Status of the spiny dogfish shark resource

off the continental U.S. Pacific Coast in 2011

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EXECUTIVE SUMMARY

Stock

Spiny dogfish (*Squalus suckleyi*) in the Northeast Pacific Ocean occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts. This assessment focuses on a portion of a population that occurs in coastal waters of the western United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The assessment area does not include Puget Sound or any other inland waters. The population within this area is treated as a single coast-wide stock, given the migratory nature of the species and the lack of data suggesting the presence of multiple stocks.

The spiny dogfish stock included in this assessment likely has interaction and overlap with dogfish observed off British Columbia. A spatial population dynamics model, which included data from several tagging studies in the Northeast Pacific Ocean, estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. Given this relatively low estimated rate of exchange, it was considered appropriate to proceed with the assessment for the limited area of species range, recognizing that the scope of this assessment does not capture all of the removals and dynamics which likely bear on the status and trends of the larger, transboundary population.

Catches

In the coastal waters of the U.S. west coast, spiny dogfish has been utilized since early 20th century. The history of dogfish utilization included a brief but intense fishery in the 1940s, which started soon after it was discovered that livers of spiny dogfish contain high level of vitamin A. During the vitamin A fishery, removals averaged around 6,821mt per year reaching their peak of 16,876 mt in 1944. The fishery ended in 1950 with the advent of synthetic vitamins. In the mid-1970s, a food fish market developed for dogfish when the species was harvested and exported to other counties, primarily Great Britain. This fishery existed until very recently and the landings averaged around 450 mt per year. For the last 10 years landings ranged between 164 and 876 mt.

Even though spiny dogfish was heavily harvested in the 1940s, in general this species is not highly prized and is mostly taken as bycatch in other commercially important fisheries. It is often discarded when bycaught. It has been taken by three major gear groups, including trawl, hook-and-line and a variety of nets. Since 2002, the discard rates in the trawl fishery were on average 85% of all encountered dogfish catch and in the hook-and-line fishery 52%.The vast majority of commercial catch (more than 90%) has been landed in Washington. A small portion of the catch is taken recreationally.

The landings of spiny dogfish were reconstructed back to 1916 from variety of published sources and databases. Gear-specific discards were also reconstructed outside the model and included as separate fleets. The fishery removals in the assessment were divided among eight fisheries – bottom trawl, bottom trawl discard, midwater trawl, hook-and-line, hook-and line discard, other gears (primarily nets), recreational fishery and at-sea hake fishery bycatch.

Table ES-1. Recent removals (mt) of spiny dogfish by fleet (BT=bottom trawl, BTD=bottom trawl discard, MDT=midwater trawl, ASH=at-sea hake fishery bycatch, HKL=hook-and-line, HKLD=hook-and-line discard, OTH=others, REC=recreational).

Year	BT	BTD	MDT	ASH	HKL	HKLD	OTH	REC	TOTAL
2001	333	941	13	237	216	128	2	9	1,879
2002	437	856	29	299	409	114	0	15	2,159
2003	194	807	8	271	237	57	9	11	1,593
2004	129	1,114	38	613	235	100	5	3	2,238
2005	129	1,517	71	355	233	78	7	4	2,396
2006	117	906	106	59	191	178	6	4	1,567
2007	63	658	98	155	217	167	0	6	1,364
2008	43	994	158	673	281	135	15	3	2,300
2009	78	587	76	164	55	181	1	4	1,147
2010	42	691	111	278	10	28	0	2	1,163

Data and Assessment

This is the first assessment for spiny dogfish off the continental U.S. Pacific Coast. In the assessment, the Stock Synthesis modeling platform (version 3.21f) was used to conduct the analysis and estimate management quantities. The modeling period begins in 1916, assuming an unfished equilibrium state of the stock in 1915. The assessment treats females and males separately due to differences in biology and life history parameters between genders.

The model includes eight fishing fleets (bottom trawl, bottom trawl discard, midwater trawl, hook-and-line, hook-and line discard, other gears, recreational fishery and at-sea hake fishery bycatch) that operate within the entire area of assessment. Fishery-dependent biological data are derived from both port and on-board observer sampling programs. Discard information is provided by the West Coast Groundfish Observer Program.

Fishery-independent data are derived from four NOAA Fisheries trawl surveys conducted by Northwest and Alaska Fisheries Science Centers on the continental shelf and slope of the Northeast Pacific Ocean, and one International Pacific Halibut Commission longline survey. Surveys data used in the assessment included abundance indices and fishery-independent biological samples that together provide information on relative trend and demographics of the spiny dogfish in the assessed area.

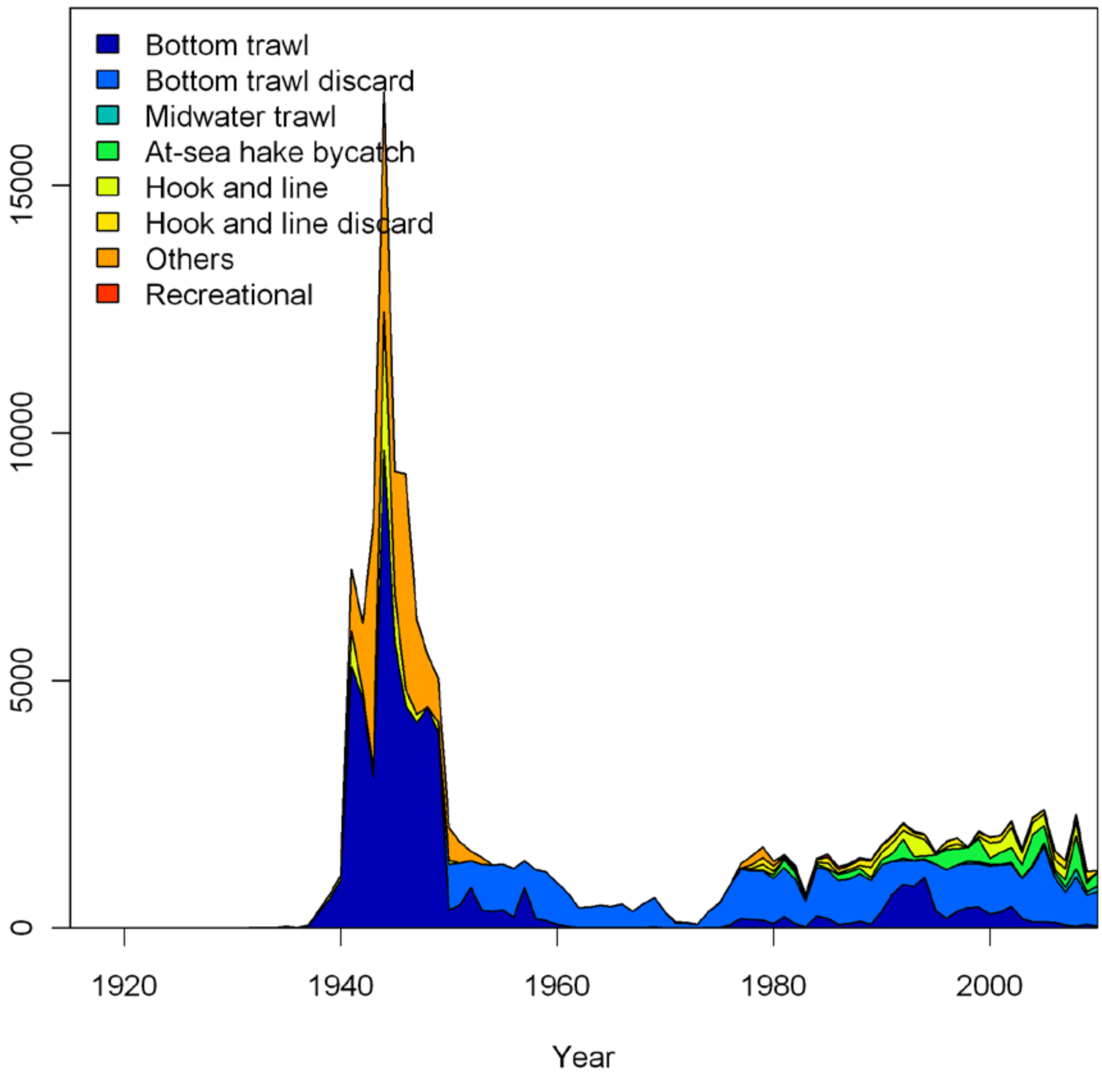

Figure ES-1. Reconstructed time series of spiny dogfish removals (mt) by fleet.

Stock spawning output

The spiny dogfish spawning output in the assessment is reported in thousands of fish. The unexploited level of spawning stock output is estimated to be 70,724 thousands of fish (95% confidence interval: 35,598-105,850). At the beginning of 2011, the spawning stock output is estimated to be 44,660 thousands of fish (95% confidence interval: 8,937-80,383), which represents 63% of the unfished spawning output level.

Historically, the spawning output of spiny dogfish showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 70% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, and the spawning output started to increase (mostly as a result of maturation of younger dogfish that were not selected by the vitamin A fishery). For the last thirty five years, spawning output of spiny dogfish has been slowly but steadily declining due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock.

Table ES-2. Recent trend in estimated spiny dogfish spawning output and depletion level.

Year	Estimated spawning stock output (1,000s)	95% confidence interval	Estimated depletion
2002	46,450	10,760-82,140	66%
2003	46,042	10,352-81,730	65%
2004	45,849	10,155-81,542	65%
2005	45,527	9,837-81,215	64%
2006	45,168	9,484-80,850	64%
2007	45,022	9,333-80,711	64%
2008	44,939	9,240-80,636	64%
2009	44,638	8,943-80,331	63%
2010	44,641	8,932-80,349	63%
2011	44,660	8,937-80,383	63%

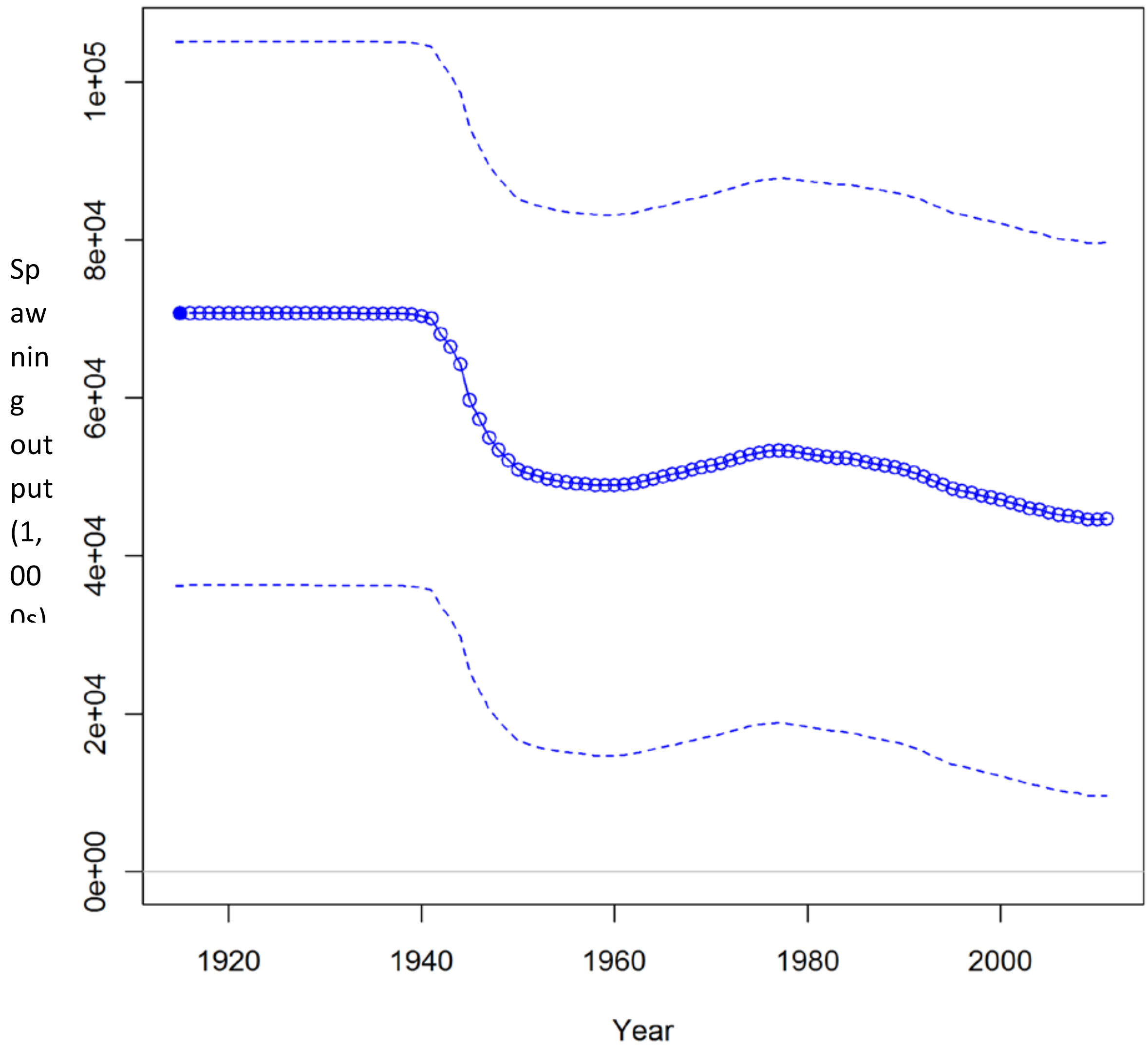

Figure ES-2. Time series of estimated spawning output of spiny dogfish (1,000s fish) with 95% confidence interval.

