	3,406	22,349	155,653	14.4%	46	-	-	-	-	-
1988	3,035	21,499	153,822	14.0%	51	-	-	-	-	-
1989	2,581	20,560	203,578	10.1%	79	-	-	-	-	-
1990	2,039	16,264	175,685	9.3%	86	-	-	-	-	-
1991	800	15,833	196,905	8.0%	246	17	683	20,600	3.3%	1,212
1992	787	17,781	152,449	11.7%	194	49	1,964	56,127	3.5%	1,145
1993	406	11,306	99,103	11.4%	244	36	1,619	42,119	3.8%	1,170
1994	569	13,959	179,073	7.8%	315	80	4,461	73,656	6.1%	921
1995	413	9,833	102,624	9.6%	248	57	3,224	74,965	4.3%	1,315
1996	510	13,813	112,776	12.2%	221	47	3,036	85,127	3.6%	1,811
1997	614	17,264	121,173	14.2%	197	67	4,670	87,410	5.3%	1,305
1998	740	17,370	120,452	14.4%	163	63	4,231	87,856	4.8%	1,395
1999	2,176	47,541	115,259	41.2%	53	92	6,740	83,419	8.1%	907
2000	2,118	48,482	116,090	41.8%	55	81	7,735	85,828	9.0%	1,060
2001	2,133	43,459	102,129	42.6%	48	106	8,524	73,474	11.6%	693
2002	1,727	37,252	63,258	58.9%	37	94	7,089	45,708	15.5%	486
2003	1,814	38,067	67,473	56.4%	37	101	7,676	55,335	13.9%	548
2004	2,668	53,411	90,258	59.2%	34	129	10,918	96,229	11.3%	746
2005	2,956	66,356	150,400	44.1%	51	108	8,997	85,914	10.5%	796

Table 5. Canadian fishery sampling summary by sector showing number of samples, total sampled weight, total fishery weight, and sampling intensity given as the percent of total catch weight sampled and catch weight per

	Canadian JV fishery sampling					Canadian Shore-based fishery sampling				
Year	No. Hauls	Sampled weight (mt)	Total fishery landings (mt)	% total weight Sampled	Weight (mt) per sample	No. Trips	Sampled weight (mt)	Total fishery landings (mt)	% total weight Sampled	Weight (mt) per sample
1988	231	4,184	49,243	8.5%	213	-	-	-	-	-
1989	261	4,679	62,618	7.5%	240	-	-	-	-	-
1990	171	3,396	68,313	5.0%	399	-	-	-	-	-
1991	632	13,054	68,133	19.2%	108	-	-	-	-	-
1992	429	8,901	68,779	12.9%	160	-	-	-	-	-
1993	500	8,929	46,422	19.2%	93	-	-	-	-	-
1994	875	15,387	85,162	18.1%	97	-	-	-	-	-
1995	183	3,770	26,191	14.4%	143	-	-	-	-	-
1996	813	14,863	66,779	22.3%	82	463	21,297	26,395	80.7%	57
1997	414	8,325	42,565	19.6%	103	1,011	44,802	49,227	91.0%	49
1998	468	9,638	39,728	24.3%	85	897	45,982	48,074	95.6%	54
1999	66	1,970	17,201	11.5%	261	1,332	66,700	70,132	95.1%	53
2000	375	6,557	15,059	43.5%	40	131	5,791	6,382	90.7%	49
2001	284	6,072	21,650	28.0%	76	689	30,852	31,935	96.6%	46
2002	-	-	-	-	-	1,033	49,189	50,769	96.9%	49
2003	-	-	-	-	-	1,183	61,110	62,090	98.4%	52
2004	595	14,620	58,892	24.8%	99	976	58,624	65,345	89.7%	67
2005	58	1,630	15,178	10.7%	262	130	12,244	85,284	14.4%	656

Table 6. U.S. fishery sample sizes for conditional age at length. Sample size shown by year and length bin represent the sum of the total number of hauls (in the at-sea fishery) and trips (in the shore-based fishery) contributing age information to each 1 cm length category.

	Year samples were taken														
Length	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
20			1		1	1	5								
21			1	2		3	9								
22		1		2		2	13								
23	1	1		4		1	23								
24	1	1		4		2	25	2				1			
25	1	3		10	1	1	29	5							
26	2	1		10	2		40	11	1		1			1	
27	2	4		9	2	1	34	9		1					
28	1	5		14	4	1	22	12			1				
29	3	4		7	10	1	21	18	6		2	1		1	2
30	5	4		4	21	1	16	37	10		1	5			3
31	3	6	2	2	27		12	38	11	3	3	8		1	9
32	5	8			30	3	6	52	23	1	3	19		2	15
33	2	9	4		46	4	9	62	23	2	3	22	3	2	15
34	4	10	5		33	9	12	66	35	6	2	49	6	3	8
35	4	7	12		24	19	16	62	39	12	1	41	16	3	10
36	5	13	28	3	17	38	28	55	51	25	1	42	29	3	13
37	5	23	56	7	19	66	49	59	55	41	2	40	60	15	9
38	3	26	71	17	12	74	59	48	62	72	7	39	79	56	17
39	2	45	99	51	11	84	78	50	58	112	16	36	88	101	40
40	6	58	114	88	17	89	94	62	62	121	43	51	97	129	79
41	10	53	146	129	25	83	84	66	69	135	78	85	104	141	120
42	9	55	141	176	36	93	85	86	77	125	107	114	112	141	129
43	9	56	160	171	44	88	88	94	72	112	121	119	121	145	125
44	10	54	160	158	65	100	101	99	69	93	124	110	117	153	127
45	8	47	147	165	72	111	101	100	69	82	115	113	113	152	125
46	9	47	142	148	74	114	107	99	75	83	101	105	106	150	130
47	7	39	132	144	84	96	114	103	74	74	79	100	102	137	133
48	10	42	128	154	83	90	122	111	70	67	63	83	92	123	118
49	8	44	136	143	76	85	122	116	69	66	58	67	83	81	98
50	4	57	123	147	83	90	105	101	71	50	52	77	59	68	74
51	5	62	135	156	89	87	113	112	59	49	25	59	40	45	49
52	6	60	140	184	85	92	107	100	66	43	24	51	31	34	40
53		69	146	178	86	94	116	106	66	28	17	52	18	22	35
54	2	64	147	186	78	105	96	104	61	20	15	44	14	15	27
55	4	58	161	176	70	102	80	86	57	11	11	27	8	14	14
56		67	139	156	66	102	65	85	44	5	3	31	5	8	15
57	1	65	131	115	58	102	56	81	32	5	4	24	5	13	8
58	1	62	94	103	41	88	39	48	32	4	3	11	3	11	8
59	2	57	95	60	47	52	34	53	17	7		11	2	4	7
60	1	56	73	60	22	60	36	37	22	2	1	7	5	6	3
61		48	60	45	26	39	30	28	15		1	8	3	5	6
62		45	52	41	16	27	20	17	9	4		7	6	1	
63		30	46	27	12	25	20	21	12	4		3	1		3
64		36	42	26	8	26	16	21	6	2		6	2	4	1
65		33	23	18	13	19	8	18	6	1		5	3	3	1
66		33	17	14	11	12	10	9	4			6	1	4	2
67		33	15	18	6	11	10	10	4	1		4	2		
68	1	28	18	13	8	9	5	6	5	2	1	3	3	2	4
69	1	25	17	10	4	7	7	6	1	3		4	1	3	
70		71	62	60	16	14	15	14	12	9		25	5	12	4

Table 6. Continued.

	Year samples were taken															
Length	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
20		2				1										
21		2														
22		1														
23		1														
24																
25																
26																
27			1									1				
28	2		2								2					
29	6		5							2	2					
30	5	1	6		1		1			8	3	6				
31	15	2	8	4			6			8	3	7	1		1	
32	22	5	5	1		1	9		2	9	2	15				
33	24	13	3	5	1		17		4	19	1	19				1
34	45	23	4	5		1	23	1	1	29	2	28	1			2
35	51	32	3	17	3		30	1	5	41	2	32	2			4
36	76	33	6	31	9		30	7	13	38	6	50	11	2		
37	84	39	22	42	19	2	23	16	17	41	18	55	19	2	1	2
38	94	37	23	45	42	4	27	32	30	54	16	61	45	6	7	3
39	98	46	58	49	64	2	33	47	36	60	24	56	80	25	23	6
40	104	50	66	44	70	6	38	59	50	53	36	61	113	61	45	25
41	95	55	78	38	66	18	35	77	56	59	43	97	128	133	90	49
42	96	59	84	50	73	31	36	83	73	49	56	100	117	199	133	125
43	93	58	82	57	81	33	50	84	97	77	85	100	100	227	216	242
44	91	54	81	64	99	38	65	70	102	70	86	112	85	203	227	309
45	82	53	81	65	99	37	73	71	90	84	89	121	63	156	225	318
46	88	53	81	63	98	36	74	57	77	63	106	136	53	106	177	267
47	82	47	84	58	95	39	72	53	51	63	120	136	61	67	105	199
48	84	48	84	62	90	38	64	41	43	47	100	153	65	49	79	114
49	73	44	82	46	91	37	59	28	25	31	95	118	74	33	39	72
50	72	36	73	30	63	33	47	27	17	17	75	86	76	33	26	46
51	74	18	59	22	34	25	30	21	7	13	55	59	68	17	8	31
52	58	9	39	9	25	23	29	11	3	9	34	50	55	15	12	9
53	43	6	35	4	15	13	10	11	3	6	17	37	48	5	5	11
54	34	6	26	7	13	10	12	5	2	3	17	34	38	7	3	6
55	20	7	20	6	8	8	7	1	4		9	10	27	4	2	3
56	15	2	15	1	4	6	4	3	1		12	8	17	3	2	4
57	14	3	15	2	5	4	1	1		3	4	11	13		2	3
58	14	2	9		6	6	3	1	1	2	3	1	7		2	1
59	11	3	9	1	2	3	3	1	1		5	2	4	1	1	2
60	14		7		3	1	1	1		1	4	4	4		2	
61	15	3	5	2	1	1	2	1		2	2	1	2			1
62	9	3	5		1	2	2		1	1	4		3		1	
63	9	3	2		1	1	1	1			1		1			
64	8		3		1		1						2			
65	8	2	2		2		1		1		2	1	1	1		
66	8	5	2					1					1			1
67	6	2			1		1								1	
68	6	2	2		1											1
69	7	1		1	1											
70	20	8	6	1	3	1	2	2					1			

Table 7. Canadian fishery sample sizes for conditional age at length. Sample size shown by year and length bin represent the sum of the total number of hauls (in the at-sea fishery) and trips (in the shore-based fishery) contributing age information to each 1 cm length. category.

	Year samples were taken																	
Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
20											1							
21												1						
22												1						
23								1				2						
24								2										
25								2										
26								1				2						
27								1										
28								1			1							
29												1					1	
30												1					1	
31									2			3	1	1				
32									2			5				2	1	
33							1	1	3			10				2	1	
34						1			3		1	7	1				2	
35	1						1		4			10	3				1	
36						1	1		8		4	16	4			1	1	
37	1				1		1		9		8	17	5		1		2	
38	1		2		1				12	1	10	19	6				2	2
39	3		3	1	2				7	7	17	26	5				3	
40	4	2	3	1	3	5			8	10	18	27	9			1	11	1
41	4	5	4	1	9	10	6	1	6	17	19	30	13	1		3	20	3
42	4	6	5	3	15	14	10	6	14	21	25	35	14	3		11	26	12
43	5	6	6	6	22	17	20	11	15	22	24	36	14	4	8	14	31	17
44	5	6	4	14	27	17	24	18	22	22	25	35	17	6	3	14	32	19
45	5	6	4	16	29	18	28	21	24	23	25	37	16	11	5	15	32	20
46	5	6	4	16	29	18	29	21	24	23	25	38	18	15	11	15	32	20
47	5	6	4	16	29	18	30	21	24	23	25	38	19	18	15	15	32	20
48	5	6	4	16	29	18	31	21	24	23	23	34	19	20	22	15	31	19
49	5	6	4	16	29	18	30	21	23	22	21	35	19	20	24	15	31	17
50	5	6	5	16	27	17	28	21	23	22	22	31	20	20	25	15	31	12
51	5	6	5	16	28	13	28	21	22	18	17	27	18	20	26	13	27	12
52	5	6	6	13	16	12	27	17	17	18	8	22	16	20	26	13	18	2
53	5	6	4	13	15	4	23	17	11	14	8	14	17	19	26	11	17	5
54	5	4	5	8	12	5	18	14	12	9	6	11	15	18	26	11	13	7
55	4	5	3	4	7	1	21	11	4	5	2	9	9	19	26	9	11	6
56	4	4	4	8	4		12	7	7	2	2	6	10	17	25	7	5	4
57	4	4	4	3	4		9	5	7	3	3	2	6	17	25	6	7	2
58	4	3	3	5	4	5	6	9	6		2	4	6	17	21	8	3	2
59	3	2	4	3	1		8	6	1	1	1	4	8	12	13	5	1	1
60	3	2	3	2	3		6	4	4	1		1	4	9	18	5	5	
61	2	1	2	2			5	4	4			1	4	7	12	3	2	1
62	1	3	4	2	1		3	1	1			1		4	12	1	1	
63	1	3	4		2		2	2			1		2	2	7	1	2	
64	1	2	2	1			3	3		1		1	1	2	2	1		1
65	1	1	2				5	1	2					3	1	1	1	1
66		1	1	1			1	1	1			2	1	1	2		1	
67		2	2					1					1	2	1			
68				1					1	1					1	1	1	
69			1	1				1									1	
70	1	4	1	1	1		2	1					1					

Table 8. Acoustic survey sampling information showing the number of hauls, number of lengths and number of hake aged by year.

Year	No. hauls	No. lengths	No. aged
1977	85	11,695	4,262
1980	49	8,296	2,952
1983	35	8,614	1,327
1986	43	12,702	2,074
1989	22	5,606	1,730
1992	43	15,852	2,184
1995	69	22,896	2,118
1998	84	33,347	2,417
2001	49	16,442	2,536
2003	71	19,357	3,007
2005	49	13.644	1,905

Table 9. Acoustic survey sample sizes for conditional age at length. Sample size shown by year and length bin represent the sum of the total number of hauls contributing age information to each 1 cm length. category.

	Number hauls by length and year										
Length	1977	1980	1983	1986	1989	1992	1995	1998	2001	2003	2005
24						2		1			
25						2		3		1	
26	1					2		2			
27					1	4		4	2		
28	1					2	2	10		1	1
29	1	1		2		5	1	13			1
30	1			3		7	2	16	3	2	4
31	2			6		7	4	20	8	2	6
32	3			8		8	9	23	14	4	7
33	4		2	8	1	8	13	23	17	4	10
34	3	4	4	9	3	8	15	31	20	8	8
35	9	7	3	9	4	7	21	31	20	8	10
36	14	9	5	11	6	6	20	30	20	8	9
37	16	10	7	8	8	6	17	36	17	9	10
38	14	12	8	10	7	5	14	39	13	14	8
39	17	10	9	5	9	8	6	50	10	14	10
40	20	12	13	6	10	7	11	44	17	29	6
41	22	11	11	12	15	10	15	55	14	43	22
42	24	10	11	21	20	24	26	62	18	56	28
43	29	12	9	21	20	28	40	66	22	55	36
44	34	13	13	20	20	36	45	64	17	59	41
45	40	16	12	21	20	38	49	57	29	61	42
46	41	18	13	21	20	39	53	49	29	53	41
47	45	19	12	17	18	37	50	51	30	55	39
48	48	21	13	18	16	34	47	46	30	43	32
49	48	24	12	16	16	30	38	31	28	41	27
50	45	22	12	16	10	22	27	22	27	32	23
51	47	22	11	16	8	18	17	9	25	28	12
52	46	21	10	11	9	14	14	5	26	24	12
53	44	19	9	13	6	6	10	6	24	19	9
54	40	18	8	8	5	3	7	4	25	12	5
55	38	17	6	9	2	4	5	2	18	12	3
56	31	19	5	4	2	5	6	2	13	7	5
57	33	16	7	4		4	3	3	10	6	2
58	27	11	2	3	3	3	5	5	10	5	1
59	19	14	3	3	2	1	2		7	3	1
60	18	7	1	4	2	1	2	1	8	6	
61	16	4	2	3		1	1	2	5	2	
62	11	3	2	2		2	4		3	5	
63	11	2	1		1	3	2		2		
64	10	2		3	1		1		4	2	1
65	8	3	1	1	1		2		3	2	1
66	8	2	1				2		2	2	
67	8	2		1			2		1	2	
68	7	4		1					2		1
69	4	3	1	1	1		1	1	4	2	1
70	7	3		1	2		3		4	6	6

Table 10. Acoustic survey estimates of Pacific whiting biomass and age composition. Surveys in 1995 and 1998 were cooperative surveys between AFSC and DFO. Biomass and age composition for 1977-89 were adjusted as described in Dorn (1996) to account for changes in target strength, depth and geographic coverage. Biomass estimates at 20 log l - 68 in 1992 and 1995 are from Wilson and Guttormson (1997). The biomass in 1995 includes 27,251 t of Pacific whiting found by the DFO survey vessel W.E. Ricker in Queen Charlotte Sound. (This estimate was obtained from 43,200 t, the biomass at -35 dB/kg multiplied by 0.631, a conversion factor from -35 dB/kg to 20 log l - 68 for the U.S. survey north of 50°30' N lat.). In 1992, 1995, and 1998, 20,702 t, 30,032 t, and 8,034 t of age-1 fish respectively is not included in the total survey biomass. In 2001-2005 no age one fish were captured in survey trawls. Estimates of biomass and numbers at age from 1977-1992 include revised based on year-specific deep-water and northern expansion factors (Helser et al. 2004).

	Total biomass at 20 log l - 68 (1,000 t)	Number at age (million)														
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1977	1915.01	0.24	151.94	144.57	902.04	82.60	115.79	1001.86	138.13	102.08	58.53	54.82	28.54	10.61	2.79	3.46
1980	2115.09	0.00	16.18	1971.21	190.90	115.65	94.42	417.83	154.83	333.21	133.62	78.76	13.26	22.81	4.75	3.49
1983	1646.68	0.00	1.10	3254.35	107.83	32.62	428.59	68.59	47.27	33.71	92.68	21.86	25.80	26.90	4.32	0.00
1986	2857.06	0.00	4555.66	119.65	21.04	148.80	2004.57	215.71	171.63	225.45	27.33	28.72	2.08	10.85	3.49	0.00
1989	1237.69	0.00	411.82	141.76	31.19	1276.32	28.43	10.08	18.30	435.18	22.95	1.75	43.08	0.00	0.00	1.76
1992	2169.20	230.71	318.37	42.50	246.38	630.74	77.96	31.61	1541.82	46.68	28.08	14.14	533.23	27.13	0.00	28.42
1995	1385.00	316.41	880.52	117.80	32.62	575.90	26.58	88.78	403.38	5.90	0.00	429.34	0.96	17.42	0.00	130.39
1998	1185.00	98.31	414.33	460.41	386.81	481.76	34.52	135.59	215.61	26.41	39.14	120.27	7.68	4.92	104.47	29.19
2001	737.00	0.00	1471.36	185.56	109.35	117.25	54.26	54.03	29.41	17.11	12.03	5.07	4.48	8.73	0.83	3.10
2003	1840.00	5.19	99.78	84.88	2146.50	366.87	92.55	201.22	133.09	73.54	74.67	24.06	14.18	14.63	10.33	14.12
2005	1265.16	8.65	601.86	61.02	180.86	129.98	1210.5	132.12	45.07	61.09	34.83	28.17	11.9	6.11	0.81	4.35

Table 11 Santa Cruz midwater trawl juvenile groudfish survey estimates of log-transformed Pacific hake abundance (Sakuma and Ralston 1997).

		All Strata		Monterey outside stratum only	
Year class	Year of recruitment	log(numbers)	SE	log(numbers)	SE
1986	1988	1.679	0.192	3.153	0.507
1987	1989	3.129	0.172	6.258	0.490
1988	1990	3.058	0.161	4.917	0.474
1989	1991	0.979	0.170	2.008	0.490
1990	1992	1.323	0.173	3.553	0.490
1991	1993	2.134	0.167	3.769	0.490
1992	1994	0.583	0.166	2.561	0.507
1993	1995	3.095	0.173	7.048	0.490
1994	1996	2.152	0.177	3.470	0.490
1995	1997	0.768	0.173	1.940	0.490
1996	1998	1.968	0.174	4.586	0.507
1997	1999	1.487	0.197	2.767	0.526
1998	2000	0.602	0.177	1.599	0.507
1999	2001	-	-	4.589	0.490
2000	2002	-	-	2.616	0.507
2001	2003	-	-	3.415	0.490
2002	2004	-	-	2.130	0.528
2003	2005	-	-	0.508	0.490
2004	2006	-	-	4.547	0.490
2005	2007	-	-	0.273	0.490

Table 12 Parameter assumptions and model configureation of Stock Synthesis II (Ver. 1.21) for Pacific hake. The alternative model imposes a prior on the Ln acoustic survey q equivalent to mean = 1.0 and standard deviation = 0.10.

Parameter	Number Estimated	Bounds (low,high)	Prior (Mean, SD)
Natural Mortality	-	NA	Fixed at 0.23
Stock and recruitment			
Ln(Rzero)	1	(11,15)	~N(15,99)
Steepness	-	NA	Fixed at 0.75
Sigma R (based on 1967-2003 R devs)	-	NA	Fixed at 1.138
Ln(Recruitment deviations): 1967-2005	39	(-15,15)	~Ln(N(0.Sigma R))
Catchability			
Ln(Acoustic survey)	-	NA	fixed at 1.0 / q prior [1]
Ln(Recruitment survey)	1	(-15,10)	~N(-1,99)
Selectivity (double logistic)			
US Fishery:			
Base Period block: 1966 - 1983			
Ascending inflection (ln trans.)	1	(1,10)	~N(3,99)
Ascending slope	1	(0.001,10)	~N(2.5,99)
Descending inflection (ln trans.)	1	(1,20)	~N(12,99)
Descending slope	1	(0.001,10)	~N(1.0,99)
Temporal blocks for all: 1984-1992, 1993-2000, 2001-2005	12	same as above	same as above
Canadian Fishery:			
Base Period block: 1966 - 1994			
Ascending inflection (ln trans.)	1	(1,20)	~N(3,99)
Ascending slope	1	(0.001,10)	~N(1.0,99)
Descending inflection (ln trans.)	1	(1,40)	~N(13,99)
Descending slope	1	(0.001,10)	~N(1.0,99)
Temporal blocks for ascending infl and slp: 1995-2000, 2001-2002, 2003-2005	6	same as above	same as above
Acoustic Survey:			
Ascending inflection (ln trans.)	1	(1,10)	~N(3,99)
Ascending slope	1	(0.001,10)	~N(1.0,99)
Descending inflection (ln trans.)	1	(1,20)	~N(7,99)
Descending slope	1	(0.001,10)	~N(1.0,99)
Individual growth			
Sex combined:			
Length at age min (age 2)	1	(10,40)	~N(33,99)
base period Lmax 1966-1983	1	(30,70)	~N(53,99)
blocks for Lmax: 1984-2005	1	(30,70)	~N(53,99)
base period von Bertalanffy K, 1966-1980 and 1987-2005	1	(0.1,0.7)	~N(0.3,99)
blocks for von Bertalanffy K, 1981-1986	1	(0.1,0.7)	~N(0.3,99)
CV of length at age min	1	(0.01,0.35)	~N(0.1,99)
CV of length at age max	-	NA	fixed at 0
Total number of parameters: 38 + 39 recruitment devs = 77	77		

[1] Alternative model includes estimation of Acoustic survey q ~ LN(0.0, 0.112)

Table 13. Maximum likelihood model parameter estimates with asymptotic standard deviations from Stock Synthesis II (Ver. 1.21) applied to Pacific hake for the base and alternative models.

	Base Model, q =1.0, h =0.75		h =0.75, q prior	
Parameter	MLE	Asympt. SD	MLE	Asympt. SD
Stock and recruitment				
Ln(Rzero)	15.42	0.05	15.537	0.062
Catchability				
Ln(Acoustic survey)	NE	NE	-0.357	0.090
Ln(Recruitment survey)	-10.970	0.259	-11.113	0.263
Selectivity (double logistic)				
US Fishery:				
Base Period block: 1966 - 1983				
Ascending inflection (ln trans.)	3.357	0.070	3.330	0.073
Ascending slope	1.673	0.077	1.690	0.078
Descending inflection (ln trans.)	11.906	0.111	11.850	0.113
Descending slope	1.058	0.049	1.044	0.048
Block 1984 - 1992				
Ascending inflection (ln trans.)	2.499	0.044	2.477	0.044
Ascending slope	2.532	0.141	2.570	0.146
Descending inflection (ln trans.)	12.530	0.147	12.440	0.149
Descending slope	1.259	0.084	1.226	0.081
Block 1993- 2000				
Ascending inflection (ln trans.)	2.955	0.056	2.945	0.056
Ascending slope	2.343	0.111	2.386	0.111
Descending inflection (ln trans.)	13.979	0.159	13.859	0.165
Descending slope	1.623	0.240	1.486	0.204
Block 2001- 2005				
Ascending inflection (ln trans.)	2.918	0.042	2.923	0.042
Ascending slope	3.051	0.137	3.060	0.137
Descending inflection (ln trans.)	13.222	0.376	13.040	0.489
Descending slope	1.742	0.403	1.547	0.427
Canadian Fishery:				
Base Period block: 1966 - 1994				
Ascending inflection (ln trans.)	5.160	0.127	5.124	0.127
Ascending slope	1.313	0.093	1.323	0.095
Descending inflection (ln trans.)	13.085	0.153	12.990	0.153
Descending slope	1.355	0.107	1.285	0.098
Base Period block: 1995 - 2000				
Ascending inflection (ln trans.)	4.670	0.316	4.528	0.301
Ascending slope	0.633	0.070	0.667	0.074
Base Period block: 2001 - 2002				
Ascending inflection (ln trans.)	3.623	0.102	3.627	0.104
Ascending slope	4.995	0.757	4.994	0.761
Base Period block: 2003 - 2005				
Ascending inflection (ln trans.)	4.715	0.136	4.705	0.137
Ascending slope	1.703	0.182	1.712	0.185
Acoustic Survey:				
Ascending inflection (ln trans.)	11.564	0.189	11.633	0.192
Ascending slope	0.944	0.038	0.936	0.039
Descending inflection (ln trans.)	2.373	0.232	2.445	0.230
Descending slope	0.859	0.043	0.865	0.043
Growth Parameters:				
Length at age min (Lmin, age 2)	33.076	0.087	33.077	0.096
Base period Lmax, 1966-1983	53.017	0.081	53.021	0.128
Block for Lmax: 1984-2005	49.890	0.057	49.893	0.113
Base period K, 1966-1980, 1987-2005	0.332	0.004	0.331	0.007
Blocks for K: 1981-1986	0.212	0.004	0.212	0.007
CV of length at age min	0.072	0.000	0.072	0.001

Table 14a. Time series of estimated 3+ biomass, spawning biomass, recruitment, and utilization for 1966-2006 from the base model using Stock Synthesis 2. U.S. and Canadian exploitation rate is the catch in biomass divided by vulnerable at the start of the year. Population (3+) and spawning biomass is in millions of tons at the start of the year. Recruitment is given in billions of age-0 fish.

	3+ Population	Spawning	Age 0	Depletion	Exploitation Rate		
Year	biomass (mt)	biomass (mt)	Recruits	% Bzero	U.S.	Canada	Sum
1966	7.832	3.814	4.974	100.00%	2.6%	0.0%	2.6%
1967	7.704	3.750	5.582	98.34%	3.4%	0.9%	4.3%
1968	7.521	3.660	5.908	95.98%	1.2%	1.6%	2.8%
1969	7.454	3.636	6.019	95.34%	1.7%	2.5%	4.2%
1970	7.459	3.628	15.027	95.14%	3.1%	2.0%	5.2%
1971	7.500	3.641	5.244	95.46%	2.5%	0.7%	3.2%
1972	7.659	3.856	2.889	101.10%	1.4%	1.2%	2.5%
1973	9.498	4.385	9.428	114.99%	2.4%	0.4%	2.8%
1974	9.609	4.589	2.368	120.32%	2.8%	0.4%	3.3%
1975	9.038	4.518	3.361	118.46%	3.0%	0.3%	3.3%
1976	9.514	4.507	1.931	118.18%	3.4%	0.1%	3.5%
1977	8.749	4.283	13.685	112.30%	2.0%	0.1%	2.1%
1978	8.175	3.990	1.774	104.63%	1.6%	0.1%	1.7%
1979	7.376	3.817	2.757	100.09%	2.2%	0.3%	2.5%
1980	8.722	4.012	33.618	105.19%	1.3%	0.4%	1.7%
1981	7.968	3.979	0.837	104.33%	2.1%	0.6%	2.7%
1982	7.248	3.771	0.357	98.88%	1.4%	0.8%	2.2%
1983	11.692	4.157	0.769	108.99%	1.2%	1.0%	2.1%
1984	11.020	4.615	17.771	121.01%	1.1%	1.0%	2.0%
1985	9.558	4.581	0.328	120.11%	1.1%	0.5%	1.6%
1986	8.215	4.197	0.851	110.04%	2.2%	1.0%	3.2%
1987	9.503	3.975	5.298	104.21%	2.1%	1.4%	3.6%
1988	8.425	3.725	2.326	97.68%	2.3%	1.9%	4.2%
1989	7.282	3.550	0.596	93.08%	3.5%	2.2%	5.6%
1990	6.833	3.259	2.859	85.45%	3.4%	1.8%	5.3%
1991	6.041	2.893	1.158	75.86%	4.7%	2.5%	7.2%
1992	4.981	2.471	0.567	64.78%	5.6%	3.0%	8.6%
1993	4.413	2.110	2.444	55.32%	4.3%	2.5%	6.7%
1994	3.772	1.816	2.910	47.62%	9.3%	5.7%	15.0%
1995	2.962	1.473	2.062	38.62%	8.7%	4.4%	13.1%
1996	2.7	1.293	1.988	33.89%	11.9%	6.7%	18.5%
1997	2.5	1.169	1.933	30.64%	13.9%	7.9%	21.8%
1998	2.2	1.056	2.814	27.70%	15.0%	8.7%	23.7%
1999	2.0	0.952	13.789	24.97%	15.9%	9.4%	25.3%
2000	1.8	0.880	0.990	23.07%	15.6%	2.5%	18.1%
2001	1.9	1.054	1.372	27.64%	12.6%	5.1%	17.8%
2002	3.8	1.485	0.234	38.93%	5.2%	4.1%	9.3%
2003	3.7	1.684	2.338	44.17%	4.4%	4.7%	9.1%
2004	3.4	1.617	1.446	42.40%	7.0%	6.3%	13.3%
2005	2.8	1.386	0.279	36.34%	10.1%	4.9%	15.0%
2006	2.5	1.178	2.192	30.89%	-	-	-
	2005 5% - 95% Asymptotic Interval			30.4% - 42.1%			
	2006 5% - 95% Asymptotic Interval			24.7% - 36.9%			

Table 14b. Time series of estimated 3+ biomass, spawning biomass, recruitment, and utilization for 1966-2006 from the alternative model using Stock Synthesis 2. U.S. and Canadian exploitation rate is the catch in biomass divided by vulnerable biomass at the start of the year. Population (3+) and spawning biomass is in millions of tons at the start of the year. Recruitment is given in billions of age-0 fish.

	3+ Population	Spawning	Age 0	Depletion	Exploitation Rate		
Year	biomass (mt)	biomass (mt)	Recruits	% Bzero	U.S.	Canada	Sum
1966	8.804	4.287	5.593	100.00%	2.3%	0.0%	2.3%
1967	8.676	4.224	6.281	98.52%	3.0%	0.8%	3.8%
1968	8.493	4.133	6.634	96.42%	1.0%	1.4%	2.5%
1969	8.426	4.110	6.748	95.88%	1.5%	2.2%	3.7%
1970	8.445	4.108	16.828	95.83%	2.8%	1.8%	4.5%
1971	8.507	4.130	5.867	96.33%	2.2%	0.6%	2.8%
1972	8.686	4.372	3.228	101.98%	1.2%	1.0%	2.2%
1973	10.741	4.962	10.523	115.75%	2.1%	0.3%	2.5%
1974	10.864	5.190	2.637	121.06%	2.5%	0.4%	2.9%
1975	10.229	5.113	3.734	119.26%	2.6%	0.3%	2.9%
1976	10.761	5.101	2.140	118.99%	3.0%	0.1%	3.1%
1977	9.908	4.851	15.097	113.16%	1.7%	0.1%	1.8%
1978	9.254	4.518	1.952	105.40%	1.4%	0.1%	1.5%
1979	8.347	4.315	3.019	100.66%	2.0%	0.2%	2.2%
1980	9.808	4.518	36.826	105.38%	1.2%	0.4%	1.5%
1981	8.953	4.469	0.914	104.25%	1.8%	0.5%	2.4%
1982	8.140	4.231	0.388	98.70%	1.2%	0.7%	1.9%
1983	12.984	4.643	0.830	108.31%	1.0%	0.9%	1.9%
1984	12.227	5.134	19.113	119.77%	1.0%	0.9%	1.8%
1985	10.607	5.088	0.351	118.68%	1.0%	0.4%	1.4%
1986	9.118	4.654	0.908	108.56%	2.0%	0.9%	2.9%
1987	10.470	4.399	5.631	102.61%	1.9%	1.3%	3.2%
1988	9.280	4.117	2.470	96.03%	2.1%	1.7%	3.8%
1989	8.026	3.913	0.632	91.29%	3.2%	1.9%	5.1%
1990	7.516	3.589	3.029	83.72%	3.1%	1.7%	4.8%
1991	6.643	3.185	1.231	74.30%	4.3%	2.3%	6.6%
1992	5.492	2.724	0.607	63.55%	5.2%	2.7%	7.9%
1993	4.866	2.330	2.640	54.34%	3.9%	2.3%	6.2%
1994	4.163	2.007	3.190	46.81%	8.6%	5.2%	13.8%
1995	3.294	1.638	2.312	38.22%	7.9%	4.0%	11.9%
1996	3.0	1.443	2.275	33.67%	10.8%	6.0%	16.8%
1997	2.8	1.314	2.275	30.66%	12.6%	7.0%	19.5%
1998	2.6	1.202	3.435	28.05%	13.4%	7.5%	20.9%
1999	2.3	1.102	17.323	25.72%	13.9%	8.0%	21.9%
2000	2.2	1.044	1.267	24.35%	13.2%	2.1%	15.3%
2001	2.3	1.288	1.787	30.04%	10.5%	4.3%	14.7%
2002	4.8	1.857	0.312	43.32%	4.2%	3.3%	7.5%
2003	4.7	2.132	3.137	49.74%	3.5%	3.7%	7.2%
2004	4.4	2.075	1.663	48.40%	5.5%	4.9%	10.3%
2005	3.7	1.826	0.323	42.59%	7.6%	3.7%	11.3%
2006	3.4	1.601	2.565	38.00%	-	-	-
	2005 5% - 95% Asymptotic Interval			35.2% - 50.1%			
	2006 5% - 95% Asymptotic Interval			29.7% - 45.0%			

Table 15a. Estimates of uncertainty as expressed by asymptotic 95% confidence intervals of spawning biomass and recruitment to age-0 from the base model. Deviations from log mean recruitment were estimated between 1967-2003 and values given for 1966 and 2004-2006 represent mean recruitment.

	Spawning biomass (millions, mt)			Recruitment to Age-0 (billions)		
		Asymptotic interval			Asymptotic interval	
Year	MLE	5%	95%	MLE	5%	95%
1966	3.814	3.460	4.161	4.974	4.536	5.447
1967	3.750	3.397	4.098	5.582	4.801	6.492
1968	3.660	3.307	4.008	5.908	5.122	6.818
1969	3.636	3.281	3.985	6.019	5.235	6.920
1970	3.628	3.264	3.987	15.027	13.242	17.060
1971	3.641	3.259	4.018	5.244	4.560	6.028
1972	3.856	3.437	4.270	2.889	2.488	3.353
1973	4.385	3.896	4.872	9.428	8.280	10.727
1974	4.589	4.061	5.114	2.368	2.049	2.738
1975	4.518	3.983	5.051	3.361	2.929	3.856
1976	4.507	3.960	5.051	1.931	1.656	2.251
1977	4.283	3.751	4.812	13.685	12.229	15.319
1978	3.990	3.491	4.487	1.774	1.519	2.073
1979	3.817	3.344	4.289	2.757	2.397	3.171
1980	4.012	3.530	4.491	33.618	30.730	36.784
1981	3.979	3.512	4.445	0.837	0.686	1.020
1982	3.771	3.334	4.207	0.357	0.272	0.467
1983	4.157	3.704	4.608	0.769	0.641	0.922
1984	4.615	4.141	5.088	17.771	16.599	18.991
1985	4.581	4.122	5.039	0.328	0.260	0.413
1986	4.197	3.787	4.606	0.851	0.740	0.978
1987	3.975	3.601	4.347	5.298	4.954	5.673
1988	3.725	3.386	4.064	2.326	2.144	2.525
1989	3.550	3.240	3.858	0.596	0.522	0.679
1990	3.259	2.982	3.535	2.859	2.662	3.067
1991	2.893	2.651	3.134	1.158	1.052	1.274
1992	2.471	2.263	2.677	0.567	0.499	0.644
1993	2.110	1.933	2.286	2.444	2.258	2.640
1994	1.816	1.665	1.966	2.910	2.673	3.163
1995	1.473	1.345	1.601	2.062	1.861	2.281
1996	1.293	1.180	1.405	1.988	1.762	2.238
1997	1.169	1.063	1.273	1.933	1.671	2.227
1998	1.056	0.954	1.157	2.814	2.365	3.328
1999	0.952	0.849	1.054	13.789	11.337	16.692
2000	0.880	0.767	0.990	0.990	0.770	1.264
2001	1.054	0.891	1.213	1.372	1.048	1.783
2002	1.485	1.217	1.746	0.234	0.147	0.371
2003	1.684	1.358	2.003	2.338	1.502	3.618
2004	1.617	1.280	1.945	1.446	0.417	5.004
2005	1.386	1.060	1.703	0.279	0.069	1.131
2006	1.178	0.857	1.491	2.192	0.366	13.103

Table 15b. Estimates of uncertainty as expressed by asymptotic 95% confidence intervals of spawning biomass and recruitment to age-0 from the alternative model. Deviations from log mean recruitment were estimated between 1967-2003 and values given for 1966 and 2004-2006 represent mean recruitment.

	Spawning biomass (millions, mt)			Recruitment to Age-0 (billions)		
		Asymptotic interval			Asymptotic interval	
Year	MLE	5%	95%	MLE	5%	95%
1966	4.287	3.764	4.810	5.593	4.955	6.313
1967	4.224	3.701	4.746	6.281	5.289	7.459
1968	4.133	3.611	4.656	6.634	5.623	7.825
1969	4.110	3.585	4.635	6.748	5.740	7.933
1970	4.108	3.572	4.645	16.828	14.480	19.557
1971	4.130	3.573	4.687	5.867	4.995	6.890
1972	4.372	3.767	4.977	3.228	2.726	3.821
1973	4.962	4.267	5.657	10.523	9.046	12.241
1974	5.190	4.450	5.929	2.637	2.237	3.109
1975	5.113	4.366	5.859	3.734	3.193	4.366
1976	5.101	4.345	5.857	2.140	1.807	2.536
1977	4.851	4.119	5.583	15.097	13.222	17.238
1978	4.518	3.832	5.204	1.952	1.646	2.315
1979	4.315	3.664	4.966	3.019	2.585	3.527
1980	4.518	3.860	5.175	36.826	32.934	41.176
1981	4.469	3.832	5.106	0.914	0.742	1.125
1982	4.231	3.633	4.830	0.388	0.294	0.511
1983	4.643	4.025	5.261	0.830	0.685	1.005
1984	5.134	4.487	5.782	19.113	17.489	20.888
1985	5.088	4.457	5.719	0.351	0.277	0.446
1986	4.654	4.085	5.223	0.908	0.782	1.055
1987	4.399	3.875	4.922	5.631	5.167	6.137
1988	4.117	3.638	4.595	2.470	2.240	2.724
1989	3.913	3.471	4.356	0.632	0.548	0.729
1990	3.589	3.189	3.989	3.029	2.771	3.311
1991	3.185	2.832	3.538	1.231	1.102	1.375
1992	2.724	2.418	3.030	0.607	0.527	0.698
1993	2.330	2.065	2.594	2.640	2.384	2.924
1994	2.007	1.778	2.235	3.190	2.848	3.573
1995	1.638	1.441	1.835	2.312	2.021	2.645
1996	1.443	1.266	1.620	2.275	1.945	2.661
1997	1.314	1.146	1.482	2.275	1.893	2.735
1998	1.202	1.037	1.368	3.435	2.774	4.253
1999	1.102	0.934	1.271	17.323	13.667	21.956
2000	1.044	0.860	1.227	1.267	0.953	1.684
2001	1.288	1.025	1.551	1.787	1.322	2.416
2002	1.857	1.437	2.277	0.312	0.192	0.505
2003	2.132	1.624	2.641	3.137	1.978	4.976
2004	2.075	1.552	2.598	1.663	0.467	5.924
2005	1.826	1.322	2.330	0.323	0.079	1.315
2006	1.601	1.109	2.093	2.565	0.428	15.370

Table 16. Three year projections of Pacific hake assuming the maximum potential catch would be removed under the 40:10 harvest control rule. Projections were based on the relative F contribution from the U.S. and Canadian fishery commensurate with the 74% and 26% coast wide national allocation.

		Spawning biomass millions mt			Depletion percent unfished biomass		
Year	Expected coastwide catch (mt)	Mean	5%	95%	Mean	5%	95%
Base model, h=0.75, q=1.0							
2006	593,750	1.174	0.857	1.491	30.8%	24.7%	36.9%
2007	358,420	0.864	0.636	1.092	22.7%	18.1%	27.2%
2008	213,220	0.679	0.485	0.873	17.8%	13.5%	22.1%
2009	183,620	0.657	0.337	0.976	17.2%	9.2%	25.3%
Alt. model, h=0.75, q prior							
2006	883,490	1.601	1.109	2.093	38.0%	29.7%	45.0%
2007	522,510	1.130	0.795	1.464	26.4%	21.0%	31.7%
2008	302,300	0.851	0.588	1.113	19.8%	15.1%	24.5%
2009	240,700	0.792	0.404	1.179	18.5%	10.0%	26.9%

Table 17. Comparison of likelihood components and derived quantities of interest from alternative models. Likelihood components in italics are not comparable to other values due to the exclusion of some data.

Likelihood components	**Base h = 0.75 q = 1.0**	**Alt. h = 0.75 q prior**	Asymptotic free m	q prior	no < 1992 q prior	h = 1.0	Asymptotic selectivity
Total negative log-likelihood	10,459.8	10,451.5	10,756.3	10,450.1	*9,958.1*	10,458.7	10,941.6
Indices	26.2	21.7	26.5	21.8	*20.9*	26.9	21.2
Length comps	1,798.3	1,800.7	1,852.4	1,799.2	*1,786.4*	1,797.9	1,835.2
Age comps	8,608.6	8,597.3	8,847.6	8,597.4	*8,121.6*	8,607.3	9,056.2
Recruitment devs	23.3	23.3	26.5	23.2	*22.9*	23.3	25.8
Parameter priors	0.0	5.1	0.0	5.3	*3.0*	0.0	0.0
Forecast devs	3.3	3.3	3.3	3.1	*3.3*	3.3	3.1
By fleet							
US. Fishery							
Length comps	1,212.9	1,217.3	1,241.9	1,215.7	1,216.5	1,212.5	1,228.5
Age comps	5,078.9	5,070.7	5,270.9	5,070.9	5,088.8	5,080.5	5,300.6
Canadian fishery							
Length comps	496.0	494.4	517.2	494.7	496.7	496.2	518.7
Age comps	2,175.2	2,176.4	2,119.3	2,177.6	2,150.1	2,174.2	2,103.5
Acoustic survey							
Index	7.3	1.9	9.6	2.0	*-0.4*	7.8	4.6
Length comps	89.4	88.9	93.3	88.8	*73.3*	89.3	88.1
Age comps	1,354.5	1,350.2	1,457.4	1,349.0	*882.6*	1,352.6	1,652.1
Recruitment survey							
Index	18.9	19.9	16.9	19.9	21.3	19.2	16.6
Derived quantities							
Sbzero	3,810,000	4,286,920	3,542,590	4,105,780	4,203,785	3,639,110	1,961,335
2006 depletion	0.308	0.380	0.197	0.407	0.495	0.337	0.097
2006 SB	1,175,000	1,600,895	1,395,620	3,342,960	4,161,910	2,454,090	379,228
2005 SPR	0.618	0.686	0.628	0.694	0.739	0.628	0.294
2006 OY	593,746	883,490	411,747	941,708	1,205,510	648,139	10

Table 18. Decision table showing the consquences of management action given a state of nature. States of nature include the base model (h=0.75, q=1.0) and the alternative model (h=0.75, q prior). The management actions include the OY from each state of nature and two constant coastwide catch scenarios.