Recruitment
The fecundity of dogfish in the Northeast Pacific Ocean has been well studied, with pregnant females having relatively few pups per litter (5 to 15), and with relatively little variability among individuals. Unlike fish producing millions of eggs, the low fecundity of dogfish suggests both low productivity in general and a more direct connection between spawning output and recruitment than for many species.

In the assessment, therefore, the spawner-recruit relationship was modeled using a functional form which allows a more explicit modeling of pre-recruit survival between the stage during which embryos can be counted in pregnant females to their recruitment as age 0 dogfish. The recruits were taken deterministically from the stock-recruit curve since the relatively large size of dogfish pups at birth (20-30cm) suggest that variability in recruitment would be lower than for a species with a larval stage, which is subject to higher mortality rates.

Table ES-3. Recent trend in estimated recruitment for spiny dogfish.

Year	Estimated recruitment (1,000s)	95% confidence interval
2002	18,043	5,591-30,494
2003	17,930	5,456-30,402
2004	17,876	5,391-30,360
2005	17,786	5,285-30,286
2006	17,685	5,166-30,203
2007	17,644	5,115-30,172
2008	17,620	5,084-30,155
2009	17,535	4,983-30,086
2010	17,536	4,980-30,091
2011	17,541	4,982-30,099

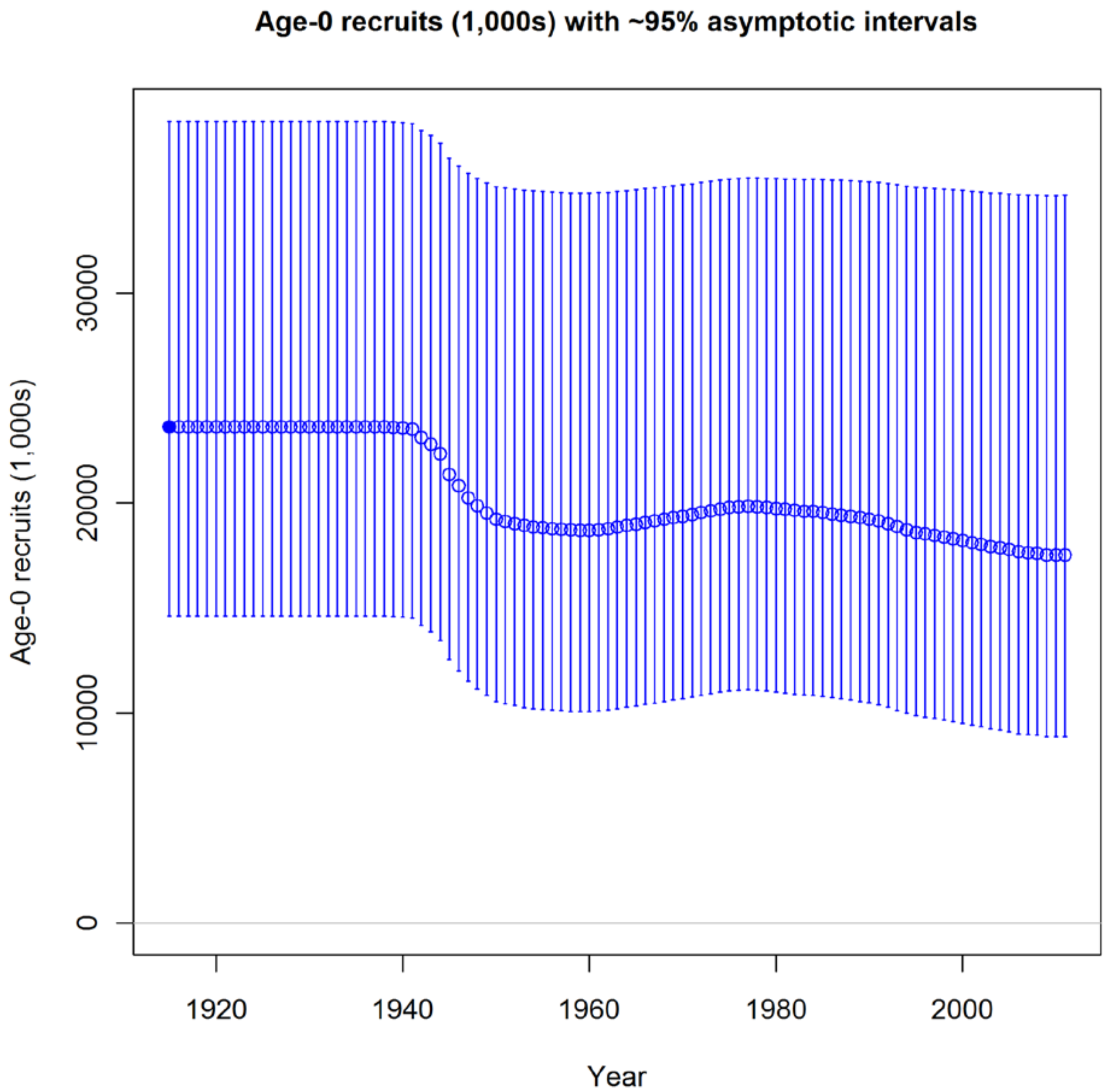

Figure ES-3. Time series of estimated recruitment (1,000s fish) with 95% confidence interval.

Reference Points

Unfished spawning stock output for spiny dogfish is estimated to be 70,724 thousands of fish (95% confidence interval: 35,598-105,850). The stock is declared overfished if the current spawning output is estimated to be below 25% of unfished level. The management target for spiny dogfish is defined as 40% of the unfished spawning output ($SB_{40\%}$), which is estimated by the model to be 28,290 thousand of fish (95% confidence interval: 14,239-42,340), which corresponds to an exploitation rate of 0.006. This harvest rate provides an equilibrium yield of 831 mt at $SB_{40\%}$ (95% confidence interval: 421-1241 mt). The model estimate of maximum sustainable yield (MSY) is 848 mt (95% confidence interval: 430-1267 mt). The estimated spawning stock output at MSY is 33,229 thousands of fish (95% confidence interval: 16,723-49,736). The exploitation rate corresponding to the estimated SPR_{MSY} of F79.26% is 0.0053.

Because of the extremely low productivity and other reproductive characteristics of the stock, fishing at the target of SPR 45% is expected to severely reduce the spawning output of spiny dogfish over the long term. Conversely, fishing at a rate that would maintain spawning output near 40% of the unfished level would require a target SPR of about 77% as estimated by the assessment model. The Council's Scientific and Statistical Committee should consider the appropriateness of using the current proxy harvest rate for spiny dogfish.

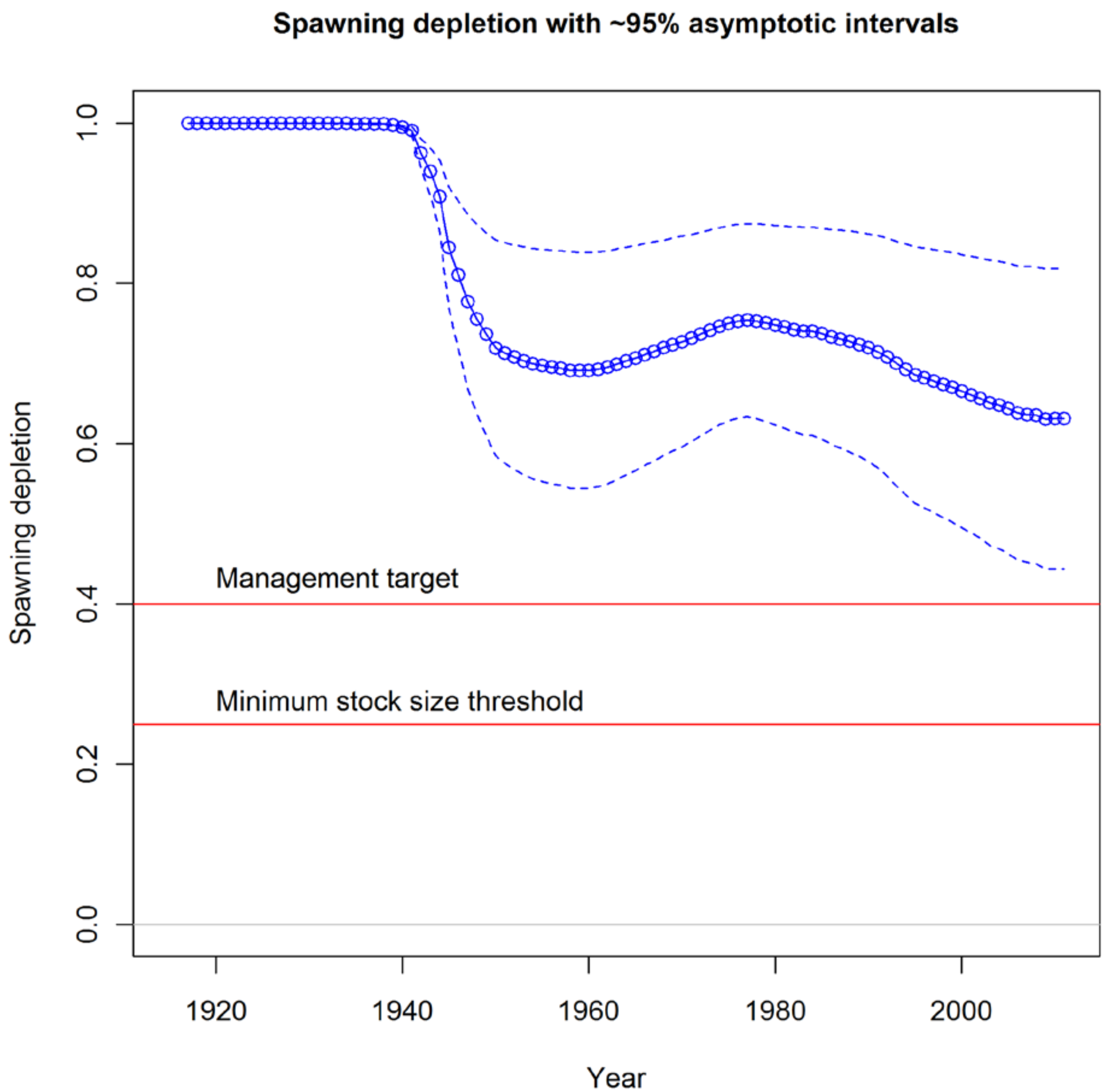

Figure ES-4.Time series of estimated spawning depletion of spiny dogfish with 95% confidence interval

Exploitation Status

The assessment shows that the stock of spiny dogfish off the continental U.S. Pacific Coast is currently at 63% of its unexploited level and, therefore, not overfished. Historically, the abundance of spiny dogfish has always been above the management target of $SB_{40\%}$. During the last 10 years, relative exploitation rates (catch/summary biomass) are estimated to have hovered around 1% and SPR is estimated to be well above current management target of SPR 45%. The assessment identified a period, which is during the vitamin A fishery in the 1940s, when the exploitation rate exceeded the current F_{MSY} proxy harvest rate.

Table ES-4. Recent trends in estimated spawning potential ratio (SPR) and exploitation rate for spiny dogfish.

Year	SPR (%)	Exploitation rate
2001	69.80%	0.00842
2002	66.32%	0.00971
2003	73.20%	0.00720
2004	64.92%	0.01014
2005	63.08%	0.01092
2006	73.37%	0.00719
2007	76.09%	0.00628
2008	63.64%	0.01061
2009	79.31%	0.00532
2010	78.97%	0.00540

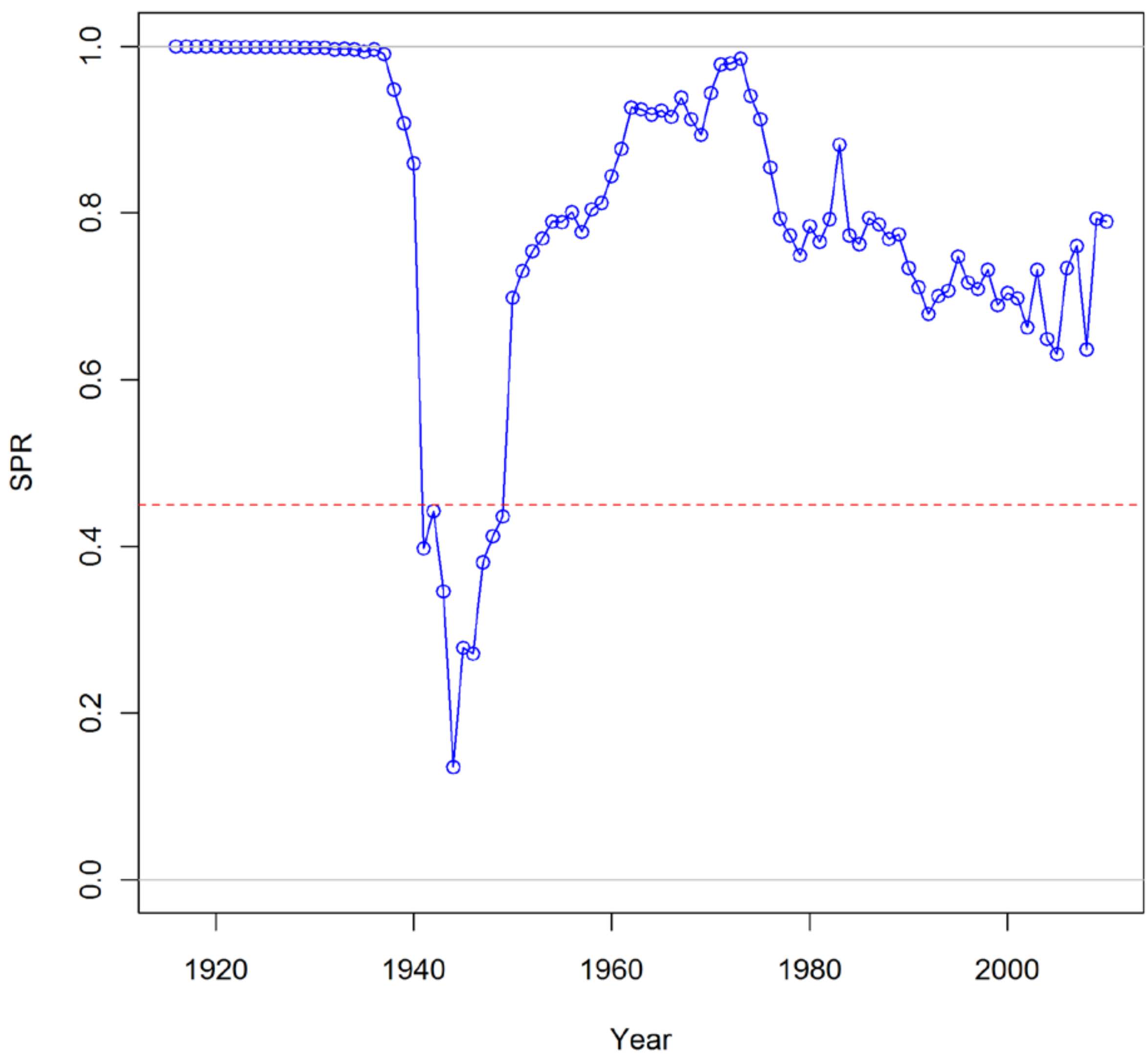

Figure ES-5. Time series of estimated spawning potential ratio (SPR) of spiny dogfish with SPR target of 0.45. Values below target reflect harvest that exceeded current overfishing proxy.

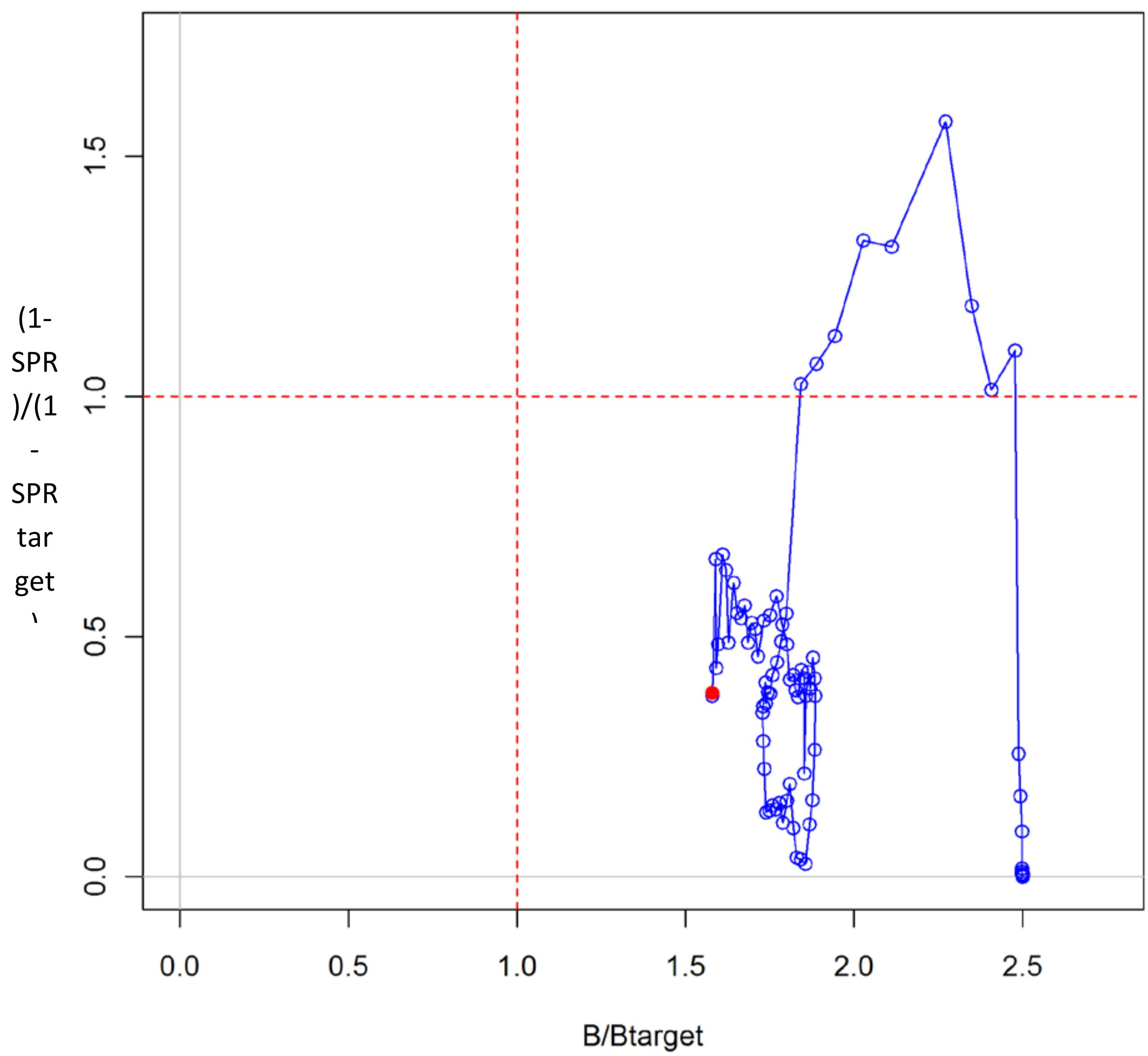

Figure ES-6. Estimated spawning potential ratio (SPR) of spiny dogfish relative to its target of 0.45 versus estimated spawning output relative to its target of $SB_{40\%}$. Red dot indicates the point that corresponds to 2011.

Management
Spiny dogfish on the west coast of the United States has been managed under the Other Fish complex since implementation of the Groundfish Fishery Management Plan (FMP) by the Pacific Fishery Management Council.

In 2005, reduction in acceptable biological catch (ABC) was instituted due to removal of the California substock of cabezon from the Other Fish complex. The same year, a 50% precautionary optimum yield (OY) reduction was implemented to accommodate uncertainty associated with managing unassessed stocks. In 2006, a trip limit for spiny dogfish was imposed for U.S. west coast waters which varied between 45 and 91 mt per two months for all gears. In 2009, another ABC reduction was implemented due to removal of longnose skate from the Other Fish complex, but the 50% OY reduction was maintained.

In 2011, reduction in overfishing limnit (OFL) was implemented due to removal of the Oregon substock of cabezon from the Other Fish complex. 50% precautionary reduction to the annual catch limit (ACL) was maintained, however, a scientific uncertainty buffer was specified as an ABC of 7,742 mt under the Amendment 23 framework.

Table ES-5. Management guidelines, recent trends in landings and estimated total catch for spiny dogfish.

	Harvest Specifications (mt) for the Other Fish Complex			
Year	**ABC/OFL**[a]	**OY/ACL**[a]	**Landings (mt)**[b]	**Total catch (mt)**
2001	14,700	14,700	810	1,879
2002	14,700	14,700	1,190	2,159
2003	14,700	14,700	730	1,593
2004	14,700	14,700	1,023	2,238
2005	14,700	14,700	801	2,396
2006	14,600	7,300	483	1,567
2007	14,600	7,300	539	1,364
2008	14,600	7,300	1,172	2,300
2009	11,200	5,600	378	1,147
2010	11,200	5,600	444	1,163

[a] The acceptable biological catch (ABC) specification prior to 2011 represents the MSY harvest level and the optimum yield (OY) represents the annual total catch limit. Implementation of Amendment 23 in 2011 changed these definitions to the overfishing limnit (OFL) as the MSY harvest level and the annual catch limit (ACL) as the annual total catch limit. Additionally, the definition of ABC changed under Amendment 23 to a level of harvest less than or equal to the OFL to accommodate the scientific uncertainty associated with estimating the OFL.
[b] Includes at-sea hake fishery bycatch and recreational catches.

Uncertainty
Uncertainty in the model was explored though asymptotic variance and sensitivity analyses. Asymptotic confidence intervals were estimated within the model and reported throughout the assessment for key model parameters and management quantities. To explore uncertainty

associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed, including increase and decrease in fishery removals, runs with different assumptions regarding historical discard, discard mortality, shape of selectivity curves, stock-recruitment parameters, and many others. The uncertainty regarding natural mortality was also explored through likelihood profile analysis. Also, a retrospective analysis was conducted where the model was re-run after successively removing data from recent years.

Decision table

Three states of nature were defined based on the alternative time series of removals and natural mortality values. The middle (base case) scenario has catch time series and natural mortality (0.064) as used in the base model. For the "low" and "high" states of nature, the base model was first modified by decreasing the entire time series of removals by 25% and increasing by 50% for low and high catch scenarios respectively. The low and high catch scenario models were further modified by subtracting one standard deviation from the 2011 spawning output value from the low catch model and adding one standard deviation to the 2011 spawning output value from the high catch model. The natural mortality for low state of nature (0.061) was selected to match one standard deviation below the 2011 spawning output for low catch scenario. The natural mortality for high state of nature (0.066) was selected to match one standard deviation above the 2011 spawning output estimate for high catch scenario. The fourth state of nature based on the retrospective analysis that excluded the last three years of the time series was added to allow for decision table to broaden the uncertainty in the assessment estimates. The net effect is to add more pessimistic state of nature, in which the spawning depletion falls below the management target of $SB_{40\%}$ in recent years.

Twelve-year forecasts for each state of nature were calculated based on removals at SPR 45% for the base model. Twelve-year forecasts were also produced with future catch fixed at the 2011-2012 OFL-based value provided by the Groundfish Management Team (GMT) and calculated as 28.4% of the total Other Fish ACL (the percentage is derived from the dogfish contribution to Other Fish OFL). Finally, twelve-year forecasts for each state of nature were calculated based on removals at SPR 77% for the base model, the level identified by the model as associated with the $SB_{40\%}$ target biomass level. Under the low state of nature, the catch at SPR 45% is projected to reduce the spawning stock output to 34.81 % of the unfished level within 12 years. In all other scenarios covered by the decision table, the spawning output remains above the 40% target level throughout the 12-year projection period. The highest level predicted in the 12 year projections is 75.65%, which occurs when the SPR 77% catch series is applied to the high state of nature. In general, there is little change in stock size over the 12 year projections for any of the combinations of state of nature and removals.