			State of Nature	
Relative probability			**0.50**	**0.50**
Model			h = 0.75, q = 1.0	h = 0.75, q prior
Management action	Total coast-wide Catch (mt)	Year	Relative depletion (2.5%-97.5% interval)	
OY Model h=0.75, q=1.0	593,746	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
	358,416	2007	0.227 (0.181-0.272)	0.310 (0.219-0.401)
	213,223	2008	0.178 (0.135-0.221)	0.263 (0.164-0.363)
	183,620	2009	0.172 (0.092-0.253)	0.254 (0.127-0.380)
OY Model h=0.75, q prior	883,490	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
	522,511	2007	0.202 (0.125-0.279)	0.268 (0.215-0.322)
	302,298	2008	0.144 (0.056-0.232)	0.202 (0.155-0.249)
	240,702	2009	0.136 (0.020-0.252)	0.188 (0.104-0.273)
Total coast-wide	200,000	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
catch = 200,000 mt	200,000	2007	0.282 (0.209-0.354)	0.351 (0.264-0.438)
	200,000	2008	0.250 (0.167-0.333)	0.315 (0.219-0.411)
	200,000	2009	0.239 (0.125-0.352)	0.299 (0.175-0.423)
Total coast-wide	400,000	2006	0.308 (0.247-0.369)	0.380 (0.304-0.457)
catch = 400,000 mt	400,000	2007	0.258 (0.184-0.332)	0.330 (0.241-0.419)
	400,000	2008	0.207 (0.122-0.292)	0.276 (0.177-0.375)
	400,000	2009	0.178 (0.063-0.294)	0.245 (0.118-0.372)

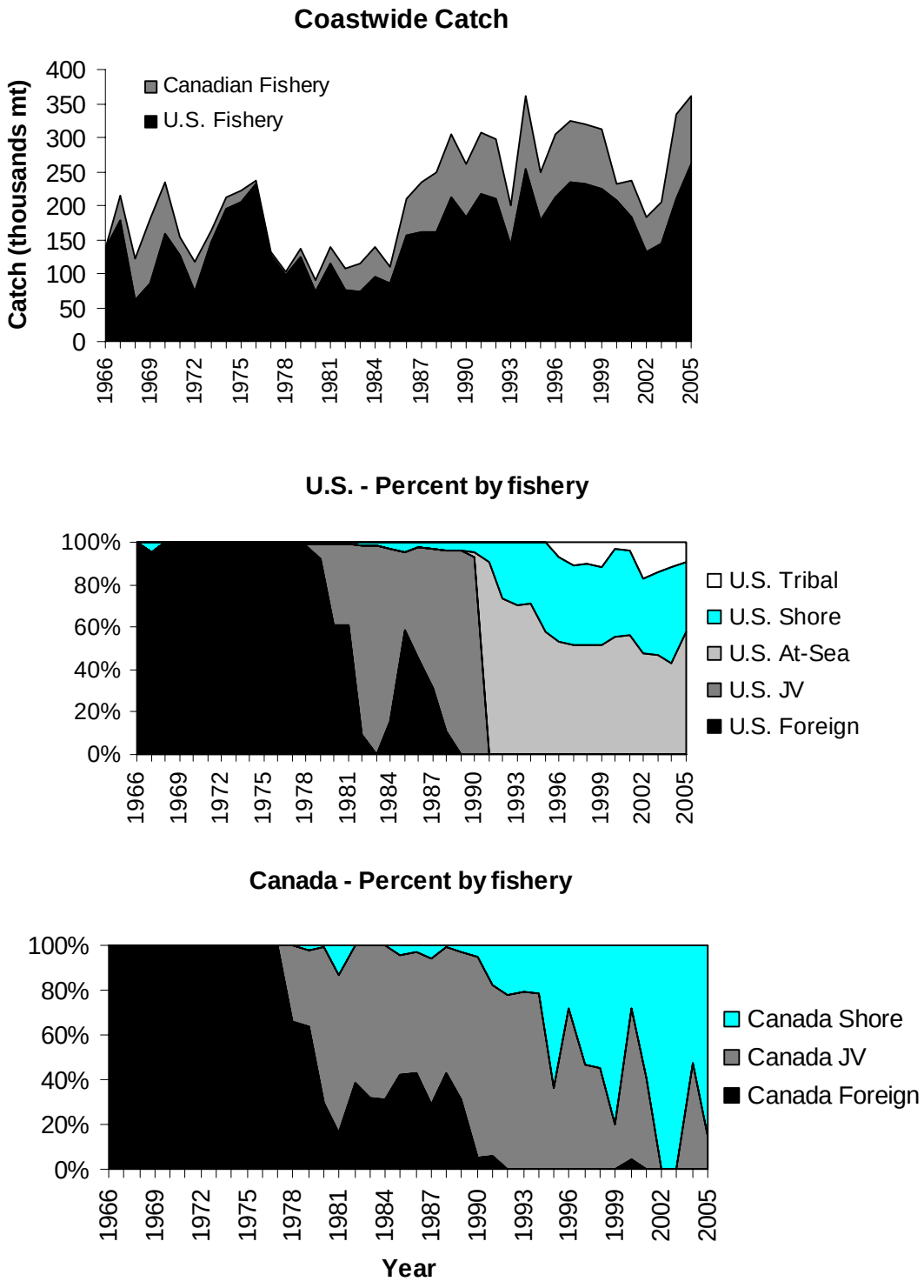

Figure 1. Pacific hake catches by fishery and national fishing sector, 1966-2005.

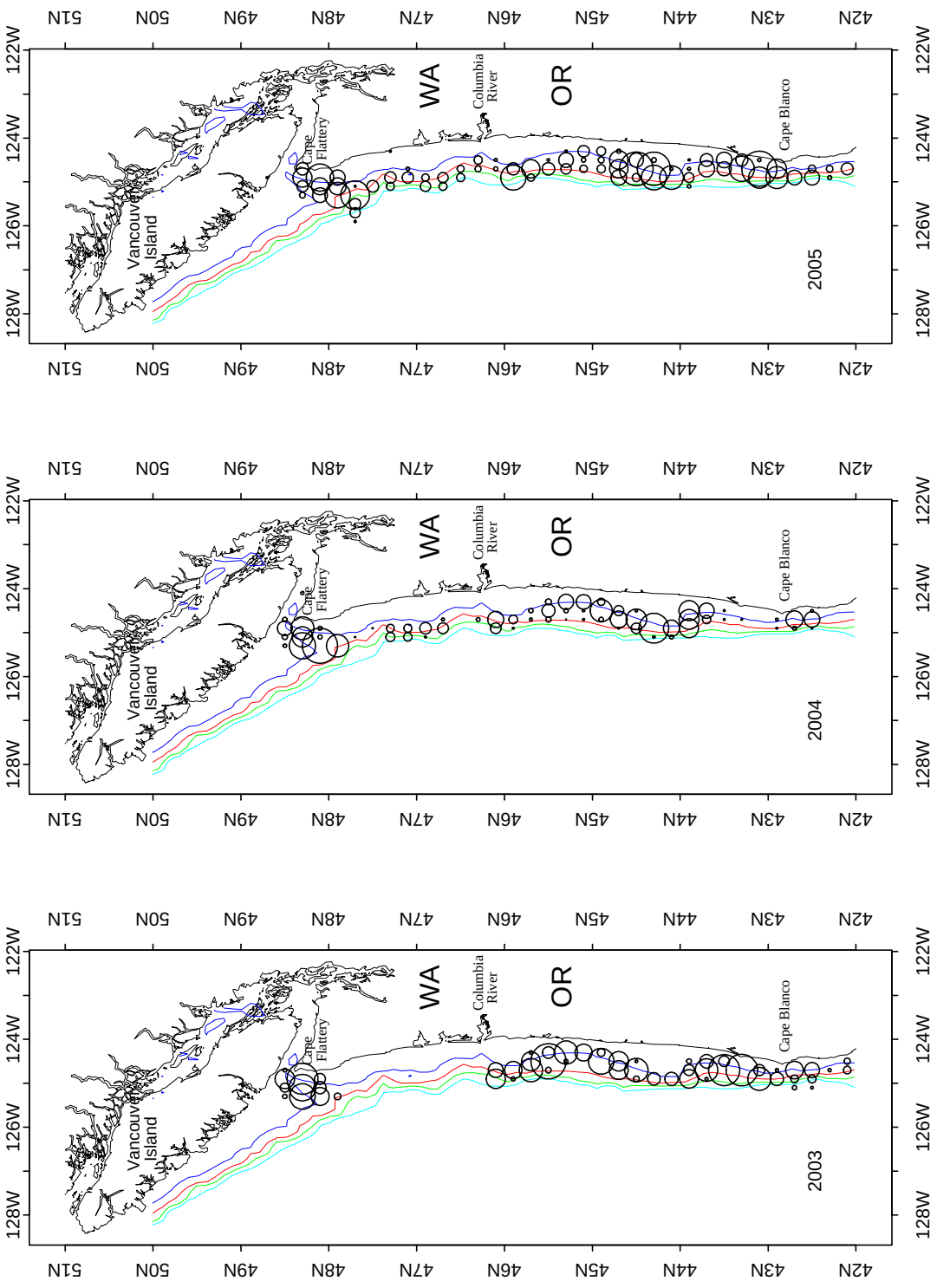

Figure 2. Distribution of at sea Pacific hake catches off the coast of the U.S. in 2003 (bottom), 2004 (middle) and 2005 (top).

US Foreign-At sea length comps

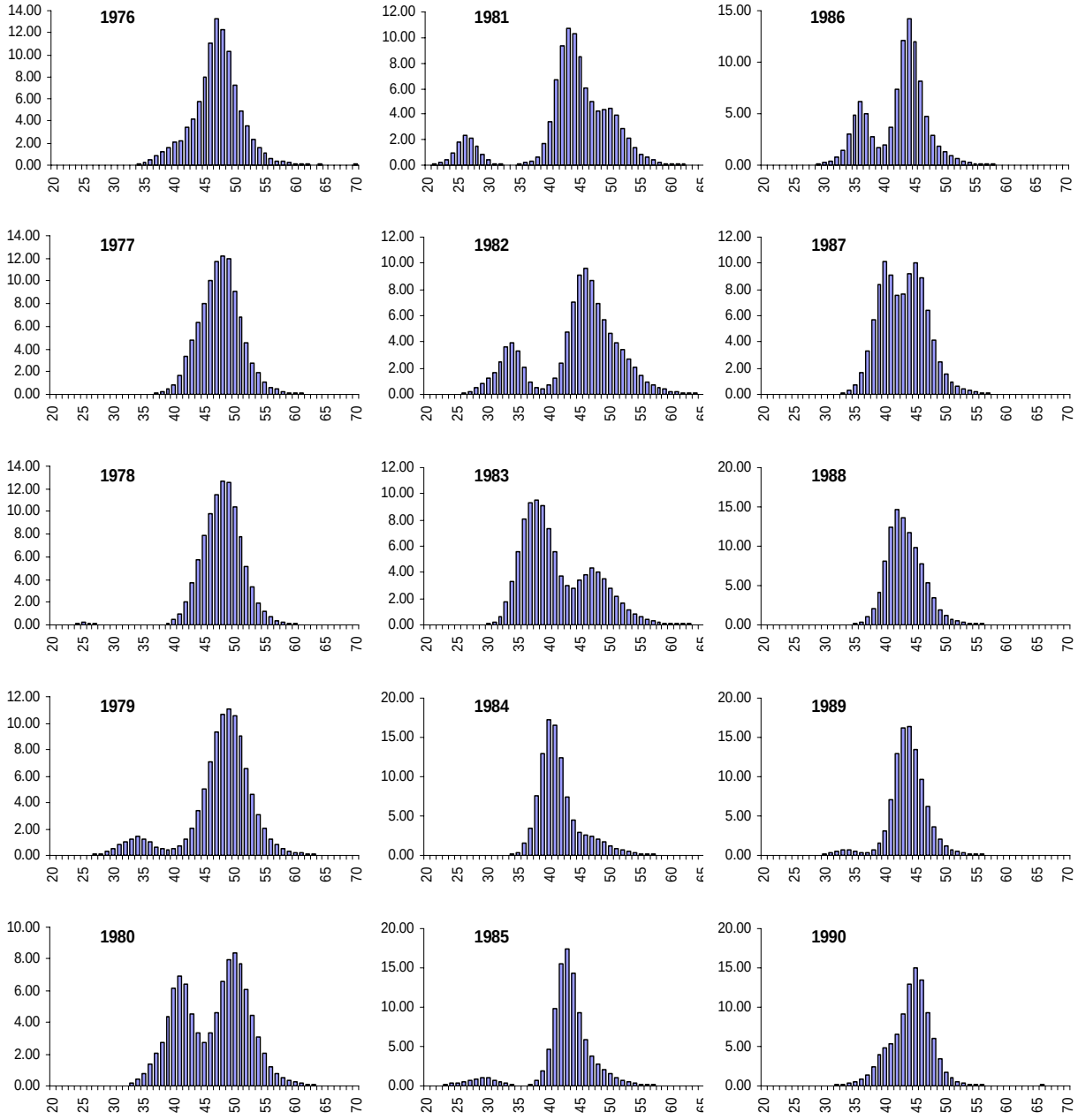

Figure 3. U.S. fishery size compositions of Pacific hake caught by foreign fisheries off the west coast of the U.S., 1975-2005

US At sea length comps

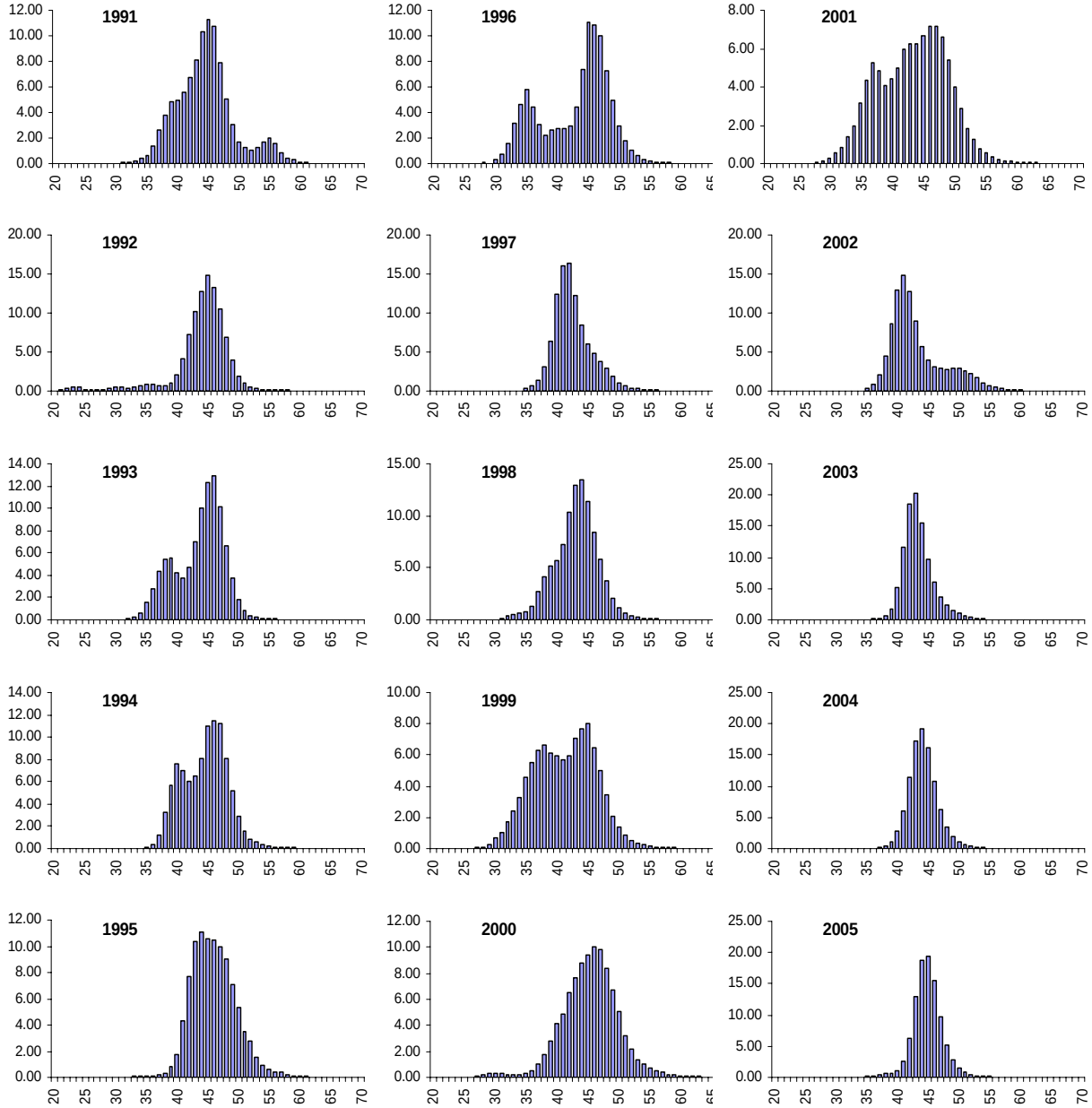

Figure 4. U.S. fishery size compositions of Pacific hake catch in the domestic at sea fishery off the west coast of the U.S., 1991-2005

US domestic shore based length comps

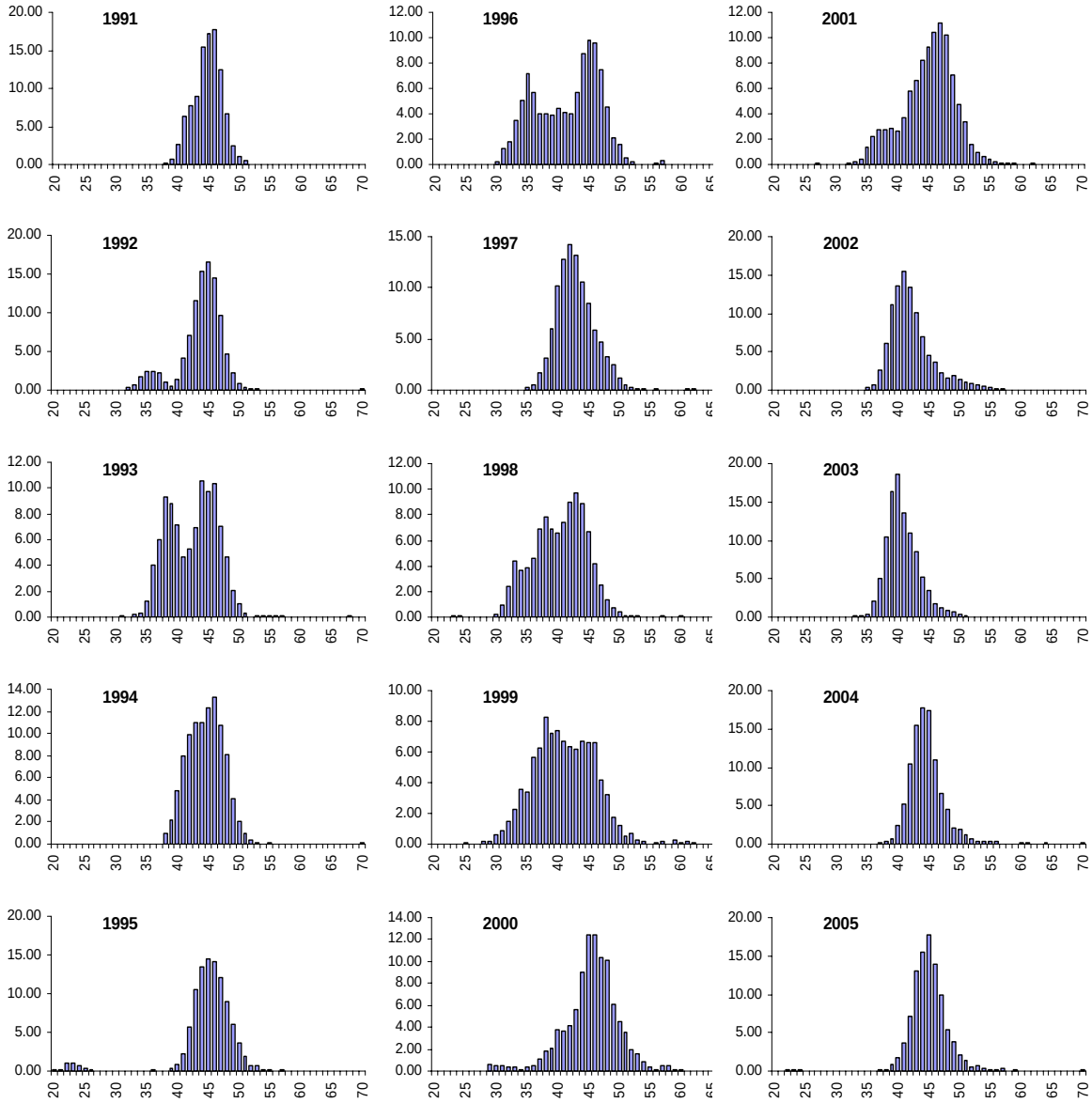

Figure 5. U.S. fishery size compositions of Pacific hake catch in the domestic shore-based fishery off the west coast of the U.S., 1991-2005

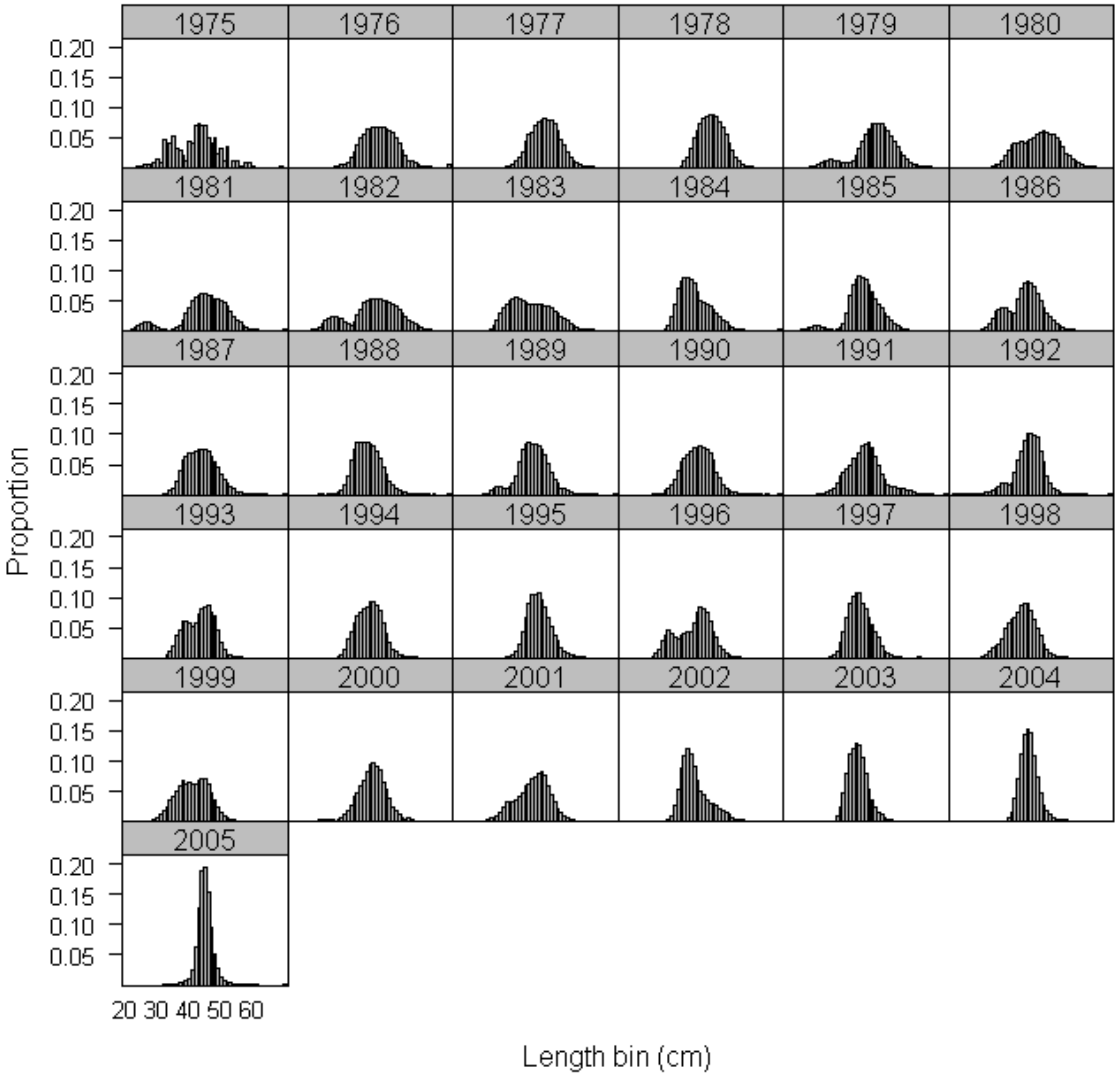

Figure 6. Composite U.S. fishery size compositions of Pacific hake from all fisheries operating off the west coast of the U.S., 1975-2005.

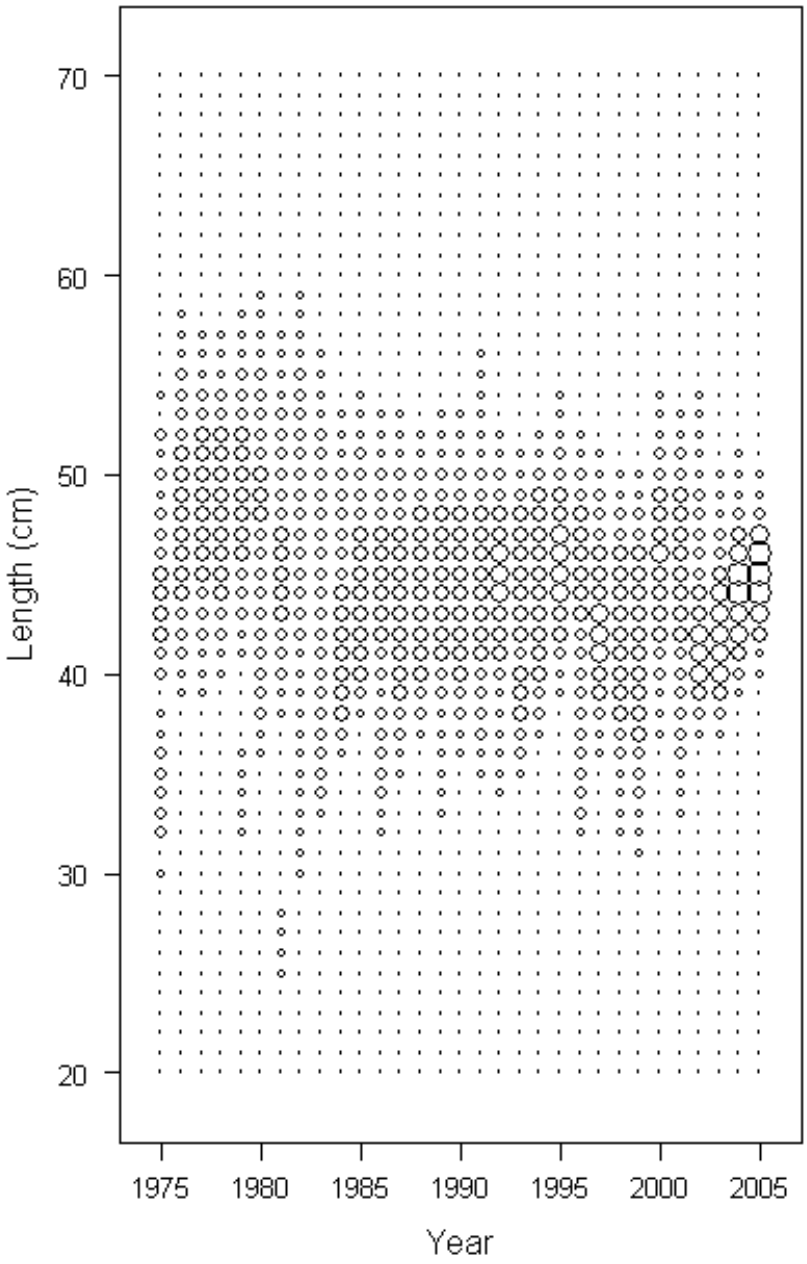

Figure 7. Composite U.S. fishery size compositions of Pacific hake from all fisheries operating off the west coast of the U.S., 1975-2005. Proportions sum to unit by year.

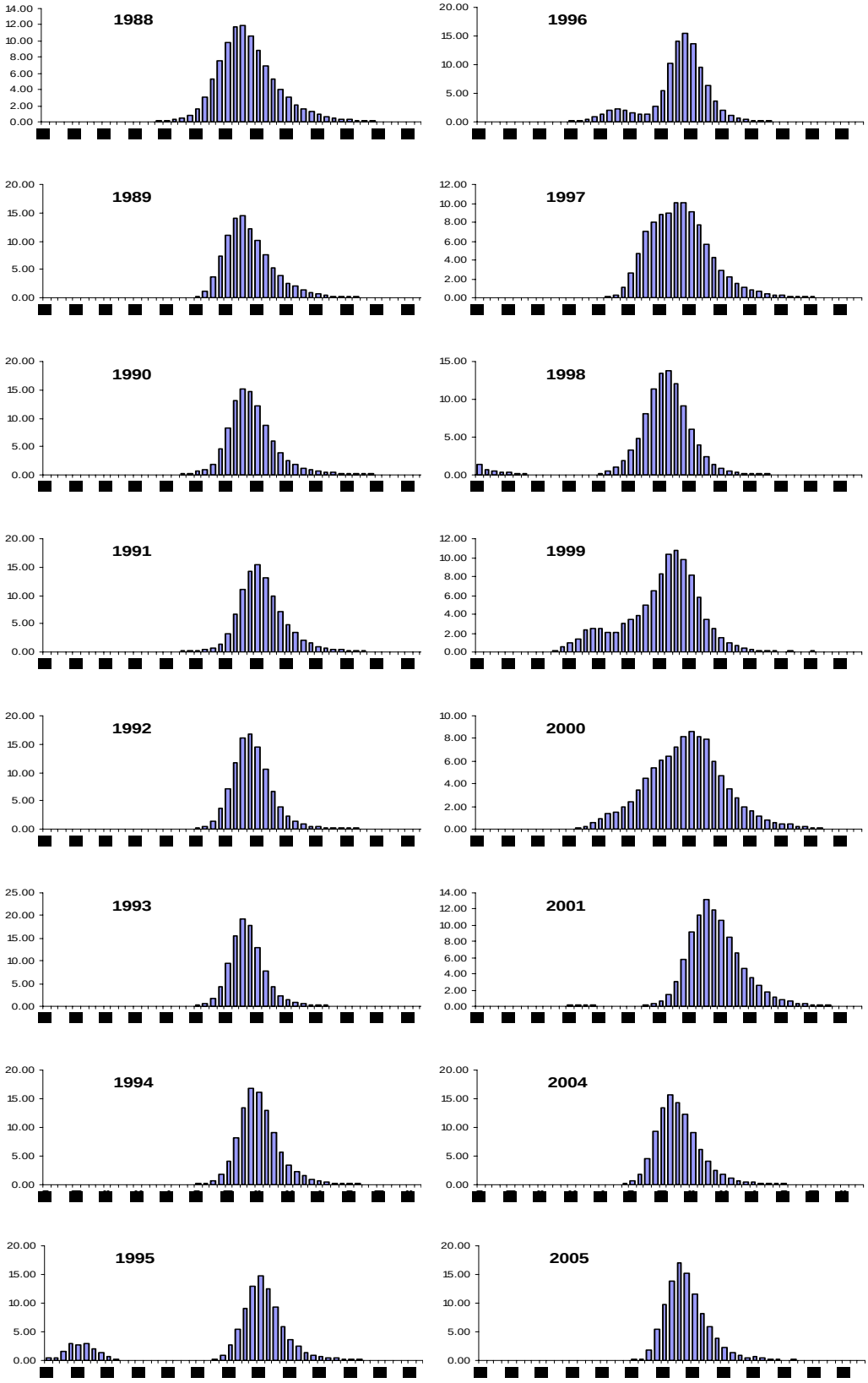

Figure 8. Canadian fishery size compositions of Pacific hake catch in the Joint-venture fishery, 1988-2005.

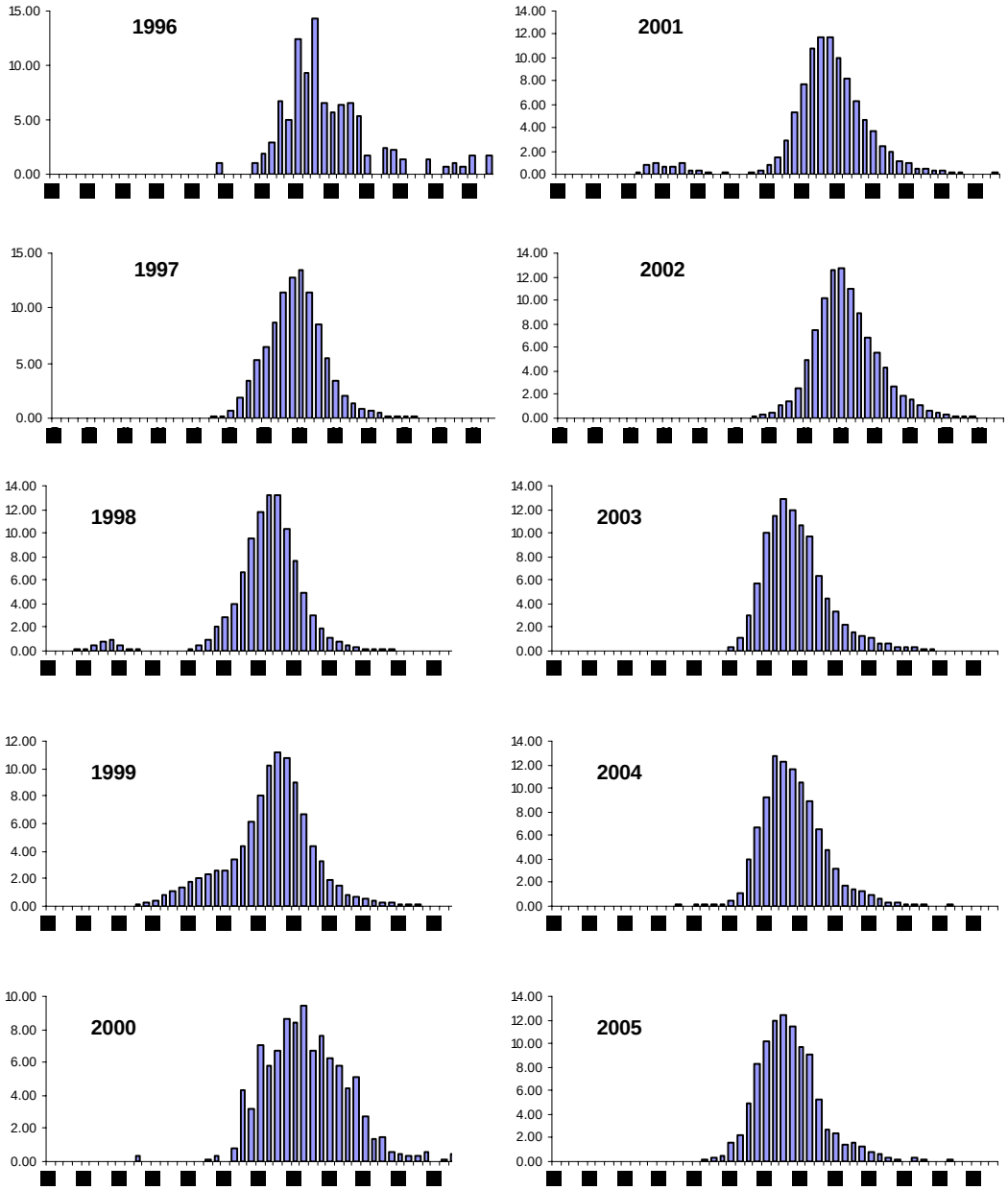

Figure 9. Canadian fishery size compositions of Pacific hake catch in the domestic shore-based fishery, 1996-2005.

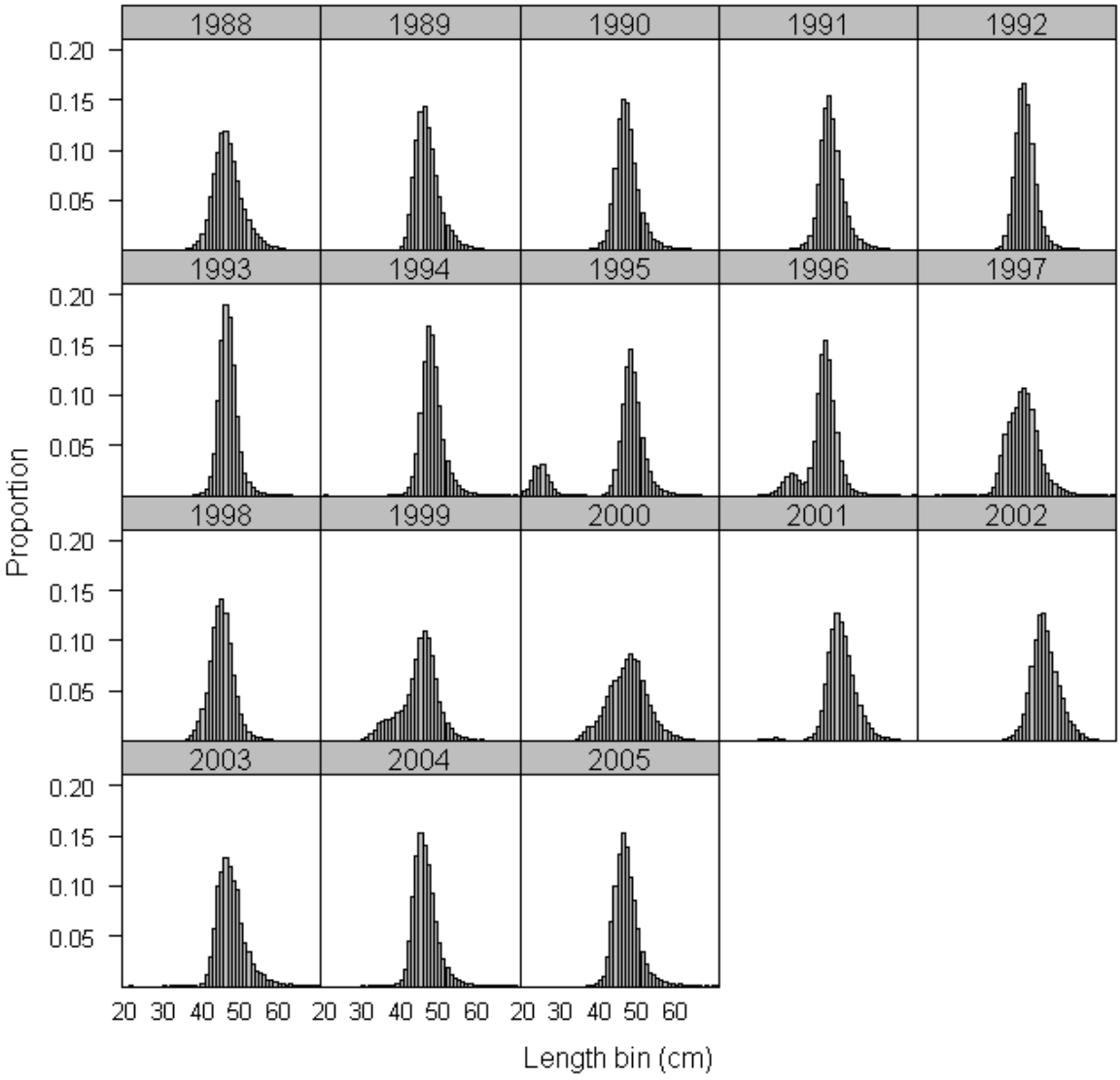

Figure 10. Composite Canadian fishery size compositions of Pacific hake from all fisheries operating in Canadian waters, 1975-2005.

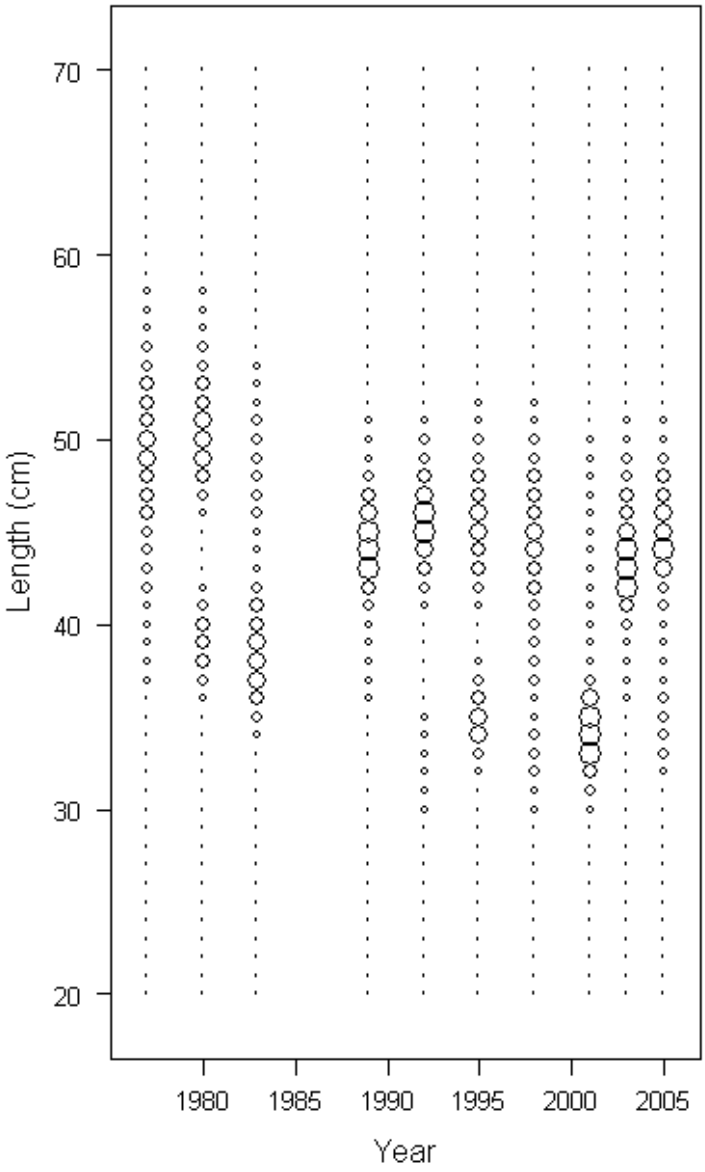

Figure 11. Composite Canadian fishery size compositions of Pacific hake from all fisheries Operating in Canadian waters., 1975-2005. Proportions sum to unit by year.

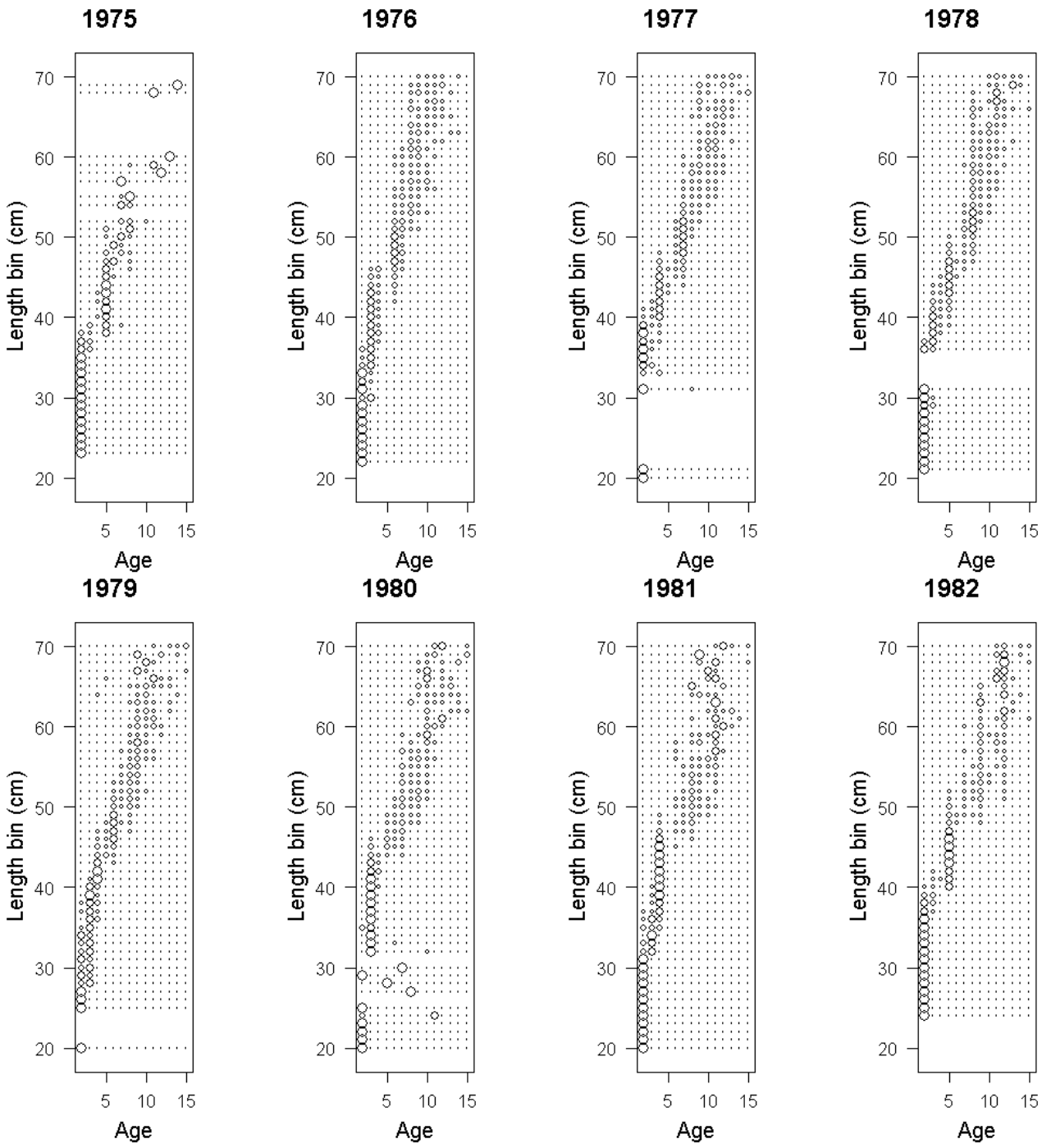

Figure 12. U.S. fishery conditional age at length compositions.

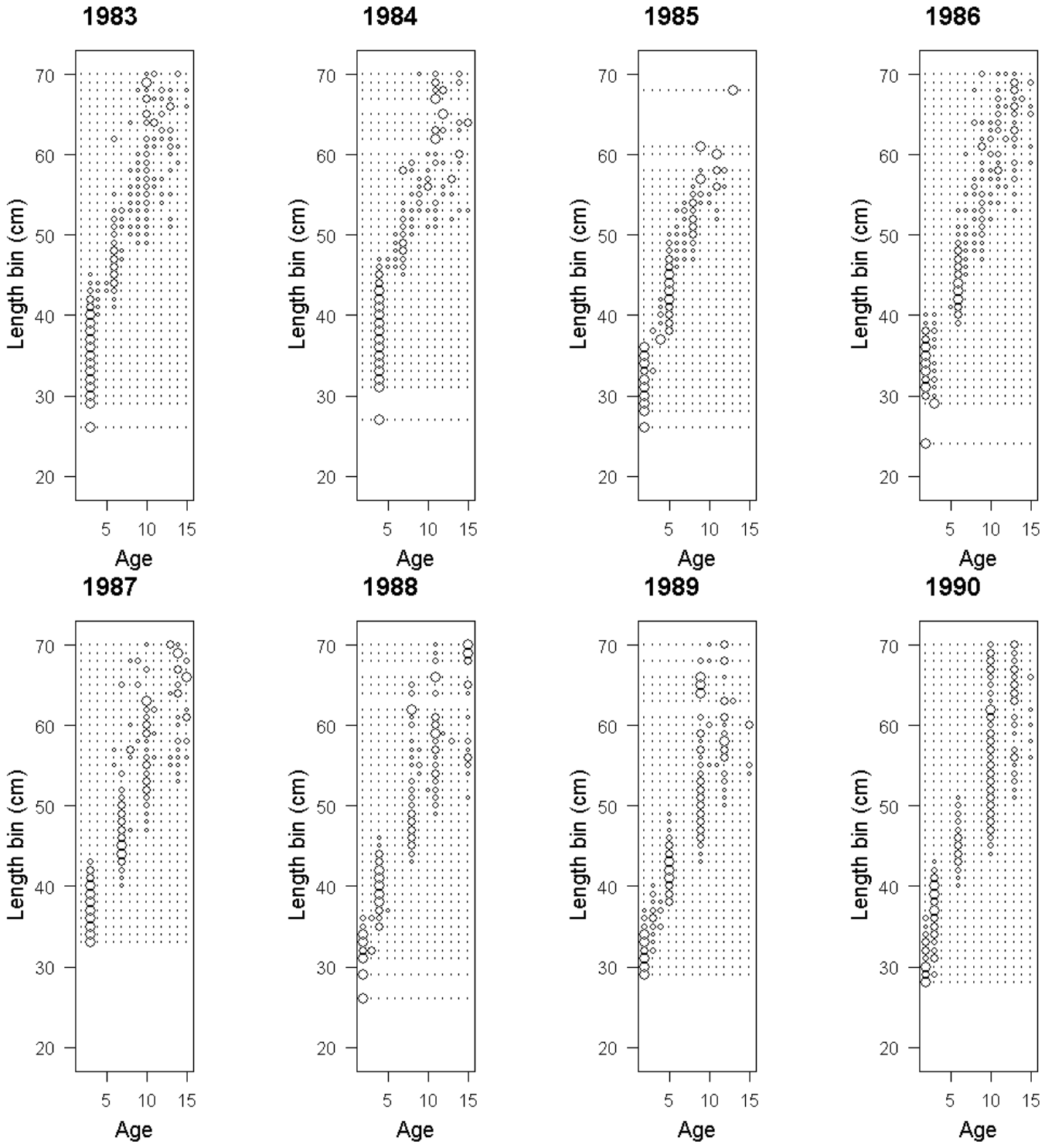

Figure 12 continued. U.S. fishery conditional age at length compositions.

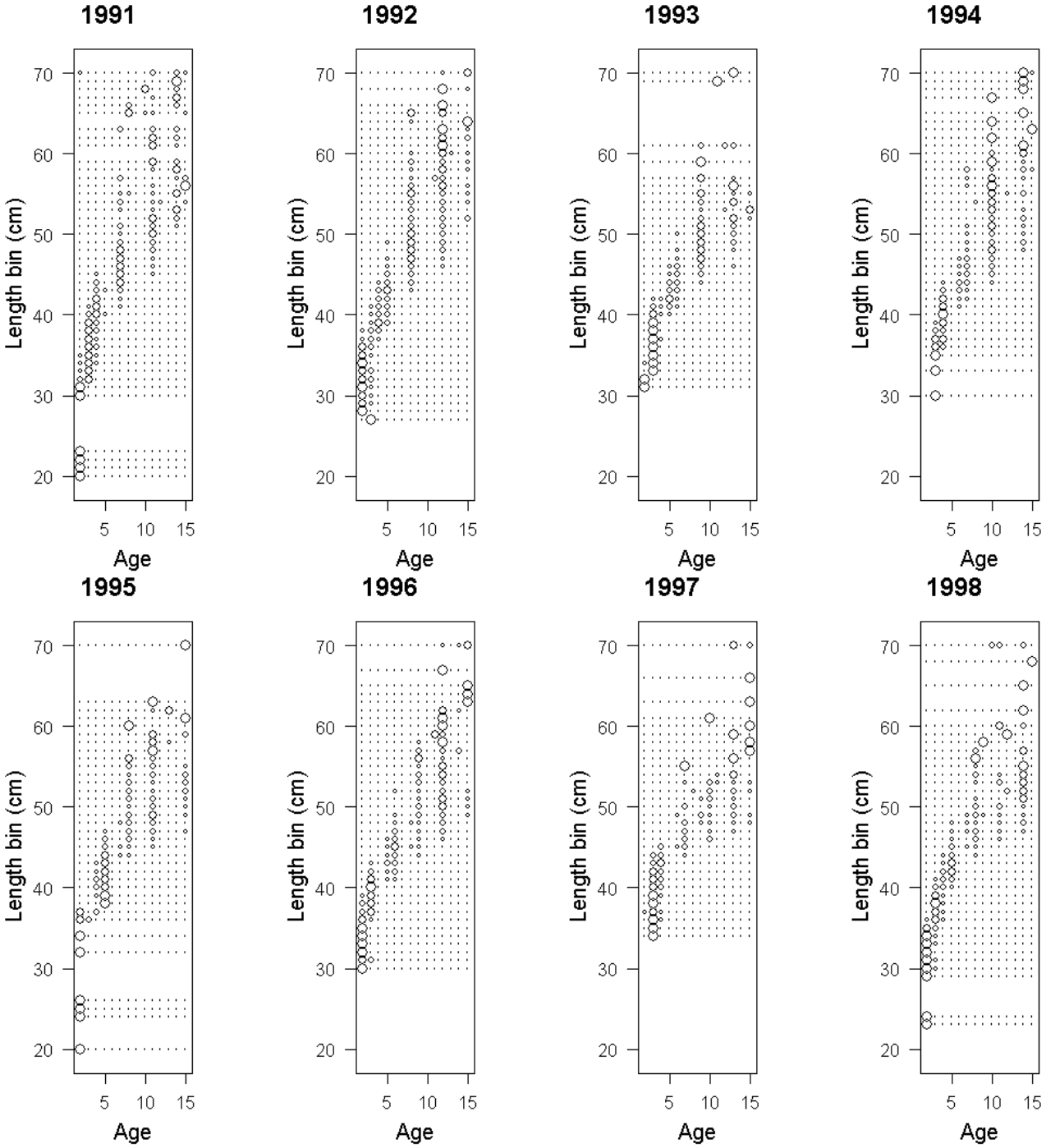

Figure 12 continued. U.S. fishery conditional age at length compositions.

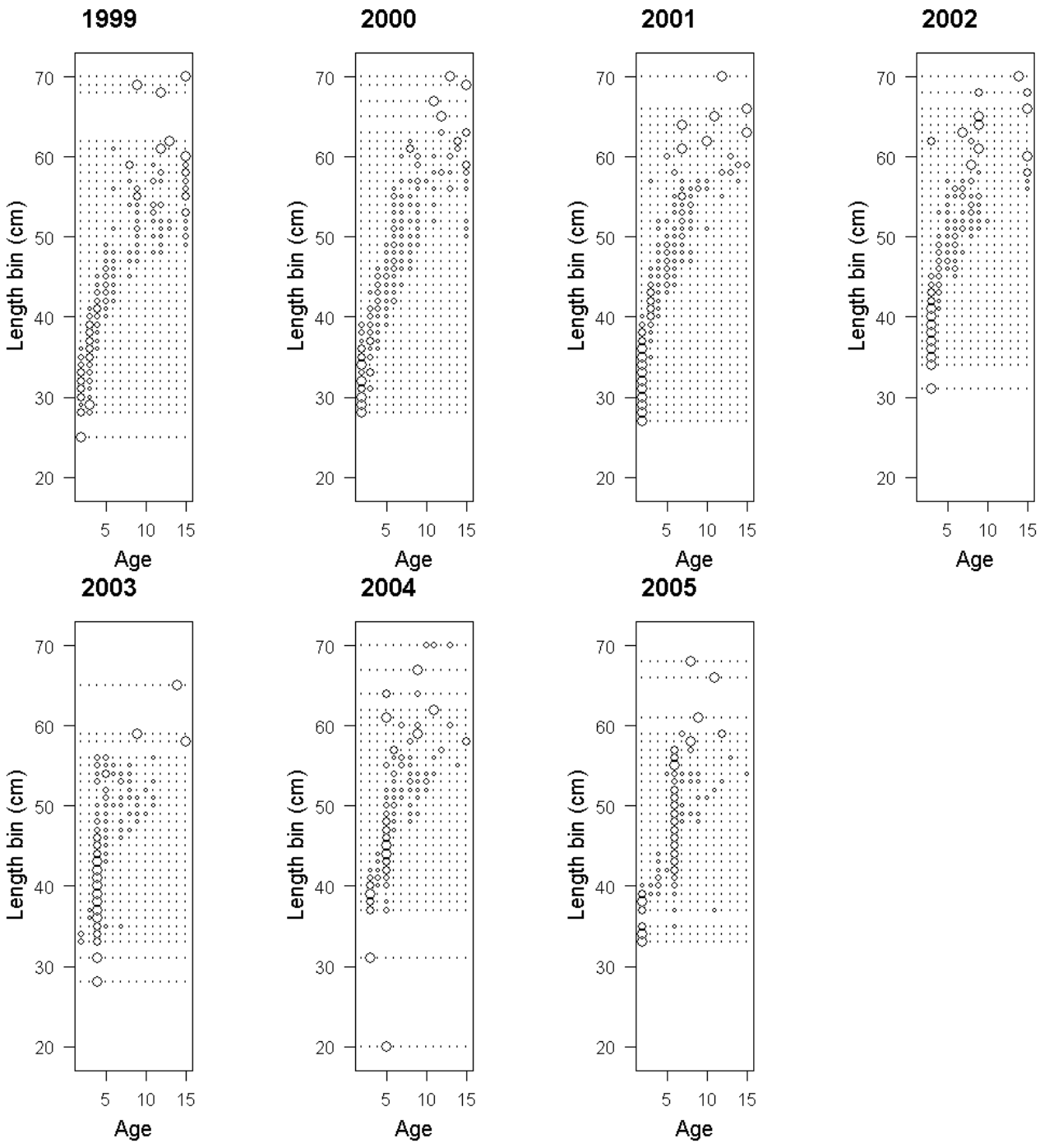

Figure 12 continued. U.S. fishery conditional age at length compositions.

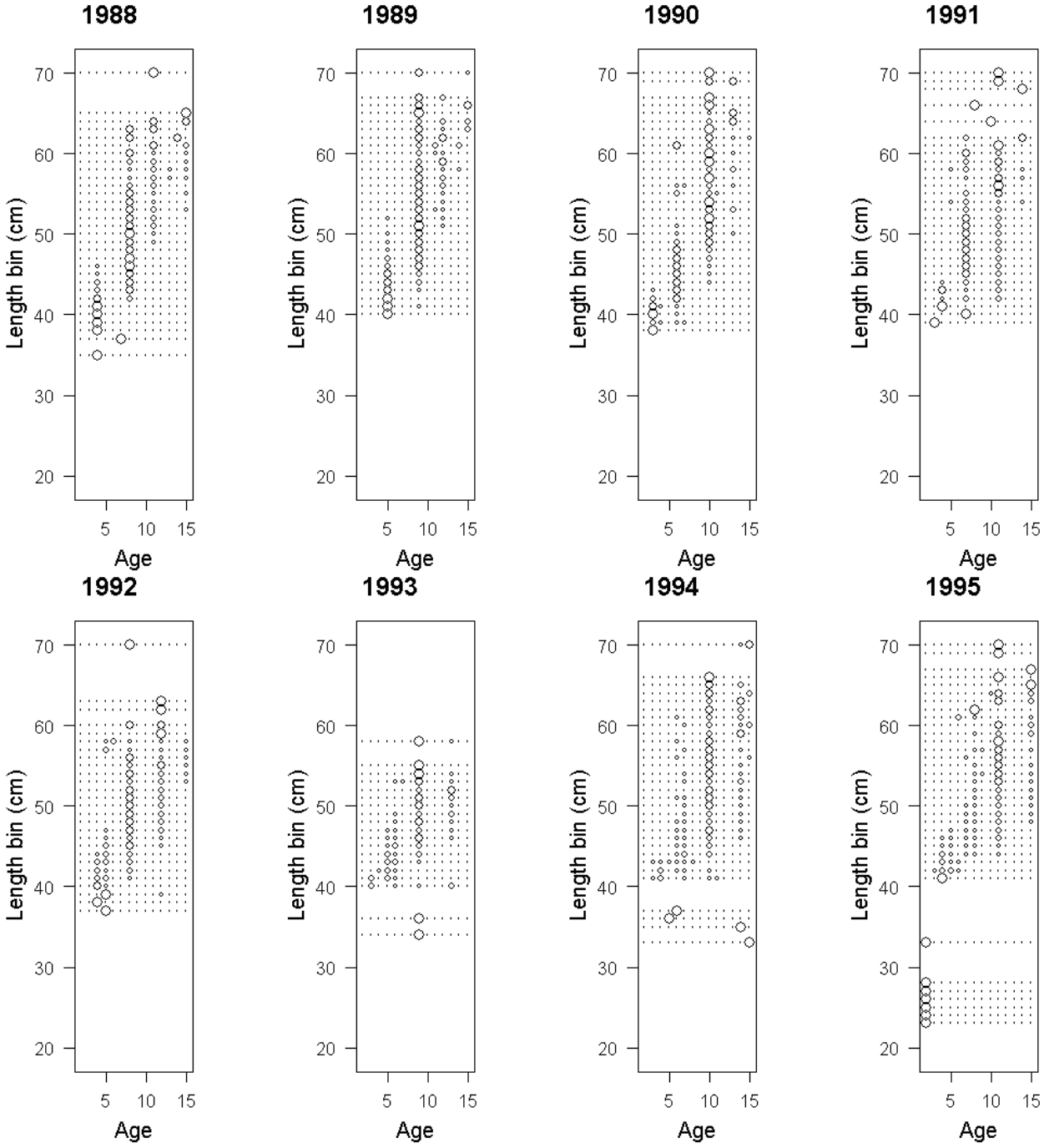

Figure 13. Canadian fishery conditional age at length compositions.

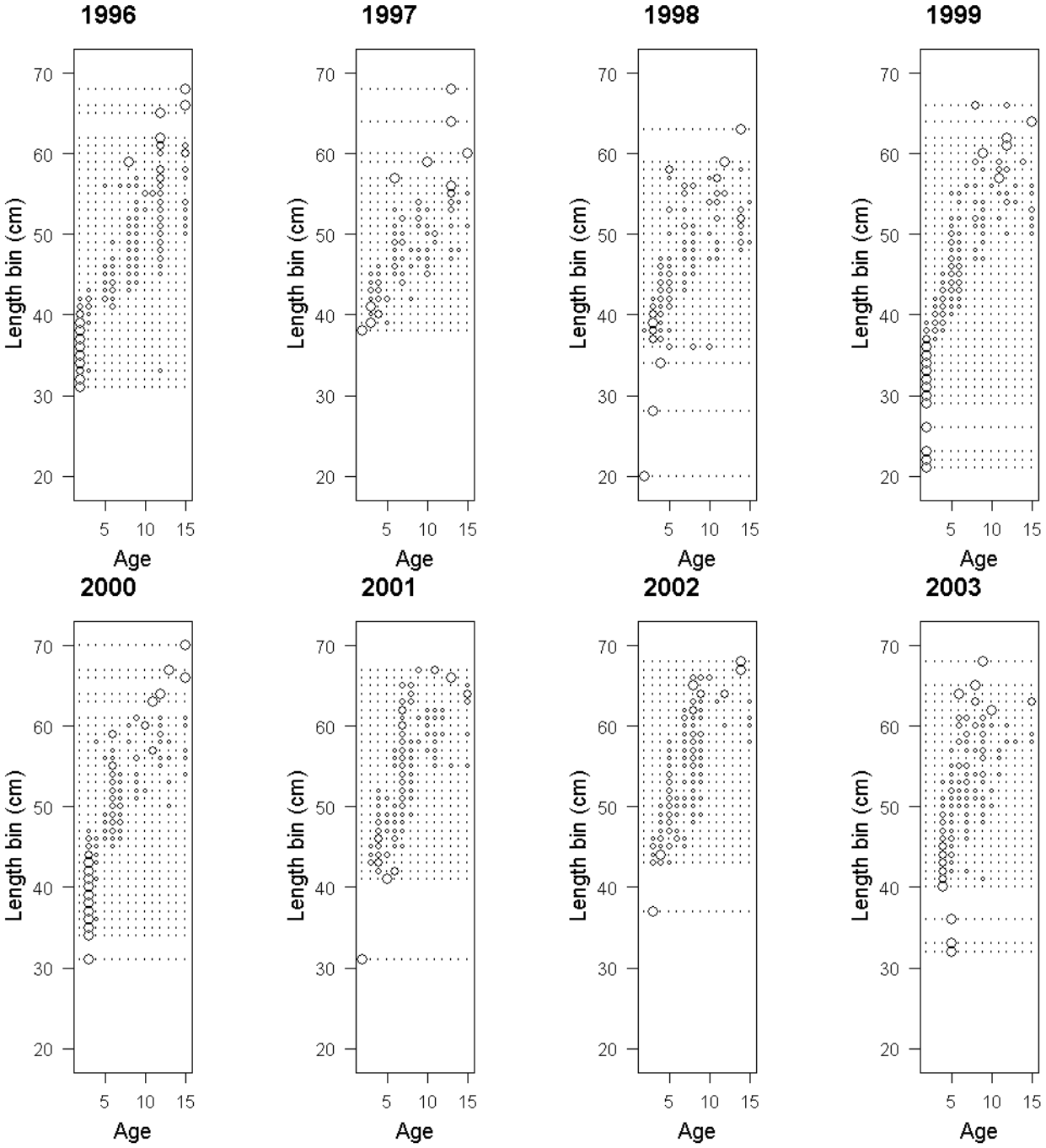

Figure 13 continued. Canadian fishery conditional age at length compositions.

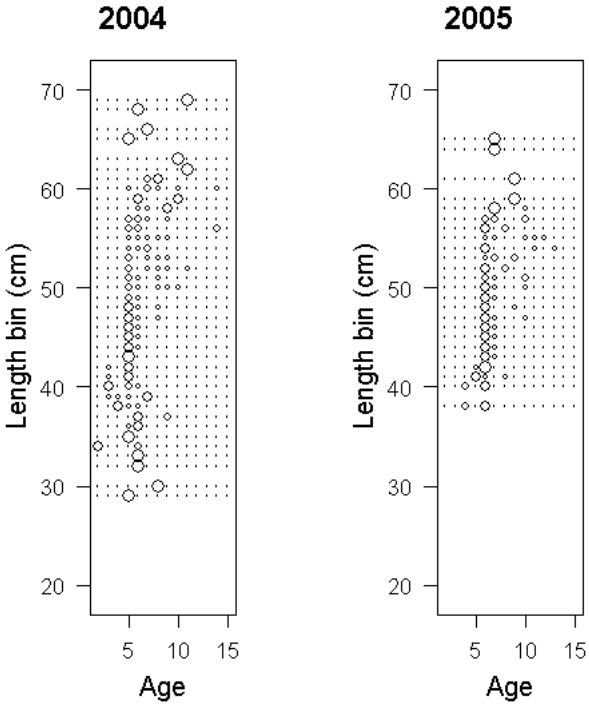

Figure 13 continued. Canadian fishery conditional age at length compositions.

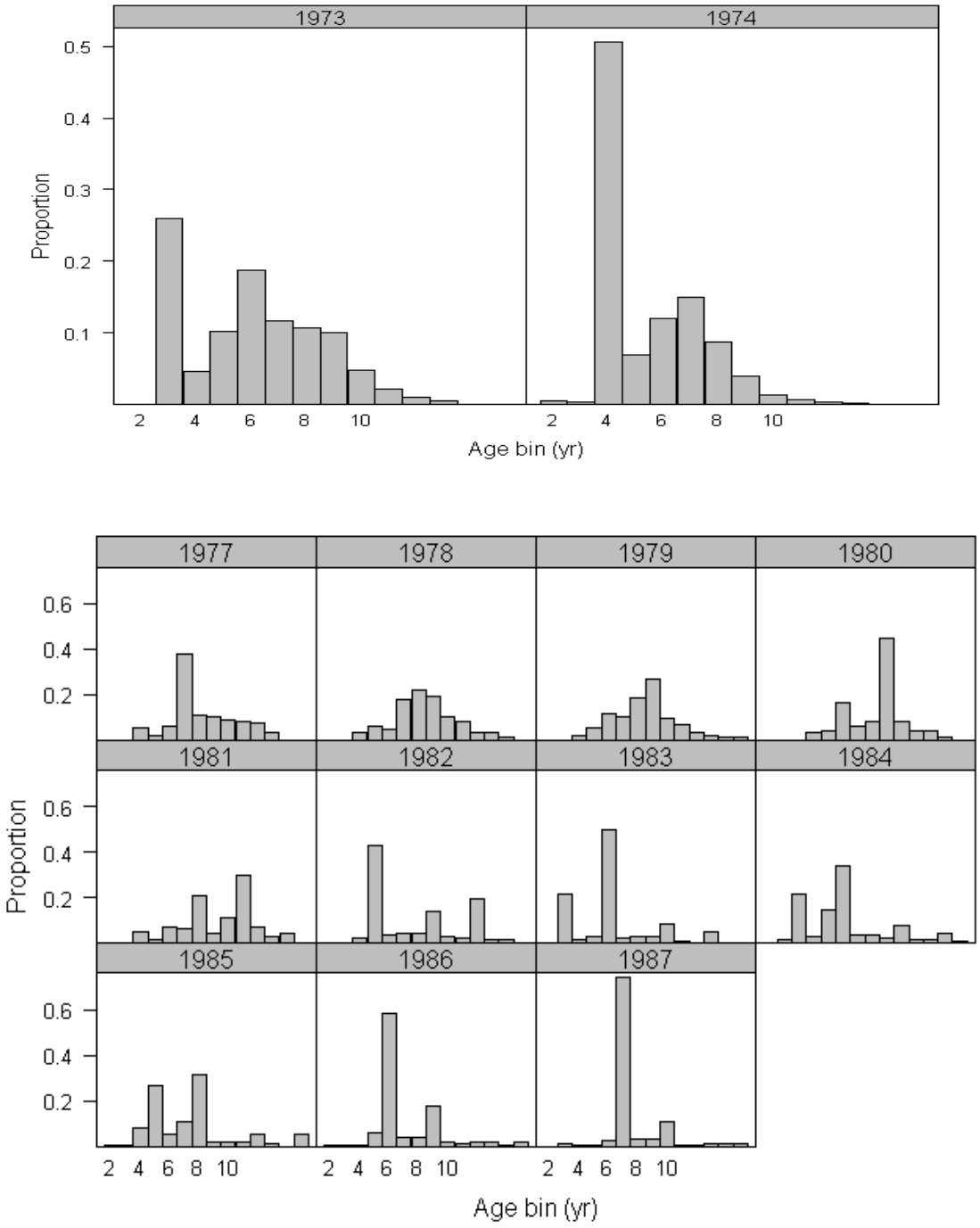

Figure 14. Top panel) U.S. fishery age composition, bottom panel) Canadian fishery age composition.

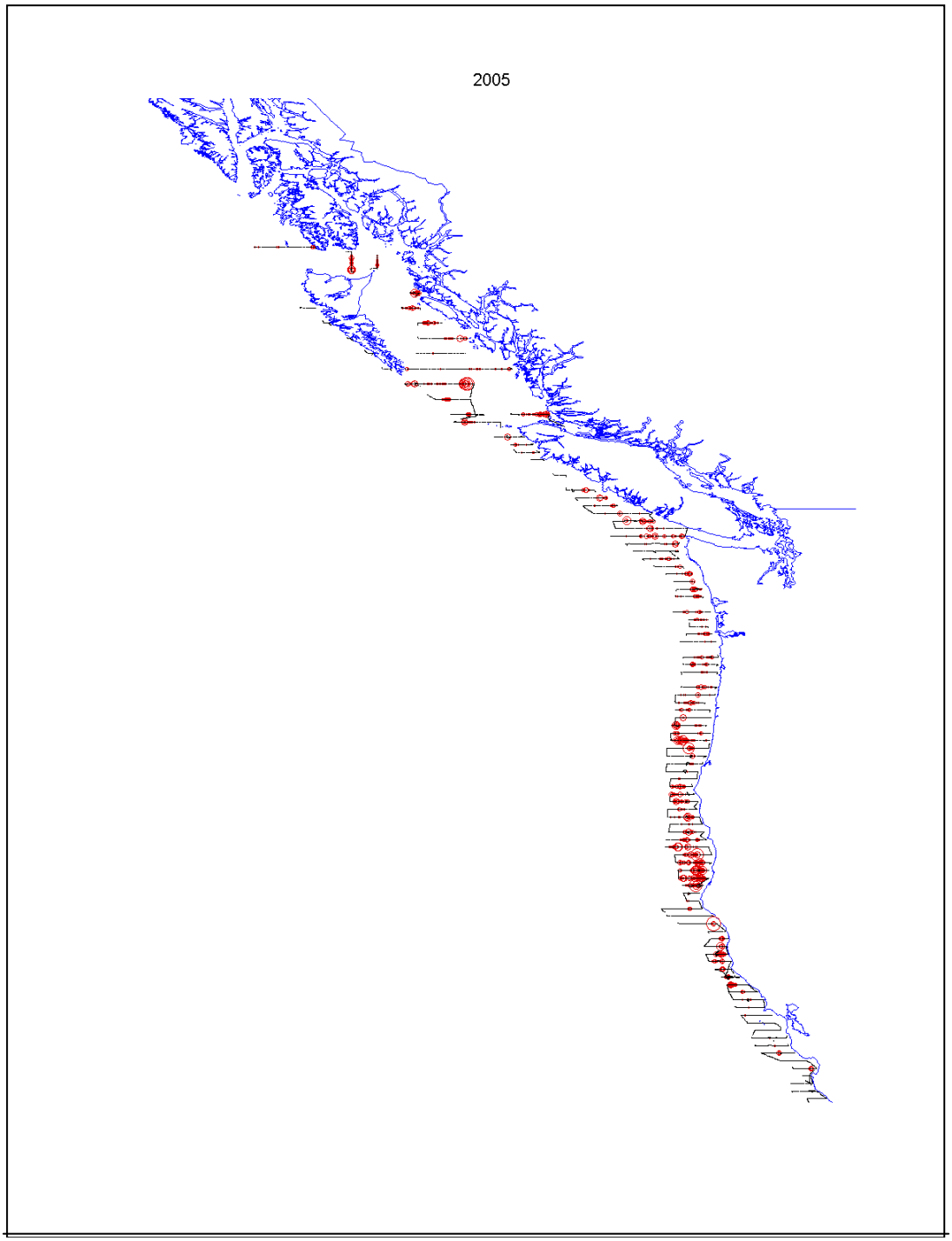

Figure 15. Line transects and distribution of acoustic backscatter in the 2005 acoustic survey.

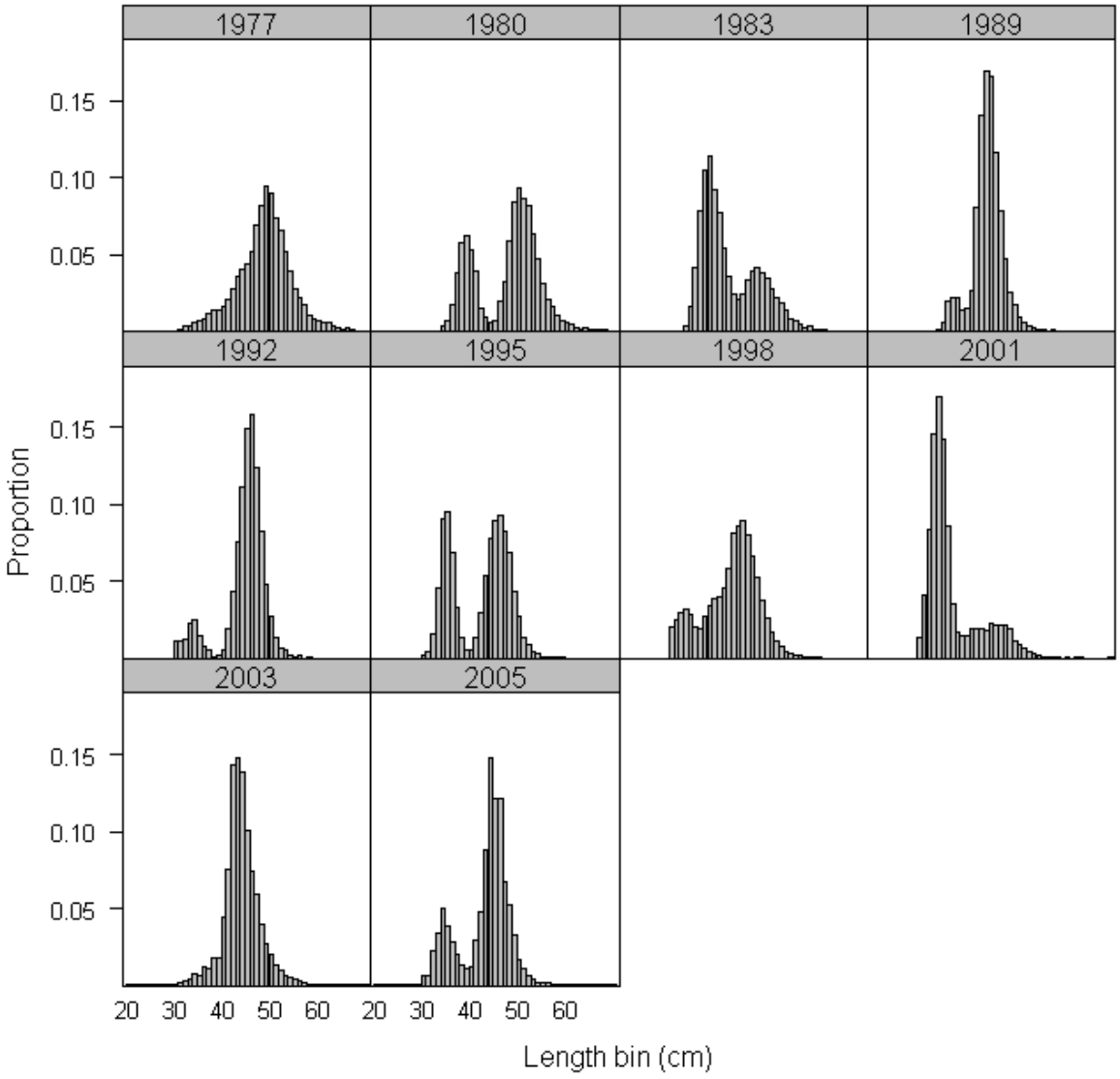

Figure 16. Acoustic survey Pacific hake size compositions sampled, 1977-2005.

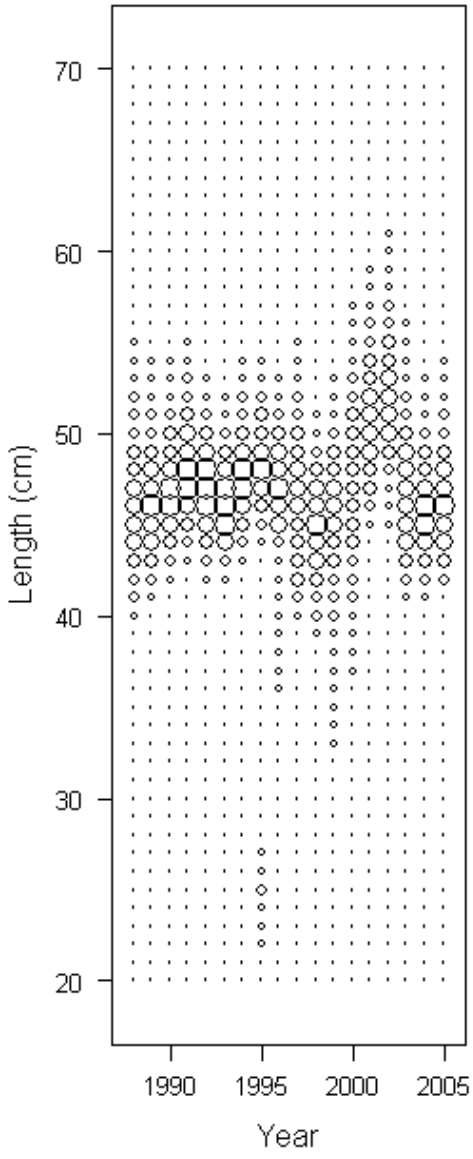

Figure 17. Composite size compositions from the acoustic survey. Proportions sum to unity by year.

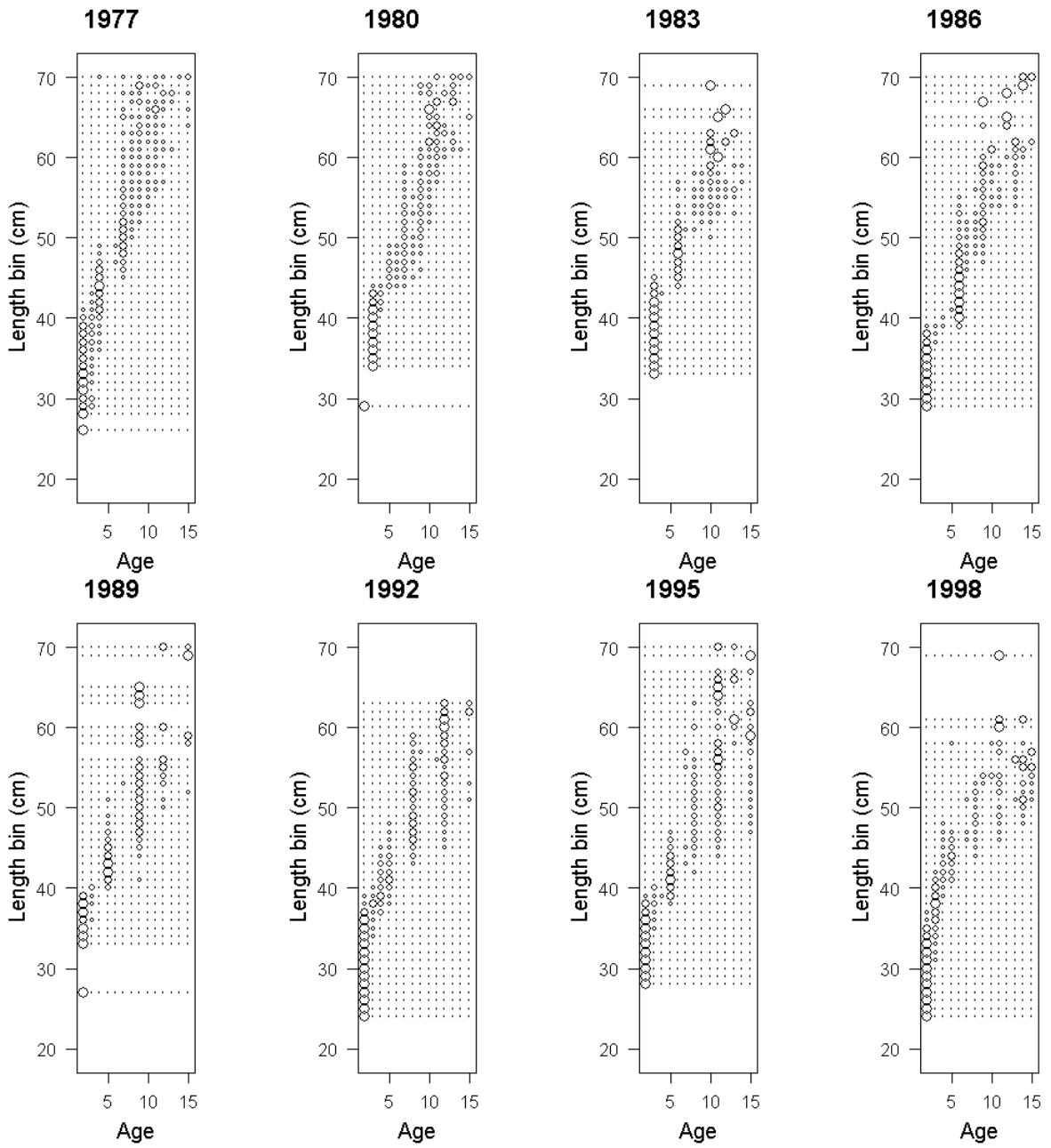

Figure 18. Acoustic survey conditional age at length compositions. Proportions sum to unit by length bin and year.

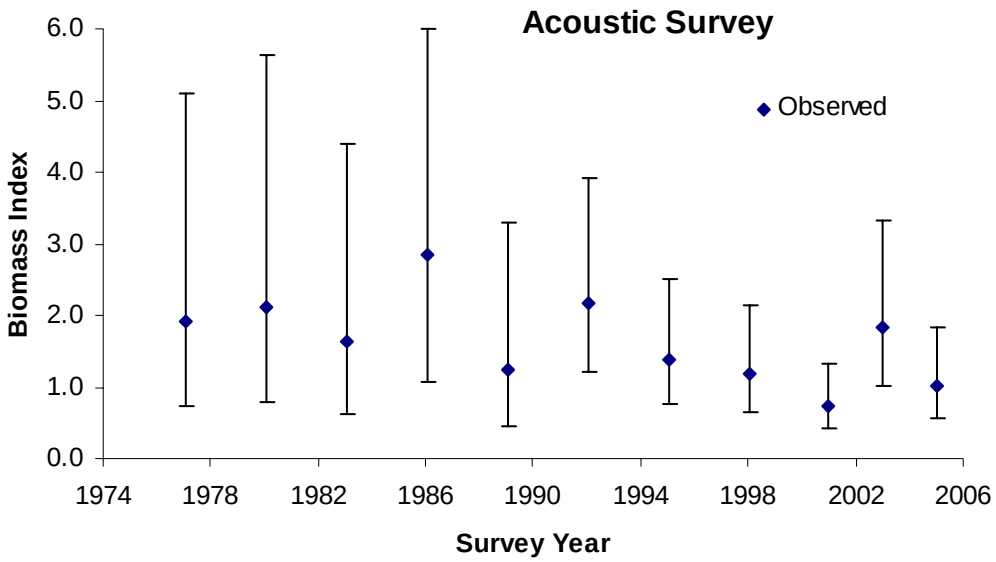

Figure 19. Time series of acoustic survey Pacific hake biomass (millions mt), 1977-2005. Error bars are not estimated but rather assumed based on the reliability of the survey.

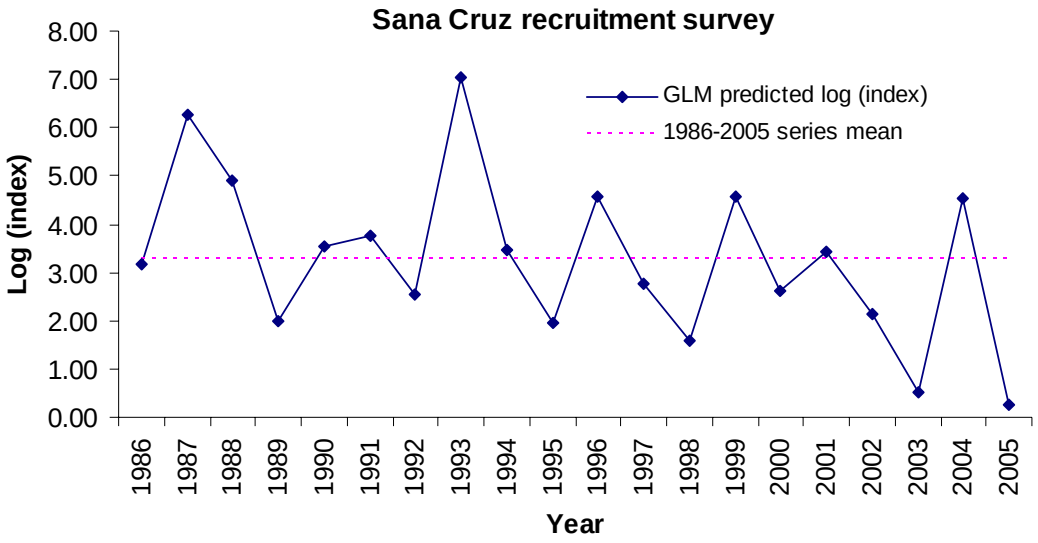

Figure 20. Time series the Santa Cruz pre-recruit survey for Pacific hake.

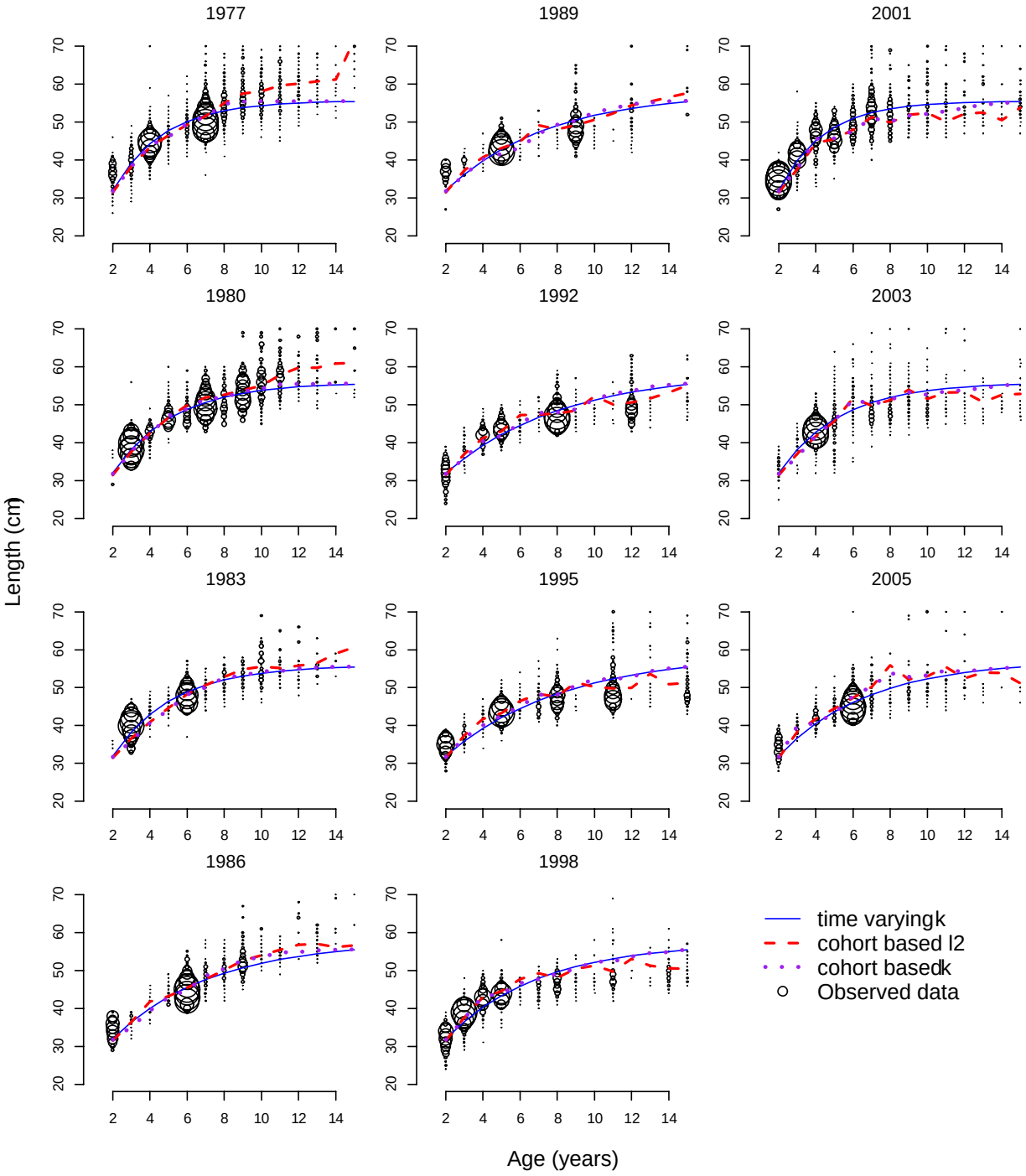

Figure 21. Time varying and cohort based fits of the von Bertalanffy growth model to Pacific hake age data from the acoustic survey, 1977-2005. Growth trajectories show expected size at age based on the different model assumed.