Research and data needs

In this assessment, several critical assumptions were made based on limited supporting data and research. There are several research and data needs which, if satisfied, could improve the assessment. These research and data needs include:

1) The ageing method for dogfish requires further research. The efforts should be devoted to both improving current ageing techniques based on dogfish spines and developing new

methods using other age structures, such as vertebrae. Double reads of dogfish spines indicate that the method of counting annuli on the unworn portion of dogfish dorsal spines is reasonably precise and has been validated using both oxytetracycline marking and bomb radiocarbon. However, more research is needed on the topic of unreadable annuli that are missing due to wear on the spines of older dogfish. Improving estimates of the statistical uncertainty associated with the age extrapolation methods would also be valuable. Ideally, an alternative method of ageing dogfish that does not rely on the highly uncertainty estimation of ages missing from worn spines may be necessary before age information can be a reliable data source in dogfish stock assessments.

2) The move to full observer coverage in 2011 will improve estimates of dogfish discard for the west coast. However, there is a considerable uncertainty in the historic discard amounts, especially prior to the commencement of the West Coast Groundfish Observer Program. Even more important is the need to improve estimates of discard mortality. Studies of this topic on the east coast used shorter tow durations than those in common fishing operations in these waters, and thus are likely to produce understimates of discard mortality. Data on tow duration could also be incorporated into future models to better refine discard mortality estimates from the trawl fishery.

3) Ongoing research using acoustic tags on dogfish released in central Puget Sound in the summer show regular seasonal movements to coastal waters during the winter and returns to Puget Sound in the subsequent summers. This suggests that biomass sampled by summertime surveys (including those from AFSC, NWFSC, and IPHC used in this analysis) may not be representative of the population size and distribution available to the fishery in other seasons. If the movements are very regular, the surveys may still provide a reliable relative index of abundance, but any differences in movement patterns due to climate or prey availability could impact these indices. Further research into how to account for such movement patterns should be conducted to inform future dogfish stock assessments. Acoustic or satellite tagging of dogfish in coastal waters could provide valuable insight into movement patterns along the coast and benefit future assessments.

4) There are high densities of dogfish close to the U.S.-Canada border, at the mouth of the Strait of Juan de Fuca which connects the outside coastal waters with the inside waters of Puget Sound and the Strait of Georgia. This distribution, combined with potential seasonal or directed movement patterns for dogfish suggest that U.S. and Canada should explore the possibility of a joint stock assessment in future years.

Table ES-6. Decision table of 12-year projections for alternative states of nature defined based on the alternative time series of removals and natural mortality of spiny dogfish and the retrospective analysis.

			Retrospective run (data from the last three years removed)		Low M, low removals		**Base model**		High M, high removals	
Forecast	Year	Total removals (mt)	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion
Forecast catch calculated from 45% SPR applied to base model	2011	3,041	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	3,010	13,622	33.08%	19,827	47.79%	44,130	62.40%	105,499	73.85%
	2013	2,980	13,122	31.86%	19,228	46.34%	43,615	61.67%	105,144	73.60%
	2014	2,950	12,631	30.67%	18,644	44.93%	43,113	60.96%	104,802	73.36%
	2015	2,921	12,150	29.50%	18,074	43.56%	42,624	60.27%	104,472	73.13%
	2016	2,893	11,678	28.36%	17,518	42.22%	42,147	59.59%	104,152	72.91%
	2017	2,866	11,214	27.23%	16,975	40.91%	41,682	58.94%	103,841	72.69%
	2018	2,839	10,757	26.12%	16,444	39.63%	41,228	58.29%	103,538	72.48%
	2019	2,813	10,307	25.03%	15,926	38.38%	40,783	57.67%	103,243	72.27%
	2020	2,787	9,865	23.95%	15,420	37.16%	40,349	57.05%	102,953	72.07%
	2021	2,763	9,430	22.90%	14,926	35.97%	39,924	56.45%	102,669	71.87%
	2022	2,738	9,002	21.86%	14,444	34.81%	39,508	55.86%	102,391	71.67%
2011-2012 OFL-derived catch	2011	1,584	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	1,584	13,977	33.94%	20,226	48.75%	44,530	62.96%	105,899	74.13%
	2013	1,584	13,822	33.56%	20,013	48.23%	44,402	62.78%	105,933	74.15%
	2014	1,584	13,666	33.18%	19,802	47.72%	44,277	62.61%	105,968	74.18%
	2015	1,584	13,509	32.80%	19,593	47.22%	44,153	62.43%	106,003	74.20%
	2016	1,584	13,350	32.42%	19,385	46.72%	44,030	62.26%	106,037	74.23%
	2017	1,584	13,189	32.03%	19,179	46.22%	43,907	62.08%	106,069	74.25%
	2018	1,584	13,025	31.63%	18,972	45.72%	43,783	61.91%	106,098	74.27%
	2019	1,584	12,858	31.22%	18,766	45.23%	43,659	61.73%	106,122	74.29%
	2020	1,584	12,688	30.81%	18,560	44.73%	43,533	61.55%	106,142	74.30%
	2021	1,584	12,513	30.38%	18,354	44.23%	43,405	61.37%	106,156	74.31%
	2022	1,584	12,334	29.95%	18,147	43.74%	43,275	61.19%	106,164	74.32%
Forecast catch calculated from 77% SPR applied to base model	2011	928	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	928	14,138	34.33%	20,406	49.18%	44,530	62.96%	105,899	74.13%
	2013	928	14,143	34.34%	20,373	49.10%	44,402	62.78%	105,933	74.15%
	2014	928	14,148	34.35%	20,341	49.02%	44,277	62.61%	105,968	74.18%
	2015	928	14,152	34.36%	20,309	48.95%	44,153	62.43%	106,003	74.20%
	2016	928	14,154	34.37%	20,278	48.87%	44,030	62.26%	106,037	74.23%
	2017	928	14,153	34.37%	20,247	48.79%	43,907	62.08%	106,069	74.25%
	2018	927	14,149	34.36%	20,214	48.72%	43,783	61.91%	106,098	74.27%
	2019	927	14,142	34.34%	20,182	48.64%	43,659	61.73%	106,122	74.29%
	2020	926	14,130	34.31%	20,147	48.56%	43,533	61.55%	106,142	74.30%
	2021	926	14,113	34.27%	20,111	48.47%	43,405	61.37%	106,156	74.31%
	2022	925	14,091	34.22%	20,073	48.38%	43,275	61.19%	106,164	74.32%

Table ES-7. Summary of recent trends in estimated spiny dogfish exploitation and stock level from the assessment model.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Landings (mt)[a]	1,190	730	1,023	801	483	539	1,172	378	444	NA
Estimated Discards (mt)	970	863	1,215	1,595	1,084	825	1,128	768	719	NA
Estimated Total Catch (mt)	2,159	1,593	2,238	2,396	1,567	1,364	2,300	1,147	1,163	NA
ABC/OFL[b] Other Fish Complex	14,700	14,700	14,700	14,700	14,600	14,600	14,600	11,200	11,200	11,150
OY/ACL[b] Other Fish Complex	14,700	14,700	14,700	14,700	7,300	7,300	7,300	5,600	5,600	5,575
SPR	66.32%	73.20%	64.92%	63.08%	73.37%	76.09%	63.64%	79.31%	78.97%	NA
Exploitation Rate (total catch/summary biomass)	0.00971	0.00720	0.01014	0.01092	0.00719	0.00628	0.01061	0.00532	0.00540	
Summary Age 1+ Biomass (B) (mt)	222,370	221,289	220,649	219,379	217,973	217,331	216,857	215,496	215,181	214,812
Spawning Stock Output (SB) (1000s fish)	46,450	46,042	45,849	45,527	45,168	45,022	44,939	44,638	44,641	44,660
Uncertainty in Spawning Stock Output estimate	10,760-82,140	10,352-81,730	10,155-81,542	9,837-81,215	9,484-80,850	9,333-80,711	9,240-80,636	8,943-80,331	8,932-80,349	8,937-80,383
Recruitment at age 0	18,043	17,930	17,876	17,786	17,685	17,644	17,620	17,535	17,536	17,541
Uncertainty in Recruitment estimate	5,591-30,494	5,456-30,402	5,391-30,360	5,285-30,286	5,166-30,203	5,115-30,172	5,084-30,155	4,983-30,086	4,980-30,091	4,982-30,099
Depletion (SB/SB_0)	65.68%	65.10%	64.83%	64.37%	63.86%	63.66%	63.54%	63.12%	63.12%	63.15%
Uncertainty in Depletion estimate									43.98%-82.26%	44.00%-82.30%

[a] Includes at-sea hake fishery bycatch and recreational catches.

[b] The acceptable biological catch (ABC) specification prior to 2011 represents the MSY harvest level and the optimum yield (OY) represents the annual total catch limit. Implementation of Amendment 23 in 2011 changed these definitions to the overfishing limnit (OFL) as the MSY harvest level and the annual catch limit (ACL) as the annual total catch limit. Additionally, the definition of ABC changed under Amendment 23 to a level of harvest less than or equal to the OFL to accommodate the scientific uncertainty associated with estimating the OFL.

Table ES-8. Summary of spiny dogfish reference points from the assessment model.

	Point estimate	**95% confidence interval**
Unfished Spawning Stock Output (SB_0) (1000s fish)	70,724	35,598-105,849
Unfished Summary Age 1+ Biomass (B_0) (mt)	304,105	NA
Unfished Recruitment (R_0) at age 0	23,634	11,895-35,372
<u>Reference points based on SB40%</u>		
MSY Proxy Spawning Stock Output ($SB_{40\%}$) (1000s fish)	28,290	14,239-42,340
SPR resulting in $SB_{40\%}$ ($SPR_{SB40\%}$)	76.87%	74.71%-79.03%
Exploitation rate resulting in $SB_{40\%}$	0.60%	NA
Yield with SPRSB$_{40\%}$ at $SB_{40\%}$ (mt)	831	421-1241
<u>Reference points based on estimated MSY values</u>		
Spawning Stock Output at MSY (SB_{MSY}) (1000s fish)	33,229	16,723-49,736
SPR_{MSY}	79.26%	77.20%-81.32%
Exploitation Rate corresponding to SPR_{MSY}	0.53%	NA
MSY (mt)	848	430-1267

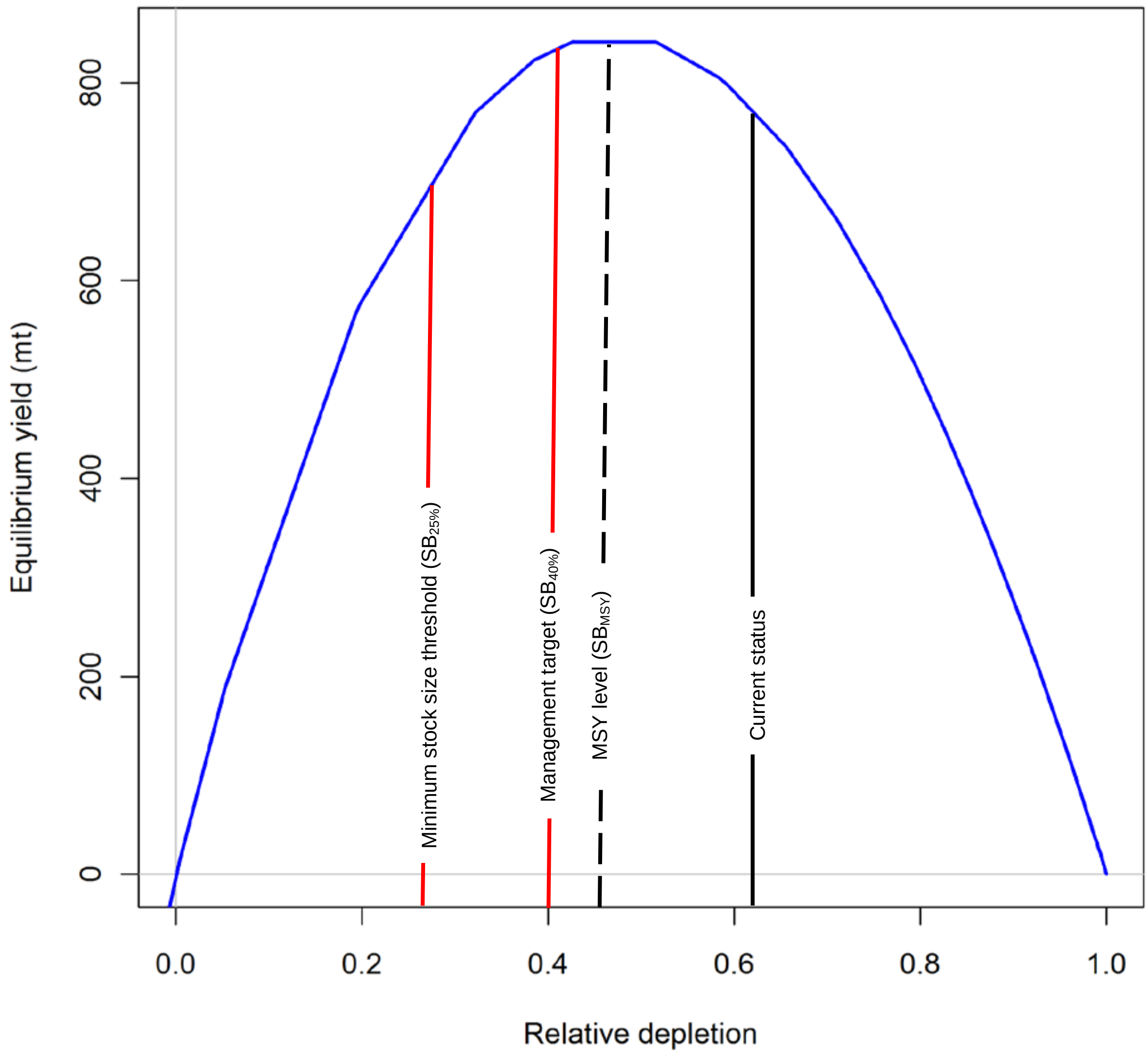

Figure ES-7. Equilibrium yield curve for spiny dogfish from the assessment model (based on Table ES-8).