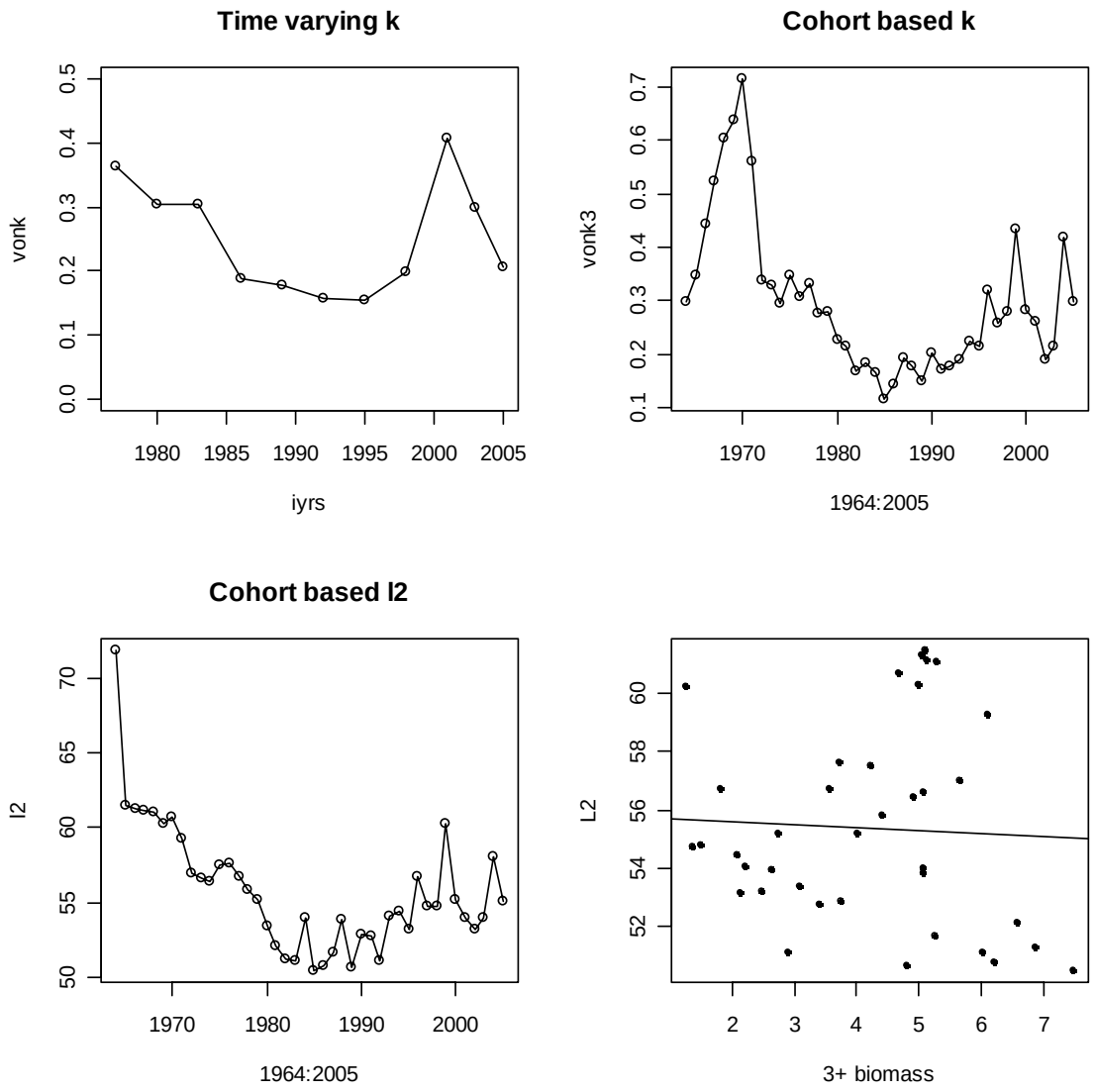

Figure 22. Time varying and cohort based fits of the von Bertalanffy growth model to Pacific hake age data from the acoustic survey, 1977-2005.

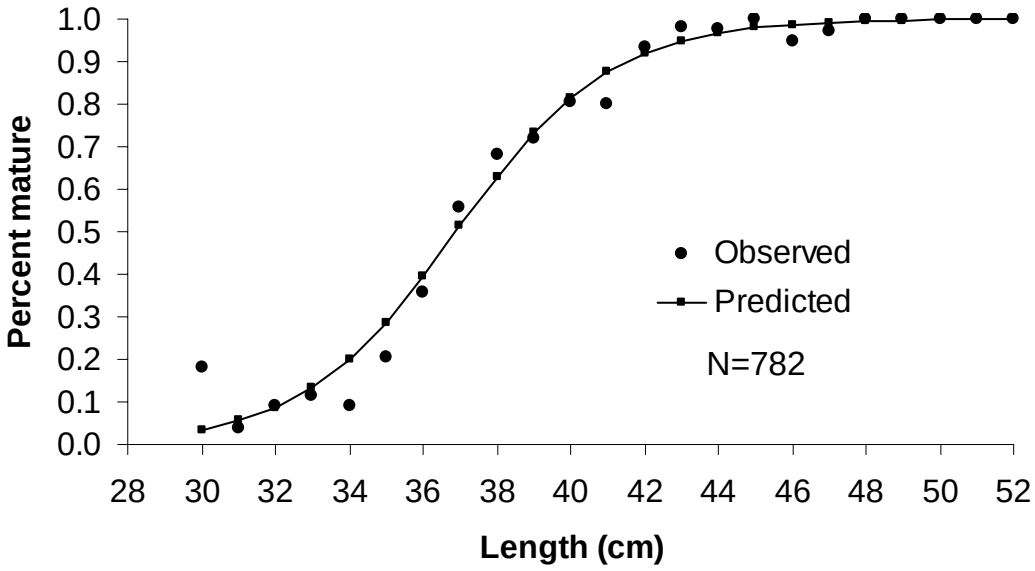

Figure 23. Predicted fraction of Pacific hake mature at length.

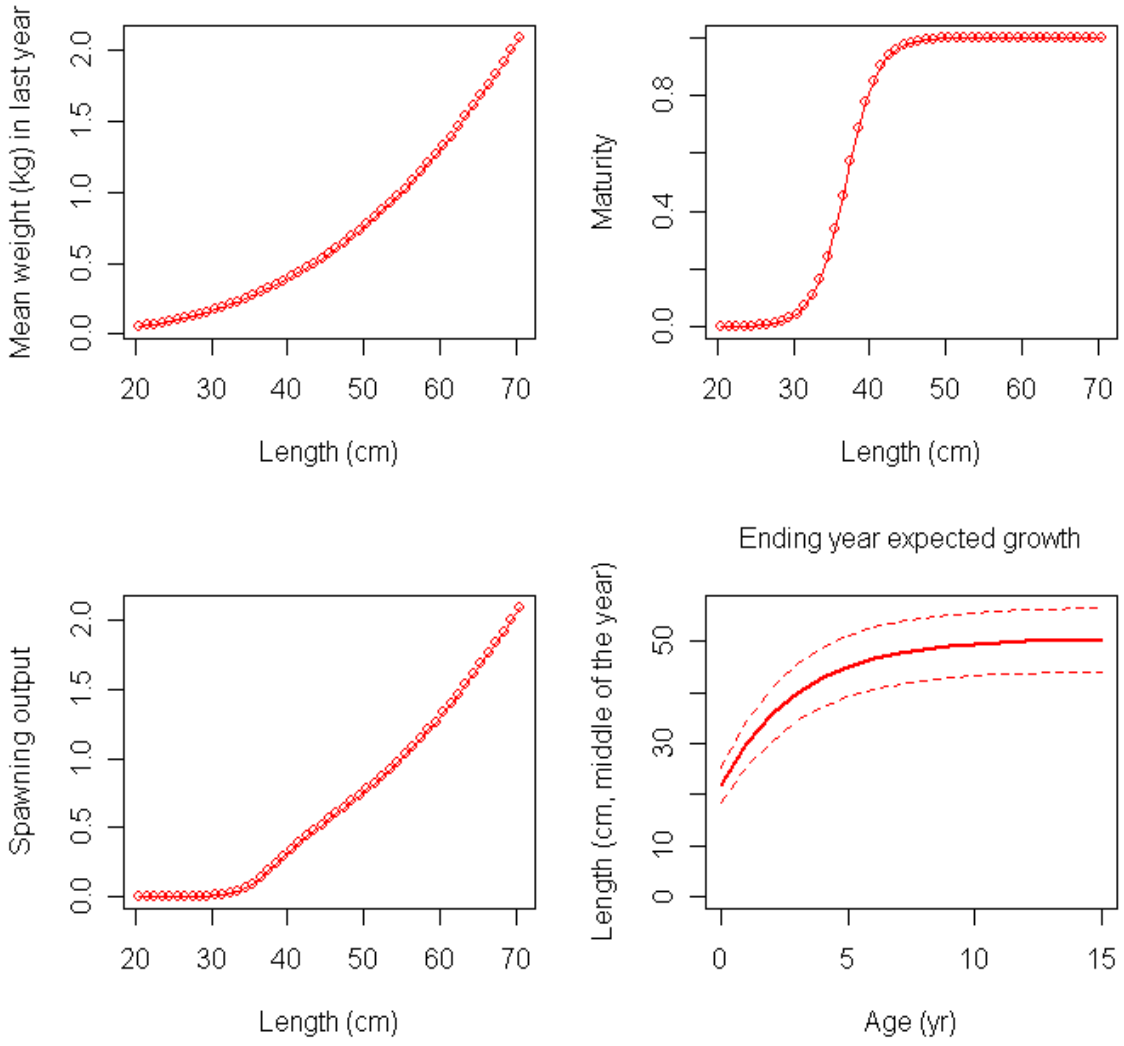

Figure24. Biological parameters (functional forms) assumed in the hake model.

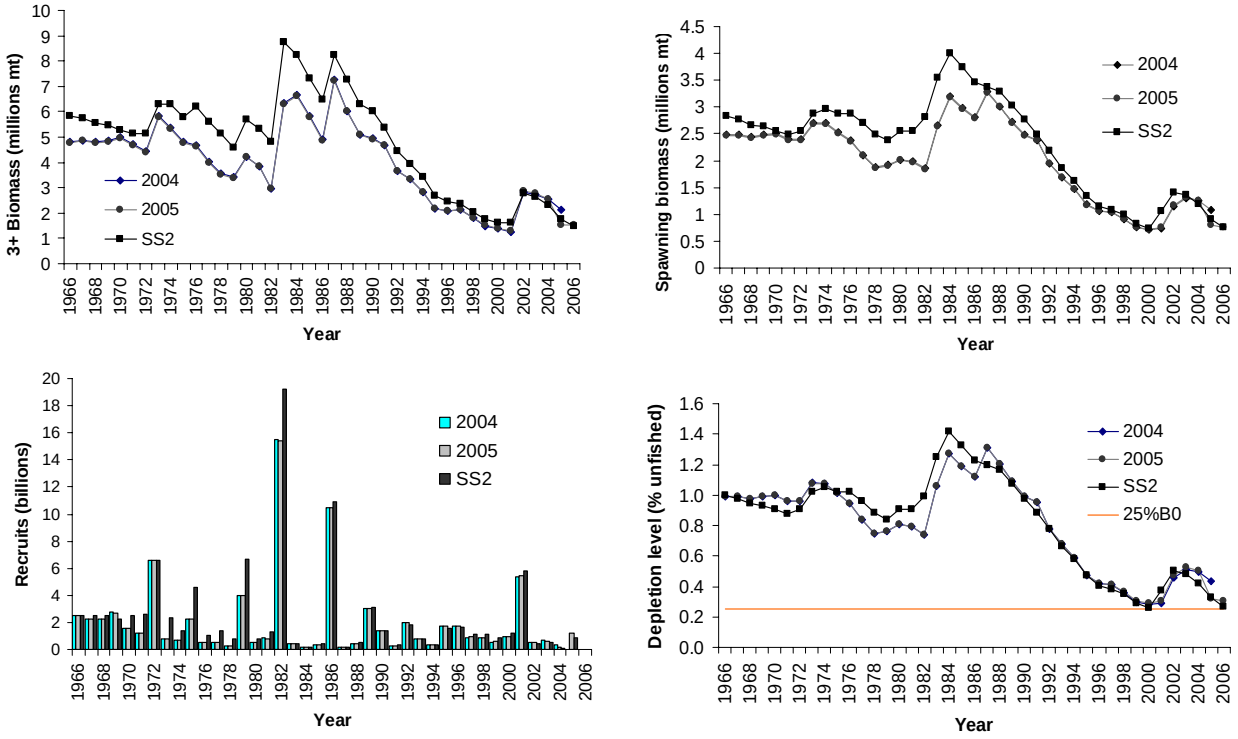

Figure 25. Time series of summary biomass (3 +), spawning biomass, recruitment (age 2) and depletion from comparative assessment model results; old hake model (Helser et. al. 2004) vs. SS2 (Methot 2005).

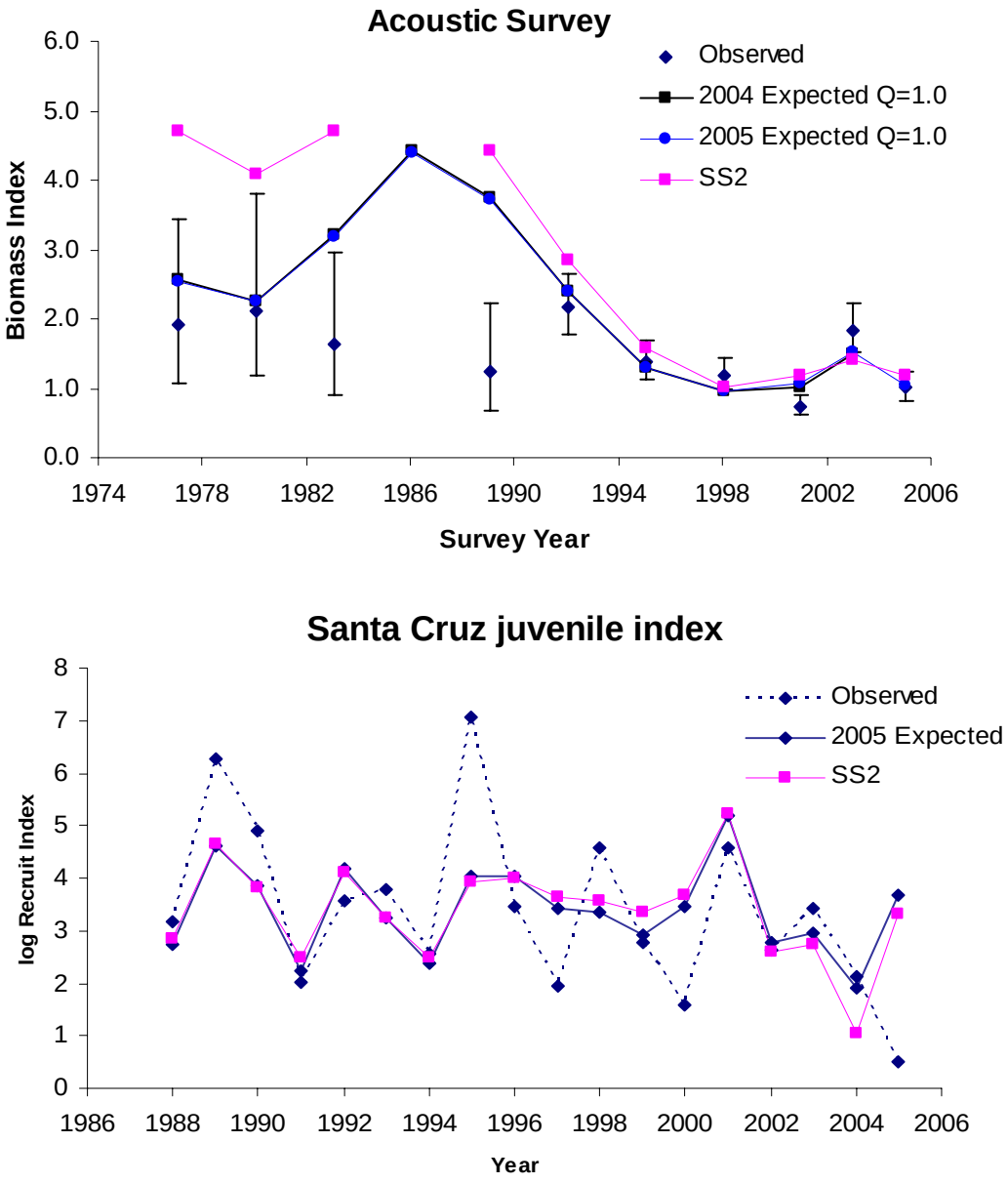

Figure 26. Predicted acoustic and juvenile survey fits from comparative assessment model results; old hake model (Helser et. al. 2004) vs. SS2 (Methot 2005).

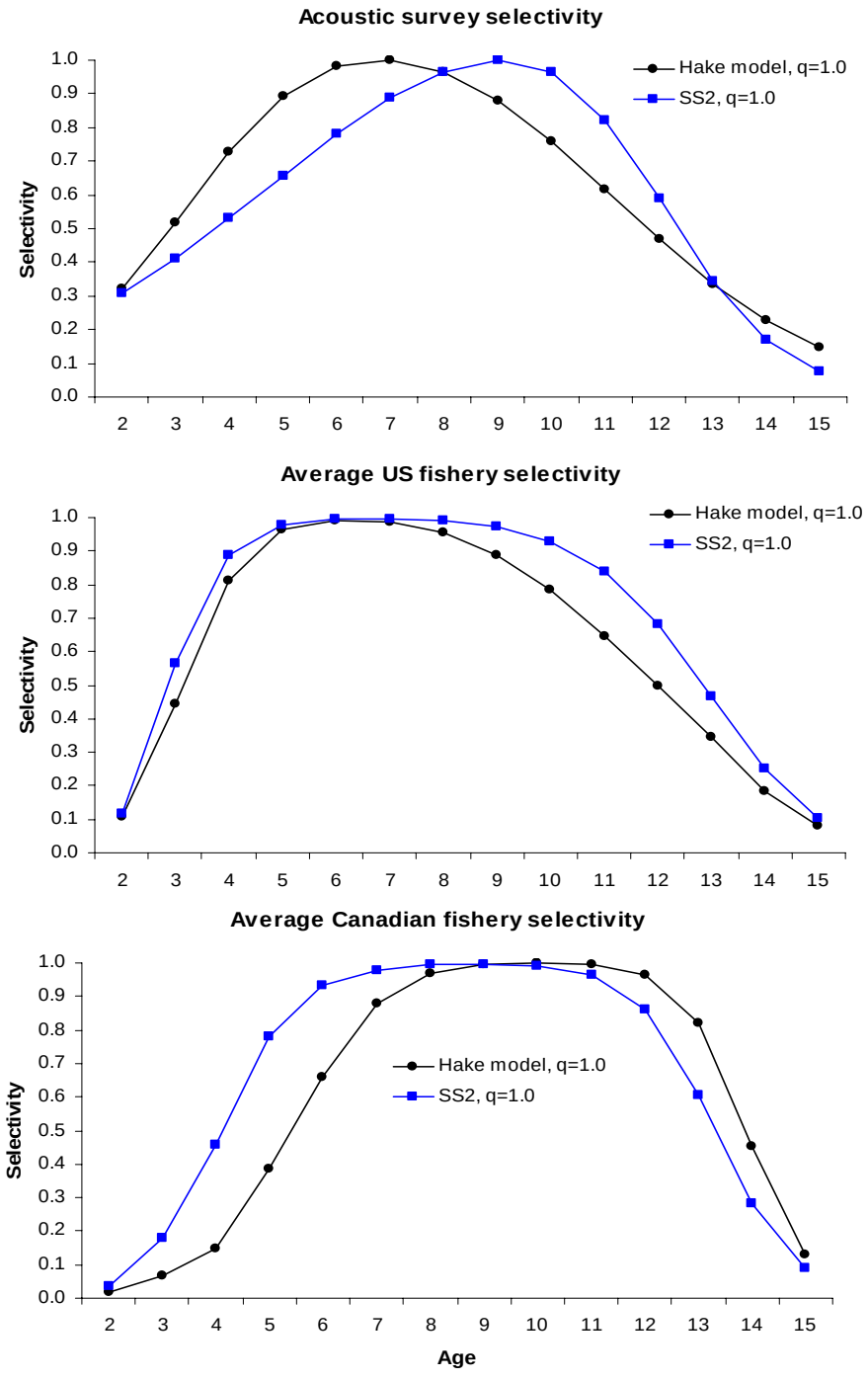

Figure 27. Estimated selectivity curves from comparative assessment model results; old hake model (Helser et. al. 2004) vs. SS2 (Methot 2005).

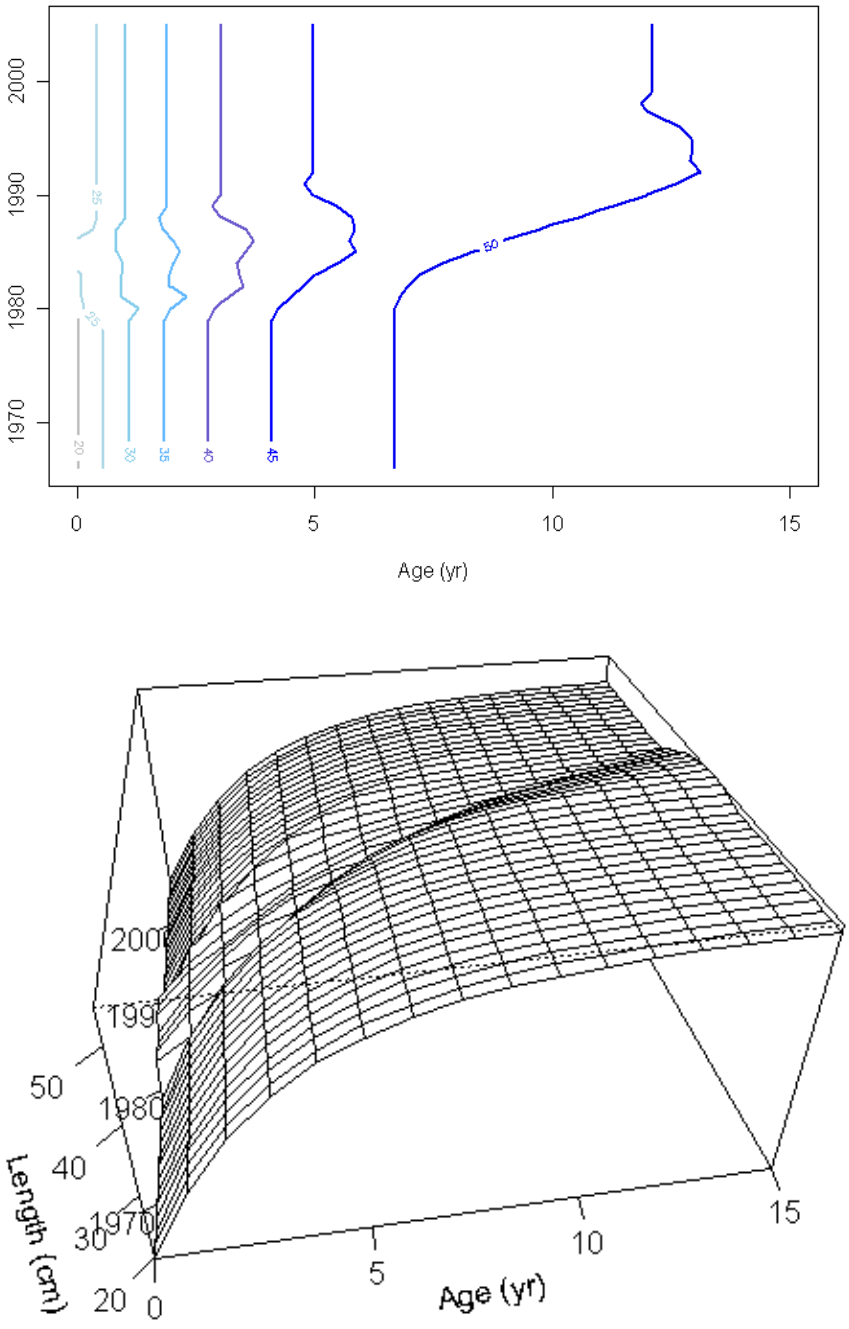

Figure 28. Time varying trajectory of growth in size at age assumed for Pacific Hake. Parameters were initially estimated but then fixed in the model.

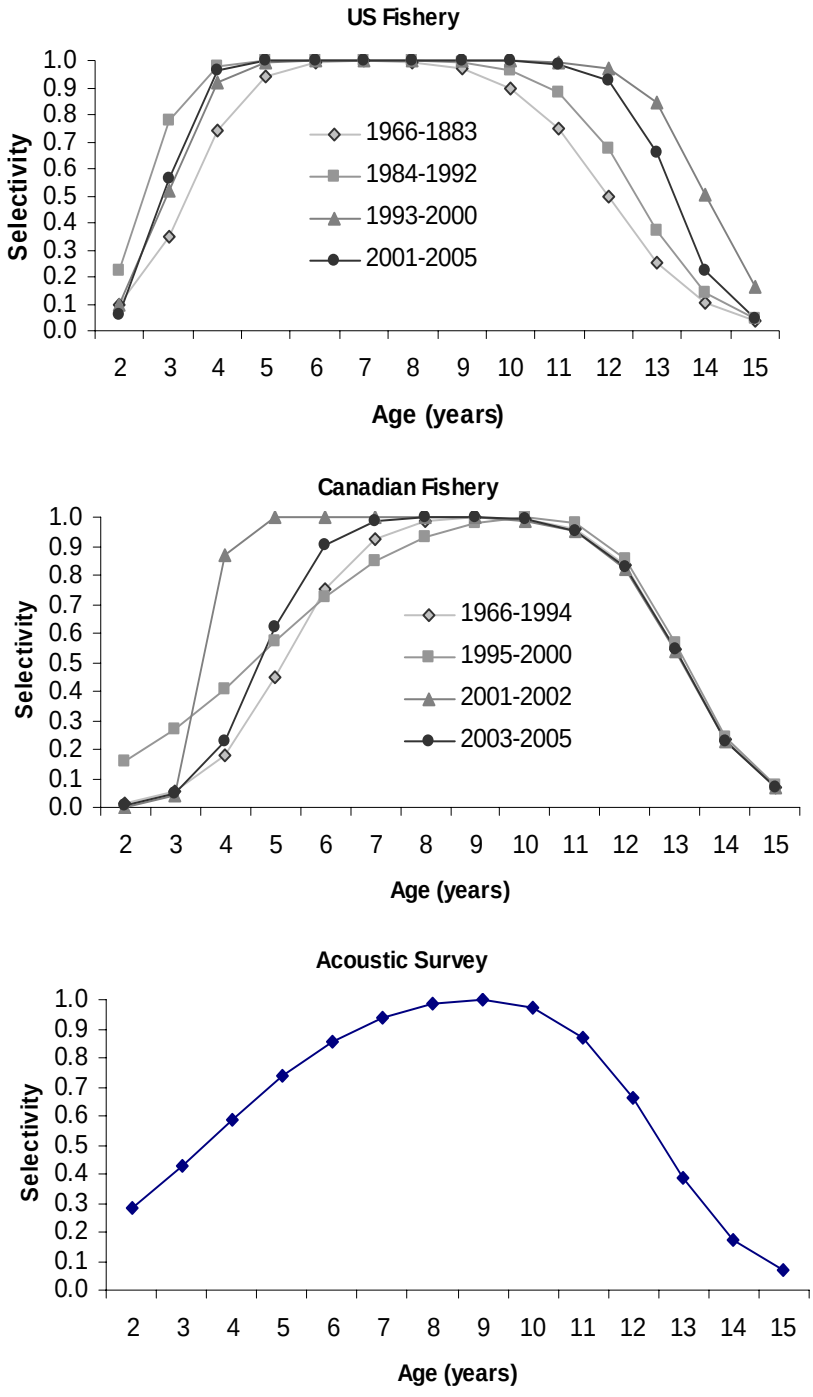

Figure 29. Estimated selectivity curves for different time blocks in the U.S. fishery, the Canadian fishery and acoustic survey. Selectivity in the acoustic survey was Assumed to be time-invariant.

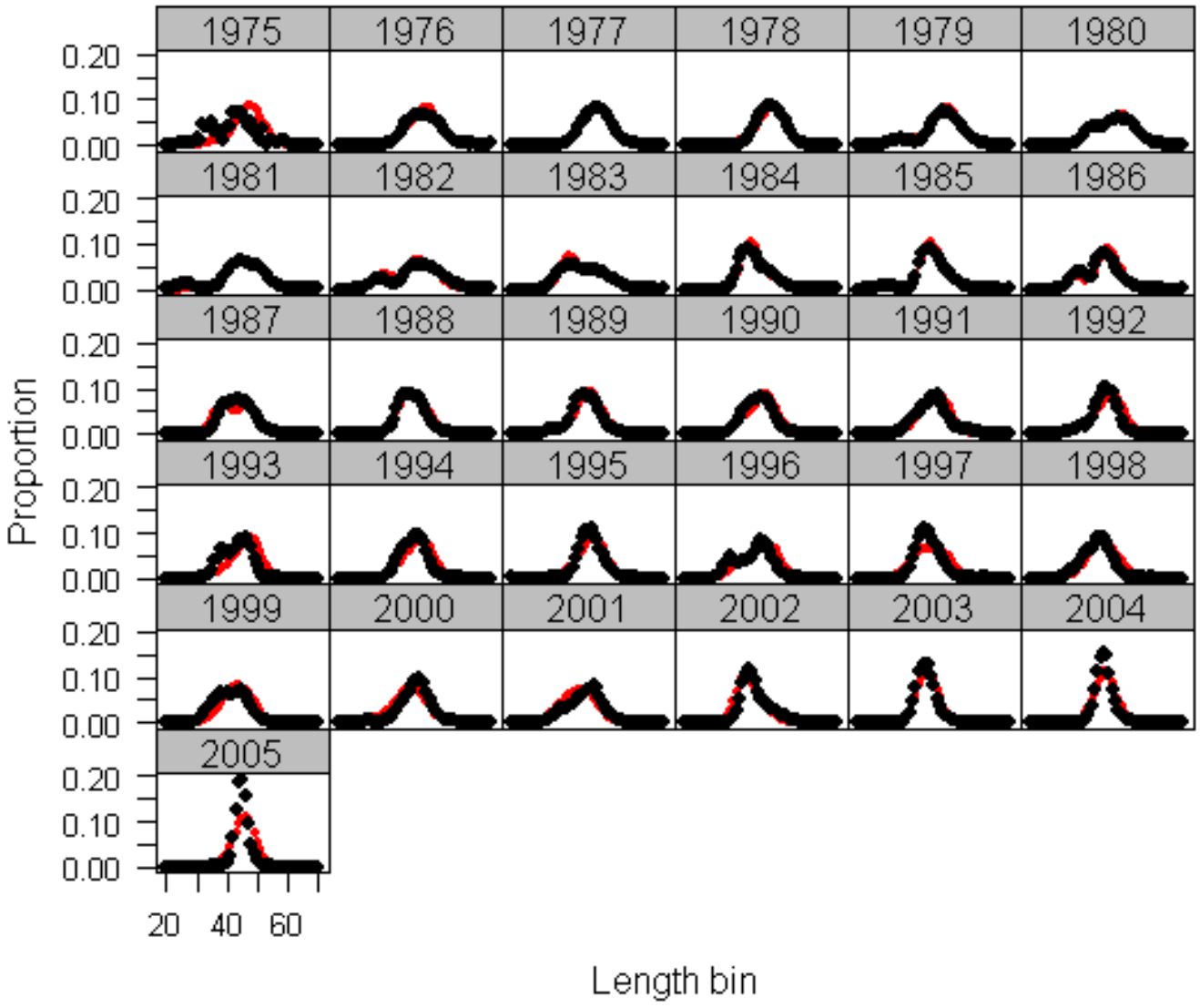

Figure 30. Predicted fits to the observed U.S. fishery length composition data.

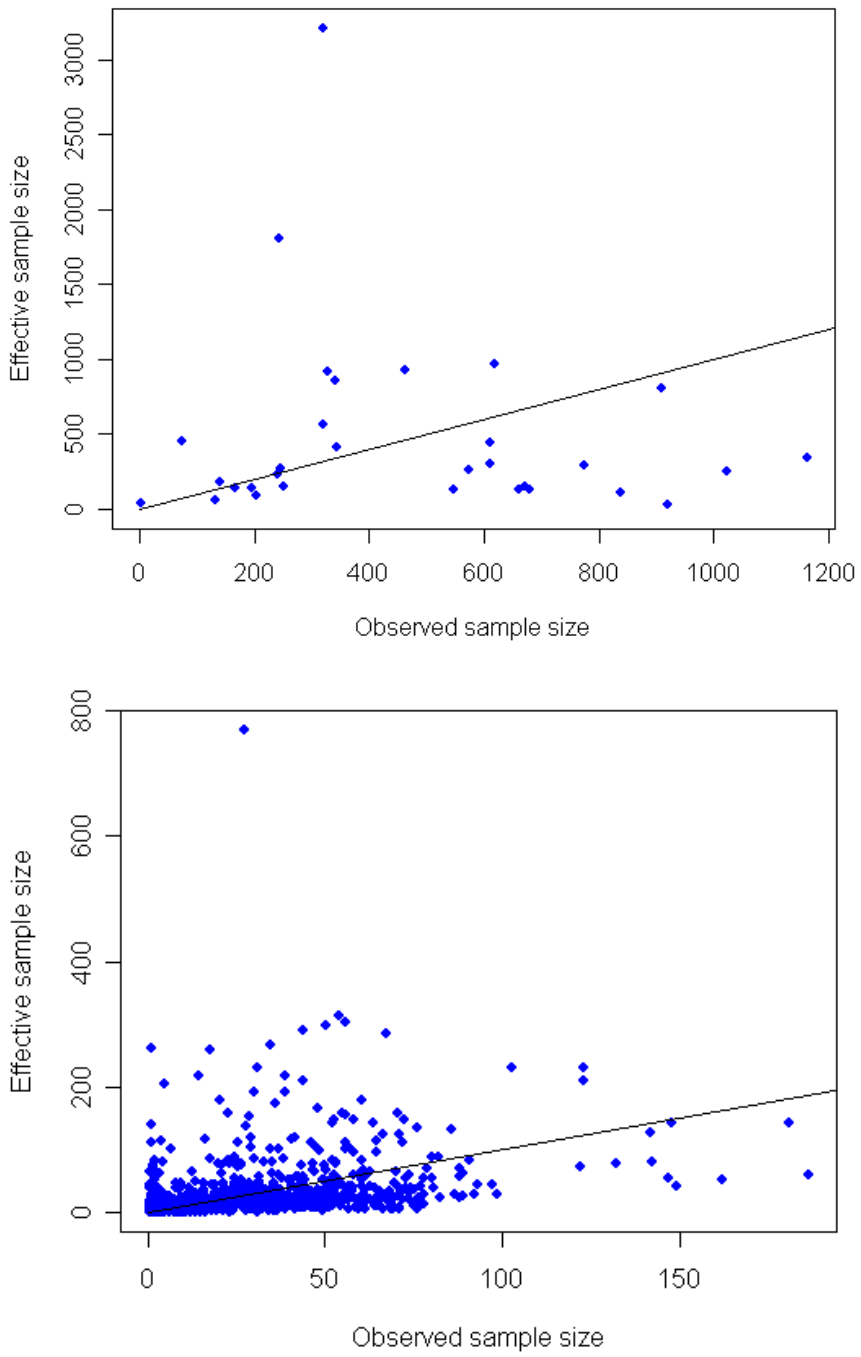

Figure 31. Effective vs. input sample sizes for the U.S. fishery length compositions (top panel) and conditional age at length compositions (bottom panel).

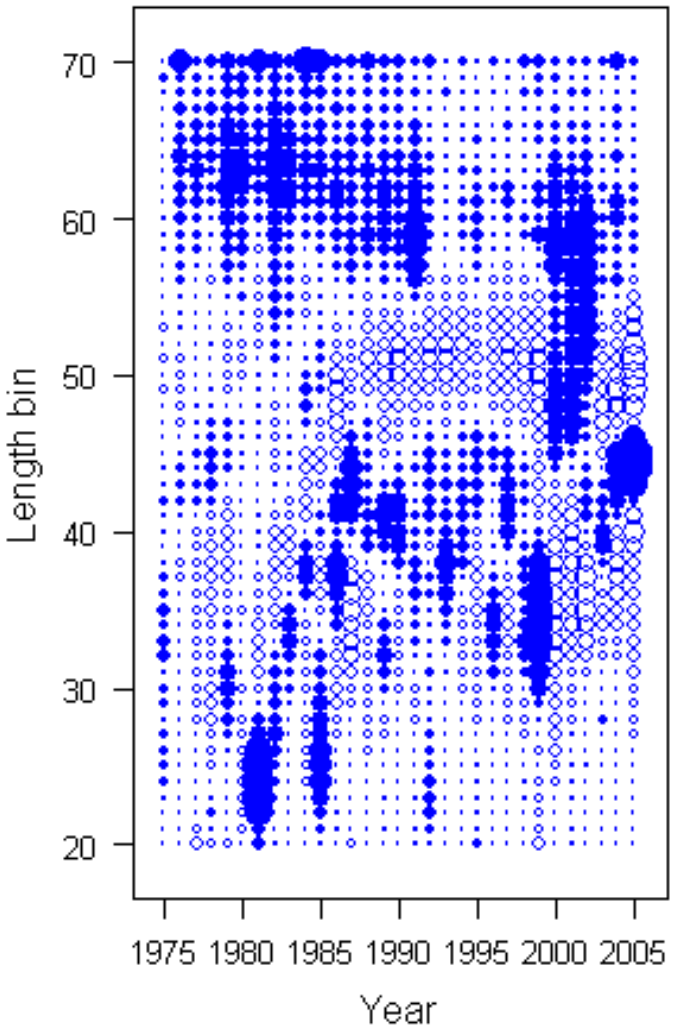

Figure 32. Pearson residuals of model fits to the U.S. fishery length composition data.

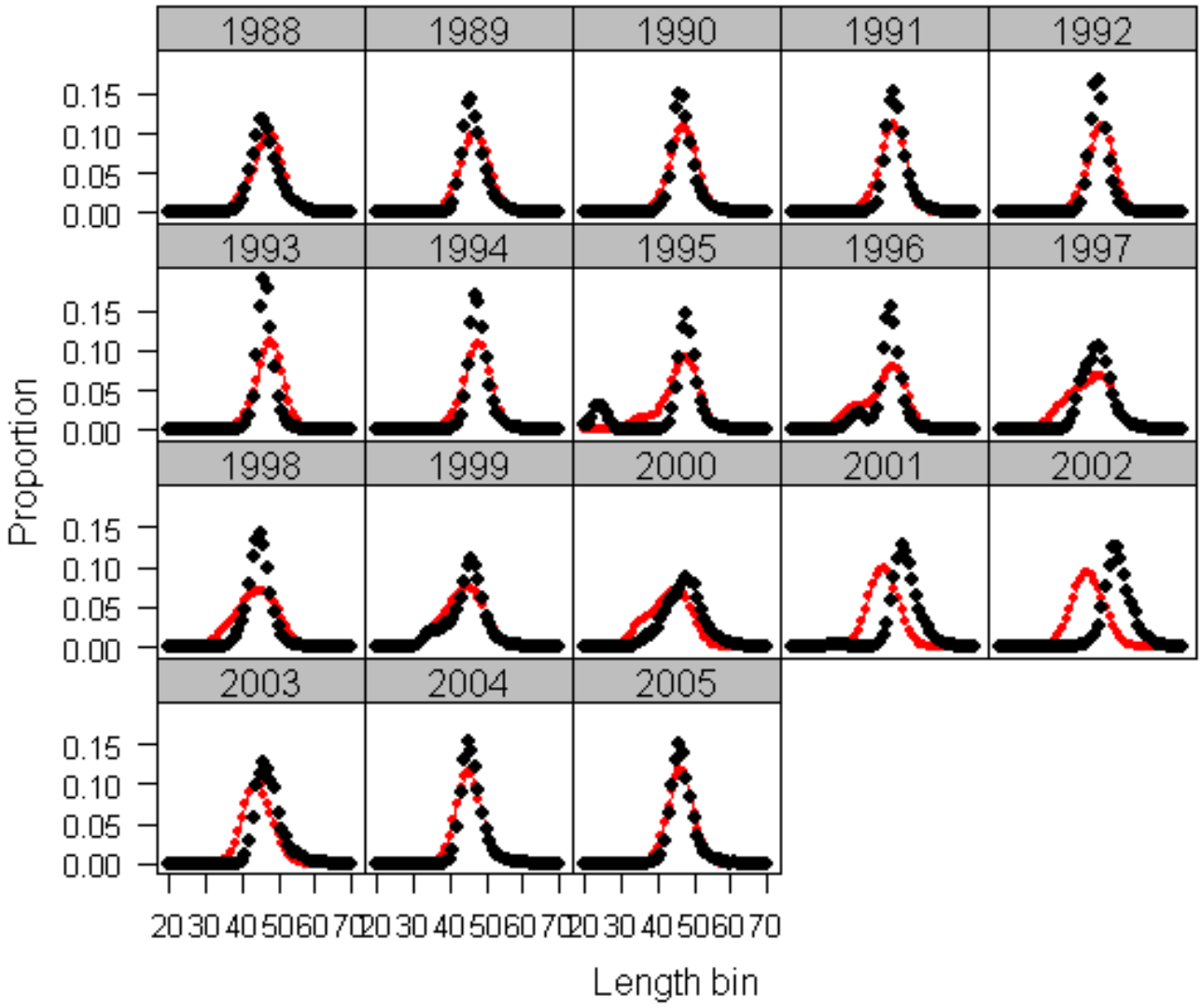

Figure 33. Predicted fits to the observed Canadian fishery length composition data.

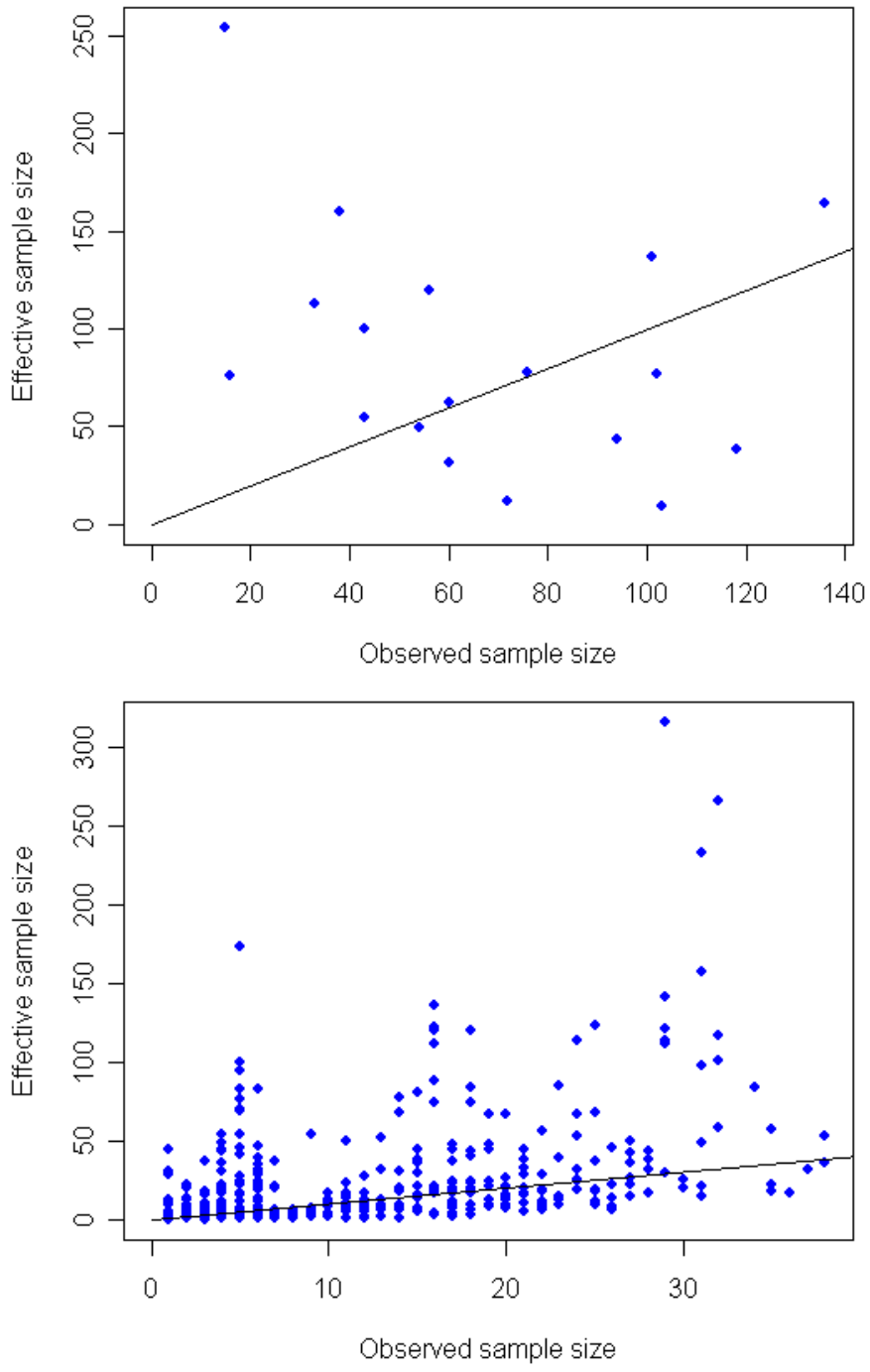

Figure 34. Effective vs. input sample sizes for the Canadian fishery length compositions (top panel) and conditional age at length compositions (bottom panel).

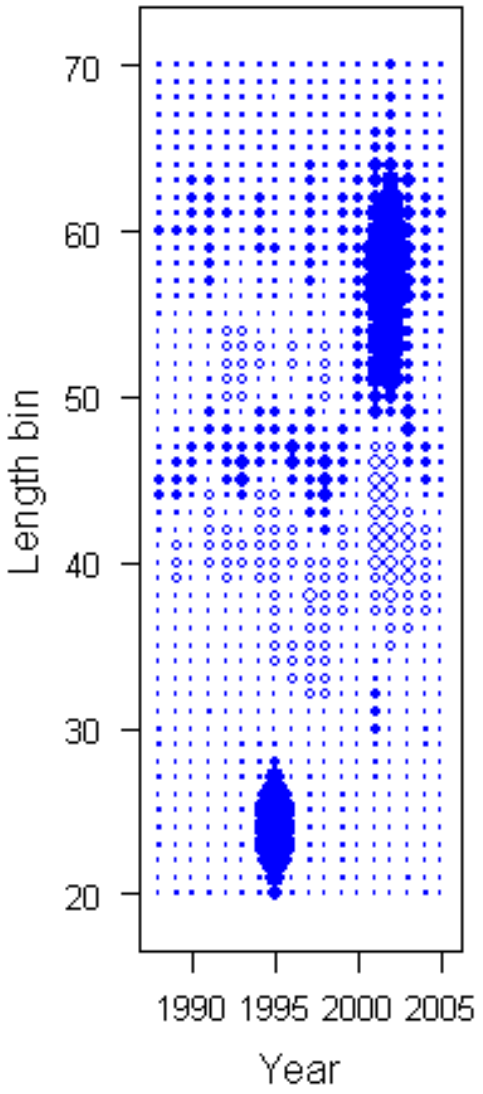

Figure 35. Pearson residuals of model fits to the Canadian length composition data.

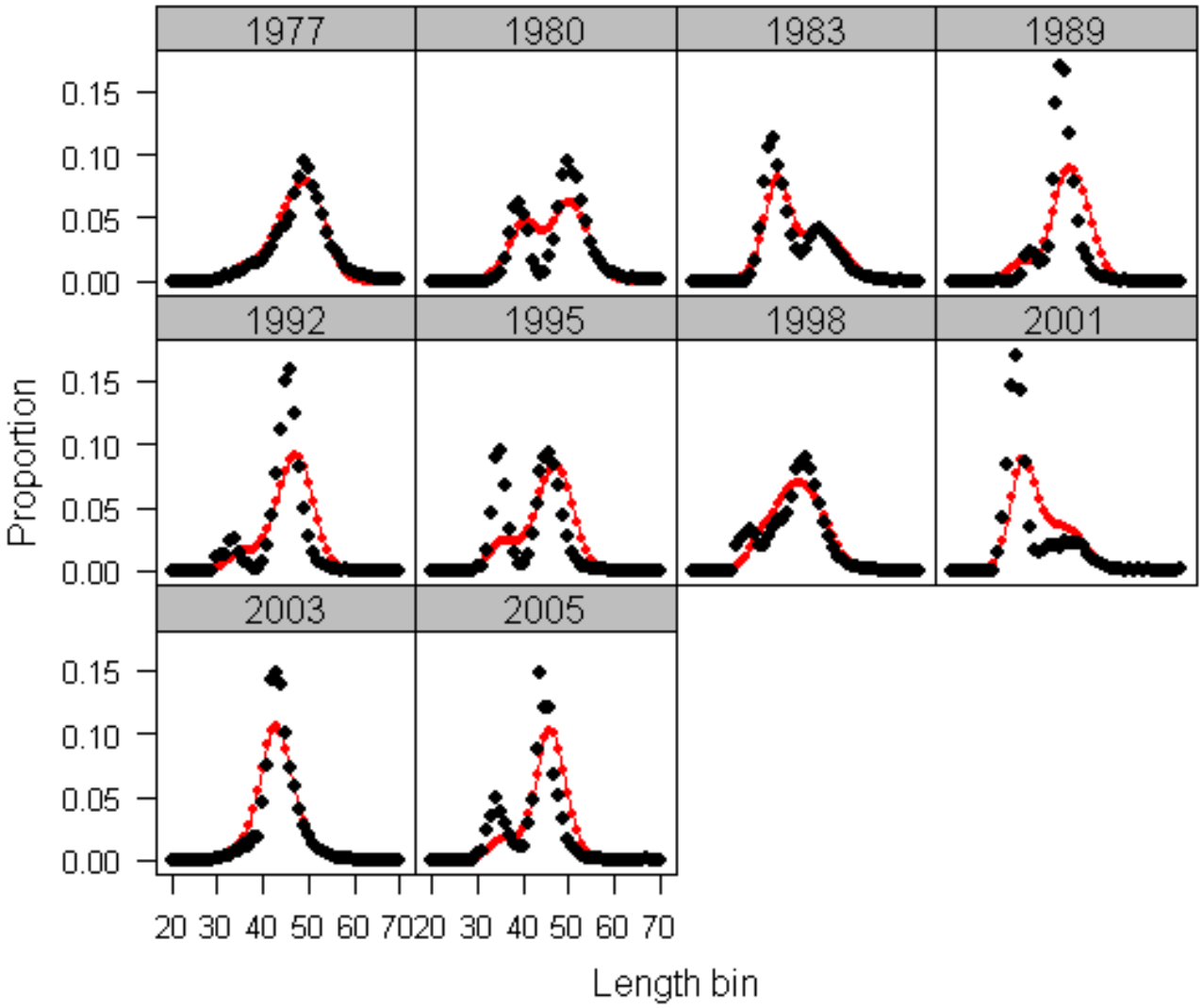

Figure 36. Predicted fits to the observed acoustic survey length composition data.

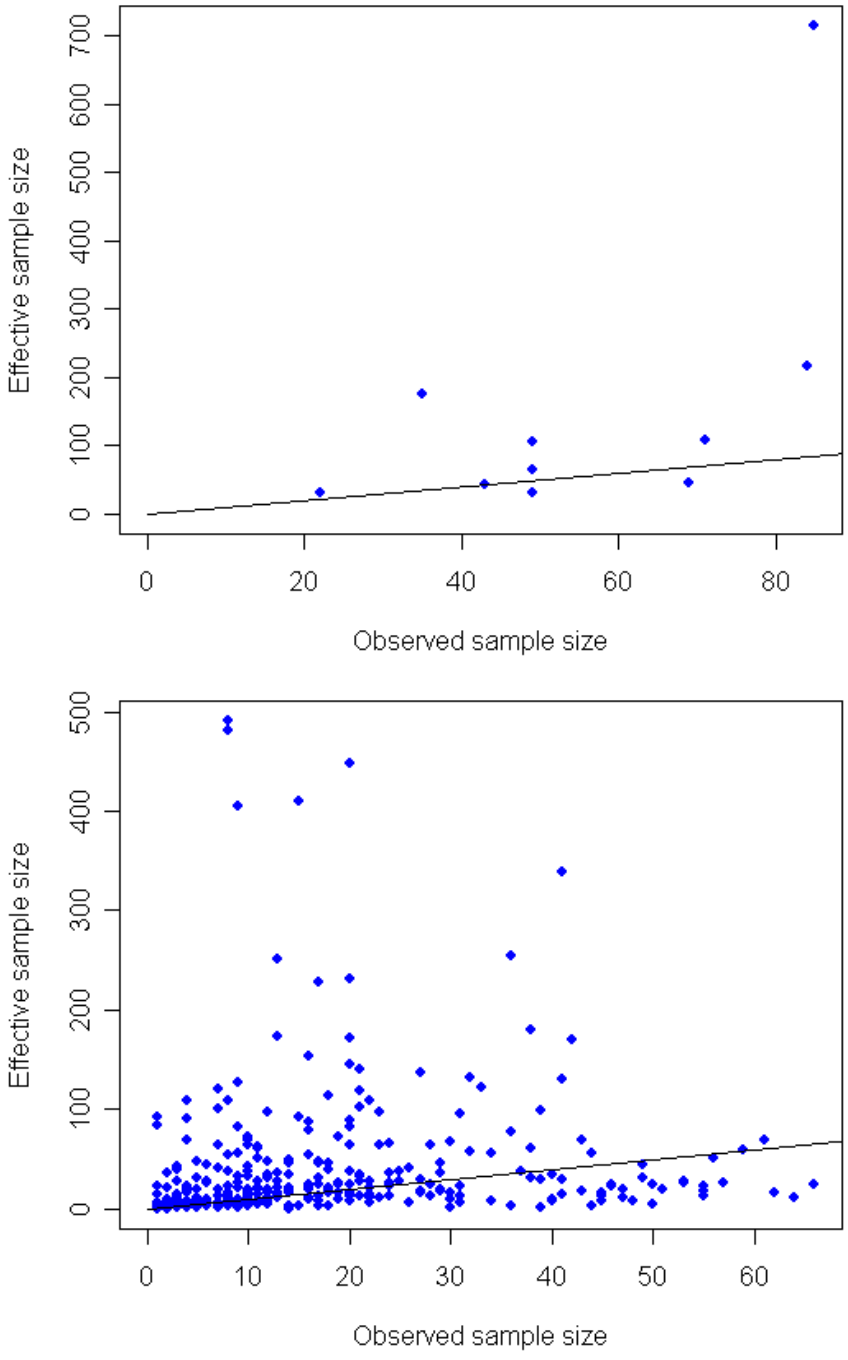

Figure 37. Effective vs. input sample sizes for the acoustic survey length compositions (top panel) and conditional age at length compositions (bottom panel).

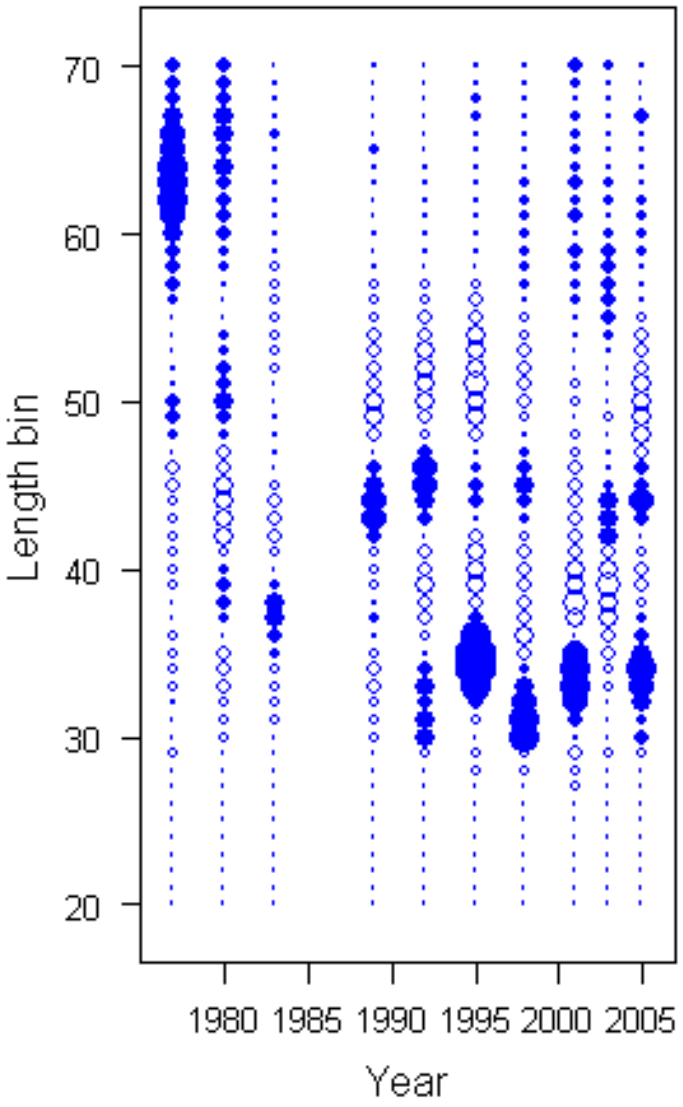

Figure 38. Pearson residuals of model fits to the acoustic survey length composition data.

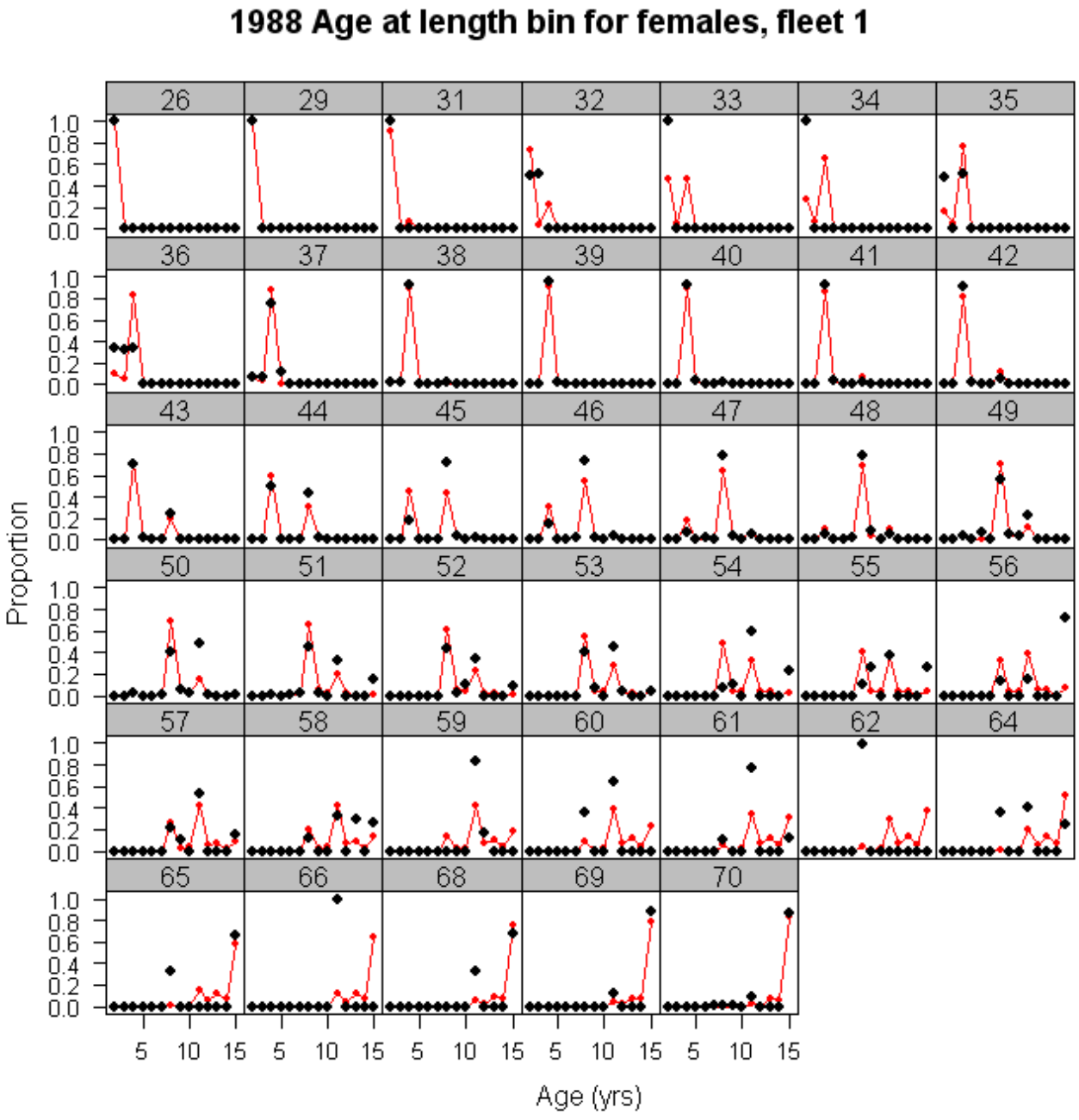

Figure 39. Model fits to the observed 1988 U.S. fishery conditional age at length data .

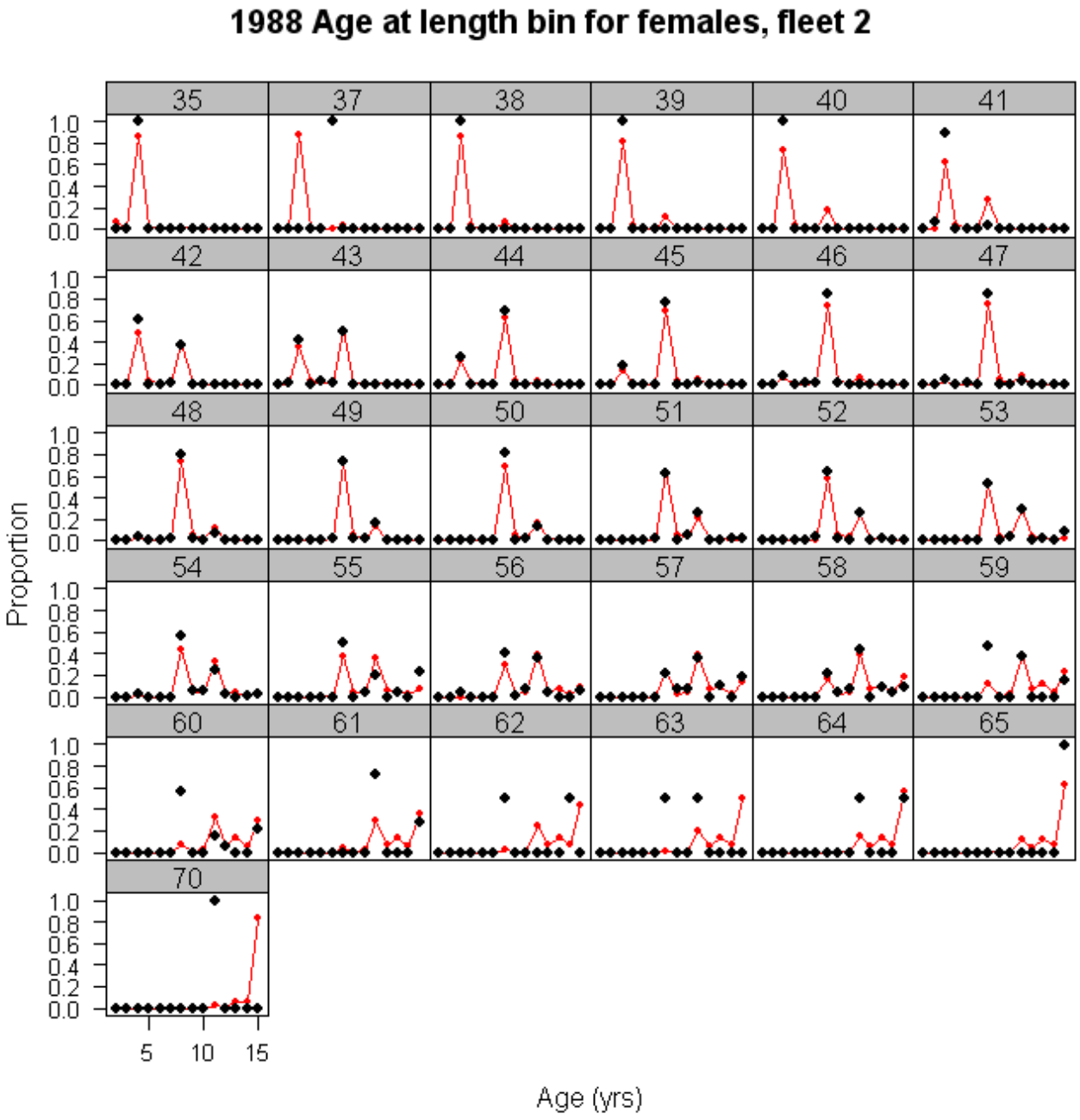

Figure 40. Model fits to the observed 1988 Canadian fishery conditional age at length data .

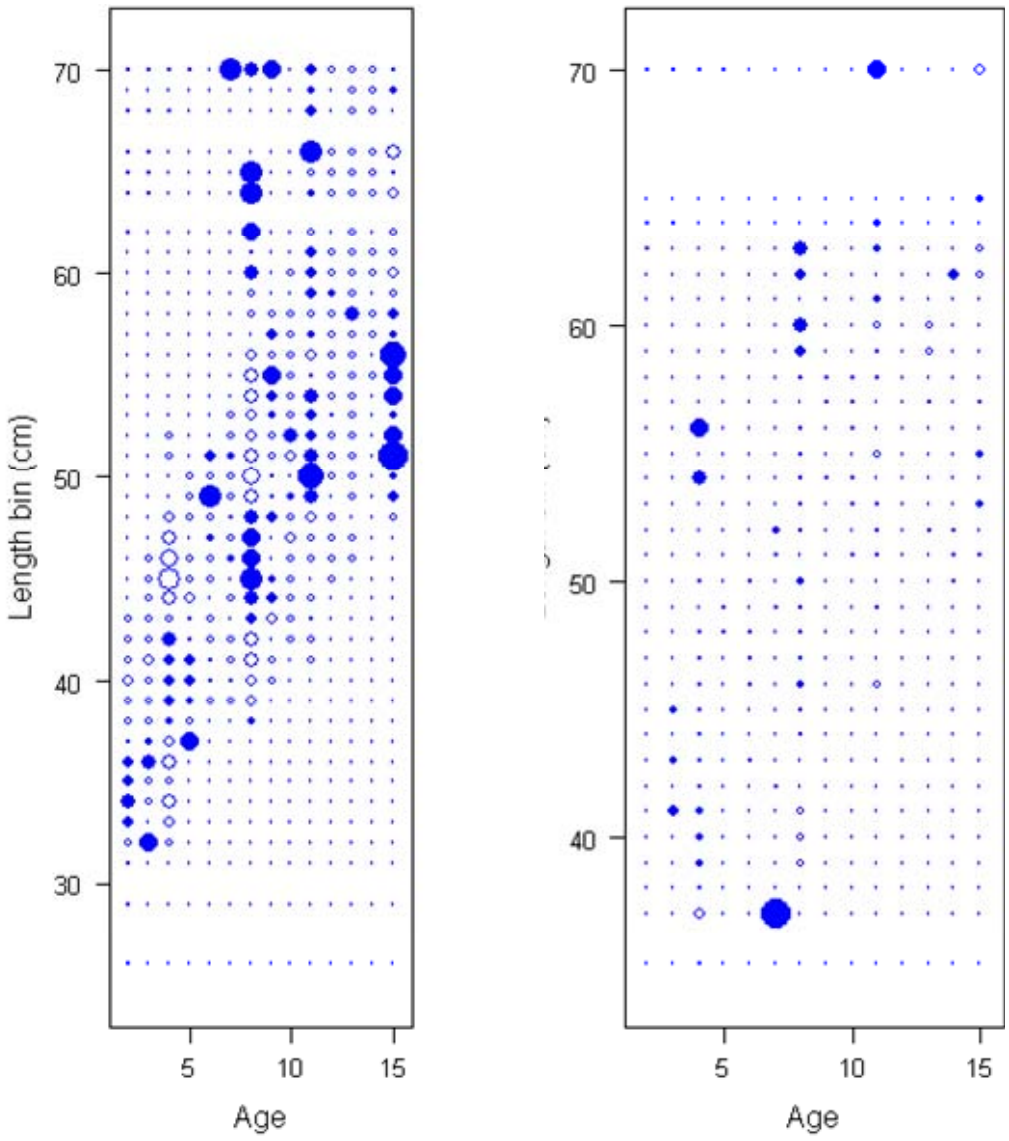

Figure 41. Pearson residuals of model fits to the 1988 U.S. fishery (left) and Canadian (right) conditional age at length data .

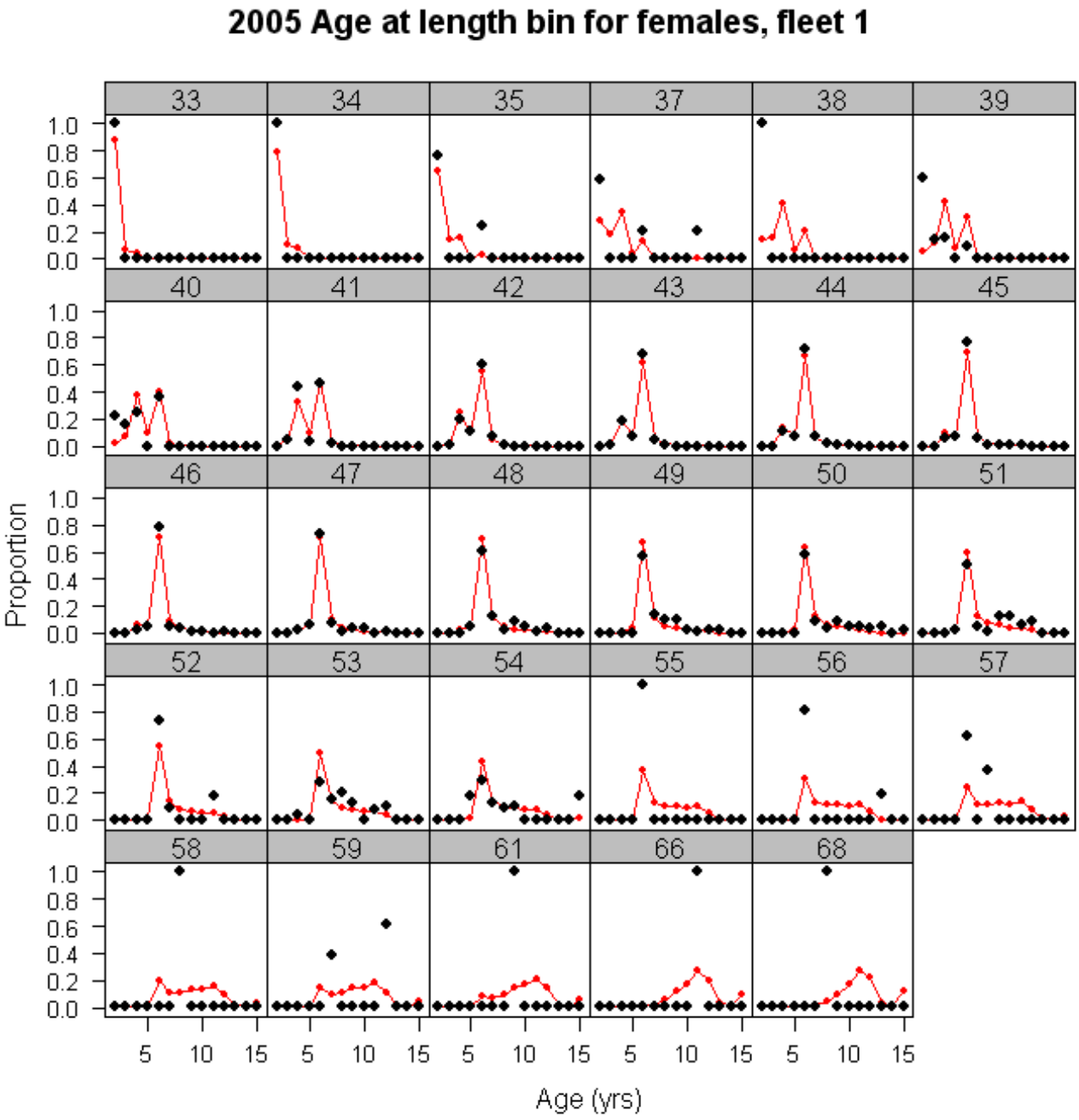

Figure 42. Model fits to the observed 2005 U.S. fishery conditional age at length data .

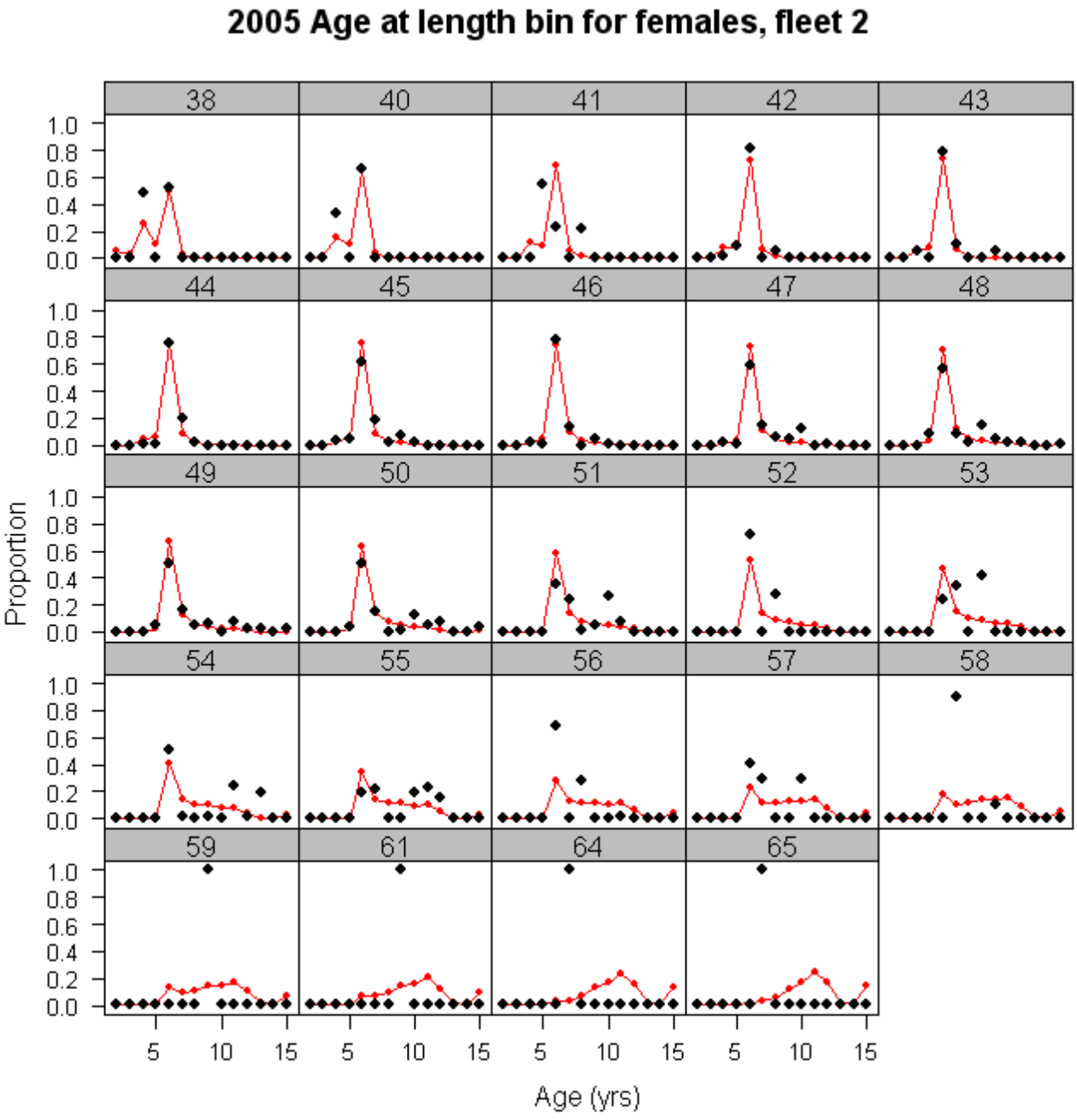

Figure 43. Model fits to the observed 2005 Canadian fishery conditional age at length data .

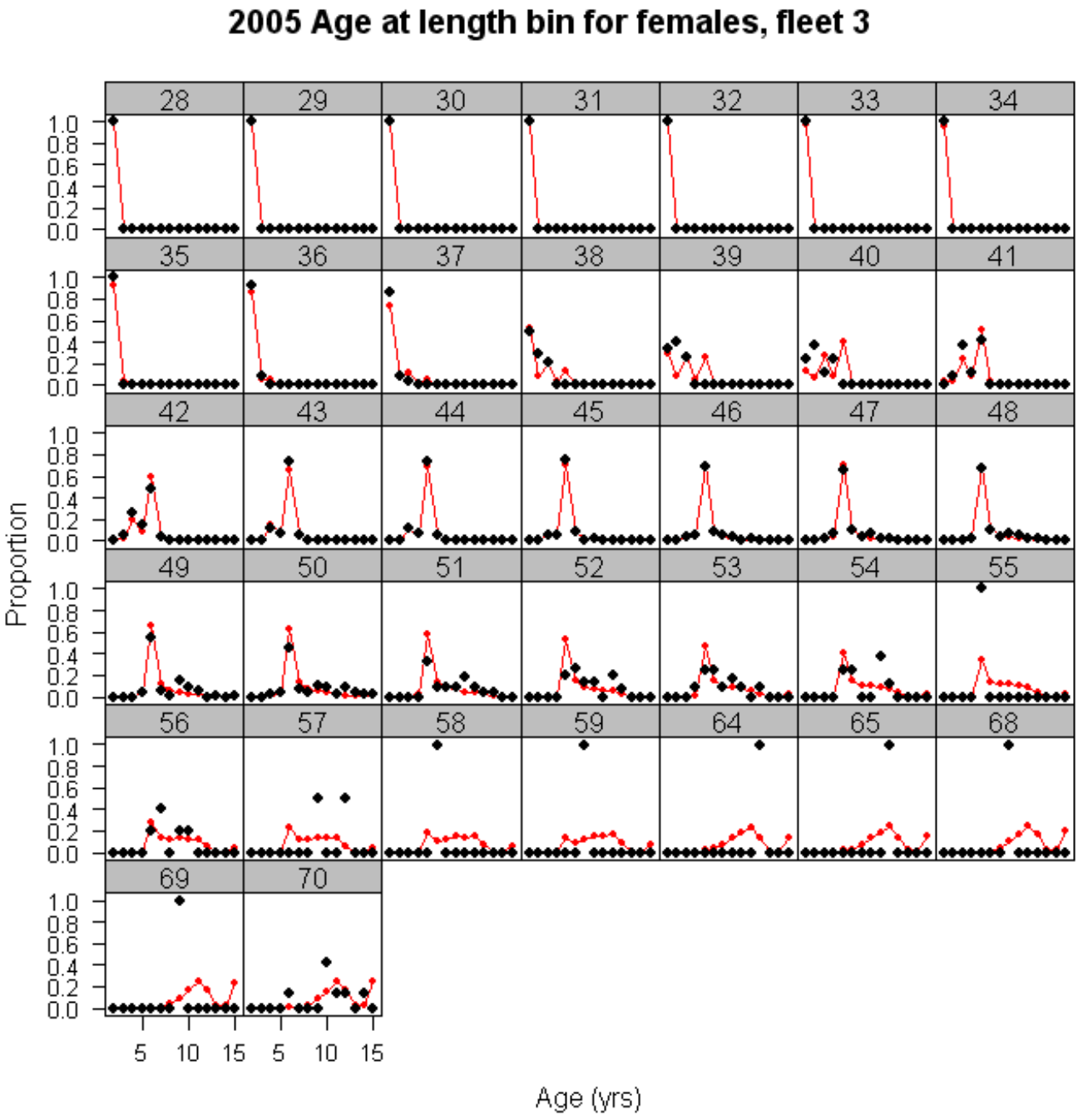

Figure 44. Model fits to the observed 2005 acoustic survey conditional age at length data .

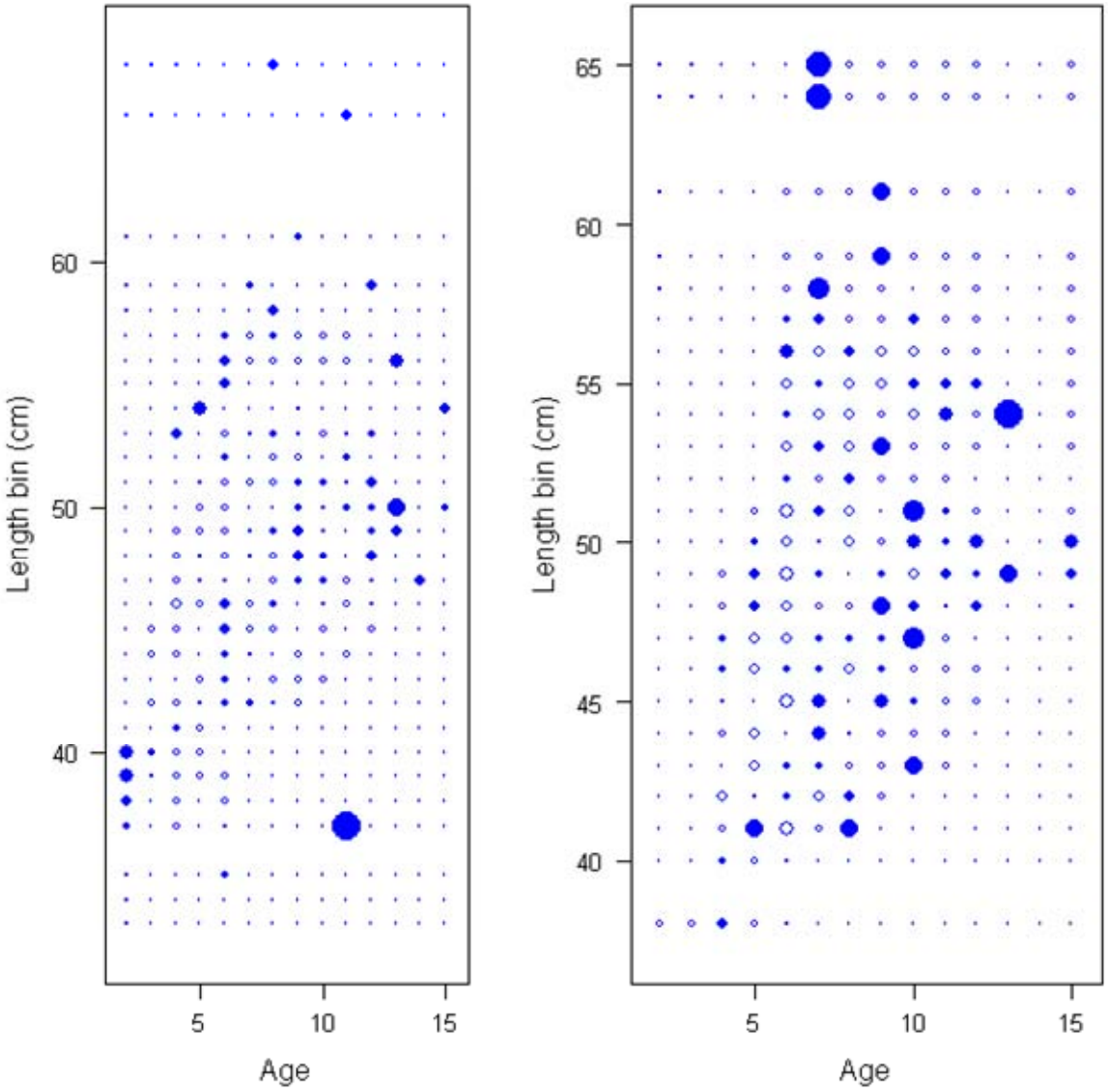

Figure 45. Pearson residuals of model fits to the 2005 U.S. fishery (left) and Canadian (right) conditional age at length data .

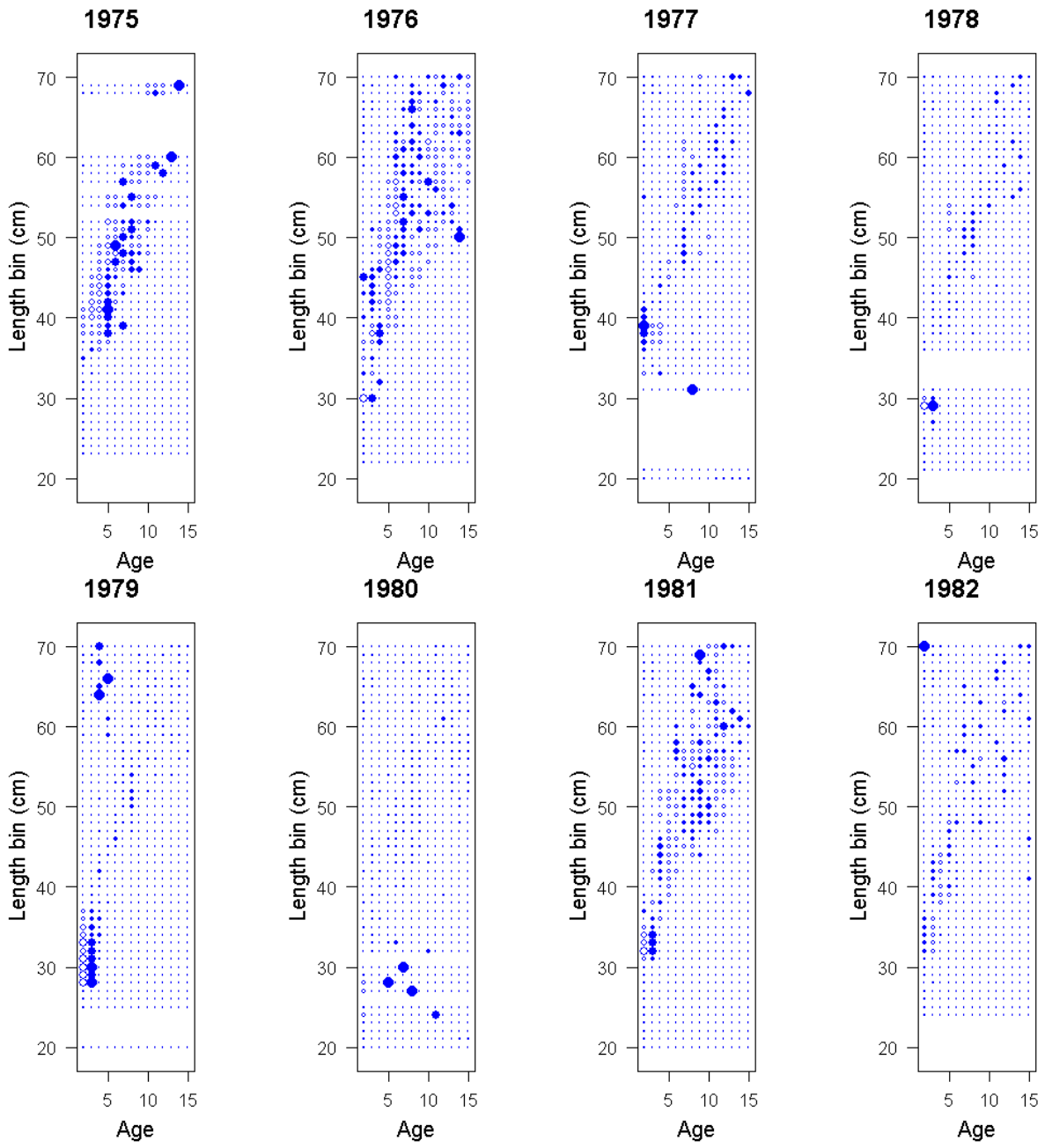

Figure 46. Standardized Pearson age at length residuals for the US fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

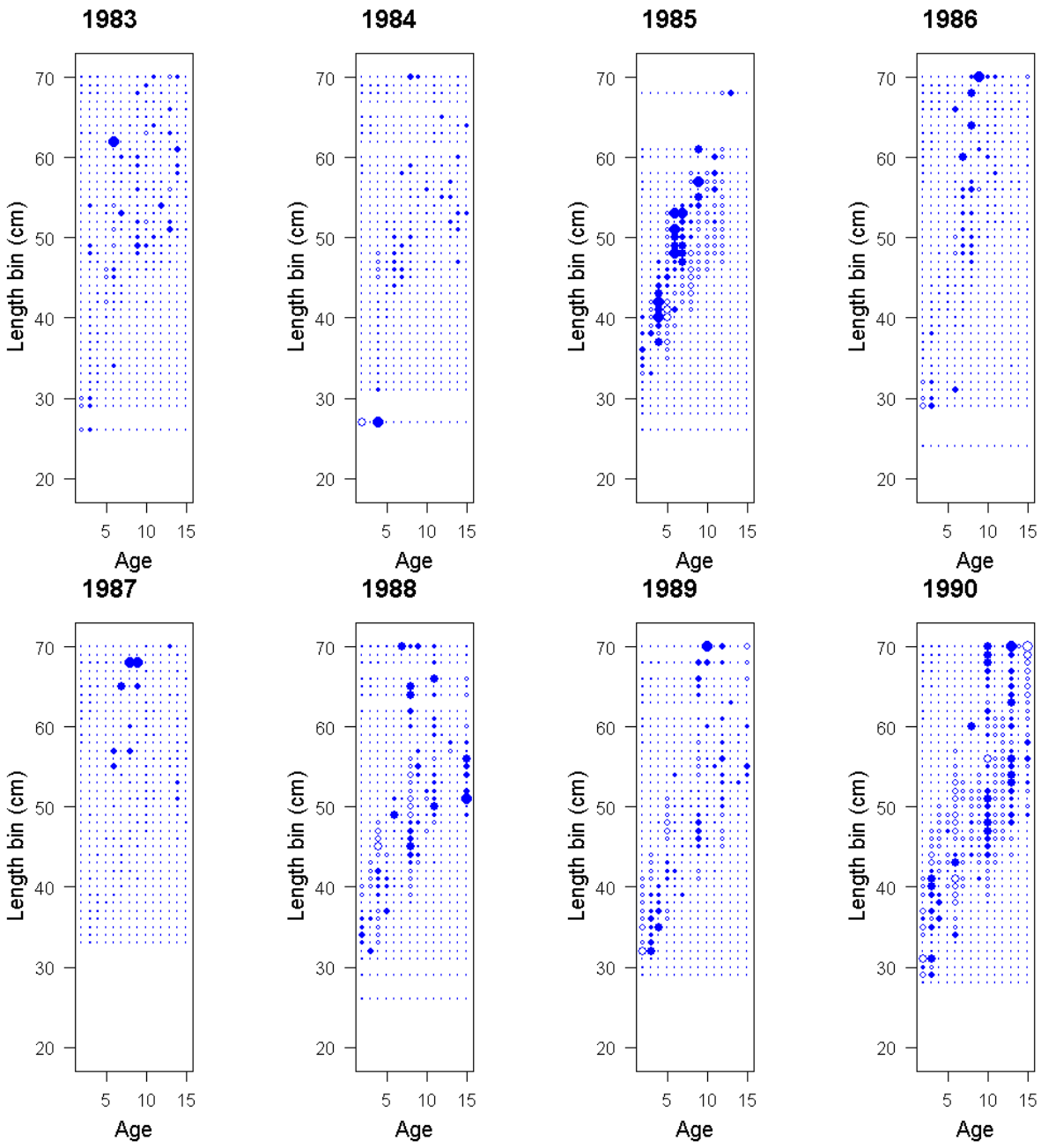

Figure 46 continued. Standardized Pearson age at length residuals for the US fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