1. Introduction

The spiny dogfish is one of the most widely distributed sharks that inhabit temperate waters in both the Pacific and the Atlantic Oceans. It is a small to medium-sized cartilaginous fish that is generally found inshore areas to offshore depths of at least 1200 m (Ebert 2003). Although frequently observed as solitary individuals, spiny dogfish also form large localized schools of hundreds if not thousands of organisms (Compagno et al. 2005, Ebert 2003, Shepherd et al. 2002).

Taxonomically, it has been problematic as to whether spiny dogfish are monospecific or contains more than one species (Ebert et al. 2010, Verissimo et al. 2010). The North Pacific spiny dogfish was originally described by George Suckley from specimens collected in Puget Sound, and designated as *Squalus suckleyi* in 1854 (Girard 1854). The original description of the species was brief and did not provide details separating it from the North Atlantic *Squalus acanthias*, and it was later designated as subspecies of the *Squalus acanthias* (Ebert et al. 2010, Verissimo et al. 2010).

Recent molecular studies, however, have consistently found strong evidence of genetic divergence between North Pacific (from the Koreas and Japan, northward to Russia, the Bering Sea and the Aleutian Islands, and eastwards in the Gulf of Alaska, British Columbia and Washington south to southern Baja California) and non-North Pacific spiny dogfish (Franks 2006, Ebert et al. 2010, Verissimo et al. 2010, Ward et al. 2007). Also, the most recent taxonomic re-evaluation of the status of the North Pacific *Squalus suckleyi* combining the use of meristic, morphological and molecular data confirmed this species to be clearly distinct from the widespread *Squalus acanthias* (Ebert et al. 2010). The genetic divergence between North Pacific and non-North Pacific groups is also consistent with distinct differences in life history characteristics; North Pacific fish mature at an older age, reach larger maximum sizes and live longer than fish occurring outside North Pacific waters.

1.1. Distribution, biology and life history

In the North America, spiny dogfish occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts (Ebert 2003, Ebert et al. 2010).

This assessment focuses on a portion of a population that occurs in coastal waters of the western United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The population within this area is treated as a single coast-wide stock. A map depicting the spatial scope of the assessment is shown in Fig. 1.

Spiny dogfish stock included in this assessment likely has interaction and overlap with dogfish observed off British Columbia, and it must be acknowledged that the scope of this assessment does not capture all of the dynamics which likely bear on the status and trends of the larger, transboundary population.

About 1300 dogfish were tagged along the coast of Washington from 1942-1946, during the period of the strong directed fishery for dogfish. Only 50 of these fish were recaptured and had tags returned (4%), of which 54% were recaptured within U.S. coastal waters, while 32% were recaptured in coastal Canada and 12% in the inside waters of Puget Sound and the Strait of Georgia. One fish was recaptured in coastal Japanese waters (7 years after being tagged). Because many of the releases were close to the U.S.-Canada border, and the fractions do not take into account the relative fishing pressure within each area, this study is of limited use in providing reliable information about dogfish movement rates.

A spatial population dynamics model (Taylor 2008), which included these tagging data (along with much larger tagging experiments conducted in Canada and inside U.S. waters of Puget Sound) estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. The model also estimated movement rates of less than 1% per year between dogfish the U.S. coastal sub-population of dogfish and that in the Puget Sound.

These sharks appear to prefer areas in which the water temperature ranges from 5 to 15^{o} C, often making latitudinal and depth migrations to follow this optimal temperature gradient (Brodeur et al. 2009). There is also evidence of seasonal movement along the coast based on both tagging data and timing of historical fisheries (Ketchen 1986). One estimate of the seasonal movement along the Pacific coast is a North-South shift of about 600 km from winter to summer (Taylor et al. 2009). This seasonal pattern is not as extreme as that found among spiny dogfish in Atlantic waters of the U.S., which are likely due to larger fluctuations in temperature. Dogfish have also been captured in high-seas salmon gillnets across the North Pacific between about 40^{o} and 50^{o} N latitude (Nakano and Nagasawa, 1996), but the extent of these wide-ranging pelagic movements is poorly understood.

The biology and life history of spiny dogfish are relatively well studied (Campana et al. 2009, Di Giacomo et al. 2009, Taylor 2008, Trubizio 2009, Tribuzio et al. 2009, Tribuzio et al. 2010, Vega et al. 2009). This species is an opportunistic feeder that consumes a wide range of prey (whatever is abundant). Schooling pelagic fish, such as herring, make up the majority of its diet. They also feed on invertebrates such as shrimp, crab and squid. In turn, dogfish are preyed upon by larger cod, hake and other spiny dogfish (Beamish et al. 1992, Brodeur et al. 2009, Tanasichuk et al. 1991). Larger species of sharks as well as seals and killer whales also feed on dogfish.

Spiny dogfish have internal fertilization and ovoviviparous development. The internal development takes place over 22-24 months, the longest gestation period known for sharks. The number of pups in each litter ranges between 5 and 15 individuals depending on the size of the female (larger females bearing more pups). The size at birth is generally between 20 and 30 cm for both genders. Male spiny dogfish are reported to grow faster than females, but females reach larger sizes. This species is the latest maturing (with 50% female maturity reported at 35.5 years) and longest lived of all elasmobranchs (Cortés 2002, Saunders and McFarlane 1993, Smith et al. 1998, Taylor 2008). Life history traits of spiny dogfish make the species highly susceptible to overfishing and slow to recover from stock depletion since its slow growth, late maturation and low fecundity are directly related to recruitment and spawning stock biomass (Holden 1974, King and McFarlane 2003).

1.2. Historical and current fishery

Spiny dogfish in the west coast of the United States have been utilized for almost a thousand years, with those in Puget Sound first used by Native Americans (Bargmann 2009). The exploitation of spiny dogfish in coastal waters, however, started in the 20th century. Even though the history of spiny dogfish utilization on the U.S. west coast included a brief but intense commercial fishery in the 1940s, in general this species is not highly prized and is mostly taken as bycatch in other commercially important fisheries.

Prior to 1936, coastal catches of spiny dogfish were extremely minimal, but in 1936, shortly after it was discovered that livers of spiny dogfish have high level of vitamin A, the large scale fishery for dogfish developed in the Pacific Northwest. Before World War II, Northeast Pacific dogfish livers could not compete with the cheaper and more potent sources of vitamin A from Europe. But when World War II started and European supplies were cut, dogfish shark livers became the major source of vitamin A in the United States, and the spiny dogfish fishery grew rapidly along the Pacific coast. The processed liver oils were used in pharmaceuticals, food processing and animal feed (Bargmann 2009, Ketchen 1986).

During the liver fishery, dogfish were targeted by three major gear groups, including setlines (which are longlines with numerous attached baited hooks spread along the bottom), set nets (many of which were old salmon gill nets and were readily available for the newly developed dogfish fishery) and bottom trawls. The timing of the dogfish liver fishery coincided with the development of bottom trawling in the U.S. Northwest, and though at the onset of the fishery the catches by trawl were low, by the mid-1940s trawling was the dominant type of fishing for dogfish.

In 1945, a sharp decline in spiny dogfish catches began. This decline occurred despite continued strong demand for vitamin A and high prices for dogfish livers, but because of decreased availability of the species in the Northeast Pacific Ocean (Bargmann 2009, Ketchen 1986). In 1950, with the advent of synthetic vitamins, demand for spiny dogfish livers declined and catches in the Northeast Pacific Ocean virtually ended.

Between 1950 and 1974, the landings of spiny dogfish remained minimal. By the late 1950s it was reported that species availability had increased. Also, in the late 1950s-early 1960s, dogfish earned a bad reputation among fishermen. They were blamed for driving off commercially valuable species such as herring and mackerel, while consuming large numbers of them. Spiny dogfish have also been observed biting through nets to get to their fish prey, releasing many of them and damaging fishing gear in the process. They were also reported damaging gear when become entangled in commercial nets. As a result, fishermen were trying to avoid areas with higher chances of dogfish catches (such as soft bottoms, for example) to prevent encountering dogfish and potentially damaging their gear.

A market opportunity for dogfish opened in mid-1970s. In Europe, spiny dogfish has long been used an inexpensive source of human food, for fish and chips in particular. A decline in European dogfish supply provided an opportunity for developing an export dogfish food fishery in the U.S. Pacific coast. Also, during the late 1970s, shark cartilage started to be used in cancer treatment, and a portion of spiny dogfish catches have since been sold for medical research and treatment (Gregory Lippert, WDFW, pers. com.). As before, three types of gear were involved in catching dogfish (bottom trawl, setlines, and sunken gill nets), but since the mid-1980s catches by gillnets have been minimal.

Spiny dogfish is a common bycatch species, often caught in other fisheries and largely discarded. For instance, it has long been bycaught in the fishery for the coastal population of Pacific hake, which is almost exclusively conducted with mid-water trawls. Large-scale harvesting of Pacific hake in the United States began in 1966, when factory trawlers from the Soviet Union and other countries began targeting this stock. After the 200-mile U.S. Exclusive Economic Zone was declared in 1977, a Joint-Venture fishery was initiated between United States trawlers and Soviet factory trawlers acting as mother-ships (larger, slower ships for fish processing and storage while at sea). By 1989 the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota, and no further foreign fishing was allowed. The Pacific hake fishery is currently 100% observed by the at-sea hake observer program (A-SHOP) and data on bycatch species, including spiny dogfish, is being routinely collected.

1.3. Fisheries off Canada and Alaska

Fisheries for dogfish off the West Coast of Canada have largely paralleled those on the West Coast of the U.S. (Ketchen 1986). They have been characterized by a large fishery targeting dogfish for livers in the 1940s, a lack of markets in the 1950s-1970s, and a smaller fishery in recent decades. Dogfish fisheries in British Columbia include both the inside waters of the Strait of Georgia and coastal waters from extending throughout the coast from the U.S.-Canada border through the Queen Charlotte Islands. In the 1940s, the largest fraction of landings occurred in Northern British Columbia, but in the past two decades, the West Coast of Vancouver Island has made up the largest component of the landings in British Columbia (Ketchen 1986, Taylor 2008). Like the fisheries in U.S. waters, fluctuations in landings in Canada have largely been driven by market forces rather than availability. Although dogfish occur throughout the Gulf of Alaska, there has never been a commercial fishery in Alaskan waters (Tribuzio 2010).

1.4. Management history and performance

This is the first time that spiny dogfish has been assessed for the west coast of the United States. This species has been managed under the Other Fish complex since implementation of the Groundfish Fishery Management Plan (FMP) by the Pacific Fishery Management Council. The summary of management history of spiny dogfish and harvest specifications for the Other Fish complex is presented in Table 1.