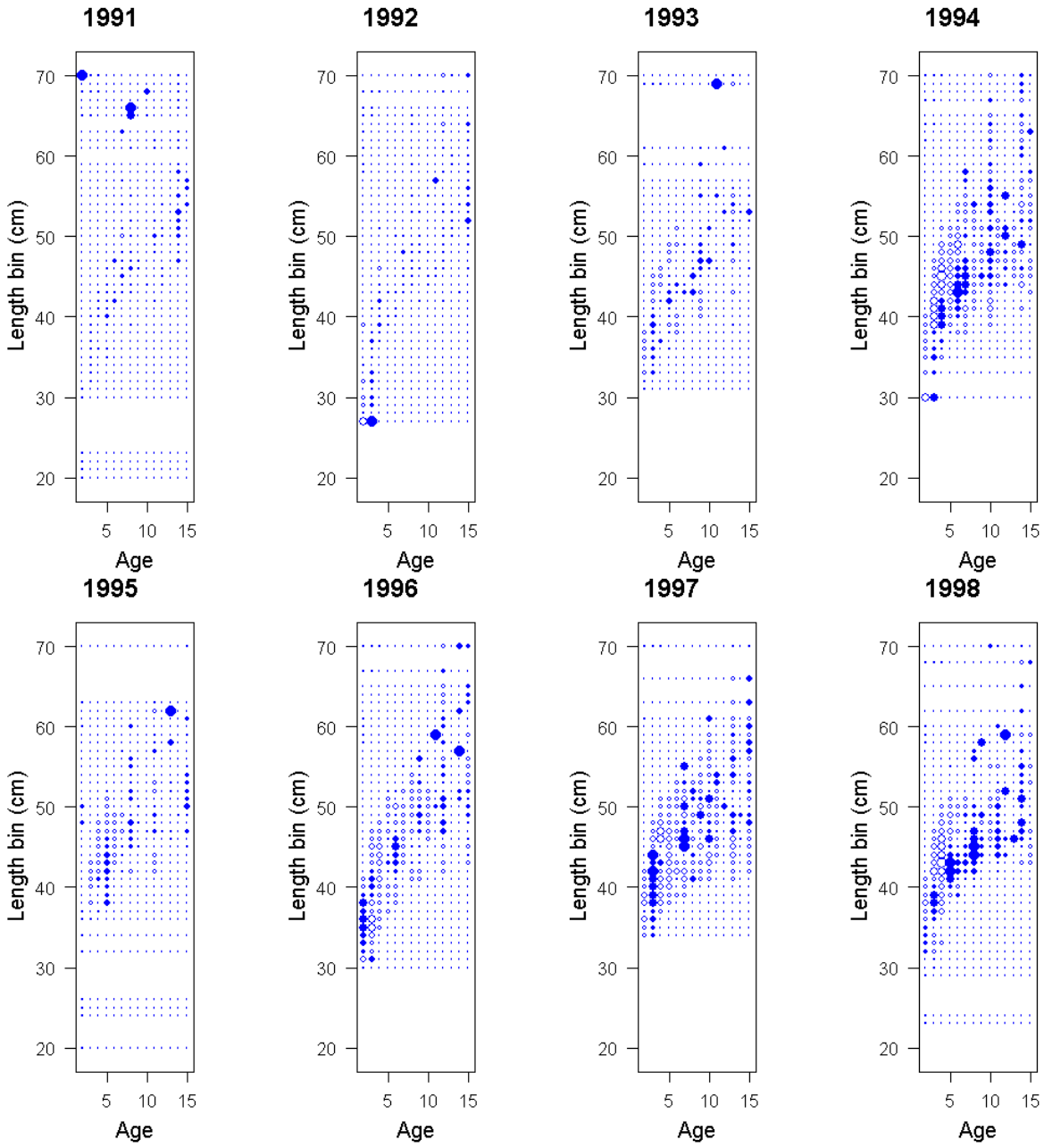

Figure 46 continued. Standardized Pearson age at length residuals for the US fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

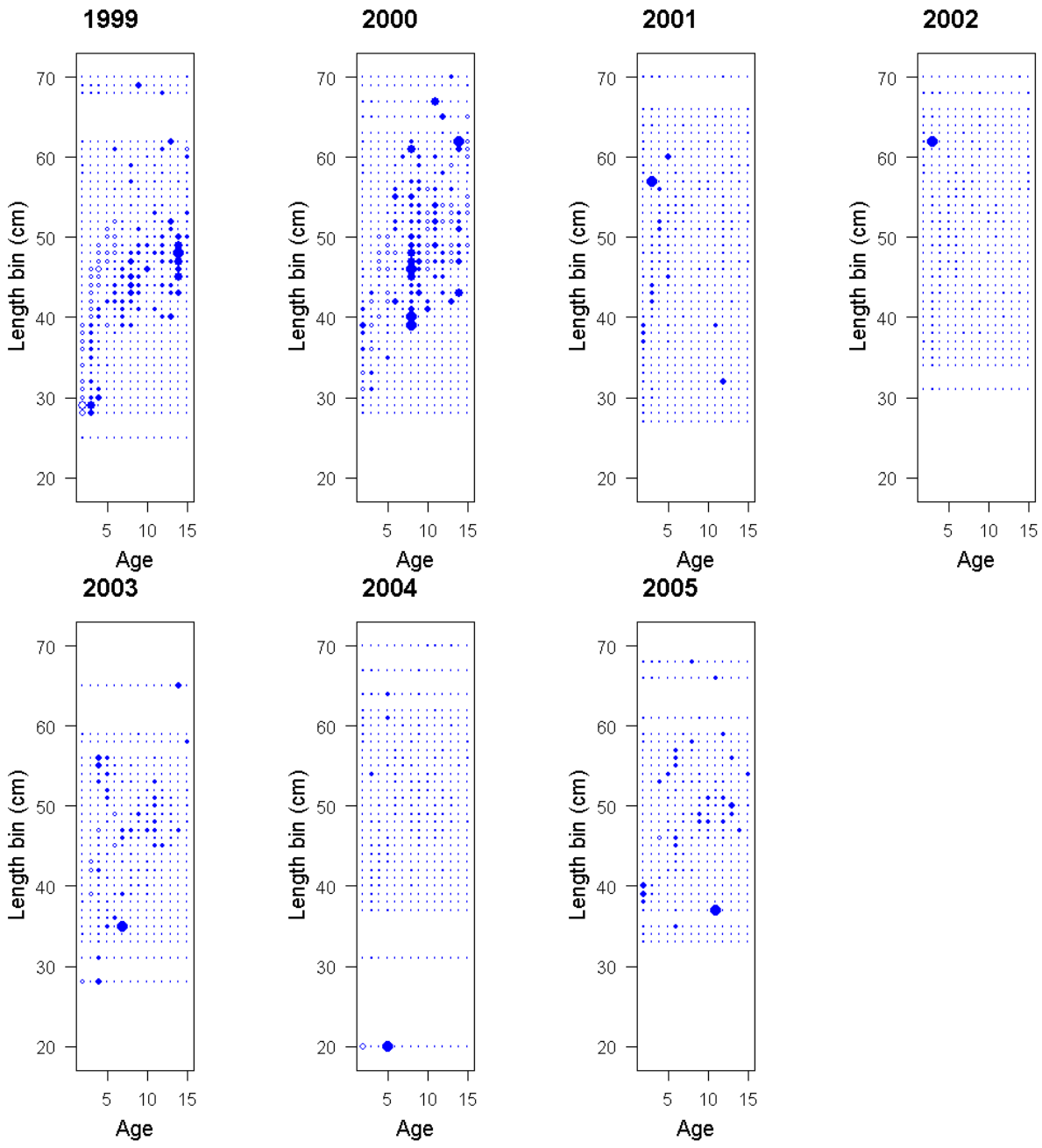

Figure 46 continued. Standardized Pearson age at length residuals for the US fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

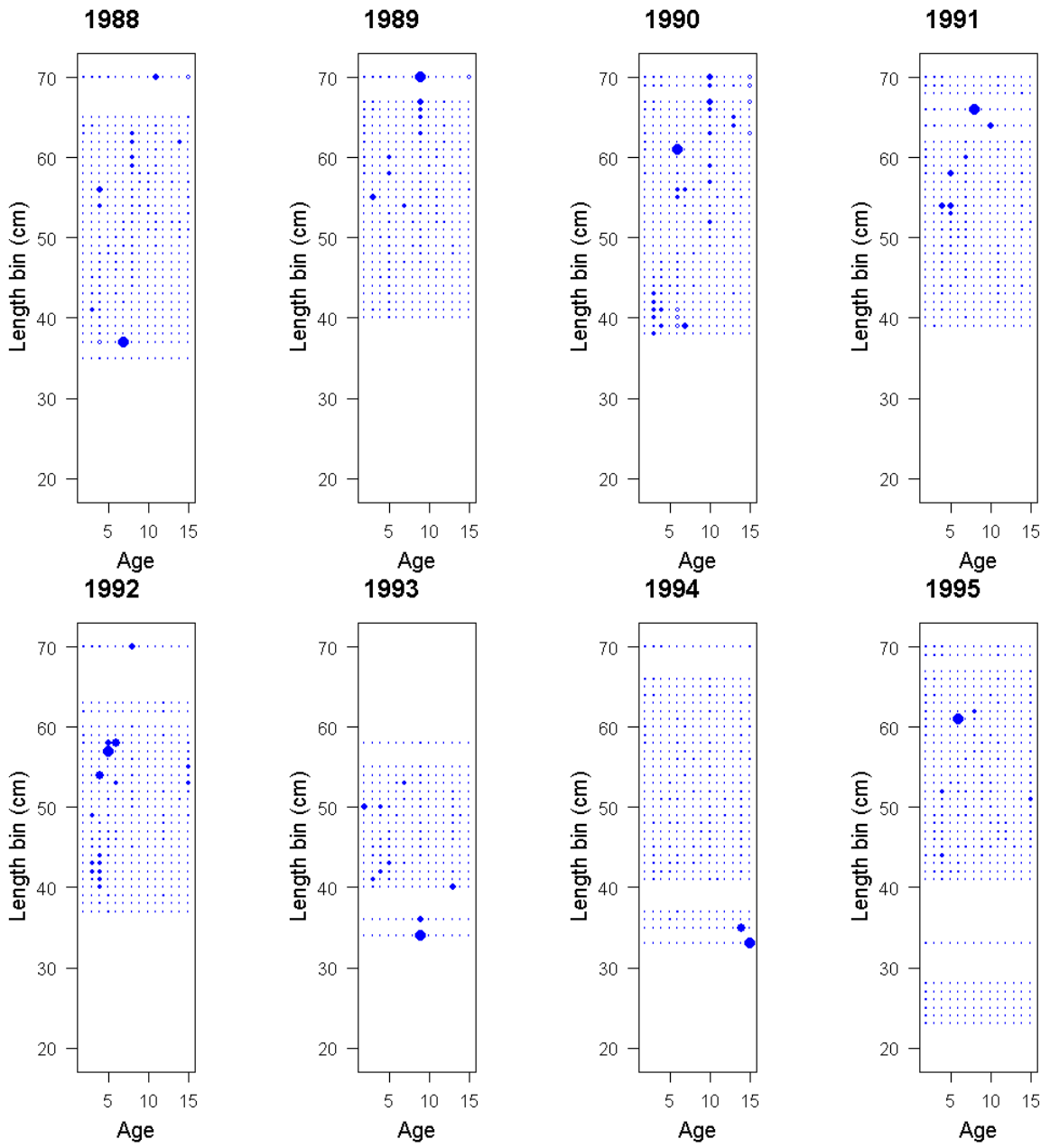

Figure 46 continued. Standardized Pearson age at length residuals for the Canadian fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

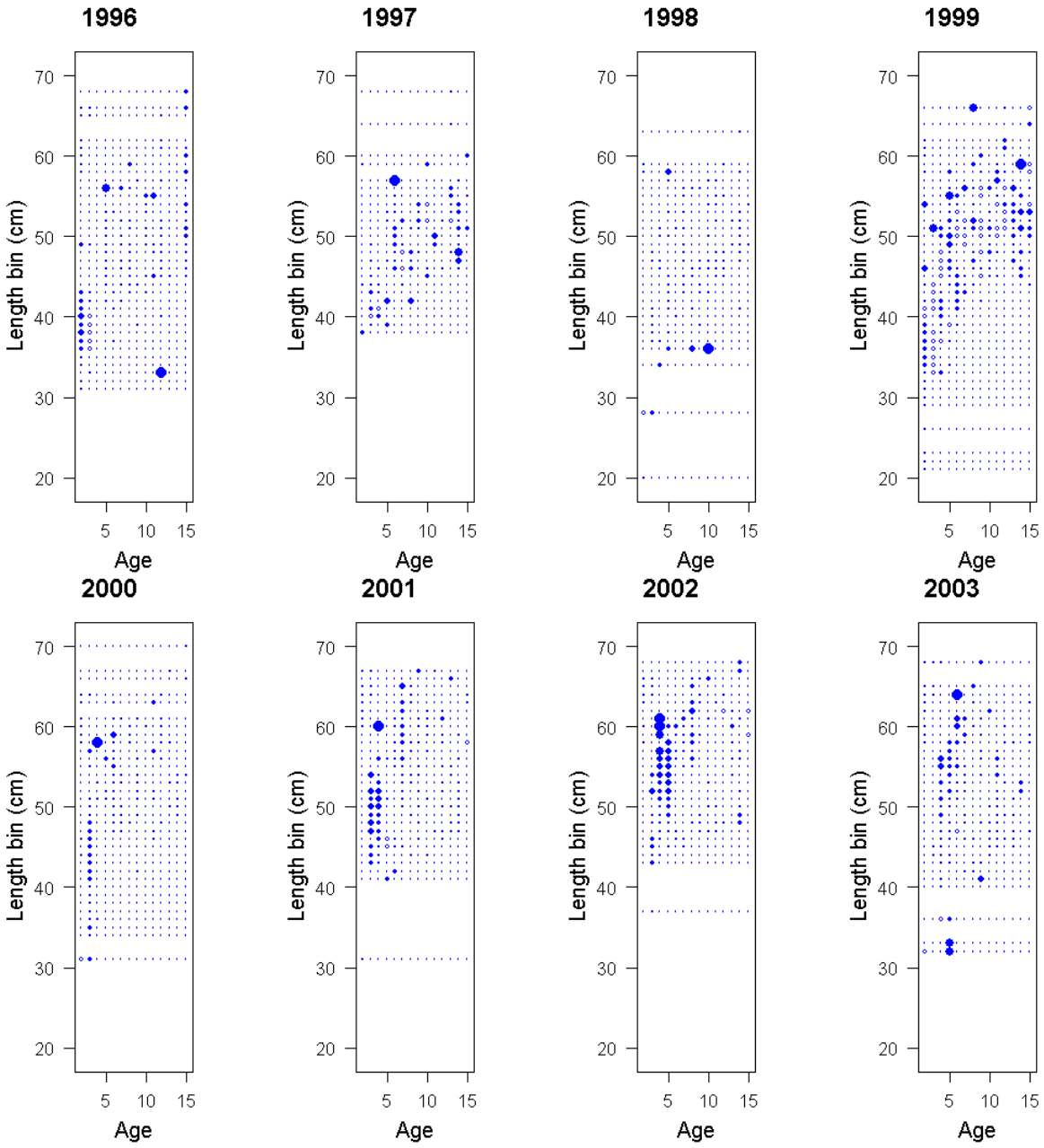

Figure 46 continued. Standardized Pearson age at length residuals for the Canadian fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

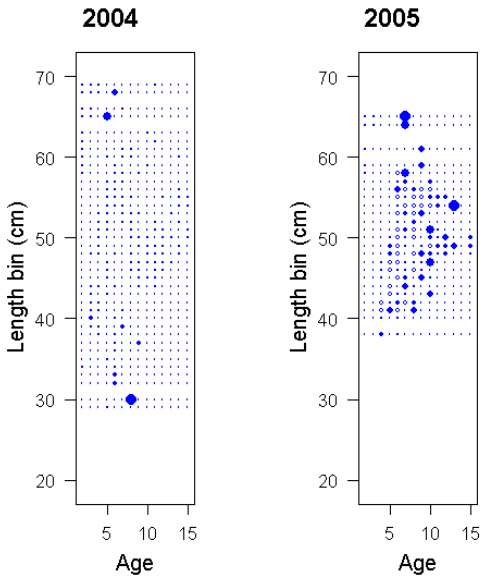

Figure 46 continued. Standardized Pearson age at length residuals for the Canadian fleet. Open circles Indicate negative residuals, filled circles indicate positive residuals.

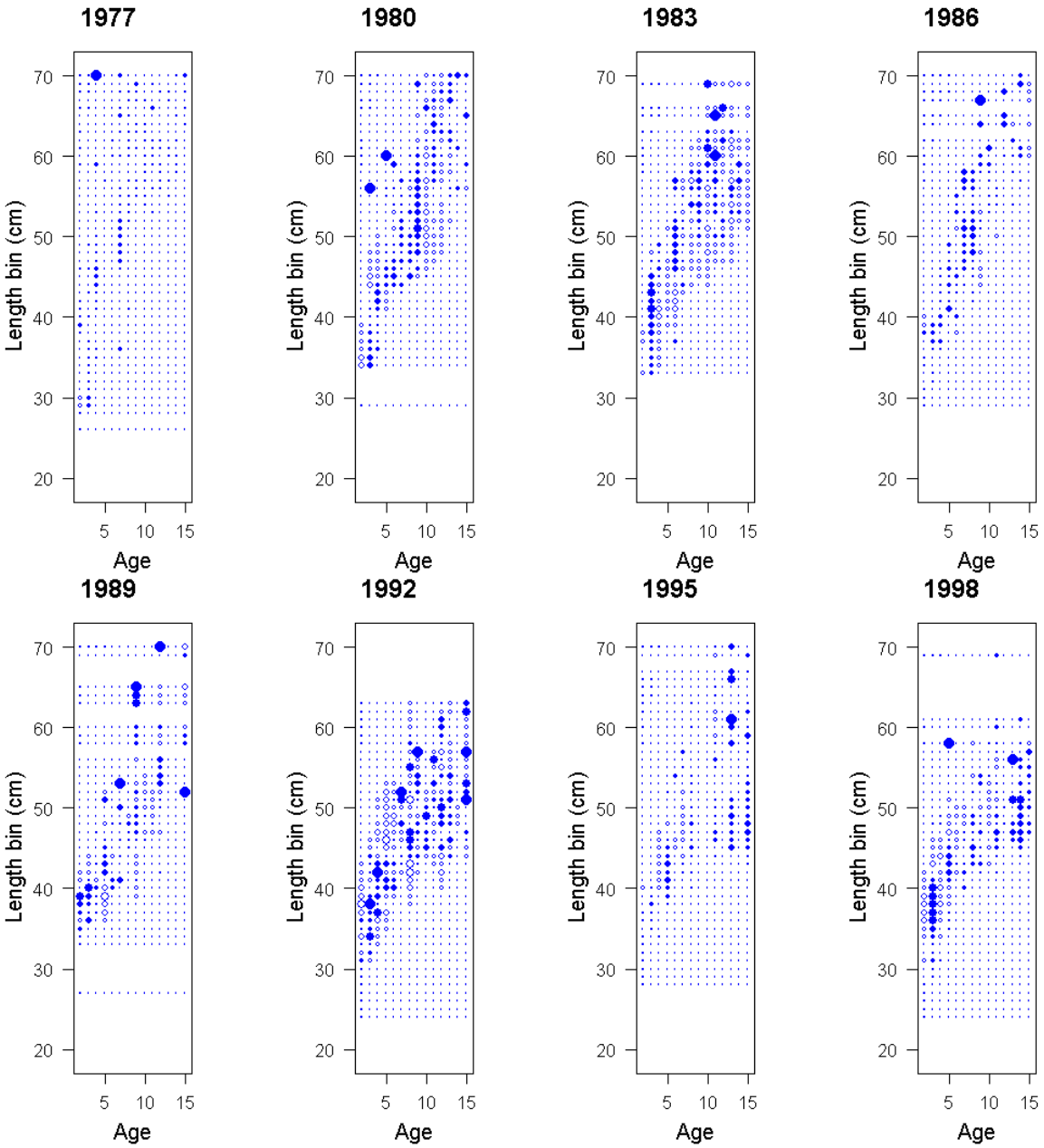

Figure 46 continued. Standardized Pearson age at length residuals for the acoustic survey. Open circles Indicate negative residuals, filled circles indicate positive residuals.

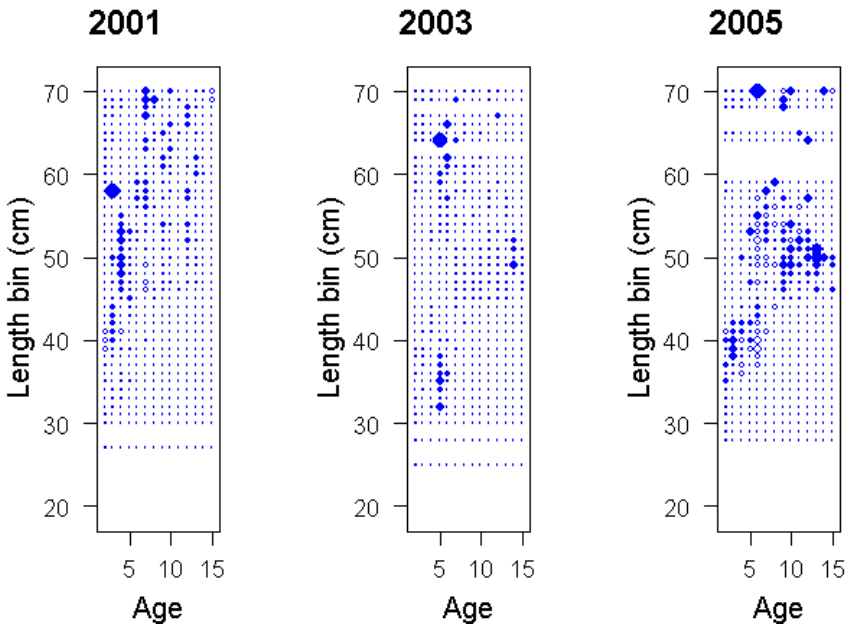

Figure 46 continued. Standardized Pearson age at length residuals for the acoustic survey. Open circles Indicate negative residuals, filled circles indicate positive residuals.

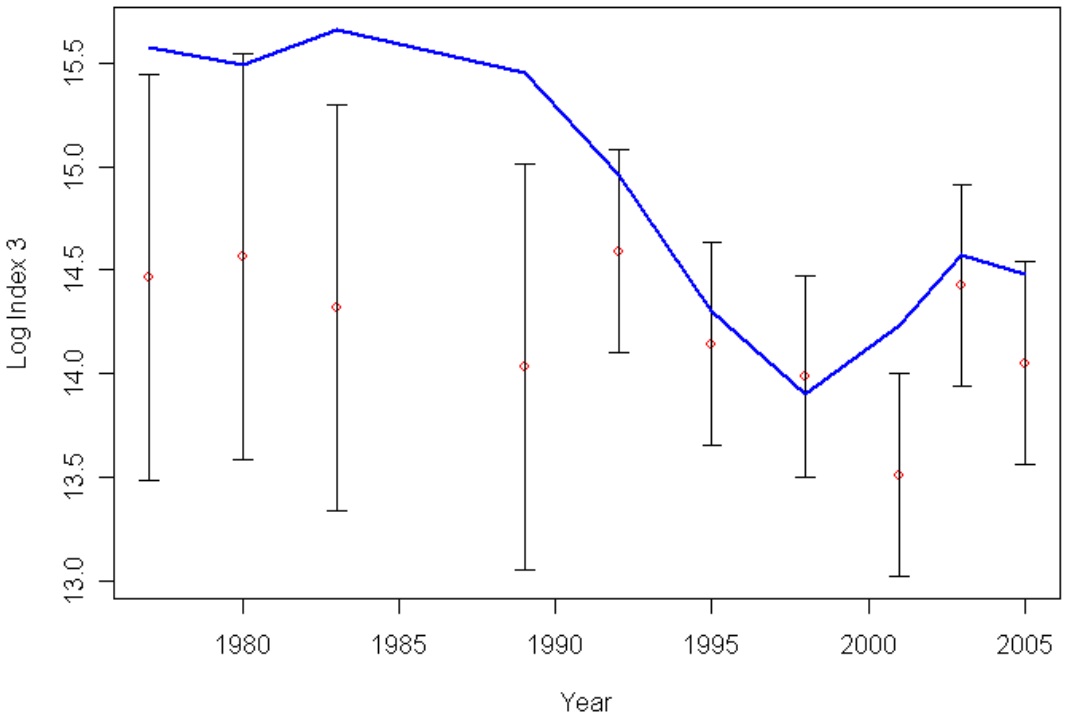

Figure 47. Predicted fit of acoustic survey biomass to the observed time series. Value are shown on a logarithmic scale.

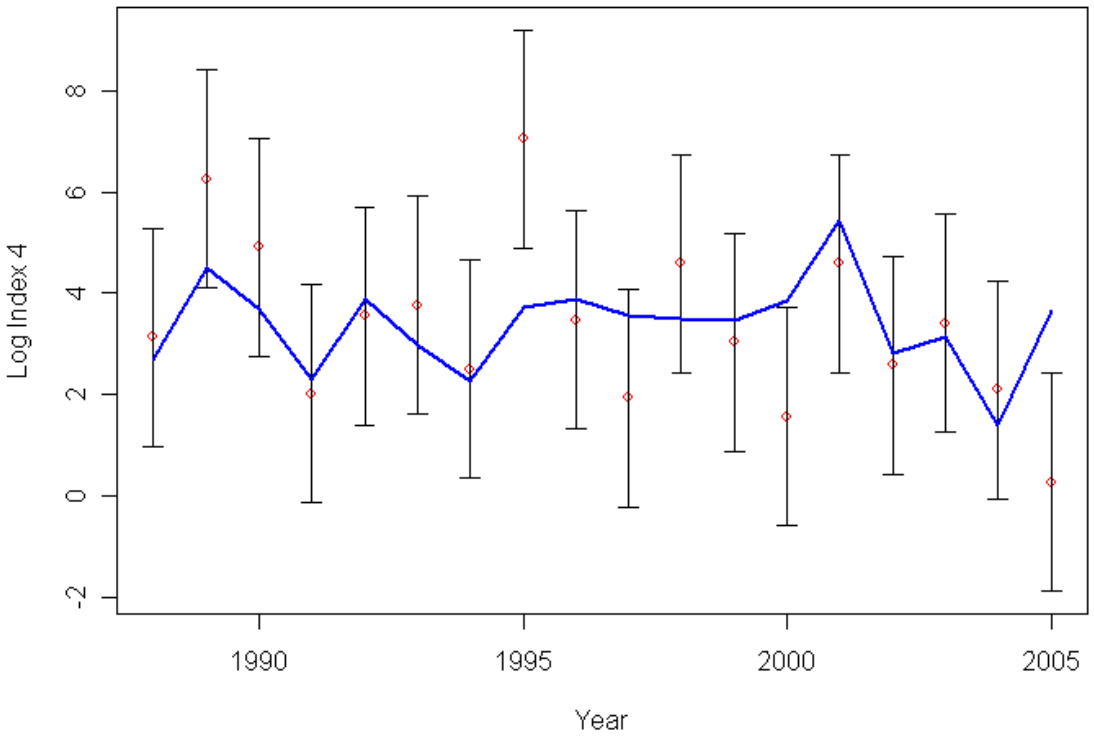

Figure 48. Predicted fit of the Santa Cruz pre-recruit hake survey ot the observed time series. Value are shown on a logarithmic scale.

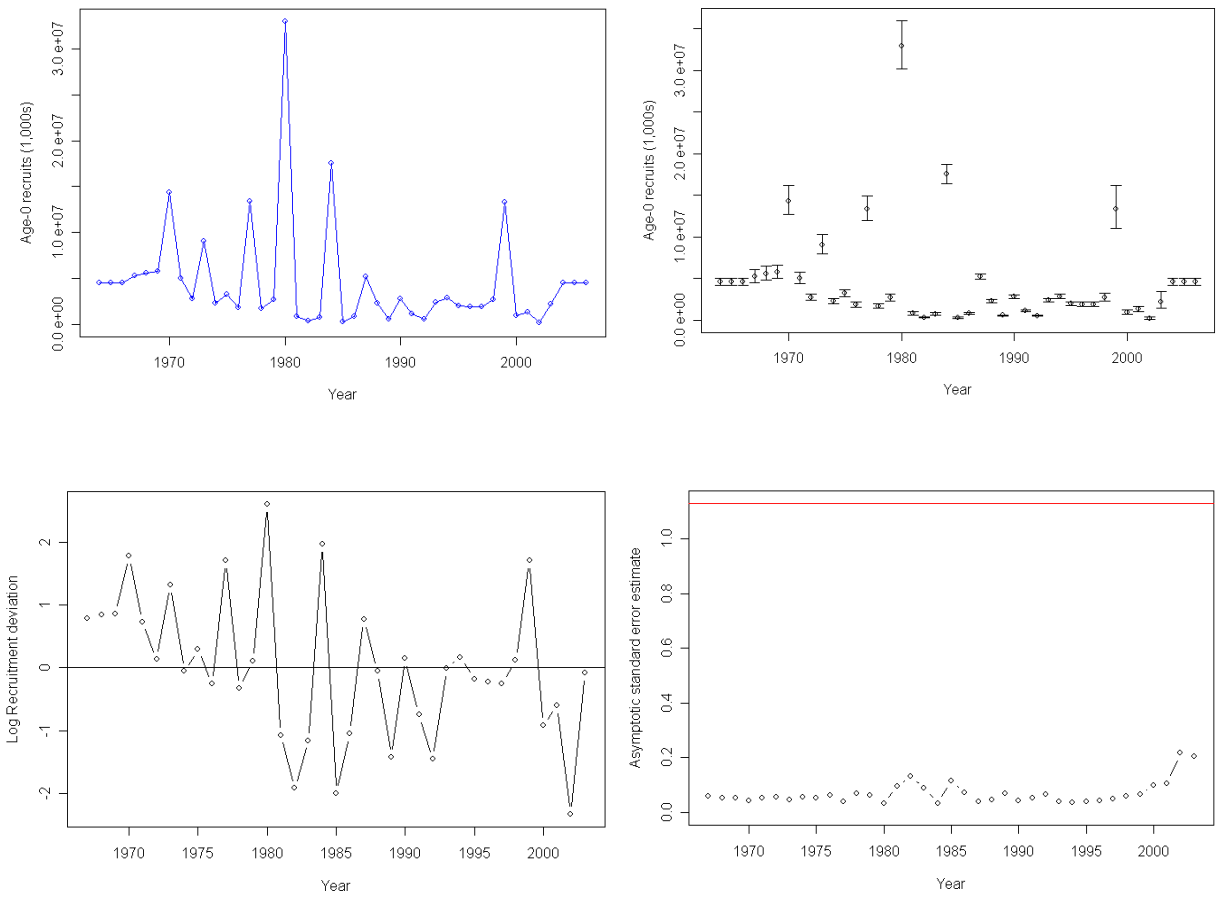

Figure 49. Estimates of Pacific hake recruitment, recruitment uncertainty, recruitment deviations and asymptotic standard errors from base SS2 model results. Recruitments were estimated from 1967-2003, but otherwise taken as mean recruitment.

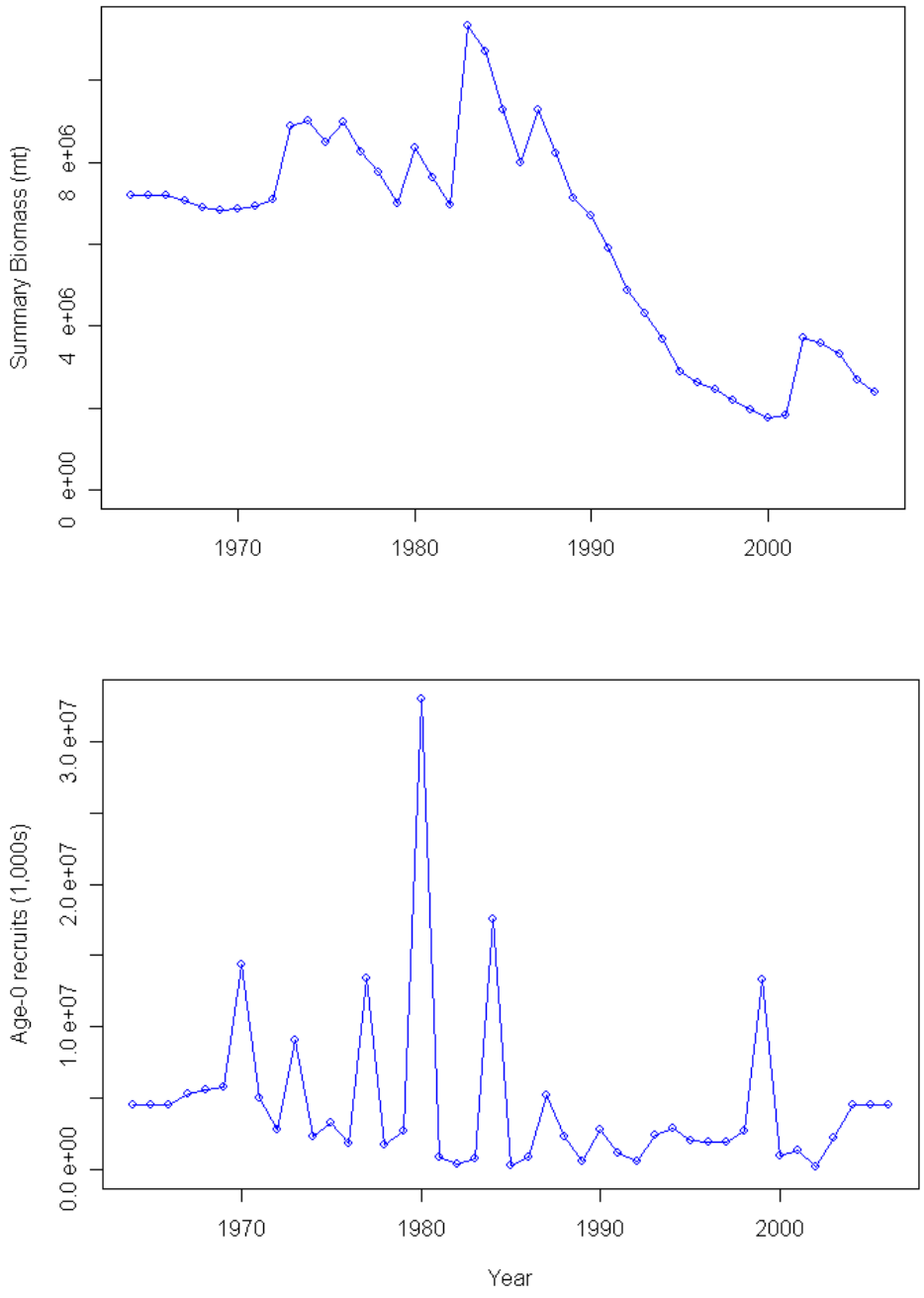

Figure 50. Estimated time series of Pacific hake summary biomass (age 3+) and recruitment from the base SS2 model.

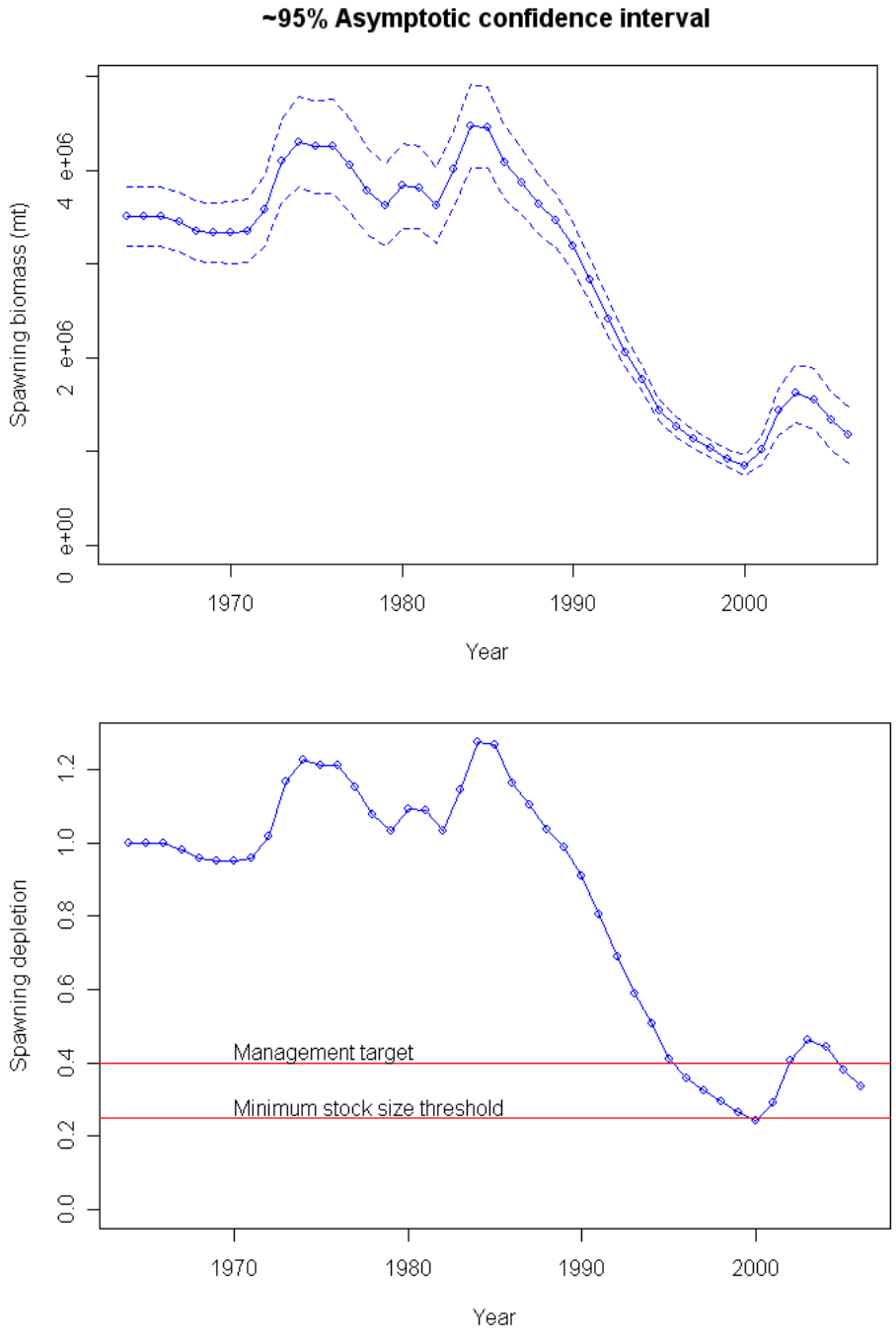

Figure 51. Estimated time series of Pacific hake spawning biomass and spawning depletion (fraction of unfished biomass) from the base SS2 model.

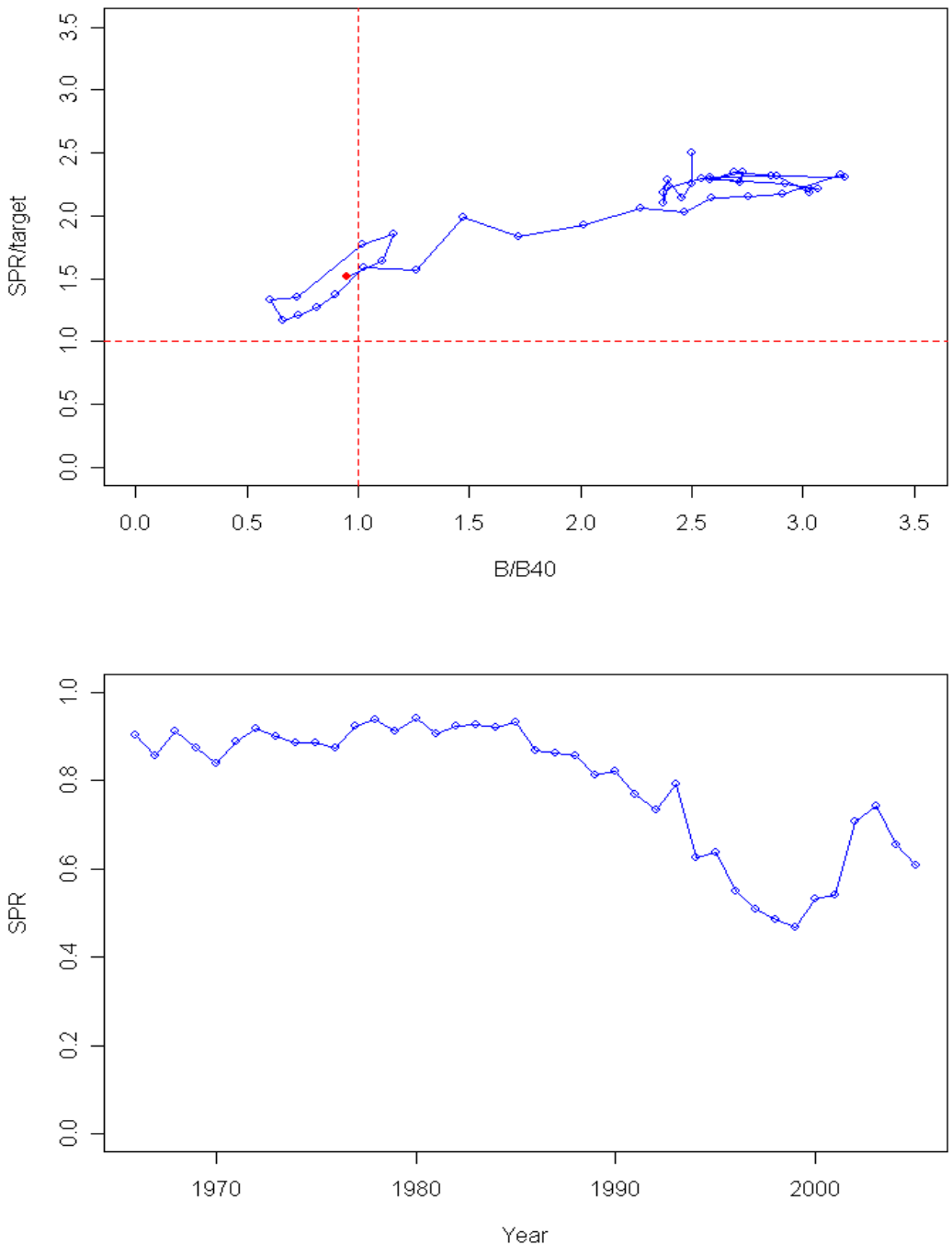

Figure 52. Estimated time series of Pacific hake spawning potential ratio (SPR) and fishery performance relative to reference point targets from the base SS2 model.

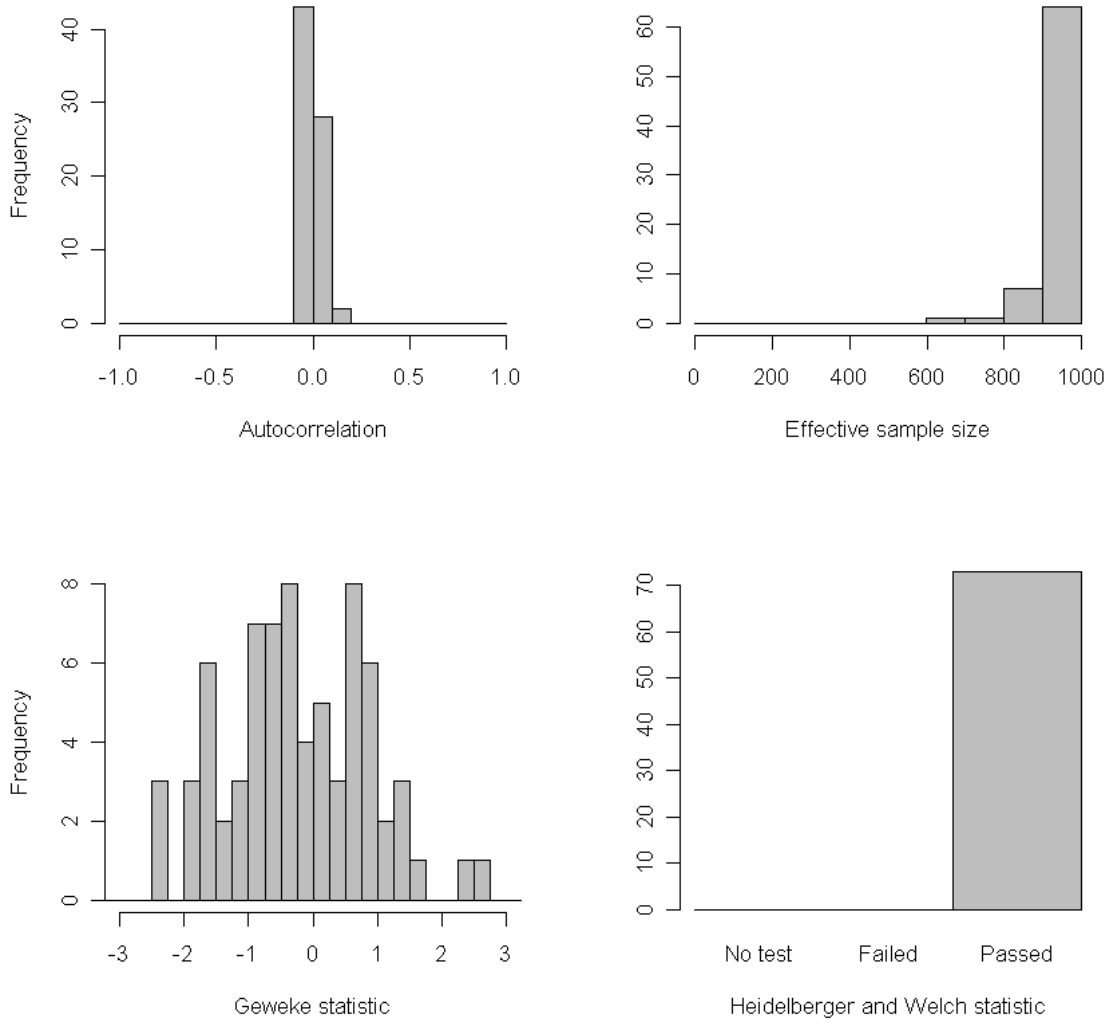

Figure 53. Summary of convergence criteria for all estimated model parameters.

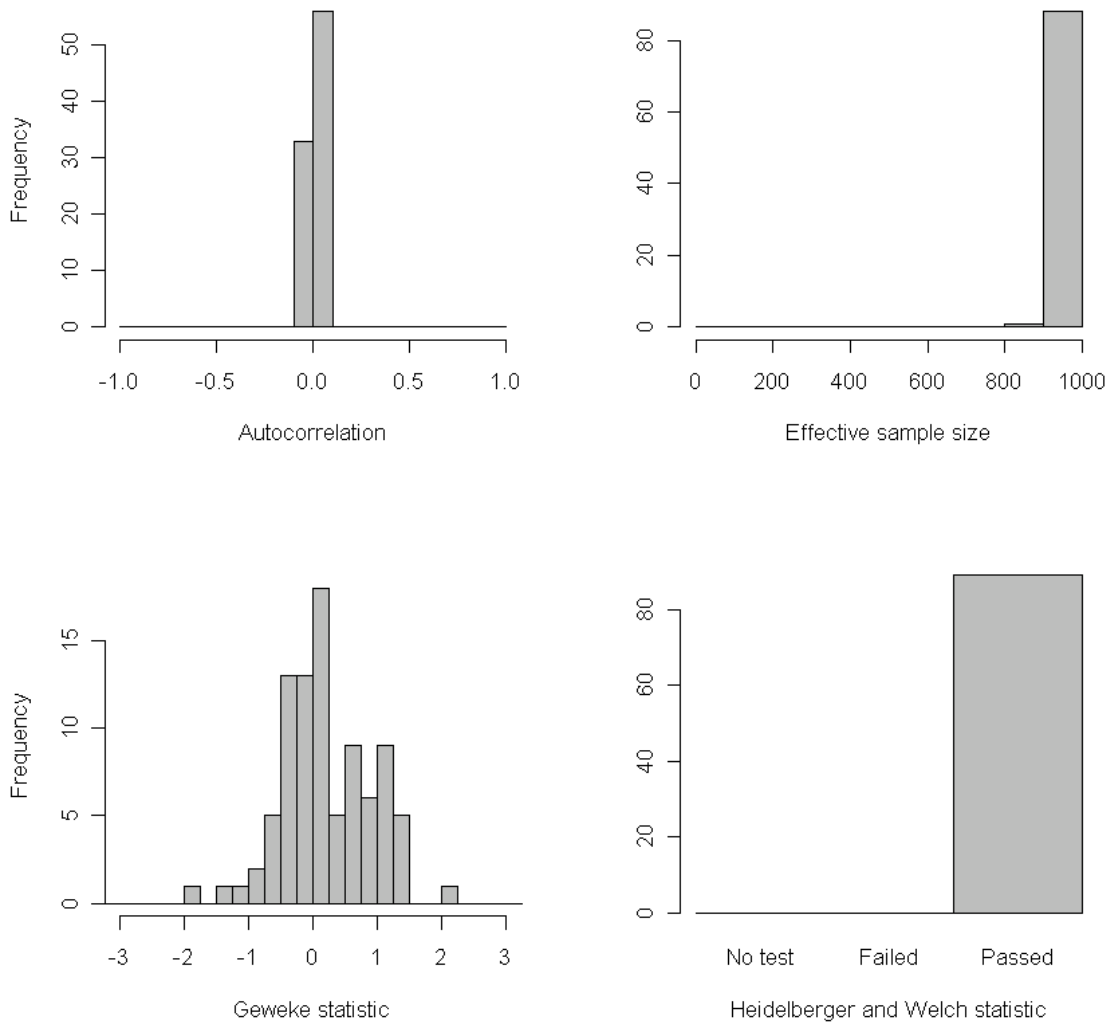

Figure 54. Summary of convergence criteria for the derived variables such as spawning biomass and recruitment time-series'.

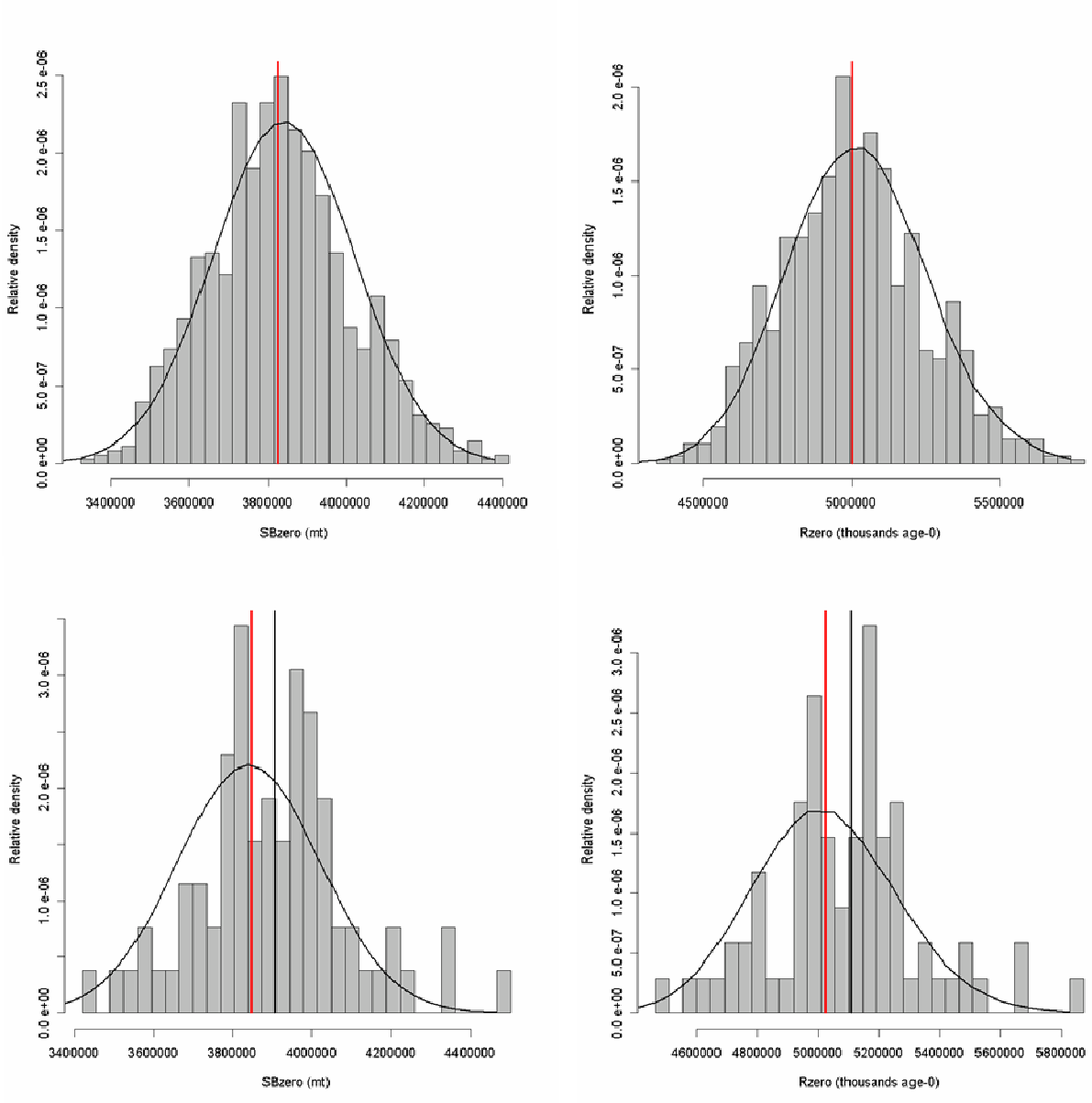

Figure 55. Top) Comparison of the posterior distributions of unfished biomass (Bzero, left column) and recruitment (Rzero, right column) from MCMC integration (bars, median shown as vertical line) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line). Bottom) Comparison of distribution of unfished biomass (SBzero) and recruitment (Rzero) from model fit to 75 parametric bootstraps of the data (red line is the "true value"; black line is the median) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line).

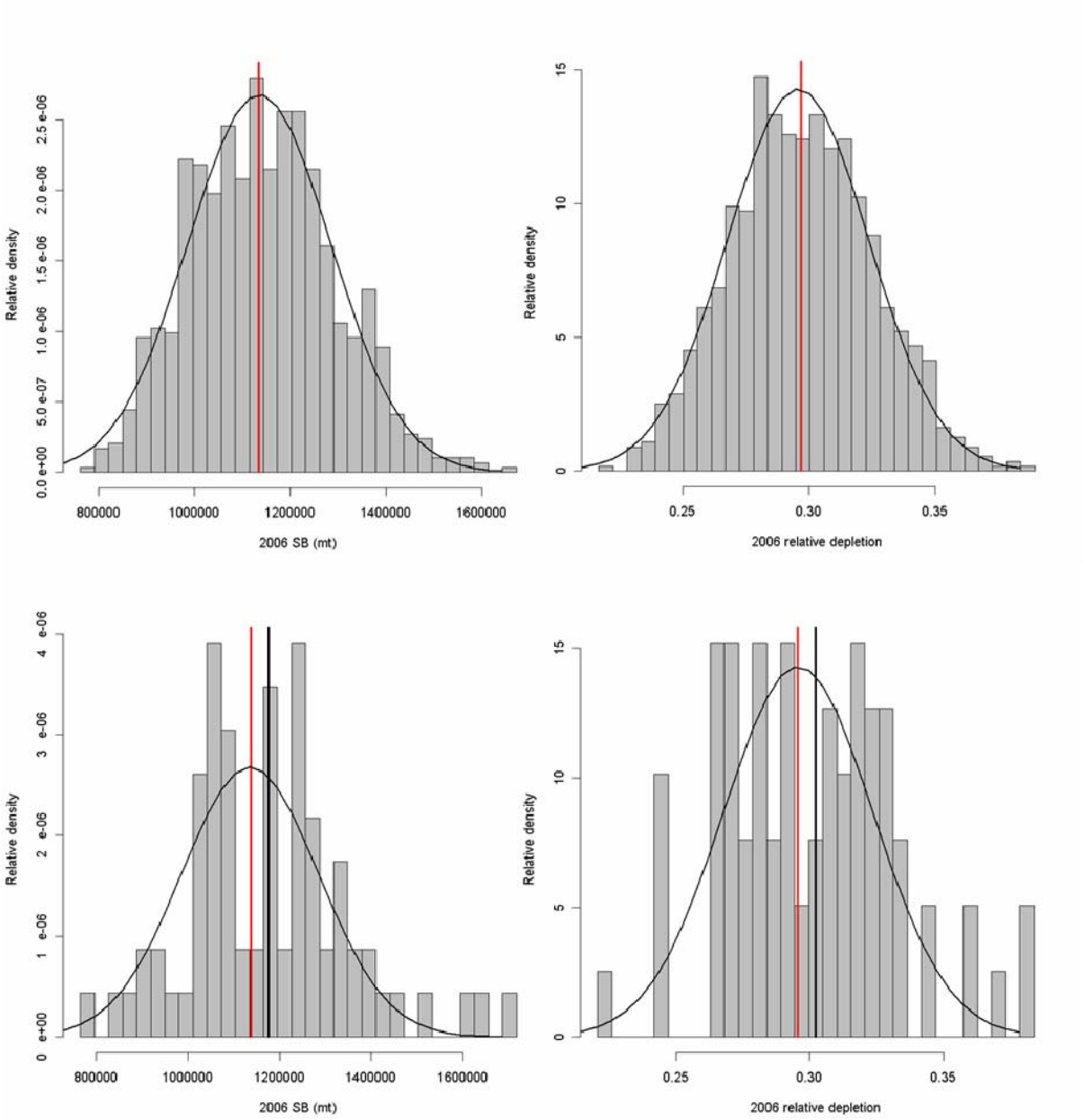

Figure 56. Top) Comparison of the posterior distributions of 2006 spawning biomass (2006 SB, left column) and 2006 relative depletion (right column) from MCMC integration (bars, median shown as vertical line) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line). Bottom) Comparison of distribution of 2006 spawning biomass and 2006 relative depletion from model fit to 75 parametric bootstraps of the data (red line is the "true value"; black line is the median) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line).

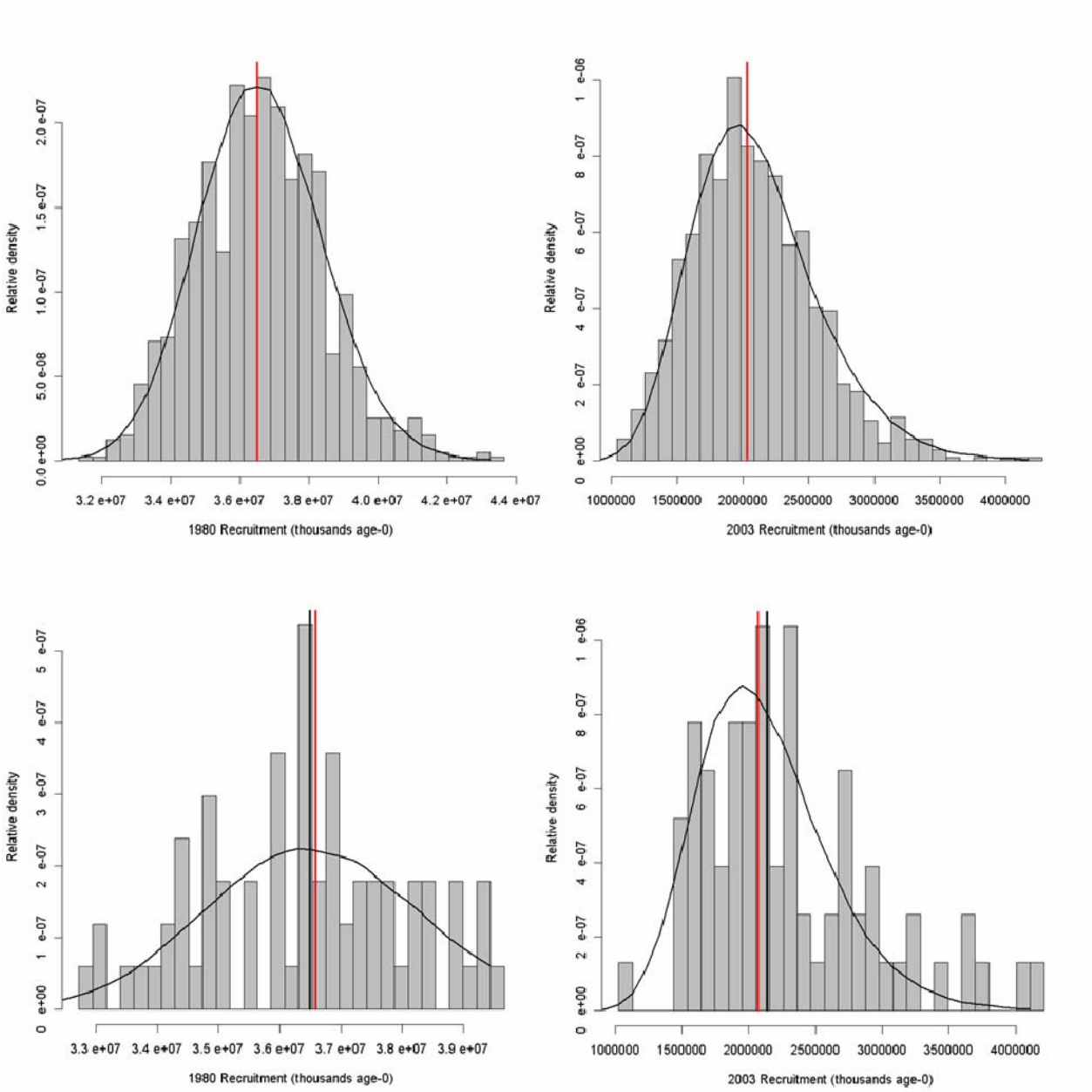

Figure 57. Top) Comparison of the posterior distributions of 1980 age-0 recruitment (left column) and 2003 age-0 recruitment (right column) from MCMC integration (bars, median shown as vertical line) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line). Bottom) Comparison of distribution of 1980 age-0 recruitment (left column) and 2003 age-0 recruitment (right column) from model fit to 75 parametric bootstraps of the data (red line is the "true value"; black line is the median) to asymptotic variance estimates from maximum likelihood estimates of the Hessian (solid line).

Appendix A: Growth Analysis

Pacific Hake Growth

There is a considerable amount of variability in the length-at-age data collected during the acoustic surveys since 1977. There are a number of ways to interpret this variability including: effects from size-selective fishing, changes in size selectivity over time, and variation in growth rates over time. Here we explore alternative explanations in hake growth by fitting alternative growth models to the length-at-age data collected in the acoustic surveys (assuming size-selectivity in the acoustic surveys has been constant over time).

The first of these models is a simple time-varying growth model, where the growth coefficient (k) is allowed to vary over time. This assumes that all extant cohorts are subject to time varying changes in the metabolic rates (presumably associated with changes in available food). This is the version of the growth model that is presently implemented in Stock Synthesis 2 (SS2). The second growth model assumes that growth is density-dependent. That is, the density of each cohort determines the overall growth rate and each cohort has its own asymptotic length. The third model is similar to the second model; however, in this case we assume the growth coefficient (k) is cohort specific.

Growth Model

We assume that hake growth follows the von Bertalanffy growth equation, which is given by:

$$L_a = L_1 + (L_2 - L_1)\left[\frac{1-\rho^{a-2}}{1-\rho^{A-2}}\right] \quad (1)$$

where L_a is the mean length at age a (a is an index for age and A corresponds to age 15), L_1 and L_2 are the mean lengths of age 2 and age 15, respectively, and ρ is the Brody growth coefficient (ρ=exp(-k), where k is the standard von Bertalanffy growth coefficient). Mean variation in length-at-age is assumed not to vary over time and the estimates of standard deviation in length-at-age is assume to be a function of 2 unknown parameters and the growth coefficient (k) only:

$$S_a = \lambda_1 \exp\left[\lambda_2\left(-1+2\frac{1-\rho^{a-2}}{1-\rho^{A-2}}\right)\right] \quad (2)$$

where λ_1 and λ_2 are unknown parameters to be estimated. Using equation 2 to describe variation in length-at-age is more desirable than estimating a fixed coefficient of variation in length-at-age as it is less confounded with the growth parameters (Fournier et al. 1991).

The following growth models assume that fish samples for size-age composition information were drawn from a multinomial distribution that includes the joint probability of sampling a fish of a given age and length. The negative log likelihood kernel for estimating growth parameters is given by:

(3) $$L = -\sum_{l}\sum_{a} n_{l,a} \ln(p_{l,a})$$

where $n_{l,a}$ is the observed sample numbers of length l and age a fish and $p_{l,a}$ are the predicted proportions. The predicted proportions sampled is the product of size selectivity (v_l), then numbers at age and the probability of being in length interval l for a given age.

(4) $$p_{l,a} = \frac{v_l N_a P(l \mid a)}{\sum_{l}\sum_{a} v_l N_a P(l \mid a)}$$

Variation in length at age was assumed to be normally distributed and we used the normal distribution to compute the probability of sampling a fish of a certain length l for a given age ($P(l|a)$). In the acoustic survey samples, we assume that size selectivity follows a simple logistic function where the length at 50% vulnerability is 35cm and the standard deviation in size selectivity is 2cm. It is possible to estimate the selectivity parameters simultaneously, but for comparative reasons we fixed these parameters at these arbitrary values. We used the conditional maximum likelihood estimate for the numbers-at-age (N_a) in the population (Taylor et al. 2005). To obtain the MLE for N_a we differentiate equation (3) with respect to N_a, set the derivative to 0 and solve for N_a, which is given by:

(5) $$N'_a = \left(\frac{n_a}{n_T}\right)\left(\frac{V_T}{\bar{v}_a}\right),$$

where $\bar{v}_a \sum_{l} v_l P(l \mid a)$ is the sum vulnerabilities-at-length in each age class weighted by $P(l|a)$, n_a and n_T are the observed sample numbers at age a and total number sampled. Substituting equation (5) into equations (4) and (3), and noting that the n_a/n_T do not change with respect to parameter values, the likelihood kernel for the conditional MLE estimates of N_a is given by:

(6) $$L = -\sum_{l}\sum_{a} n_{l,a} \ln\left(\frac{v_l P(l \mid a)}{\bar{v}_a}\right)$$

The parameter vector to estimate for a single length-age matrix consists of the growth parameters for estimating the mean length-at-age (l_1, l_2, k) and the parameters that describe the variation in length at age (λ_1, λ_2).

Time varying k

In the case of adding time varying effects on the growth coefficient k, we estimated vector of growth coefficients k_t (one for each survey year and 15 parameters in total were estimated). In this case, the l_1 and l_2 parameters of the growth model were assumed to be time invariant and inter annual variation in mean length-at-age was assumed to arise through inter annual variability in metabolic rates (k_t).

Cohort effects

In the case of assuming cohort density determines the overall growth rate, we estimated a vector of $l_{2,g}$ parameters or a vector of growth coefficients k_g, where the g subscript denotes a specific cohort. In the acoustic survey data, spanning 1977 to 2005, there are

42 cohorts between the ages of 2 and 15 (a total of 46 parameters were estimated). Not all cohorts are sampled with the same frequency during each survey year. For example, in 1977, the 1963-1965 cohorts (representing the age 13-15 age classes in 1977) are only represented once in the length-age data. Similarly, the age 2 and 3 year classes sampled in 2005 are only represented once in the data. We used a weak informative normal prior on the cohort specific parameters in the form of:

$$P(\theta_g) = \ln(\sigma) + \frac{\sum_g \left(\theta_g - \bar{\theta}\right)^2}{2\sigma^2} \quad (7)$$

where θ_g represents the cohort specific parameter being estimated. In the case of estimating $l_{2,g}$ parameters, the standard deviation for the prior distribution was set to 25cm, and the case of estimating k_g parameters the standard deviation for the prior distribution was set to 0.25. The effect of this prior is minimal for cohorts that are represented more than once in the data.

Results

The motivation for using the cohort based model is apparent in the observed length-age data (Figure 1) whereby some of the cohorts appear to grow at different rates than other cohorts sampled in the same year. For example, the age-5 and age-6 cohorts sampled in 1980 appear to have the same mean length indicating that the age-5 cohort is growing faster than the age-6 cohort. Similarly, the age-4 cohort appears to be growing faster than the age-5 cohort in 2001. Of the 3 alternative growth models, the model with cohort specific l_2 values explains more of the variation in the length-age data versus the time varying k model and cohort k model (Table 1).

Table 1. Parameter estimates and corresponding fits and AICs for the 3 alternative growth models. For the time varying k model the mean estimate of k is presented and for the cohort models the mean estimate of l2 and k are presented.

Growth Model	ln(L)	n	AIC	L1	L2	k	λ_1	λ_2
Time Varying k	32701.2	15	65372.4	31.99	55.42	0.25	3.93	0.34
Cohort l2	32572.5	46	65053.0	31.48	55.80	0.29	3.88	0.24
Cohort k	32738.1	46	65384.2	31.77	55.57	0.30	3.98	0.30

Comments on Growth Analysis

Note that these cohort based models do not assume the cumulative affects of size selective fisheries. To properly represent the cumulative affects of size selective fisheries in this approach, the cohort based growth model should be integrated into the assessment model itself. In this case it would not be necessary to use the conditional MLE for the numbers-at-age; this information could be provided from the stock assessment model it self.

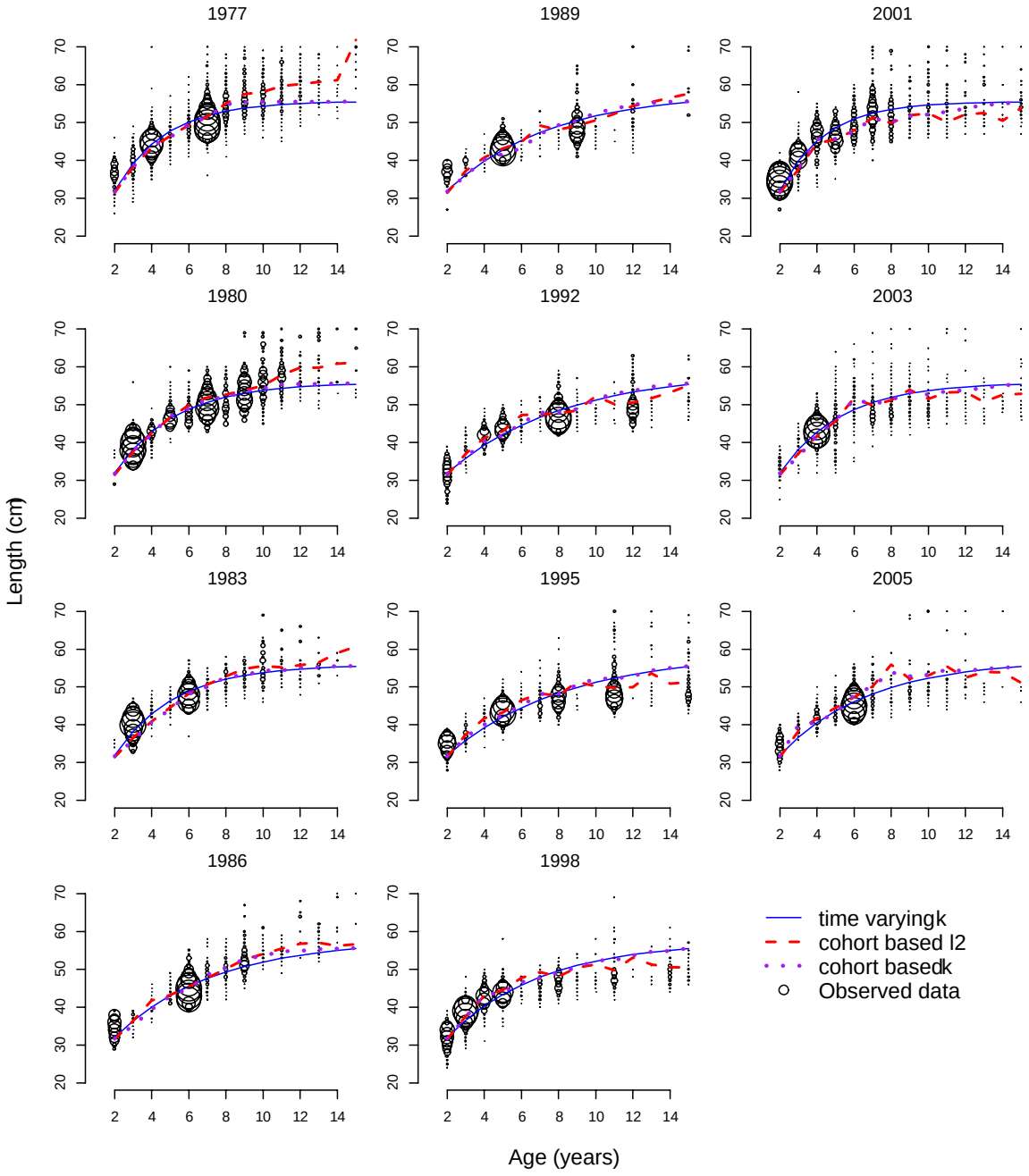

Figure 1. Length-at-age data collected from the acoustic surveys where the diameter of the circle is proportional to the sample size collected. Three separate growth models were fit to the data using a multinomial likelihood criterion. In the first model it was assumed that the growth coefficient (k) varies over time (time varying k), the second model assumes that the asymptotic length of each cohort varies (cohort based l2) and the third model assumes that the growth coefficient for each cohort varies over time (cohort based k).

It is probably not necessary to estimate growth parameters for each cohort in the model, rather to use a functional relationship that relates the effect of cohort density on the mean

asymptotic size attained by each cohort. Based on the acoustic survey data alone and an arbitrary selectivity curve for the acoustic survey, there is a weak relationship between the 3+ biomass and the asymptotic length (Figure 2). We also examined the relationship between age-2 recruits and l_2, but found no significant relationship. Integrating the cohort based growth model into the assessment model would allow for additional data sources from the commercial length-age sampling to provide more information about growth parameters for more of the cohorts; however, we suspect that this would create additional confounding with time varying selectivity parameters already in use in the assessment model. Alternatively, an explicit density-dependent growth model could easily be integrated into the assessment frame work, where the l_2 parameter varies

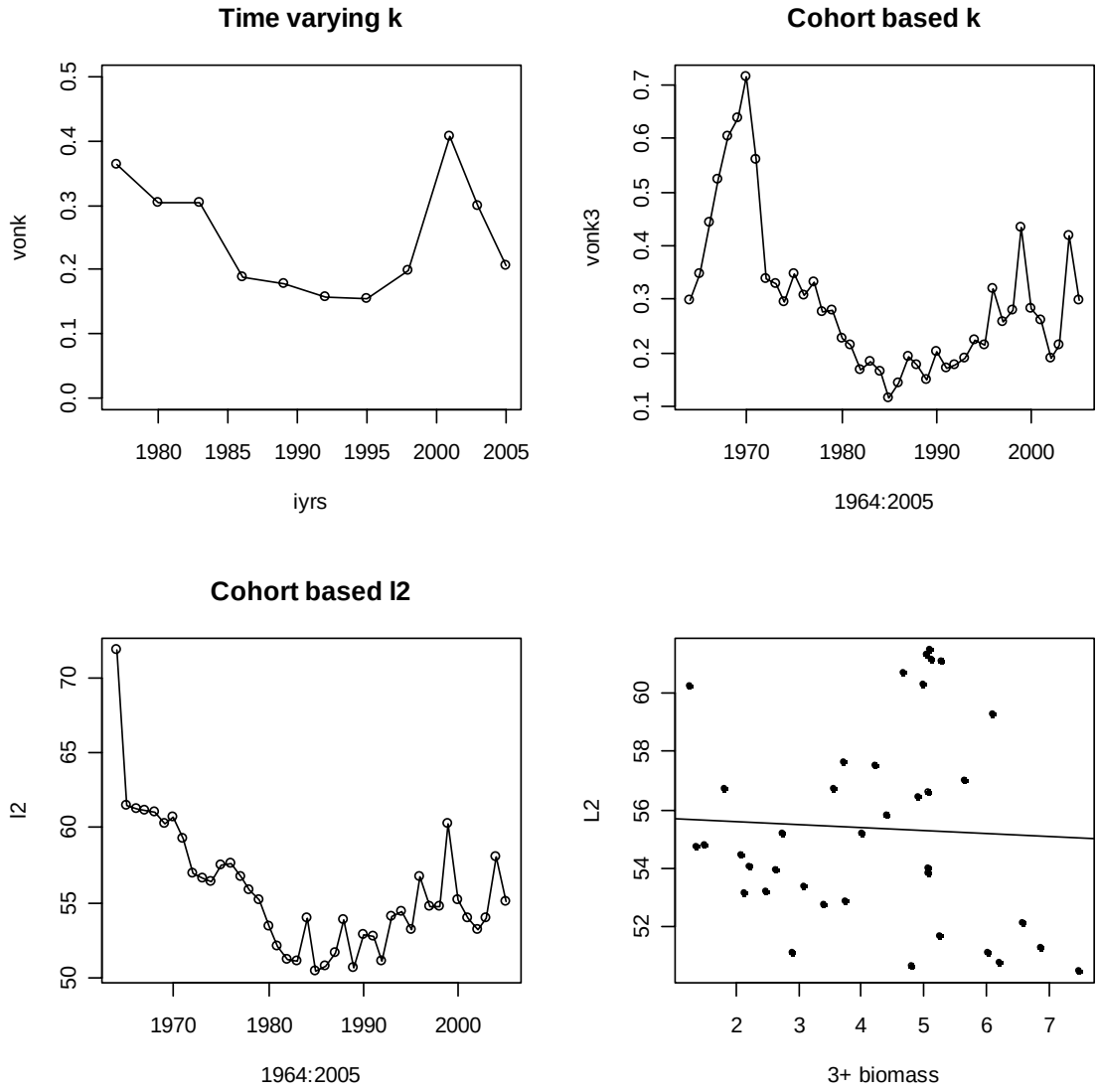

Figure 2. Estimates of time varying k and cohort based k and l2 parameters obtained from fitting the growth models to acoustic survey length-age data. Also, the relationship between estimates of l2 and 3+ biomass from the 2004 assessment is shown in the lower right panel.

according to stock density. Based on historical observations of changes in mean weight at age over time, incorporating the effects of overall stock density into growth may be the most parsimonious explanation of changes in hake growth.

Fournier, D., J. Sibert, and M. Terceiro. 1991. Analysis of Length Frequency Samples with Relative Abundance Data for the Gulf of Maine Northern Shrimp (*Pandalus borealis*) by MULTIFAN Method. Can. J. Fish. Aquat. Sci. **48**:591-598.

Taylor, N. G., C. J. Walters, and S. J. D. Martell. 2005. A new likelihood for simultaneously estimating von Bertalanffy growth parameters, gear selectivity, and natural and fishing mortality. Can. J. Fish. Aquat. Sci **62**:215-223.

APPENDIX B: SS2 Control and Data files

hake ss2 version 1.ctl

```
# datafile:_hake ss2.dat
1  #_N_growthmorphs

#_assign_sex_to        each_morph_(1=female;_2=male)
1

1  #_N_Areas_(populations)

#_each_fleet/survey_operates_in_just_one_area
#_but_different_fleets/surveys_can be assigned_to_share_same_selex
1  1        1        1        #area_for_each_fleet/survey

0  #do_migration_(0/1)

6  #_N_Block_Designs
4
1
1
3
3
2
# Lmin
1982        1987
1988        1999
2000        2002
2003        2005
#K blocks
1980        1986
#1988        1993
#1994        1997
#1998        1999
#2000        2002
#2003        2005
# Lmax blocks
1984        2005
#1994        1997
#1998        2002
#2003        2005
# US Fish sel blocks
1984        1992
1993        2000
2001        2005
# Can sel blocks
1995        2000
2001        2002
2003        2005
# US inf1 blocks
1984        2000
2001        2005

#Natural_mortality_and_growth_parameters_for_each_morph
4  #_Last_age_for_natmort_young
15 #_First_age_for_natmort_old
2  #_age_for_growth_Lmin
12 #_age_for_growth_Lmax
-3 #_MGparm_dev_phase
#LO        HI        INIT      PRIOR     PR_type   SD        PHASE     env-variable        use_dev   dev_minyr dev_maxyrdev_stddev
0.05       0.6       0.23      0.23      0         0.8       -3        0         0         0         0.5       0         0
   #M1_natM_young
-3 3         0         0         0         0.8       -3        0         0         0         0         0.5       0         0
   #M1_natM_old_as_exponential_offset(rel_young)
10 40        33        33        0         99        3         0         0         0         0         0.5       0         0
   #M1_Lmin
30 70        50        50        0         99        3         0         0         0         0         0.5       3         2
   #M1_Lmax
0.1        0.7       0.30      0.40      0         99        3         0         0         0         0         0.5       2         2
   #M1_VBK
0.01       0.35      0.10      0.10      0         99        4         0         0         0         0         0.5       0         0
   #M1_CV-young
```

```
-3 3 0.32 0 0 0.8 -4 0 0 0 0 0.5 0 0 #M1_CV-old_as_exponential_offset(rel_young)
#-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_natM_young_as_exponential_offset(rel_morph_1)
#-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_natM_old_as_exponential_offset(rel_young)
#-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_Lmin_as_exponential_offset
#-3 3 0 0 0 0.8 -2 0 0 0 0 0.5 0 0 #M2_Lmax_as_exponential_offset
#-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_VBK_as_exponential_offset
#-3 3 0 0. 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_CV-young_as_exponential_offset(rel_CV-young_for_morph_1)
#-3 3 0 0. 0 0.8 -3 0 0 0 0 0.5 0 0 #M2_CV-old_as_exponential_offset(rel_CV-young)

# Add 2+2*gender lines to read the wt-Len and mat-Len parameters
-3 3 7.0E-06 7.0E-06 0 0.8 -3 0 0 0 0 0.5 0 0 #Female wt-len-1
-3 3 2.9624 2.9624 0 0.8 -3 0 0 0 0 0.5 0 0 #Female wt-len-2
-3 3 36.89 36.89 0 0.8 -3 0 0 0 0 0.5 0 0 #Female mat-len-1
-3 3 -0.48 -0.48 0 0.8 -3 0 0 0 0 0.5 0 0 #Female mat-len-2
-3 3 1. 1. 0 0.8 -3 0 0 0 0 0.5 0 0 #Female eggs/gm intercept
-3 3 0. 0. 0 0.8 -3 0 0 0 0 0.5 0 0 #Female eggs/gm slope
#-3 3 0 0 0 0.8 -3 0 0 0 0 0.5 0 0 #Male wt-len-1

# pop*gmorph lines For the proportion of each morph in each area
0 1 1 1 0 0.8 -3 0 0 0 0 0.5 0 0 #frac to morph 6 in area 1

# pop lines For the proportion assigned to each area
0 1 1 1 0 0.8 -3 0 0 0 0 0.5 0 0 #frac to area 1

# Enter maturity at age (multiplied by 0.5 for female mature biomass)
#0 0 0.088 0.3305 0.445 0.4845 0.493 0.498 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5

#_custom-env_read
0 #_ 0=read_one_setup_and_apply_to_all_env_fxns; 1=read_a_setup_line_for_each_MGparm_with_Env-var>0

#_custom-block_read
1 #_ 0=read_one_setup_and_apply_to_all_MG-blocks; 1=read_a_setup_line_for_each_block x MGparm_with_block>0
# LMIN
#10 40 30 33 0 99 3
#10 40 30 33 0 99 3
#10 40 30 33 0 99 3
#10 40 30 33 0 99 3
# Lmax
30 70 50 50 0 99 3
#30 70 50 50 0 99 3
#30 70 50 50 0 99 3
# K
0.1 0.7 0.30 0.40 0 99 3
#0.1 0.7 0.30 0.40 0 99 3
#0.1 0.7 0.32 0.40 0 99 3
#0.1 0.7 0.35 0.40 0 99 3
#0.1 0.7 0.30 0.40 0 99 3
#0.1 0.7 0.30 0.40 0 99 3

# LO HI INIT PRIOR Pr_type SD PHASE

#_Spawner-Recruitment_parameters
```

```
1  # SR_fxn:  1=Beverton-Holt
#LO            HI          INIT        PRIOR       Pr_type     SD          PHASE
11 31          14.2        15          0           99           2          #Ln(R0)
0.2            1           0.75        1           2           0.2         -4          #steepness
0  2           1.139       1.2         0           0.8         -3          #SD_recruitments
-5 5           0           0           0           1           -3          #Env_link
-5 5           0           0           0           1           -4          #init_eq
0  #env-var_for_link
#  recruitment_residuals
#  start_rec_year          end_rec_year          Lower_limit          Upper_limit          phase
   1967        2003        -15         15          2

#init_F_setupforeachfleet
#LO            HI          INIT        PRIOR       PR_type     SD          PHASE
0  1           0.0         0.01        0           99           -1
0  1           0.0         0.01        0           99           -1

#_Qsetup
#_add_parm_row_for_each_positive_entry_below(row_then_column)
#-Float(0/1)   #Do-power(0/1)          #Do-env(0/1)          #Do-dev(0/1)  #env-Var          #Num/Bio(0/1)          for          each          fleet          and
   survey
0  0           0           0           0           1
0  0           0           0           0           1
1  0           0           0           0           1
1  0           0           0           0           0

#LO            HI          INIT        PRIOR       PR_type     SD          PHASE
-5 .5           0           0           0           99          -1          # Acoustic survey
-15            10           7           4           0           99           1          # recruit survey

#_SELEX_&_RETENTION_PARAMETERS
#Pattern       Retention(0/1)          Male(0/1)  Special
# Size_selex
0  0           0           0           #_fleet_1
0  0           0           0           #_fleet_2
0  0           0           0           #_acoustic
0  0           0           0           #_recruit

#_Age_selex
#13            0           0           0           #_fleet_1
#13            0           0           0           #_fleet_2
#13            0           0           0           #_acoustic

19 0           0           0           #_fleet_1
19 0           0           0           #_fleet_2
19 0           0           0           #_acoustic
11 0           0           0           #_recruit

#LO            HI          INIT        PRIOR       PR_type     SD          PHASE     env-variable          use_dev     dev_minyr dev_maxyrdev_stddev
   Block_Pattern

#2             60     45      10     0      99       -4     0      0      0      0       0.5     0      0       #peak
#0.0000  0.1     0.0          0      0      99       -2     0      0      0      0       0.5     0      0       #init
#-5       5       0.0     0.3     0      99        2     0      1      1975    2004    0.1     0      0       #infl
#0.0000  10      0.3     0.3     0      99        2     0      1      1975    2004    0.1     0      0       #slope1
#-10      100     -4      -4      0      99       -2     0      0      0      0       0.5     0      0       #final
#-5       5      0.0     0.5     0      99        2     0      1      1975    2004    0.1     0      0       #infl2
#0.0001  10      0.3     .3      0      99        2     0      1      1975    2004    0.1     0      0       #slope2
#0.      25      1      0.2      0      99       -2     0      0      0      0       0.5     0      0       #width of top

#2             60     50      8      0      99       -3     0      0      0      0       0.5     0      0       #peak
#0.0000  0.1     0.0          0      0      99       -2     0      0      0      0       0.5     0      0       #init
#-5       5       0.0     1.7     0      99        2     0      1      1988    2004    0.1     0      0       #infl
#0.0001  10      0.3     1.0     0      99        2     0      1      1988    2004    0.1     0      0       #slope1
#-10      10      -2      -2      0      99        2     0      0      0      0       0.5     0      0       #final
#-5       5      0.0     0.1     0      99        2     0      0      0      0       0.5     0      0       #infl2
#0.0001  10      0.3     0.1     0      99        2     0      0      0      0       0.5     0      0       #slope2
#0.      25      2       2       0      99       -4     0      0      0      0       0.5     0      0       #width of top

1  20      3.2  3              0              99      5      0              0              1975          2004          0.005         4              2              #inf_1
```

```
0.00001 10 2.5 2.5 0 99 5 0 0 1975 2004 0.005 4 2 #slp_1
1 40 11.8 12 0 99 5 0 0 1975 2004 0.005 4 2 #inf_2
0.00001 10 1.0 1.0 0 99 5 0 0 1975 2004 0.005 4 2 #slp_2
2 2 1 2 0 99 -2 0 0 0 0 0.5 0 0 #min_age
2 2 0 2 0 99 -2 0 0 0 0 0.5 0 0 #

1 20 4.0 3 0 99 5 0 0 1988 2004 0.05 5 2 #inf_1
0.00001 10 1.5 0.9 0 99 5 0 0 1988 2004 0.05 5 2 #slp_1
1 40 13.8 7 0 99 5 0 0 0 0 0.5 0 0 #inf_2
0.00001 10 1.0 0.5 0 99 5 0 0 0 0 0.5 0 0 #slp_2
2 2 2 2 0 99 -2 0 0 0 0 0.5 0 0 #min_age
2 2 0 2 0 99 -2 0 0 0 0 0.5 0 0 #

1 20 3.3 3 0 99 5 0 0 0 0 0.5 0 0 #inf_1
0.00001 10 0.775 0.9 0 99 5 0 0 0 0 0 0.5 0 0 #slp_1
1 40 7.84 7 0 99 5 0 0 0 0 0.5 0 0 #inf_2
0.00001 10 0.507 0.5 0 99 5 0 0 0 0 0 0.5 0 0 #slp_2
2 2 2 2 0 99 -2 0 0 0 0 0.5 0 0 #min_age
2 2 0 2 0 99 -2 0 0 0 0 0.5 0 0 #

0 40 0 0 0 99 -1 0 0 0 0 0.5 0 0 #min_age
0 40 0 0 0 99 -1 0 0 0 0 0.5 0 0 #min_age

#_custom-env_read
0 #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_read_1_each;

#_custom-block_read
1 #_ 0=read_one_setup_and_apply_to_all;_1=Custom_so_see_detailed_instructions_for_N_rows_in_Custom_setup

# US inf1 blocks
1 20 3.2 3 0 99 5
1 20 3.2 3 0 99 5
1 20 3.2 3 0 99 5

# US slp1 blocks
0.00001 10 2.5 0.9 0 99 5
0.00001 10 2.5 0.9 0 99 5
0.00001 10 2.5 0.9 0 99 5

# US inf2 blocks
1 40 11.8 7 0 99 5
1 40 11.8 7 0 99 5
1 40 11.8 7 0 99 5

# US slp2 blocks
0.00001 10 1.0 0.5 0 99 5
0.00001 10 1.0 0.5 0 99 5
0.00001 10 1.0 0.5 0 99 5

# Can inf1 blocks
1 20 5.5 3 0 99 5
1 20 5.5 3 0 99 5
1 20 5.5 3 0 99 5

# Can slp1 blocks
0.00001 10 1.5 0.9 0 99 5
0.00001 10 1.5 0.9 0 99 5
0.00001 10 1.5 0.9 0 99 5

# LO HI INIT PRIOR PR_type SD PHASE
-6 #_phase_for_selex_parm_devs

0 0 0 0
0 0 0 0
0 0 0 0
.3 1 1 1
.5 1 1 1
1 1 1 1

1 #_max_lambda_phases:_read_this_Number_of_values_for_each_componentxtype_below
```

```
1  #_include (1) or not (0) the constant offset For Log(s) in the Log(like) calculation
#_survey_lambdas
0  0              1              1
#_discard_lambdas
0  0              0              0
#_meanbodywt
0
#_lenfreq_lambdas
1  1              1              0
#_age_freq_lambdas
1  1              1              0
#_size@age_lambdas
0  0              0              0
#_initial_equil_catch
1
#_recruitment_lambda
1
#_parm_prior_lambda
1
#_parm_dev_timeseries_lambda
1
# crashpen lambda
100
#max F
0.9

999              #_end-of-file
```

1966 #_styr
2005 #_endyr
1 #_nseas
12 #_months/season
1 #_spawn_seas
2 #_Nfleet
2 #_Nsurv
fishery1%fishery2%survey1%survey2
0.5 0.5 0.5 0.0001 #_surveytiming_in_season
1 #_Ngenders
15 #_Nages
0 0 #_init_equil_catch_for_each_fishery
#_catch_biomass(mtons):_columns_are_fisheries,_rows_are_year*season
137000 700 # 1966
177662 36713 # 1967
60819 61361 # 1968
86280 93851 # 1969
159575 75009 # 1970
127913 26699 # 1971
74133 43413 # 1972
147513 15126 # 1973
194109 17150 # 1974
205656 15704 # 1975
231549 5972 # 1976
127502 5191 # 1977
98372 5267 # 1978
124680 12435 # 1979
72352 17584 # 1980
114760 24361 # 1981
75577 32157 # 1982
73150 40774 # 1983
96332 42109 # 1984
85439 24962 # 1985
154964 55653 # 1986
160448 73699 # 1987
160698 88106 # 1988
210996 94920 # 1989
183800 75992 # 1990
217505 89753 # 1991
208576 88334 # 1992
141222 58213 # 1993
252729 108800 # 1994
177589 72181 # 1995
212901 93174 # 1996
233423 91792 # 1997
232817 87802 # 1998
224522 87333 # 1999
208418 22402 # 2000
182377 53585 # 2001
132115 50796 # 2002
143492 62090 # 2003
210487 124185 # 2004
249109 100462 # 2005