In 2005, reduction in acceptable biological catch (ABC) was instituted due to removal of the California substock of cabezon from the Other Fish complex. The same year, 50% precautionary optimum yield (OY) reduction was implemented to accommodate uncertainty associated with managing unassessed stocks. In 2006, trip limit for spiny dogfish was imposed for U.S. west coast waters which varied between 45 mt and 91 mt per two months for all gears. In 2009, another ABC reduction was implemented due to removal of longnose skate from the Other Fish complex, 50% OY reduction was maintained.

In 2011, reduction in overfishing limnit (OFL) was implemented due to removal of the Oregon substock of cabezon from the Other Fish complex. 50% precautionary reduction to the annual catch limit (ACL) was maintained, however, a scientific uncertainty buffer was specified as an ABC of 7,742 mt under the Amendment 23 framework.

2. Assessment data

The data used in the assessment are summarized in Figure 2. These data include both fishery-dependent and fishery-independent sources.

2.1. Fishery-dependent data

The fishery removals were divided in the assessment among eight fleets. Six of them are catch fleets, including bottom trawl, midwater trawl, hook-and-line, other gears (primarily nets), at-sea hake fishery bycatch, and recreational fishery. Bottom and midwater trawls were treated separately to reflect differences in gear selectivity since length frequencies of catch landed by the midwater trawl were dominated by smaller size fish than those of bottom trawl.

Spiny dogfish are often discarded when caught. Two out of six catch fleets (bottom trawl and hook-and-line) represent landed catch only, and not the total removals. Two discard fleets, therefore, were created to represent discard in bottom trawl and hook-and-line fleets. The amounts of dogfish discarded were estimated externally to the model, and time series of dead discard (discard amount by year multiplied by discard mortality) were included in the model the same way as catch for other fleets.

Removals of spiny dogfish were reconstructed back to 1916, assuming a zero equilibrium catch in 1915. The reconstructed time series of spiny dogfish removals by fleet are presented in Fig.3 and Table 2. Figure 4 shows the spatial distribution of spiny dogfish catch, as observed by the West Coast Groundfish Observer Program between 2002 and 2010.

2.1.1. Commercial landings

Estimates of recent commercial landings of spiny dogfish (between 1981 and 2010) were obtained from the Pacific Fisheries Information Network (PacFIN), a regional fisheries database that manages fishery-dependent information in cooperation with west coast state agencies and NOAA Fisheries (www.pacfin.com). PacFIN reports both targeted catch and retained bycatch. Catch data were extracted by gear type and then combined into the fishing fleets used in the assessment.

Time series of historical (pre-1981) landings by fleet were reconstructed for each state separately and then combined to produce annual coast-wide estimates. Commercial landings summarized by fleet are shown in Fig. 5. The methods used to reconstruct historical landings are described below.

2.1.1.1. Washington

The vast majority of spiny dogfish commercial landings were made in Washington (Fig. 6). The records of spiny dogfish landings from the coastal waters of Washington were available since 1939. Landings between 1939 and 1940 were estimated from the 1939 and 1941 issues of Bulletins of Washington Department of Fisheries (which reported the total Washington landings, Puget Sound and the coastal area together) along with early catch records from Puget Sound provided by WDFW (Gregory Lippert, WDFW, pers. com.). The differences between values from the two sources gave the 1939 and 1940 estimates for coastal landings.

Records of spiny dogfish landings from 1941 were recently compiled by Bargmann (2009) based on earlier publications by Alverson and Stansby (1963) and Ketchen (1986). Between 1941 and 1956, it was a common practice not to land dogfish in the round (with processors removing the livers in their plants), but to land only the dogfish livers and discard the carcasses at sea (Bergman, 2003). To convert the liver weight to round weight, a variety of expansion factors (ranging between 8.33 and 10) were developed for different areas and periods (Averson and Stanley 1963, Holland 1957, Ketchen 1986). Bargmann (2009) reports dogfish landings in round weight. In Bargmann (2009), however, landings are not attributed to specific gears. Therefore, we used the Fisheries Statistics of the United States (which reports dogfish landings by gear, but in liver weight) to calculate the proportions of different gear contribution and applied these proportions to the Bargmann (2009) time series. The Fisheries Statistics of United States were available only through 1977. For 1978-1980 (the last three years of the pre-PacFIN era), we used 1975-1980 average gear proportions reported in Bargmann (2009) to apportion Washington dogfish landings time series among gears.

2.1.1.2. Oregon

Oregon records of dogfish landings go back to 1940. Historically, spiny dogfish was reported in Oregon as both “Grayfish” and “Shark, Grayfish.” Time series of Oregon historical landings of spiny dogfish were provided by the Oregon Department of Fish and Wildlife (ODFW), which in collaboration with Northwest Fisheries Science Center (NWFSC), conducted a reconstruction of historical groundfish landings in Oregon (Karnowski et al. 2011).

A variety of data sources were used to reconstruct historical landings of spiny dogfish, including Oregon Department of Fish and Wildlife’s Pounds and Value reports derived from the Oregon fish ticket (landing receipt) line data (1969-1989), Fisheries Statistics of the United States (1927-1977), Fisheries statistics of Oregon (Cleaver 1951, Smith 1956), Reports of the Technical Sub-Committee of the International Trawl Fishery Committee (now the Canada-U.S. Groundfish Committee) (1942-1975) and many others.

It appears that (unlike Washington) Oregon landings of spiny dogfish sharks in the Fisheries Statistics in the United States were reported as round weights. The footnotes in the Fisheries Statistics of the United States indicate that although most carcasses of spiny dogfish prior to 1956 were discarded at sea, the poundage reported includes the total volume of “grayfish” caught. The Oregon records of spiny dogfish landings in the Fisheries Statistics of the United States were consistent with Bargmann (2009), who provided the total landed catch of spiny dogfish in Oregon as well.

A small portion of spiny dogfish in Oregon was also landed within the Animal Food market category, a portion of various fish that went to feed mink for the fur trade. Prior to World War II, mink food mainly consisted of red meat, but when meat became increasingly difficult and expensive to obtain, Oregon mink ranchers started to use fish fillet carcasses as a protein source for mink (Niska 1969). When the demand for fish fillet carcasses exceeded the supply, whole fish were specifically targeted to supplement the carcasses (Niska 1969). Spiny dogfish landings within Animal Food market category were reconstructed by Karnowski et al. (2011) back to 1942 from Jones and Harry (1961), Niska (1969), reports of the Technical Sub-Committee of the International Trawl Fishery Committee, Fisheries Statistics of the United States and ODFW Pounds and Values reports. Spiny dogfish was reported in the Animal Food between 1942 and 1979, and we added the estimated values by year to bottom trawl landings since Animal Food was landed exclusively by bottom trawl.

2.1.1.3. California

Time series of California gear-specific landings of spiny dogfish during the most recent "historical" period (between 1969 and 1980) were available from the California Cooperative Groundfish Survey (CalCOM) database.

Earlier landing records (between 1931 and 1968) were recently reconstructed by the Southwest Fisheries Science Center (SWFSC) (Ralston et al. 2010), but as is the case with Washington, these landings were not appointed to specific gear. To apportion early historical landings among gears, we applied Oregon dogfish gear proportions by year between 1940 and 1968 to California dogfish landings. Between 1931 and 1939, we assumed the gear compositions to be an average of the earliest three years of Oregon gear compositions.

2.1.2. Recreational removals

Recreational catches contributed a relatively small amount to overall removals of spiny dogfish (Fig. 3). Unlike commercial catches, the vast majority of recreational removals occurred in California (Fig. 7). The data on recreational removals of spiny dogfish were obtained from RecFIN (www.recfin.com), a regional source of recreational data managed by the Pacific States Marine Fisheries Commission (PSMFC) and directly from state agencies. RecFIN reports catches by fishing mode, including shore modes (man-made, beach and bank) and boat modes (party and charter boats, private and rental boats). Essentially, all the spiny dogfish recreational catches came from the boat modes (Fig. 8), and, therefore, all recreational removals in the assessment were combined and reported as one fishery. Recreational catches were reconstructed by state, and the approaches used to derive recreational catches are described below.

2.1.2.1. Washington

The records of spiny dogfish recreational catches in the coastal waters of Washington go back to 1980. No mention of a coastal recreational harvest of dogfish was found prior to that. Dogfish are encountered sporadically in the ocean fisheries, and are almost always released (96% average release rate). The total estimated removals has been minimal (on average 0.4 mt per year since 1980). Information on recreational catches has been collected by both state (WDFW Ocean Sampling Program (OSP)) and federal (Marine Recreational Fisheries Statistic Survey (MRFSS)) programs. From 1980-2003 (excluding the years 1990-1992), the MRFSS program provided effort information from a random-digit dialing protocol and catch/trip information from intercept interviews. OSP has estimated total ocean recreational catch and effort by boat type, port and catch area since the 1960s (with the spiny dogfish information available since 1990). Boat trip sampling is conducted randomly by OSP to generate catch estimates for most ocean-caught species, including sharks. The OSP reports removals of spiny dogfish within the "Shark/Skate" catch category, but anecdotal evidence suggests that the majority of this category is comprised of spiny dogfish (with a small number of blue and sixgill sharks and skates). Since 2002 release data on all marine fish by species have also been estimated within OSP from angler interviews.

MRFSS data were obtained via the RecFIN database and OSP data were received directly from WDFW (Wendy Beeghley, pers. com.). From 1995 to present, the RecFIN database contains catch estimates generated by the OSP while prior to 1995 it is mostly MRFSS-generated catch estimates. WDFW expressed several concerns with MRFSS dogfish data. Particularly, between 1980 and 1986 and in 1989, MRFSS focused on bottom fish effort alone (and not on salmon effort), and dogfish caught and released by salmon anglers were not included in the estimate of recreational removals. Between 1995 and 2003, even though all anglers were interviewed, there have been concerns with the allocation of sampling effort between the coast and the Puget Sound. Therefore, we used data collected by OSP where possible (1990-2010) and MRFSS data when OSP data were not available (1980-1989).

To estimate the proportion of spiny dogfish within the OSP "Shark/Skate" category, we compared MRFSS removals of spiny dogfish relative to removals of other sharks and skates. We found that no other sharks and skates were reported by MRFSS, and, therefore, assumed removals of OSP "Shark/Skate" to be representative of spiny dogfish removals.

To estimate the amount of released fish in OSP data for the 1990-2001 period (prior to when OSP started to sample released catch), we calculated an average release rate from OSP data for 2002-2010 period and applied this rate to the 1990-2001 retained catch data. Finally, to estimate the proportion of dead discard in OSP data on released catch (this type of information has never been collected by OSP), we applied the ratio of dead discard to total discard from MRFSS to the entire OSP data series (1990-2010).

2.1.2.2. Oregon

The records of Oregon recreational catch of spiny dogfish go back to 1979, and the amount of reported removals was minimal through the entire time series (with the average of 0.1 mt). The information on Oregon recreational catches was collected by the Oregon Ocean Recreational Boat Survey (ORBS) (1979- present) and by the federal MRFSS program (between 1980 and 2003, excluding the years 1990-1992).

The MRFSS data and the most recent ORBS data (2004 forward) were obtained via the RecFIN database. The early ORBS data (1979-2000) were provided by ODFW (Mark Freeman, pers. com.), but these early data included only the number of fish landed, neither discard nor average fish weights were reported. RecFIN provides data on the total amount of fish landed (catch type A) as well as dead (catch type B1) and alive (catch type B2) discard. No dead discard was reported for spiny dogfish (but there were records of alive discard); therefore Oregon recreation removals were equal to type A catch.

In the assessment, we used ORBS data (received from ODFW) for the period between 1979 and 2000 and the data from RecFIN for the period between 2001 and 2010. Since ORBS catch data reported the number of fish retained, we converted these numbers into weight using average fish weight from RecFIN to estimate the time series of Oregon removals in metric tons by year.

2.1.2.3. California

California catches comprised the largest portion of spiny dogfish recreation removal with an average of 18 mt by year since 1981. Information on recreational catches has been collected by both the California Recreational Fisheries Survey (CRFS) and federal MRFSS programs. MRFSS program ended in 2003. In 2004, the California Department of Fish and Game (CDFG), in cooperation with the Pacific States Marine Fisheries Commission (PSMFC), started the California Recreational Fisheries Survey (CRFS) program to replace the MRFSS sampling program in California. This program aims to increase sampling effort for better catch and effort estimation, to increase spatial resolution of catches, and to identify targeted species.

The data from both programs are available via the RecFIN database, and these data were used to reconstruct time series of California recreational dogfish removals (retained catch plus dead discard, A+B1). Removal in 1980 (93 mt) was found to be much higher than catches in other years. The RecFIN removals for other species in the 1980 were also found to be higher than those in other years. Anecdotal evidence suggests that effort during 1980, the first year of the MRFSS program, was likely poorly estimated, and therefore, the 1980 data point was excluded from the California time series of recreation catches. The average value of 1989 and 1993 was used for 1990-1992, the years when MRFSS data were not available.

Limited information on historical (prior to 1980) recreation catches in California is available from annual reports from the Commercial Passenger Fishing Vessel (CPFV) sampling program, but none of those contained records of spiny dogfish catches.

2.1.3. Bycatch in Pacific hake fishery

The annual amounts of spiny dogfish bycatch in the Pacific hake fishery are available from the North Pacific Database Program (NORPAC). That time series cover the period between 1977 and 2010 and include catches removed by foreign and domestic fisheries as well as those obtained during the time of Joint Ventures (JV).

In recent years (1991-2010) virtually 100% of hauls in the hake fishery are sampled for catch and species composition by the at-sea hake observer program (A-SHOP), and the total catch (retained and discarded) are estimated for both targeted and bycatch species for each haul. To derive the total amount of spiny dogfish bycatch by year, we simply summed the estimated catch in every haul within a year.

Prior to 1991, not every haul was sampled. For these years, NORPAC provided an expansion factor (one for each year), which is a ratio of total hauls to sampled hauls. We used these year-specific expansion factors to estimate the total amount of spiny dogfish caught by multiplying the amount of total catch in sampled hauls by the expansion factor. There were some records of dogfish data for years 1975-1976, but data in both years appear to be incomplete (in 1975, for example, there are only 5 records on spiny dogfish).

2.1.4. Discard

When not targeted, spiny dogfish is still common bycatch in fisheries for other commercially valuable species and is often discarded. A lack of market was identified as the main reason for discarding dogfish (Rogers and Pikitch 1992). Since 2002, the West Coast Groundfish Observer Program (WCGOP) has collected bycatch and discard information on board fishing vessels in the trawl and fixed gear fleets, along the entire coast and produced total fishing mortality estimates for all species observed. Prior to 2002, there were two studies of bycatch and discard in the trawl fishery, including the Enhanced Data Collection Project (EDCP) and the Pikitch study (Pikitch 1987, Pikitch et al. 1988).

The EDCP (administered by the ODFW) collected data on bycatch and discard of groundfish species off the Oregon coast from late 1995 to early 1999 (Sampson, pers.com.). The project had limited spatial coverage (Oregon waters only) and spiny dogfish was reported within the "Shark" category (no species composition samples were collected). Also, the EDCP primarily focused on the deepwater complex, or "DTS" (Dover sole, thornyheads and sablefish), and since spiny dogfish is a mostly shelf species, the project estimates of "Shark" discard rates might be not representative of the overall trawl fleet discard. For these reasons, the EDCP data were not included in the assessment.

The Pikitch study (Pikitch 1987, Pikitch et al. 1988) was conducted between 1985 and 1987, primarily within the Columbia INPFC area (Rogers and Pikitch 1992). Participation in the study was voluntary and included vessels using bottom, midwater and shrimp trawl gears. Discard rates were estimated using observations of retained and discarded catch of spiny dogfish. Because of the limited spatial coverage, the estimated discard rates from the Pikitch study were used as points for comparison with discard fleet time series, estimated from WCGOP data.
The WCGOP provided the time series of total mortality estimates in trawl and hook-and-line fleets between 2002 and 2009. The data included landings and discards of spiny dogfish (summed to total mortality, and aggregated by year and fleet). We calculated discard ratios of spiny dogfish relative to spiny dogfish encountered catch. We then explored a number of variables (and their combinations) as possible predictors of spiny dogfish discard, using linear regression analysis.

Coast-wide landings of spiny dogfish were found to be the most significant predictor of dogfish discard rates (R^2=0.92, p< 0.0001), with higher discard associated with smaller landings (Fig. 9). A similar linear relationship was found for hook-and-line gear, where spiny dogfish landed catch was the best examined predictor of discard ratios (R^2=0.65, p= 0.0002, Fig. 10). No other relationship examined was statistically significant (p>0.05). Specifically, the following predictors of spiny dogfish discard rates were explored, but rejected for both trawl and fixed gear (R^2 associated with regression for each predictor is also provided):

- Landings of all groundfish species. A regression resulted in R^2 of 0.05 when landings of groundfish species included those of Pacific hake, and in R^2 of 0.07 when hake landings were excluded.
- Landings of subsets of species that co-occur with spiny dogfish. There have been two studies which examined assemblages of groundfish species caught together in the groundfish trawl fishery on the U.S. West Coast. Rogers and Pikitch (1992) employed several clustering techniques to analyze data from the Pikitch study and define consistent assemblages of species. Heery and Cope (pers.com.) did the same, but using 2002-2008 WCGOP data. Both studies yielded similar results of no consistent or strong associations between spiny dogfish and other species, even though dogfish was a part (but in small amounts) of each of the identified assemblages. One of the clustering methods used by Rogers and Pikitch (1992) identified a dogfish assemblage (in which most of the catch was spiny dogfish), but these results were not consistent with other clustering techniques used. Cope and Haltuch (pers.com.) used two clustering methods to identify groundfish assemblages from fishery-independent data collected by the AFSC triennial and NWFSC shelf-slope surveys (both of these surveys were used in this assessment, Section 2.2). Spiny dogfish was found to be a part of two assemblages: (A) the "dover-hake-rex-slender sole" complex, and (B) the "English-sanddab-petrale" complex, even though it was not among "core" assemblage species consistently caught together. We used all the species from (A) and (B) assemblages identified by Cope and Haltuch and their combinations to explore possible relationships between the landings of these subsets of species and spiny dogfish discard. Those regressions did not yield R^2 values larger than 0.2.
- Price per pound of spiny dogfish. The regression resulted in an R^2 of 0.03, and R^2 value did not change when simple average or catch-weighted price per pound was used.

In addition, we explored patterns of dogfish discard by state and season, but no specific patterns were evident, other than the ones described above.

We used the relationships between spiny dogfish landings and discard ratios derived from the WCGOP data to reconstruct discard amounts in bottom trawl and hook-and-line fleets back to 1950, when the vitamin A fishery ended. Prior to 1950, it was assumed that all fish were retained. We compared our estimated trawl discard ratios for 1986 and 1987 with those calculated from the Pikitch study. Both estimates were very close, with the discard rate just above 90% (calculated as a ratio of dogfish discarded catch to total encountered catch of dogfish).

Given the lack of historical discard data and uncertainty in discard estimates, we conducted a number of sensitivity analyses with alternative assumptions regarding discard of spiny dogfish, including one with a minimum threshold applied for historical discard (i.e. discard was not allowed to drop below a specified amount). The uncertainty in discard was also explored when the entire time series of removals (landings and discard) were either increased or decreased (the details are provided in Section 7.1).

For at-sea hake fishery, we had data on the total removals of spiny dogfish (retained and discarded catch together), and therefore, there was no need to estimate time series of discard separately. Also, the discard mortality in at-sea hake bycatch fleet was assumed to be 100%, mostly due to long duration of hauls and large amount of fish brought on board. Figure 11 shows a snapshot of spiny dogfish bycatch within the at-sea hake fishery to support the assumption of 100% discard morality for this fleet.

There have been no studies performed on discard mortality of spiny dogfish in the Northeast Pacific Ocean for neither bottom trawl nor hook-and line fleet. In spiny dogfish assessments conducted elsewhere, different values of discard mortality were assumed, from 5% to 50% for bottom trawl and from 6% to 75% for hook-and-line gears, but all sources noted considerable uncertainty in these estimates. We assumed trawl discard mortality to be 100% (analogous to midwater trawl targeting Pacific hake), and hook-and-line discard mortality to be 50%. Given the uncertainty in assumed values, alternative assumptions regarding discard mortality in both fleets were explored via sensitivity analyses (see Section 7.1.3).

For the midwater and other gear fleets, no discard information was ever collected. The landings in both fleets were minimal, except for the period of the vitamin A fishery and in the beginning of food fish fishery in the 1970s when other gear catches increased. We assumed discard for these two fleets to be zero, recognizing that this might be an underestimation; the uncertainty in commercial removals were explored through the sensitivity analyses (see Section 7.1.1).

2.1.5. Fishery biological data

Biological information for commercial landings was obtained from PacFIN. Washington data was also received directly from WDFW (Theresa Tsou, pers. com.). Most of the biological samples of landings were collected by port samplers at the dock. A portion of biological samples (on discarded dogfish) were collected by observers at sea during the period of an Exempted Fishing Permit (EFP) fishery in 2003 and 2004, issued by the NMFS to the WDFW to measure the bycatch rates of canary rockfish and yelloweye rockfish in the dogfish fishery.

The biological data from the Pacific hake fishery collected by the A-SHOP were available through NORPAC. Recreational fishery data were obtained via the RecFIN database. Finally, biological information for trawl and hook-and-line discard was provided by WCGOP.

The biological data included sex, length and age data on individual organisms (amount varied by data source, Fig. 2). When lengths were measured as fork lengths (the case of commercial landings and A-SHOP data), measurements were converted to total "natural" (measured without extending the tail) lengths using the relationships estimated by Cheng (WDFW, pers. com.).

2.1.5.1. Length composition data

The summary of sampling efforts by fleet, state and year which were used to generate length frequency distributions are shown in Table 3. We used only randomly collected samples. Most of the length data were reported for females and males separately, except for recreational and hook-and-line discard data collected by EFP observers that was reported for both genders combined.

Majority of the length samples from landed catch were collected in Washington, but since the vast majority of spiny dogfish landings were made in Washington (Fig. 6), it was considered appropriate to use mostly Washington data to represent coast-wide fleets.

The initial input sample sizes (N_{input}) for length frequency distributions by year were calculated as a function of the number of trips and number of fish sampled using the method developed by Stewart and Miller (NWFSC):

$$N_{input} = N_{trips} + 0.138N_{fish} \qquad \text{when} \quad \frac{N_{fish}}{N_{trips}} < 44$$

$$N_{input} = 7.06N_{trips} \qquad \text{when} \quad \frac{N_{fish}}{N_{trips}} \geq 44$$

The method is based on analysis of the input and model derived effective sample sizes from west coast groundfish stock assessments. A piece-wise linear regression was used to estimate the increase in effective sample size per sample based on fish-per-sample and the maximum effective sample size for large numbers of individual fish (Stewart and Miller, pers.com.).

2.1.5.2. Age data

Unlike teleost fish, dogfish lacks hard structures commonly used for age determination (Ketchen 1975, Gallagher and Nolan 1999), and the traditional method of estimating the age of dogfish has been to count the growth bands visible on the surface of their second dorsal fin spine (Ketchen 1975, Beamish and McFarlane 1987). These bands are deposited annually, as validated using recaptures of tagged dogfish injected with oxytetracycline (McFarlane and Beamish 1987), and bomb radiocarbon studies (Campana et al. 2006).

The dorsal spines are, however, subject to wear, and the majority of spines are believed to have included some annuli that can no longer be counted. A method of accounting for these missing ages was proposed by Ketchen (1975). The relationship between spine diameter at the least readable point and the number of missing ages could be approximated by the relationship between the base diameter and number of ages counted on the spines of younger dogfish that were determined to be unworn. Ketchen (1975) modeled this relationship using the equation:

$$Y = \alpha X^{\beta}$$

where X is the spine base diameter in millimeters, Y is the estimated age in years from conception, and α and β are constant coefficients.

Another method of extrapolating the number of missing ages on worn spines has recently been proposed (Cheng 2011). This new approach assumes that the spine diameter grows according to a von Bertalanffy growth curve and estimates the number of missing ages as a random effect in a nonlinear mixed effects model fit to 3 diameter measurements along the unworn part of the dorsal spine. The assumption of growth according to the von Bertalanffy function is reasonable given a strong correlation (ρ = 0.95) between spine base diameter and fish total length. Furthermore, the use of multiple measurements along the spine and accounting for individual variability in spine growth are valuable additions to account for in calculating the number of missing ages.

For this assessment, age estimates for both the older Ketchen (1975) method (hereafter described as “Age Method 1”) and the newer Cheng (2011) method (hereafter described as “Age Method 2”) were considered. The age data were provided by WDFW for 4843 fish sampled including 4252 samples from commercial fisheries starting in 2003 and 591 from the 2010 NWFSC shelf-slope survey. Ages estimated using the newer, Age Method 2, were provided by WDFW, along with measurements of spine diameter and annuli counts, which were then used to apply Age Method 1 for comparison.