30 #_N_cpue_and_surveyabundance_observations
#_year seas index obs se(log)
1977 1 3 1915000 0.5
1980 1 3 2115000 0.5
1983 1 3 1647000 0.5
1989 1 3 1238000 0.5
1992 1 3 2169000 0.25
1995 1 3 1385000 0.25
1998 1 3 1185000 0.25
2001 1 3 737000 0.25
2003 1 3 1840000 0.25
#2005 1 3 1073563 0.25
2005 1 3 1265000 0.25
1986 1 4 22.90 1.1
1987 1 4 522.17 1.1
1988 1 4 137.14 1.1

1989 1 4 7.45 1.1
1990 1 4 34.92 1.1
1991 1 4 43.34 1.1
1992 1 4 12.27 1.1
1993 1 4 1150.56 1.1
1994 1 4 32.14 1.1
1995 1 4 6.96 1.1
1996 1 4 98.89 1.1
1997 1 4 20.78 1.1
1998 1 4 4.74 1.1
1999 1 4 98.40 1.1
2000 1 4 13.25 1.1
2001 1 4 30.42 1.1
2002 1 4 8.08 1.1
2003 1 4 1.66 1.1
2004 1 4 94.31 1.1
2005 1 4 1.31 1.1

2 #_discard_type
0 #_N_discard_obs

0 #_N_meanbodywt_obs

-1 #_comp_tail_compression
0.0001 #_add_to_comp
51 #_N_LengthBins
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 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 63 64 65 66 67 68 69 70
59 #_N_Length_obs
#Yr Seas Flt/Svy Gender Part Nsamp datavector(female-male)
1975 1 1 0 0 13 0.0000 0.0000 0.0000 0.1310 0.4138 0.4138 0.6101 0.6101
0.3291 0.7411 1.5447 0.9566 4.6455 4.0107 4.1898 5.3717 3.0869 2.8926 2.0167 1.0373 4.3164 4.0849
7.0859 7.4219 7.1653 7.1658 4.9095 4.0224 5.0698 2.3889 3.2625 1.2916 3.4063 0.0000 1.1843 1.0342
0.3465 0.4138 0.8734 0.9032 0.3465 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.1310 0.1742
0.0000
1976 1 1 0 0 249 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0016 0.0000
0.0056 0.0033 0.0383 0.0461 0.0619 0.0983 0.2605 0.2710 0.4635 0.5851 0.9688 1.7104 2.6494 3.7108
5.1325 5.6852 6.3574 6.5997 6.6614 6.7014 6.7809 6.7467 6.3412 6.0203 5.7434 5.0318 4.0850 2.9869
2.1415 1.3175 1.1743 0.7971 0.5916 0.4178 0.3714 0.2021 0.3217 0.1198 0.0626 0.1229 0.0766 0.0428
0.4921
1977 1 1 0 0 1071 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0018 0.0134 0.0376 0.0706 0.1661 0.4152 0.6903 1.1624 1.8450 2.7529
4.3062 5.5899 5.8003 7.0414 7.6587 8.0144 8.2014 8.0120 7.8118 7.2003 6.2315 4.7967 3.7873 2.7235
1.7045 1.2366 0.8199 0.5163 0.3222 0.2985 0.1799 0.1885 0.1195 0.0886 0.0573 0.0324 0.0296 0.0462
0.0296
1978 1 1 0 0 1135 0.0000 0.0137 0.0335 0.0204 0.0187 0.0129 0.0269 0.0195
0.0268 0.0177 0.0119 0.0196 0.0000 0.0052 0.0068 0.0000 0.0232 0.0374 0.1341 0.4019 1.1005 1.8736
3.2463 4.8921 6.2182 7.2486 8.1810 8.5122 8.8032 8.7842 8.3771 7.6130 6.8721 5.5053 3.9908 2.9505
1.7999 1.1040 0.6053 0.4234 0.2603 0.2115 0.1333 0.0826 0.1005 0.0837 0.0252 0.0539 0.0204 0.0118
0.0858
1979 1 1 0 0 1539 0.0037 0.0097 0.0000 0.0000 0.0045 0.0116 0.0377 0.1272
0.2419 0.3627 0.6064 0.9330 1.0785 1.2116 1.3609 1.1767 1.0738 0.9737 0.8697 0.7638 1.0134 1.2884
2.1901 3.1243 4.4482 5.5505 6.5905 7.3083 7.4803 7.3508 7.1915 6.8207 6.1776 5.2697 4.4570 3.4610
2.5085 1.9857 1.3847 1.0024 0.6851 0.4921 0.3971 0.2037 0.1600 0.1547 0.1172 0.0869 0.0479 0.0772
0.1275
1980 1 1 0 0 811 0.0091 0.0023 0.0015 0.0000 0.0073 0.0000 0.0000 0.0087
0.0126 0.0458 0.0204 0.0433 0.1149 0.2228 0.5250 0.7315 1.2779 2.1458 3.0350 3.7493 4.1531 4.0760
4.3104 4.0557 4.3473 4.6273 5.0774 5.6263 5.8858 6.0686 5.8665 5.5856 5.4307 5.0389 4.3970 3.5729
2.4554 2.0179 1.4813 1.1084 0.7881 0.5016 0.3861 0.4173 0.1653 0.1672 0.1005 0.0862 0.0783 0.0779
0.0960
1981 1 1 0 0 1093 0.0800 0.1084 0.3599 0.7080 0.9938 1.3236 1.4714 1.4205
1.1953 0.9210 0.5505 0.3604 0.3151 0.1801 0.1889 0.2756 0.5729 0.9527 1.7359 2.9281 4.0255 5.0184
5.6197 6.0028 6.2402 6.2228 6.0960 5.8936 5.4876 5.3678 5.1780 4.8316 4.1992 3.4228 2.5465 1.9163
1.4854 1.0655 0.5759 0.4974 0.3794 0.2661 0.1841 0.1667 0.1191 0.0804 0.0909 0.0528 0.0518 0.0368
0.2368
1982 1 1 0 0 1142 0.0012 0.0006 0.0006 0.0069 0.0278 0.0623 0.1581 0.3195
0.4785 0.7517 1.1521 1.7236 2.2861 2.4465 2.4854 2.2689 2.0172 1.5572 1.1535 1.1139 1.6668 2.6606
3.7590 4.8387 5.2255 5.3355 5.4254 5.3001 5.2641 5.1765 5.0040 4.8301 4.5324 4.1043 3.5769 3.1039
2.2985 1.8991 1.4468 1.2094 0.8385 0.6099 0.4744 0.3877 0.2877 0.1802 0.1433 0.1309 0.0730 0.0768
0.1282

1983 1 1 0 0 1069 0.0000 0.0000 0.0000 0.0000 0.0000 0.0019 0.0039 0.0049
0.0079 0.0489 0.1747 0.4093 0.9641 1.9860 3.0671 3.7988 4.5641 5.0988 5.4378 5.5811 5.4899 5.2058
4.8753 4.4715 4.3545 4.5081 4.6308 4.5736 4.3279 4.1003 3.7933 3.3540 3.0048 2.5516 2.1759 1.7089
1.3795 0.9958 0.7211 0.5140 0.4447 0.4355 0.3254 0.2806 0.1772 0.1214 0.0937 0.0720 0.0499 0.0400
0.0738
1984 1 1 0 0 2035 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0105 0.0637 0.2676 0.8974 2.4412 4.6053 7.0343 8.2610 8.8066 8.8926
8.7328 8.0202 6.4816 5.1629 4.8620 4.4832 4.1105 3.7143 3.0779 2.4524 1.9414 1.4921 1.0246 0.7090
0.4861 0.3571 0.2395 0.2084 0.1822 0.1480 0.1098 0.1142 0.0654 0.0783 0.0392 0.0748 0.0613 0.0518
0.2390
1985 1 1 0 0 2061 0.0087 0.0274 0.0648 0.1319 0.2167 0.3147 0.4723 0.5712
0.7749 0.8416 0.8311 0.7368 0.6614 0.4257 0.2871 0.2003 0.2466 0.5571 1.2729 2.9829 5.8356 7.8579
8.7403 9.0648 8.9656 8.5779 7.5892 6.4114 5.4273 4.5509 3.8589 2.9729 2.3139 1.7167 1.2206 0.8974
0.6230 0.3798 0.2779 0.1994 0.1635 0.1281 0.0756 0.1044 0.0668 0.0528 0.0551 0.0356 0.0388 0.0281
0.1439
1986 1 1 0 0 3878 0.0000 0.0016 0.0013 0.0000 0.0013 0.0028 0.0096 0.0200
0.0693 0.1515 0.3138 0.5911 1.1404 2.1111 3.2822 3.7332 3.8731 3.7860 3.3537 2.7946 3.0905 5.3259
7.2056 8.0638 8.2040 8.0180 7.5393 6.3690 4.9986 3.8386 3.0525 2.3423 1.8172 1.3727 1.0227 0.6270
0.4857 0.3479 0.2423 0.1877 0.1401 0.1158 0.0973 0.0599 0.0422 0.0187 0.0227 0.0287 0.0125 0.0215
0.0526
1987 1 1 0 0 3406 0.0007 0.0003 0.0003 0.0034 0.0017 0.0011 0.0010 0.0046
0.0057 0.0063 0.0188 0.0204 0.0694 0.2387 0.6284 1.1515 2.2635 4.1013 5.6298 6.4771 6.8780 6.9840
7.1824 7.5291 7.5888 7.4579 7.1477 6.4886 5.4910 4.4749 3.4480 2.5218 1.8452 1.3414 0.9380 0.5999
0.3987 0.3065 0.1802 0.1242 0.0990 0.0605 0.0629 0.0346 0.0404 0.0319 0.0267 0.0229 0.0186 0.0088
0.0434
1988 1 1 0 0 3035 0.0007 0.0000 0.0000 0.0000 0.0017 0.0093 0.0120 0.0258
0.0340 0.0449 0.0486 0.0299 0.0550 0.0644 0.1627 0.3887 0.8553 1.5375 3.2362 5.6799 7.6535 8.5678
8.8030 8.8150 8.6617 8.3324 8.0693 7.2917 6.1416 4.5565 3.2785 2.2118 1.6226 1.0448 0.8112 0.4643
0.3538 0.2647 0.2094 0.1601 0.0876 0.0695 0.0400 0.0650 0.0289 0.0369 0.0335 0.0233 0.0179 0.0229
0.0740
1989 1 1 0 0 2581 0.0005 0.0067 0.0011 0.0040 0.0045 0.0000 0.0043 0.0110
0.0275 0.1121 0.3024 0.6741 1.0166 1.2433 1.2873 1.1719 1.1842 1.3513 1.8609 3.2026 5.4862 7.6096
8.4166 8.5480 8.5158 8.3558 8.1199 7.4837 6.5009 5.1206 3.5657 2.4235 1.8394 1.2021 0.9268 0.6719
0.4551 0.2600 0.2193 0.2046 0.1429 0.0997 0.0843 0.0574 0.0486 0.0286 0.0164 0.0259 0.0302 0.0163
0.0577
1990 1 1 0 0 2039 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0011
0.0165 0.0335 0.0560 0.1147 0.2150 0.3131 0.6847 1.0370 1.6040 2.5415 3.9025 5.3464 6.1623 6.6671
7.1218 7.7462 7.9435 8.0196 7.9224 7.6186 6.9470 5.6783 3.7969 2.7834 1.6893 1.1798 0.7962 0.5256
0.3690 0.2677 0.2133 0.1416 0.0824 0.0778 0.0709 0.0621 0.0564 0.0224 0.0350 0.0320 0.0178 0.0174
0.0702
1991 1 1 0 0 817 0.0253 0.0066 0.0046 0.0095 0.0000 0.0000 0.0037 0.0188
0.0188 0.0064 0.0447 0.1253 0.2715 0.4231 0.8148 1.2033 2.0136 2.9728 3.5959 4.2063 4.7795 5.9500
6.1653 6.8269 8.1632 8.4062 8.7522 7.8287 6.3656 4.8131 3.4933 2.4196 1.6501 1.3979 1.2589 1.1846
1.1067 0.9981 0.8329 0.6915 0.3356 0.2210 0.1430 0.1272 0.0789 0.0680 0.0615 0.0107 0.0326 0.0170
0.0554
1992 1 1 0 0 836 0.0281 0.0667 0.0757 0.0833 0.0847 0.0681 0.0818 0.0962
0.1170 0.1903 0.2537 0.4457 0.6030 0.7764 1.1068 1.3336 1.8384 2.0298 1.6095 1.8875 3.7787 5.8426
7.3393 8.9692 10.0915 10.2542 9.9512 9.4832 7.3533 5.4802 3.2085 1.8284 1.2047 0.7084 0.4253 0.3018
0.2260 0.1613 0.1262 0.0848 0.0840 0.0563 0.0546 0.0267 0.0317 0.0166 0.0102 0.0082 0.0162 0.0065
0.0938
1993 1 1 0 0 442 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0070
0.0000 0.0000 0.0082 0.1118 0.0949 0.4661 1.0299 1.9220 3.7253 4.5722 6.2424 6.2361 5.8973 5.3501
5.8937 7.2187 8.3169 8.6226 8.8043 7.5067 7.1225 4.6537 2.7273 1.3580 0.5706 0.4606 0.3049 0.2458
0.1720 0.1125 0.0270 0.0518 0.0266 0.0349 0.0235 0.0061 0.0025 0.0025 0.0047 0.0000 0.0576 0.0000
0.0085
1994 1 1 0 0 649 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0015 0.0141 0.0015 0.0170 0.0052 0.0191 0.0819 0.1821 0.6538 1.5734 3.1216 4.4610 5.8132 6.9431
7.4792 8.1627 8.4792 9.3948 9.4855 8.9230 7.8291 5.9172 4.1409 2.6141 1.4632 1.0154 0.6571 0.4624
0.2675 0.1930 0.1728 0.1298 0.1028 0.0608 0.0196 0.0257 0.0226 0.0176 0.0132 0.0044 0.0019 0.0104
0.0457
1995 1 1 0 0 470 0.1038 0.0228 0.0198 0.0284 0.0357 0.0357 0.0357 0.0198
0.0000 0.0000 0.0091 0.0078 0.0571 0.0912 0.1238 0.1013 0.2443 0.2585 0.5044 1.1955 2.3724 4.4641
6.6707 9.0914 10.4171 10.4798 10.8746 9.6864 8.4629 6.6830 5.2642 3.6818 2.8972 1.8339 1.2249 0.8681
0.5701 0.5399 0.2679 0.2461 0.1648 0.1209 0.0787 0.0556 0.0218 0.0338 0.0073 0.0208 0.0036 0.0000
0.0018
1996 1 1 0 0 557 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0151 0.0148
0.0575 0.0624 0.3453 0.9726 1.5831 3.0203 3.8219 4.7231 4.1074 3.4972 3.3323 3.8879 4.0162 4.3223
4.5049 5.8851 7.4956 8.5752 8.2382 7.4850 6.1778 4.4124 3.4555 2.1185 1.4007 0.7752 0.5304 0.3100
0.2074 0.2374 0.1246 0.0495 0.0525 0.0369 0.0385 0.0192 0.0183 0.0234 0.0000 0.0000 0.0104 0.0000
0.0381

1997 1 1 0 0 681 0.0000 0.0000 0.0000 0.0000 0.0000 0.0054 0.0000 0.0000
0.0000 0.0000 0.0004 0.0129 0.0242 0.0621 0.1670 0.5697 1.1618 2.5034 4.2684 6.5930 9.1337 10.3301
10.9611 10.6951 9.1385 8.2452 6.7816 5.6553 4.4197 3.4122 2.0201 1.2148 0.7188 0.4538 0.3833 0.2249
0.2018 0.0783 0.1077 0.0375 0.0815 0.0931 0.1300 0.0086 0.0097 0.0081 0.0552 0.0051 0.0000 0.0129
0.0138
1998 1 1 0 0 803 0.0000 0.0019 0.0000 0.0356 0.0312 0.0000 0.0000 0.0018
0.0050 0.0307 0.1578 0.5719 1.1926 1.8658 1.8962 2.1940 3.1873 4.9169 5.9828 6.3878 6.7259 7.5506
8.9308 9.1918 8.9787 7.9720 6.5252 5.1066 3.8389 2.3801 1.5499 0.8679 0.5270 0.3689 0.2026 0.1499
0.1612 0.1050 0.0570 0.0861 0.0879 0.0039 0.0120 0.0034 0.0132 0.0171 0.0161 0.0014 0.0454 0.0000
0.0642
1999 1 1 0 0 2268 0.0028 0.0000 0.0000 0.0030 0.0088 0.0298 0.0088 0.0562
0.1532 0.3180 0.7684 1.1024 1.6890 2.4598 3.4549 4.0658 5.0615 5.8249 6.6752 6.3233 6.6134 6.1512
6.1289 6.7057 6.9914 7.0649 6.3137 4.8892 3.6905 2.3132 1.5526 1.0083 0.7842 0.4498 0.3077 0.1635
0.1629 0.1472 0.0544 0.1511 0.0529 0.0800 0.0497 0.0106 0.0125 0.0187 0.0165 0.0089 0.0198 0.0152
0.0657
2000 1 1 0 0 2199 0.0008 0.0000 0.0000 0.0000 0.0000 0.0049 0.0230 0.0779
0.1520 0.3576 0.3585 0.3253 0.2198 0.2314 0.2139 0.3953 0.6127 1.1692 1.9467 2.6461 4.1004 4.7630
5.8897 6.8340 8.3000 9.5471 9.8429 9.2381 8.5885 6.6670 5.2995 3.7409 2.5171 1.7399 1.2479 0.7236
0.4943 0.5228 0.3619 0.2084 0.1557 0.1254 0.0844 0.0832 0.0432 0.0291 0.0261 0.0251 0.0104 0.0289
0.0260
2001 1 1 0 0 2239 0.0040 0.0047 0.0000 0.0142 0.0049 0.0144 0.0049 0.0450
0.0368 0.1065 0.2524 0.5181 0.7379 1.0920 1.5401 2.4071 3.1572 3.3718 3.3389 3.6980 4.1295 4.9045
5.9444 6.3796 6.9969 7.3855 8.0234 8.2212 7.5621 5.8676 4.3308 3.3034 2.0719 1.5149 0.9362 0.6821
0.4124 0.2491 0.1603 0.1745 0.1023 0.0504 0.0731 0.0517 0.0206 0.0268 0.0330 0.0073 0.0166 0.0030
0.0161
2002 1 1 0 0 1821 0.0000 0.0000 0.0000 0.0000 0.0000 0.0153 0.0000 0.0005
0.0005 0.0009 0.0349 0.0455 0.0237 0.0205 0.1192 0.3983 0.9800 2.6734 5.4078 8.8163 10.7909 12.1021
11.2284 9.1867 6.7869 5.1606 4.4545 3.5139 3.1230 2.9931 2.6154 2.2683 1.8634 1.5485 1.1389 0.7967
0.4894 0.3872 0.2213 0.1985 0.1627 0.1216 0.0636 0.0584 0.0544 0.0301 0.0271 0.0061 0.0231 0.0117
0.0366
2003 1 1 0 0 1915 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0300 0.0000 0.0000 0.0387 0.0022 0.0769 0.0808 0.1733 0.9888 2.3873 4.6812 8.0242 11.1703 11.9985
12.9450 12.6406 10.5481 8.0278 5.3379 3.5339 2.3350 1.6809 1.1599 0.7129 0.4354 0.2866 0.2158 0.1281
0.1050 0.0474 0.0597 0.0310 0.0171 0.0142 0.0162 0.0138 0.0066 0.0076 0.0093 0.0099 0.0000 0.0080
0.0143
2004 1 1 0 0 2797 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0007 0.0016 0.0038 0.0089 0.0000 0.0000 0.0081 0.0131 0.0296 0.1831 0.6135 1.4590 3.7500 7.0232
11.1220 14.3372 15.4579 14.7871 10.8375 7.4020 4.8577 2.7464 1.7989 1.2653 0.6564 0.3878 0.2692 0.2233
0.2484 0.0934 0.0338 0.0283 0.0757 0.0703 0.0158 0.0102 0.0581 0.0045 0.0151 0.0173 0.0045 0.0044
0.0767
2005 1 1 0 0 3064 0.0039 0.0031 0.0026 0.0020 0.0000 0.0023 0.0000 0.0000
0.0000 0.0030 0.0024 0.0063 0.0239 0.0509 0.0915 0.1204 0.1841 0.4387 0.5751 0.6107 1.1091 2.4939
6.2652 12.8750 18.8037 19.4426 15.5383 9.6723 5.1798 2.7770 1.4521 0.8477 0.4493 0.3130 0.1687 0.1364
0.0896 0.0711 0.0473 0.0281 0.0267 0.0180 0.0129 0.0096 0.0076 0.0067 0.0072 0.0038 0.0045 0.0044
0.0175
1988 1 2 0 0 38 0.0000 0.0000 0.0000 0.0015 0.0042 0.0013 0.0000 0.0012
0.0000 0.0026 0.0047 0.0016 0.0109 0.0287 0.0347 0.1011 0.1622 0.2725 0.4999 0.8217 1.6591 3.0254
5.2973 7.5743 9.8487 11.8018 11.9507 10.6459 8.8695 6.9198 5.2416 4.0676 3.0620 2.1469 1.6566 1.2806
0.8882 0.6213 0.4338 0.3289 0.2480 0.1422 0.0926 0.0926 0.0635 0.0281 0.0175 0.0131 0.0143 0.0048
0.0143
1989 1 2 0 0 43 0.0040 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0008
0.0000 0.0000 0.0000 0.0000 0.0000 0.0079 0.0039 0.0013 0.0116 0.0234 0.0729 0.1029 0.3302 1.1841
3.6208 7.3076 11.0626 13.9101 14.3775 12.2475 10.0729 7.4976 5.3460 3.8031 2.5146 1.9580 1.3638 0.8697
0.6090 0.4848 0.2969 0.2583 0.2076 0.1215 0.0985 0.0644 0.0415 0.0313 0.0347 0.0133 0.0026 0.0093
0.0314
1990 1 2 0 0 33 0.0025 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0146 0.0089 0.0665 0.0878 0.1169 0.2445 0.6916 0.8924
1.9520 4.6396 8.2469 13.1450 15.1195 14.6946 12.1628 8.7682 6.0184 3.8082 2.6119 1.7409 1.1643 0.8935
0.7293 0.4191 0.3702 0.2793 0.2472 0.1841 0.1927 0.1571 0.0847 0.0648 0.0653 0.0228 0.0194 0.0370
0.0351
1991 1 2 0 0 56 0.0020 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0031 0.0100 0.0000 0.0033 0.0073 0.0033 0.0288 0.0615 0.1335 0.1961 0.2554 0.5079
0.7854 1.3650 3.2862 6.6629 11.0345 14.2636 15.4089 13.1927 9.9821 7.0393 4.8797 3.3430 2.1798 1.4970
1.0171 0.7579 0.5609 0.3871 0.3152 0.2666 0.1598 0.1119 0.0769 0.0668 0.0524 0.0185 0.0272 0.0168
0.0327
1992 1 2 0 0 60 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0015 0.0000 0.0000 0.0000 0.0017 0.0017 0.0070 0.0113 0.0170 0.1428 0.4641
1.4115 3.5680 7.2311 11.7795 16.0994 16.7776 14.5902 10.6207 6.6180 3.9245 2.3324 1.3938 0.8834 0.5575
0.3640 0.2610 0.2263 0.1462 0.1277 0.1166 0.0871 0.0495 0.0532 0.0353 0.0125 0.0261 0.0057 0.0117
0.0424

1993 1 2 0 0 60 0.0102 0.0000 0.0000 0.0017 0.0000 0.0014 0.0000 0.0014
0.0103 0.0061 0.0079 0.0053 0.0019 0.0014 0.0039 0.0054 0.0045 0.0070 0.0187 0.0581 0.2378 0.6761
1.7934 4.2474 9.5096 15.5218 19.1337 17.8105 12.9661 7.8210 4.2887 2.2775 1.3447 0.7572 0.4675 0.3220
0.2047 0.1464 0.1057 0.0596 0.0460 0.0213 0.0202 0.0200 0.0028 0.0151 0.0076 0.0100 0.0072 0.0031
0.0103
1994 1 2 0 0 76 0.0391 0.0037 0.0033 0.0034 0.0025 0.0051 0.0019 0.0009
0.0027 0.0026 0.0015 0.0000 0.0017 0.0023 0.0013 0.0090 0.0121 0.0202 0.0211 0.0403 0.1377 0.3263
0.7286 1.8425 4.1592 8.2000 13.3817 16.8869 16.0807 12.8616 9.0190 5.6153 3.4957 2.2325 1.5106 0.9776
0.6701 0.4595 0.3314 0.2424 0.1778 0.1279 0.0899 0.0687 0.0405 0.0392 0.0236 0.0318 0.0200 0.0084
0.0378
1995 1 2 0 0 43 0.5433 0.5663 1.5444 2.8853 2.8406 3.0367 2.0194 1.2639
0.6258 0.1966 0.0873 0.0440 0.0292 0.0483 0.0254 0.0278 0.0167 0.0000 0.0000 0.0034 0.0068 0.0722
0.2495 0.9728 2.6665 5.3574 9.1578 12.8613 14.7039 12.3917 9.3775 5.8628 3.5750 2.4331 1.2689 0.9287
0.6043 0.4867 0.3577 0.3214 0.1383 0.1170 0.0715 0.0482 0.0518 0.0412 0.0355 0.0100 0.0000 0.0113
0.0151
1996 1 2 0 0 54 0.0024 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0069 0.0168 0.0622 0.1235 0.2794 0.4614 0.8566 1.3516 1.9391 2.2300 2.0055 1.5635 1.2560
1.4221 2.7105 5.4517 10.2072 14.0882 15.4694 13.5617 9.5714 6.3589 3.5570 2.0126 1.1256 0.7121 0.4531
0.2665 0.2264 0.1552 0.0981 0.0831 0.0799 0.0618 0.0397 0.0297 0.0245 0.0246 0.0090 0.0115 0.0090
0.0244
1997 1 2 0 0 102 0.0000 0.0000 0.0045 0.0045 0.0175 0.0095 0.0180 0.0283
0.0240 0.0361 0.0300 0.0346 0.0303 0.0320 0.0191 0.0136 0.0307 0.1000 0.2532 0.9009 2.1714 3.9752
6.0868 7.3180 8.2774 8.8846 10.3676 10.7128 10.2442 8.6087 6.4056 4.5583 3.0897 2.2322 1.5336 1.0943
0.7586 0.6056 0.3728 0.2314 0.2456 0.1737 0.1118 0.0810 0.0760 0.0483 0.0550 0.0183 0.0299 0.0052
0.0394
1998 1 2 0 0 94 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0291 0.0055 0.0152 0.0201 0.0309 0.0786 0.2148 0.4806 0.9896 1.9114 3.1067 4.6458
7.7507 10.9445 13.0675 13.7215 12.3742 9.4706 6.3908 4.2349 2.5262 1.4915 0.9287 0.5946 0.3971 0.2716
0.2143 0.1214 0.1003 0.0878 0.0475 0.0406 0.0232 0.0258 0.0235 0.0122 0.0057 0.0036 0.0029 0.0049
0.0093
1999 1 2 0 0 136 0.0000 0.0140 0.0037 0.0090 0.0010 0.0034 0.0066 0.0057
0.0316 0.0521 0.1189 0.3614 0.7028 1.1060 1.7214 1.9452 2.0639 2.0924 2.2368 2.8403 3.0093 3.6328
4.6785 6.2507 8.1427 10.3291 10.9685 10.3095 8.5619 6.2326 3.9248 2.8442 1.7230 1.1824 0.7861 0.5753
0.4115 0.2814 0.1936 0.1657 0.0846 0.1275 0.0871 0.0396 0.0642 0.0204 0.0157 0.0201 0.0028 0.0078
0.0104
2000 1 2 0 0 16 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0002 0.0115 0.0269 0.0783 0.2229 0.5715 0.8796 1.3716 1.4679 1.9613 2.4665 3.4212
4.4835 5.4263 6.1167 6.3849 7.2244 8.1919 8.6751 8.1729 7.9389 6.0299 4.6940 3.5788 2.7613 1.9144
1.6095 1.1091 0.8607 0.6031 0.4619 0.4388 0.2513 0.2007 0.1381 0.0794 0.0489 0.0472 0.0230 0.0196
0.0364
2001 1 2 0 0 72 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0095
0.0067 0.0587 0.2057 0.2672 0.2541 0.2360 0.2768 0.1680 0.1071 0.0729 0.0268 0.0359 0.0413 0.0228
0.1328 0.3029 0.7079 1.4757 3.0338 5.7325 8.9079 11.2086 12.8480 11.8996 10.4744 8.4391 6.5580 4.7269
3.5529 2.5374 1.8422 1.1844 0.7793 0.5817 0.3953 0.2782 0.2220 0.1321 0.1047 0.0273 0.0319 0.0287
0.0642
2002 1 2 0 0 103 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0116 0.0168 0.0046 0.0046 0.0049 0.0295 0.0076 0.0620 0.0081 0.0366
0.1599 0.2942 0.4882 1.1396 1.3920 2.5956 4.8810 7.4663 10.1087 12.5335 12.7077 11.0521 8.9671 6.8943
5.5104 4.3519 2.7694 1.8741 1.5376 1.1212 0.6999 0.4071 0.2684 0.1780 0.1428 0.0868 0.0675 0.0483
0.0700
2003 1 2 0 0 118 0.0000 0.0078 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0091 0.0000 0.0376 0.0168 0.0530 0.0391 0.0327 0.0427 0.0346 0.0000 0.2505 1.1718
2.9946 5.7363 9.9890 11.3838 12.8838 11.9749 10.6071 9.6759 6.2904 4.3829 3.3957 2.1501 1.5351 1.2581
1.0889 0.6767 0.5597 0.3709 0.3422 0.3288 0.1696 0.2269 0.0750 0.0465 0.0194 0.0403 0.0334 0.0069
0.0614
2004 1 2 0 0 101 0.0023 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0023 0.0064 0.0000 0.0070 0.0080 0.0116 0.0067 0.0323 0.0295 0.0828 0.1954 0.6188 1.7741
4.5173 8.9999 13.0525 15.3074 14.1836 12.1532 9.2861 6.4924 4.2643 2.8084 1.8428 1.1967 0.7829 0.6262
0.4351 0.3246 0.2555 0.1571 0.1370 0.0928 0.0753 0.0591 0.0316 0.0263 0.0152 0.0227 0.0202 0.0102
0.0464
2005 1 2 0 0 15 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0725 0.1077 0.1977 0.6648 0.9805
2.9974 6.5045 9.9976 13.1943 15.2801 13.8470 10.8480 8.5224 5.6856 3.3915 2.2879 1.4004 1.1228 0.7615
0.6550 0.4855 0.3073 0.1842 0.0406 0.2334 0.0693 0.0561 0.0344 0.0426 0.0048 0.0000 0.0066 0.0000
0.0161
1977 1 3 0 0 85 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0762 0.1870 0.4156 0.4018 0.6304 0.6719 0.8313 1.2122 1.3716 1.3716 1.5932 2.1543
2.7847 3.6021 4.1009 4.3918 5.1676 6.9825 8.2433 9.4417 8.9983 7.4397 6.5738 5.2092 3.8930 2.7847
2.2582 1.7872 1.1153 0.8728 0.7551 0.5819 0.5611 0.3671 0.3117 0.1940 0.2078 0.1316 0.0485 0.0554
0.0554

1980 1 3 0 0 49 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0241 0.0000 0.0241 0.0723 0.3135 0.6872 1.7483 3.7618 5.6909 6.1249 5.2689 3.8582
1.5192 0.8922 0.5426 0.7596 1.9050 3.2433 5.8235 8.3193 9.2838 8.5483 8.1022 6.2937 4.7263 3.0625
2.0979 1.5915 1.0851 0.6872 0.6028 0.4943 0.2773 0.1688 0.2411 0.1206 0.1326 0.1206 0.1085 0.0603
0.0603
1983 1 3 0 0 35 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0232 0.0116 0.0348 0.4295 1.6369 4.1560 7.8941 10.5410 11.4465 9.2408 7.7084 5.4678
3.6568 2.4611 2.1477 2.4611 3.3666 4.0051 4.2141 3.8542 3.5407 2.8326 2.2638 1.8923 1.4511 0.8591
0.7198 0.4644 0.2786 0.3367 0.1741 0.1393 0.0929 0.0580 0.0116 0.0116 0.0580 0.0116 0.0116 0.0232
0.0000
1989 1 3 0 0 22 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0534 0.0356 0.0000 0.0356 0.1956 0.5513 1.9029 2.2230 2.1697 1.3694 1.5472 2.6143
7.9673 13.8182 16.6993 16.3258 11.4885 7.7361 4.6239 2.4898 1.6895 0.9248 0.5513 0.3557 0.2668 0.1601
0.1067 0.0178 0.1423 0.0000 0.0178 0.0000 0.0000 0.0178 0.0178 0.0356 0.0000 0.0000 0.0000 0.0000
0.0178
1992 1 3 0 0 43 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.9966 1.0747 1.1451 2.0523 2.2678 1.3747 0.7046 0.4705 0.1384 0.2064 0.5554 1.7227
3.9070 6.9265 10.1668 13.5941 14.4537 11.2977 7.4794 4.4176 2.5313 1.2286 0.5984 0.4789 0.2226 0.1257
0.1510 0.0318 0.0608 0.0354 0.0260 0.0126 0.0029 0.0043 0.0014 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
1995 1 3 0 0 69 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.2414 0.3534 1.4379 4.0874 8.1213 8.5327 6.1473 2.9749 1.2684 0.5451 0.5222 1.2059
2.6843 4.8278 6.9954 8.0774 8.3294 7.4855 6.1477 3.8777 2.5148 1.2530 0.8335 0.3644 0.2652 0.1357
0.0966 0.0656 0.0532 0.0414 0.0348 0.0181 0.0073 0.0056 0.0032 0.0024 0.0091 0.0226 0.0176 0.0037
0.0037
1998 1 3 0 0 84 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 1.9111 2.3583 2.7987 2.9771 2.6344 1.9192 1.7780 2.5431 3.2512 3.6925 3.7927 4.3047
5.4560 7.6075 8.0688 8.4396 7.5478 6.2551 4.9928 3.5322 2.5057 1.6519 1.0415 0.7464 0.4515 0.3132
0.2538 0.1641 0.1156 0.0562 0.0557 0.0423 0.0236 0.0210 0.0125 0.0035 0.0053 0.0059 0.0084 0.0061
0.0135
2001 1 3 0 0 49 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 1.3525 4.1216 8.3658 14.6019 16.9774 14.2018 8.5876 3.5231 1.6717 1.4485 1.5298 1.9460
1.9285 1.9610 1.8787 2.2680 2.1509 2.2040 2.1926 1.9429 1.1800 0.8779 0.6301 0.4768 0.3006 0.2136
0.1543 0.1206 0.0551 0.0789 0.0185 0.0621 0.0381 0.0841 0.0565 0.0314 0.0243 0.0261 0.0014 0.0354
0.0687
2003 1 3 0 0 71 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0944 0.1537 0.3314 0.4047 0.7614 0.6356 1.1926 1.0760 1.7630 1.7640 4.4833 7.5862
14.3289 14.8713 13.9081 10.0821 7.4014 5.8903 3.9399 2.7178 1.9627 1.3133 0.9244 0.6519 0.4871 0.3781
0.2422 0.1693 0.1103 0.1016 0.0309 0.0101 0.0184 0.0231 0.0085 0.0160 0.0057 0.0028 0.0028 0.0046
0.0249
2005 1 3 0 0 49 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.5764 0.6518 2.2930 3.3930 4.9816 3.7852 2.8587 2.0472 1.2751 1.0973 1.1591 2.8742
4.7100 8.8084 14.7650 12.1110 12.1030 6.6716 5.1654 3.3105 1.6901 1.0512 0.6182 0.3690 0.1856 0.1908
0.1801 0.0734 0.0314 0.0457 0.0478 0.0314 0.0335 0.0175 0.0161 0.0124 0.0118 0.0879 0.0000 0.0000
0.0131

14 #_N_age_bins
2 3 4 5 6 7 8 9 10 11 12 13 14 15
1 #_N_ageerror_definitions
0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 13.5
14.5 15.5
0.000001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001
0.0001 0.0001
#0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001 0.0000001
0.0000001 0.0000001

2212 #_N_Agecomp_obs
Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)
1973 1 1 0 0 1 1 51 60 0.00000 0.25999 0.04498 0.10099 0.18700
0.11699 0.10699 0.10001 0.04801 0.02098 0.00903 0.00502 0.00000 0.00000
1974 1 1 0 0 1 1 51 60 0.00439 0.00331 0.50658 0.06924 0.11978
0.14944 0.08681 0.03846 0.01208 0.00550 0.00331 0.00111 0.00000 0.00000
1975 1 1 0 0 1 4 4 1 100.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1975 1 1 0 0 1 5 5 1 100.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1985 1 1 0 0 1 16 16 1 100.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

1985	1	1	0	0	1	17	17	1	100.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	18	18	2	0.0000	0.0000	100.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	19	19	7	4.9113	33.6362	0.0000	61.4525	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	20	20	16	0.0000	0.0000	21.2589	78.7411	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	21	21	43	0.6274	0.1817	27.1075	69.0188	3.0646
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	22	22	78	0.0000	0.0000	14.4384	76.7545	8.8071
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	23	23	107	0.0000	0.0000	12.9545	83.5932	3.4523
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	24	24	121	0.0000	0.0000	8.5546	88.6021	2.5742
0.2690	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	25	25	124	0.0000	0.0000	3.9961	89.7364	6.2003
0.0672	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	26	26	115	0.0000	0.0000	2.3387	88.6879	6.4600
0.9930	1.5205	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	27	27	101	0.0000	0.0000	1.0296	80.0792	9.9326
4.9880	3.9706	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	28	28	79	0.0000	0.0000	0.9827	61.6474	10.3871
15.2938	11.6891	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	29	29	63	0.0000	0.0000	0.0000	41.5022	24.1526
17.8557	16.1533	0.3363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	30	30	58	0.0000	0.0000	0.0000	29.5440	16.5183
17.8796	34.1454	1.9127	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	31	31	52	0.0000	0.0000	0.0000	15.1122	13.5739
15.4814	50.7642	4.7016	0.0084	0.0000	0.3583	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	32	32	25	0.0000	0.0000	0.0000	4.4790	24.6862
8.7998	54.3793	0.0000	5.1079	0.0000	2.5479	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	33	33	24	0.0000	0.0000	0.0000	0.0000	0.0000
15.8630	66.9781	1.3128	4.1447	11.7015	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	34	34	17	0.0000	0.0000	0.0000	0.0000	16.1168
29.9989	38.7397	0.0000	5.4183	9.7263	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	35	35	15	0.0000	0.0000	0.0000	0.0000	0.0000
9.0182	50.5774	20.5277	11.5148	0.0000	8.3619	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	36	36	11	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	39.8294	35.8073	18.3288	4.8177	1.2168	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	37	37	3	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	14.0538	0.0000	0.0000	67.0945	18.8517	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	38	38	4	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	6.6840	93.3160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	39	39	3	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	10.4694	0.0000	51.1219	38.4087	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	41	41	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	42	42	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1985	1	1	0	0	1	49	49	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000	0.0000					
1986	1	1	0	0	1	5	5	1	100.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	10	10	1	0.0000	100.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	11	11	5	79.8566	20.1434	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	12	12	8	83.6901	9.8684	0.0000	0.0000	6.4415
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	13	13	19	74.7533	25.2467	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	14	14	22	89.5239	10.4761	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	15	15	49	89.2371	10.3292	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4337	0.0000	0.0000					
1986	1	1	0	0	1	16	16	41	93.1547	6.8453	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1986	1	1	0	0	1	17	17	42	89.9281	10.0719	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					

1986 1 1 0 0 1 18 18 40 76.5963 20.2151 2.2675 0.0000 0.9210
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1986 1 1 0 0 1 19 19 39 53.4605 36.1108 4.3440 2.3386 3.7462
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1.5984 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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7.3691 0.2965 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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1986 1 1 0 0 1 44 44 3 0.0000 0.0000 0.0000 0.0000 0.0000
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0.0000 28.2930 17.9409 14.1465 26.8878 0.0000 12.7319 0.0000 0.0000
1986 1 1 0 0 1 46 46 5 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 38.4089 5.6215 25.3539 0.0000 30.6157
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0.0000 0.0000 0.0000 5.2497 10.3457 15.6332 51.8557 0.0000 11.6660
1986 1 1 0 0 1 48 48 4 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 6.0976 34.7513 0.0000 16.6121 42.5390 0.0000
1986 1 1 0 0 1 49 49 3 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 14.2360 0.0000 0.0000 14.2360 0.0000 71.5281 0.0000 0.0000
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0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 54.2903 0.0000 45.7097
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1987 1 1 0 0 1 15 15 6 0.0000 100.0000 0.0000 0.0000 0.0000
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1987 1 1 0 0 1 16 16 16 0.0000 100.0000 0.0000 0.0000 0.0000
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0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

1994	1	1	0	0	1	19	19	50	1.8680	48.6707	47.0787	2.3826	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	20	20	78	0.0000	15.1851	80.2214	1.7943	2.4395
0.3597	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	21	21	92	0.0000	7.4672	81.4237	2.4783	6.7482
1.8826	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	22	22	101	0.0000	2.2666	79.6364	3.2295	12.6035
2.2640	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	23	23	110	0.0000	0.1925	67.5244	0.4179	17.5069
12.0614	0.0000	0.0000	1.1983	0.0000	0.0000	0.0000	1.0985	0.0000					
1994	1	1	0	0	1	24	24	119	0.0000	0.7053	34.7015	1.1278	33.2490
22.2028	0.0000	0.0000	6.0003	0.0000	0.0000	0.0000	2.0131	0.0000					
1994	1	1	0	0	1	25	25	137	0.0000	0.0000	17.3120	1.5657	29.6653
33.2830	0.0000	0.0000	16.9740	0.0000	0.3196	0.0000	0.4824	0.3980					
1994	1	1	0	0	1	26	26	137	0.0000	0.3011	4.5976	1.0668	23.0907
37.0423	0.1912	1.7357	28.9353	0.0000	0.0802	0.0000	2.8166	0.1426					
1994	1	1	0	0	1	27	27	137	0.0000	0.0000	1.2714	0.5974	21.1297
34.7632	0.6325	0.8620	30.5817	0.4105	0.6265	0.0000	8.9734	0.1516					
1994	1	1	0	0	1	28	28	132	0.0000	0.0000	3.1579	0.0000	11.8576
36.3994	0.6855	0.2132	38.4685	0.2357	0.0000	0.0000	8.2000	0.7822					
1994	1	1	0	0	1	29	29	129	0.0000	0.0000	0.0000	0.0000	5.7130
24.4473	2.3976	0.3604	54.2546	0.0000	1.0564	0.0000	9.6954	2.0752					
1994	1	1	0	0	1	30	30	119	0.0000	0.0000	0.0000	0.0000	0.3652
22.6783	0.9316	0.0000	45.0842	0.0000	0.2567	0.0000	27.7171	2.9669					
1994	1	1	0	0	1	31	31	81	0.0000	0.0000	0.9535	0.0000	2.6385
24.3381	4.2003	1.1585	43.4636	0.0000	3.4730	0.6564	16.6180	2.5002					
1994	1	1	0	0	1	32	32	47	0.0000	0.0000	0.0000	0.0000	1.1444
19.6826	0.0000	0.0000	56.1426	0.0000	3.6309	0.0000	19.0465	0.3531					
1994	1	1	0	0	1	33	33	30	0.0000	0.0000	0.0000	0.0000	6.8912
5.3691	0.0000	0.0000	47.7638	0.0000	0.0000	0.0000	32.3602	7.6157					
1994	1	1	0	0	1	34	34	16	0.0000	0.0000	0.0000	0.0000	0.0000
4.4743	0.0000	0.0000	80.0104	0.0000	0.0000	1.7563	13.7590	0.0000					
1994	1	1	0	0	1	35	35	14	0.0000	0.0000	0.0000	0.0000	0.0000
6.4833	16.5006	0.0000	70.7904	0.0000	0.0000	0.0000	6.2257	0.0000					
1994	1	1	0	0	1	36	36	9	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	57.4999	0.0000	12.5099	0.0000	29.5010	0.4892					
1994	1	1	0	0	1	37	37	4	0.0000	0.0000	0.0000	0.0000	0.0000
12.0634	0.0000	0.0000	87.9366	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	38	38	7	0.0000	0.0000	0.0000	0.0000	0.0000
15.2486	0.0000	0.0000	72.0846	0.0000	0.0000	0.0000	12.6668	0.0000					
1994	1	1	0	0	1	39	39	6	0.0000	0.0000	0.0000	0.0000	0.0000
28.2282	0.0000	0.0000	14.9682	0.0000	0.0000	0.0000	41.1625	15.6411					
1994	1	1	0	0	1	40	40	2	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	82.0092	0.0000	0.0000	0.0000	17.9908	0.0000					
1994	1	1	0	0	1	41	41	3	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	40.7924	0.0000	0.0000	0.0000	59.2076	0.0000					
1994	1	1	0	0	1	42	42	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000					
1994	1	1	0	0	1	43	43	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	44	44	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000					
1994	1	1	0	0	1	45	45	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	46	46	2	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000					
1994	1	1	0	0	1	48	48	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1994	1	1	0	0	1	49	49	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000					
1994	1	1	0	0	1	50	50	1	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000					
1994	1	1	0	0	1	51	51	5	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	81.4970	18.5030					
1995	1	1	0	0	1	1	1	1	100.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1995	1	1	0	0	1	5	5	1	100.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
1995	1	1	0	0	1	6	6	1	100.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					

1995 1 1 0 0 1 7 7 1 100.0000 0.0000 0.0000 0.0000 0.0000
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0.0000 0.0000 100.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

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   0.0000 0.0000 0.0000 42.8571 14.2857 14.2857 0.0000 14.2857 0.0000

0 #_N_MeanSize-at-Age_obs
#Yr Seas Flt/Svy Gender Part Ageerr Ignore datavector(female-male)
#                                samplesize(female-male)

0 #_N_environ_variables
0 #_N_environ_obs

999
```