The calculation of parameters for Age Method 1 was based on 513 unworn spines. This included 260 samples from commercial fisheries and 253 from the 2010 NWFSC shelf-slope survey. Only the first readings were used (no double reads). The resulting parameters estimates were α = 2.1636, β = 1.4564 for females, and α = 2.1353, β = 1.4264 for males. Fits of the estimated relationship to the measurements of unworn spines are shown in Fig. 12.

The two ageing methods produced very different age estimates for the largest fish when missing ages were extrapolated. For the 1043 fish with length greater than 80 cm, the mean difference between ages from Age Method 1 and Age Method 2 was 12.4 years.

The patterns of length at age also show strong differences between ageing methods. The pattern of male length at age for ages calculated using Age Method 1 is more consistent between worn and unworn spines than Method 2 (Figs. 13-15). For example, of the 205 age samples from male dogfish with length between 45 and 50 cm, the mean age of the 70 fish with unworn spines was 9.3 years, whereas the mean estimated age associated with the 135 worn spines was 11.3 years when estimated by Age Method 1 and 17.2 years when extrapolated by Age Method 2.

It is expected that there be a correlation between age and degree of wear, so the older fish at a given size would be expected to have more worn spines. However, a contributing factor to the large difference in ages between two methods is the pattern that the number of missing ages calculated using Age Method 2 is at minimum 3 years (which produces a 3-year gap in estimated ages at the outset between those determined from the unworn spines and those with extrapolated annuli, Fig. 13), as opposed to Method 1, where the spine diameter at the last readable point in some cases estimated to be narrower than the diameter at birth and thus no annuli are estimated as missing (Fig. 12).

The pattern of female length at age does not appear to follow von Bertalanffy function well for either age method (Fig. 14), with the distribution of age and length for the largest fish less consistent with that of younger fish when Age Method 1 is applied.

Although in the assessment, we explored a variety of ways to utilize age data (including, downweighting age data to 0.1 in the likelihood compared to values of 1.0 for the other data source), the base model does not include age data, since some aspects of both methods raised questions about the ageing process, and further research into these methods would be valuable.

Furthermore, both methods depend on measurements of spine diameter, which are highly correlated with total length of fish, and therefore, any estimated ages, which include an extrapolation for missing ages, are not independent from the length measurements.

2.2. Fishery-independent data

The assessment utilizes fishery-independent data from four bottom trawl surveys conducted on the continental shelf and slope of the Northeast Pacific Ocean by NOAA Fisheries' Northwest (NWFSC) and Alaska Fisheries Science Centers (AFSC), including: 1) AFSC triennial shelf survey, 2) AFSC slope survey, 3) NWFSC shelf-slope survey, and 4) NWFSC slope survey, as well as one hook-and-line survey conducted by the International Pacific Halibut Commission (IPHC). Details on latitudinal and depth coverage of trawl surveys by year are presented in Table 4.

The AFSC triennial survey was conducted every third year between 1977 and 2004 (in 2004 this survey was conducted by the NWFSC using the same protocols). Survey methods are most recently described in Weinberg et al. (2002). The basic design was a series of equally spaced transects from which searches for tows in a specific depth range were initiated. Over the years, survey area varied in depth and latitudinal range (Table 4). Prior to 1995, the depth range was limited to 366 m (200 fm) and the surveyed area included four INPFC areas (Monterey, Eureka, Columbia and U.S. Vancouver). After 1995, the depth coverage was expanded to 500 m (275 fm) and the latitudinal range included not only four INPFC areas covered by the earlier years, but also part of the Conception area with a southern border of 34°50' N. For all years, except 1977, the shallower surveyed depth was 55 m (30 fm); in 1977 no tows were conducted shallower than 91 m (50 fm). Because of the differences in depth surveyed in 1977 and the large number of "water hauls", when the trawl footrope failed to maintain contact with the bottom (Zimmermann et al. 2001) the data from the 1977 survey were not used in the assessment. The tows conducted in Canadian and Mexican waters were also excluded.

In the assessment, the triennial survey was divided into two periods – between 1980 and 1992, and between 1995 and 2004; separate catchability coefficients (Q) were estimated for each time period. This was done to account for differences in spatial coverage before and after 1995 (Table 4) and to reflect a change in the timing of the survey. In its early years, the survey was conducted from mid-summer to early fall, but from 1995 on, the survey began at least a full month earlier (Fig. 16).

The AFSC slope survey was initiated in 1984. The survey methods are described in Lauth (2000). Prior to 1997, the survey was conducted in different latitudinal ranges each year (Table 4). In this assessment, only data from 1997, 1999, 2000 and 2001 were used – these years were consistent in latitudinal range (from 34°30' N. latitude to the U.S.-Canada border) and depth coverage (183-1280 m; 100-700 fm).

The NWFSC shelf-slope survey has been conducted annually since 2003, and the data between 2003 and 2010 were used in the assessment. The survey consistently covered depths between 55 and 1280 m (30 and 700 fm) and the latitudinal range between 32°34' and 48°22' N. latitude, the extent of all five INPFC areas on the U.S. west coast (Table 4). The survey is based on a random-grid design, and four industry chartered vessels per year are assigned an approximately equal number of randomly selected grid cells. The survey is conducted from late May to early October, and is divided into two passes, with two vessels operating during each pass. The survey methods are described in detail in Keller et al. (2007).

The NWFSC slope survey was conducted annually from 1999 to 2002 (Keller et al. 2007). The surveyed area ranged between 34°50' and 48°07' N. latitude, encompassing the U.S. Vancouver, Columbia, Eureka, Monterey INPFC areas, and a portion of the Conception, and consistently covered depths from 100 to 700 fm (183-1280 m) (Table 4).

The IPHC has conducted an annual longline survey for Pacific halibut off the coast of Oregon and Washington since 1997 (no surveys were performed in 1998 or 2000). Beginning in 1999, this has been a fixed station design, with roughly 1,800 hooks deployed at 84 locations each year (station locations differed in 1997, and are therefore not comparable with subsequent surveys). Dogfish catch has historically occurred at many of the 84 stations in the design (Fig. 17). Dogfish bycatch has been recorded during this survey on the first 20 hooks of each 100-hook skate (one skate is the basic unit of longline survey gear). The gear used to conduct the survey, while designed to efficiently sample Pacific halibut, is similar to longline gear that has been used in some targeted dogfish fisheries. Some variability in exact sampling location is practically unavoidable, and leeway is given in the IPHC methods to center the set on the target coordinates while allowing wind and currents to dictate the actual direction in which the gear is deployed. This can result in different habitats being accessed at each fixed deployment location across years.

2.2.1. Survey indices

Indices of abundance for each of the four bottom trawl surveys were derived using a generalized linear mixed model (GLMM), including vessel-specific differences in catchability (via inclusion of random effects), for each survey time series following the methods of Helser et al. (2004). This assessment's GLMM indices were generated using the same basic method, but reprogrammed by John Wallace (NWFSC, pers. com.) utilizing a package which uses OpenBUGS (http://www.openbugs.info) (an offshoot of WinBUGS) running under the statistical programming language R. The Delta-GLMM approach explicitly models both the zero and non-zero catches and allows for skewness in the distribution of catch rates through the use of a gamma or lognormal error structure. Index uncertainty is estimated using a Markov Chain Monte Carlo (MCMC) approach as described in Helser et al. (2007). The survey indices and standard error of the natural log of biomass estimated in this assessment are shown in Table 5.

The bottom trawl survey indices (Table 5) show significant changes in abundance throughout the survey time series, which are not consistent with what is known about the dynamics of *K*-strategy organisms, such as spiny dogfish. Such fish exhibit slow growth, late maturation, a long gestation period and low fecundity. A pattern of high variability in abundance from year to year was especially pronounced for the NWFSC shelf-slope survey (Table 5), for which abundance of spiny dogfish was shown to decrease more than in half in 2004 and then again in 2005. The most probable explanation for high variability in index estimate by year is that it reflects patchiness in the spatial distribution of spiny dogfish, when survey can encounter either a large school, only diffusely scattered individuals, or none at all (“zero tows”). The spiny dogfish often forms large schools, which supports the hypothesis of patchy distribution, and extreme variation in density of fish (among hauls) encountered by a survey.

In the NWFSC shelf-slope survey, most of the positive dogfish hauls occurred shallower than 183 m (100 fm) as shown in Fig.18. The average amount of spiny dogfish in a positive haul was 45 kg, and 95% of positive hauls were less than 85 kg. However, a few hauls had between 4,000 and 16,585 kg of dogfish (Fig. 19), and the estimates for survey index in years with those large hauls are the highest (Fig. 19, Table 5). This indicates that the gamma distribution used within the GLMM to estimate survey indices cannot adequately describe abundance of schooling fish such as spiny dogfish. Currently, a research is under way to develop alternative error distributions for GLMM approach, for example applying mixture distribution methods (Thorson et al., 2011) to account for schooling and solitary individuals. However, since these techniques are not currently available, additional variance was estimated for all trawl surveys used in the model to account for patchiness in spiny dogfish distribution and highly variable catches.

The IPHC longline survey catch data were standardized using a Generalized Linear Model (GLM) with binomial error structure. Catch-per-hook was modeled, rather than catch per station due to the variability in the number of hooks deployed and observed each year. The binomial error structure was considered logical, given the binary nature of capturing (or not) a dogfish on each longline hook. The modeling approach is identical to that used in recent yelloweye rockfish assessments (Stewart et al. 2009), which includes a more detailed description of survey design and methods.

The IPHC index trends are fairly stable over the full time series (1999 through 2010). This index is both the longest time series available for dogfish, and is also less subject to the influence of a few large tows that appear to drive some of the variability in the trawl surveys described above. Additional variance was added to IPHC survey as well, but it was fixed at a relatively low level of 0.1, and the alternative assumptions regarding the value of additional variance added to this survey was explored via sensitivity analysis (see Section 7.1.5).

2.2.2. Survey biological data

Biological data were collected within three trawl surveys, including AFSC triennial and slope surveys and NWFCS shelf-slope survey. No biological samples were available for the NWFSC slope and IPHC surveys. The available biological data included sex, length, age and weight of individual fish (amount varied by survey, Fig. 2). The length data were used to develop length frequency distributions and weights, sampled within NWFSC shelf-slope survey, were used to estimate Weight-Length relationship by gender (Section 2.3.4). No ages were explicitly used in the model (see Section 2.1.5.2 for details).

2.2.2.1. Length composition data

Length frequency distributions were derived by year for three out of five surveys (for which data were available). A summary of sampling efforts by survey and year which were used to generate length frequency distributions are shown in Table 6. When a large proportion of the length data were recorded as unidentified sex, the sexes were combined (as in the case of the 1998 AFSC triennial survey and 1998 AFSC slope survey). The 1986 and 1993 length data from AFSC triennial survey were not used in the assessment, since very few fish were samples (for each survey) and all of them were collected in a single haul.

The initial input sample sizes for the survey length frequency distribution data were calculated as a function of both the number of fish and number of tows sampled using the method developed by Stewart and Miller (NWFSC, pers.com.):

$N_{input} = N_{tows} + 0.0707N_{fish}$ when $\frac{N_{fish}}{N_{trips}} < 55$

$N_{input} = 4.89N_{tows}$ when $\frac{N_{fish}}{N_{tows}} \geq 55$

2.3. Biological parameters

Several biological parameters used in the assessment were fixed at the externally estimated values, which were either derived from the available data or obtained from published sources. The data and approaches used to estimate biological parameters (fixed in the model) are described below.

2.3.1. Natural mortality

To estimate natural mortality *M*, we explored several methods that relate *M* with different life history parameters, including longevity, growth rate and age-at-maturity (Charnov 1993, Hoenig 1983, Jensen 1996, Rikhter and Efanov 1976, Roff 1986). Hoenig (1983) developed a model that related total mortality to the maximum age of fish. Since Hoenig's analysis was based largely on unexploited fish stocks, total mortality in his model is often assumed to be natural mortality. Based on the Hoenig's method the natural mortality of spiny dogfish was estimated at 0.064 yr^{-1}. This estimated value is within a range of those estimated for spiny dogfish by other studies. It is also consistent with natural mortality for dogfish shark in the Northeast Pacific Ocean (0.065) estimated by Smith et al. (1998). The value 0.064 $yr^{-1}$was used in the base model, and a likelihood profile analysis was performed to explore how informative the data in model are regarding the value of *M*.

2.3.2. Growth

The von Bertalanffy growth function (von Bertalanffy 1938) was used to model the relationship between length and age in spiny dogfish. This is the most widely applied somatic growth model in fisheries (Haddon 2001), and has been commonly used to model growth in spiny dogfish. Also, the most recent evaluation of the growth models for spiny dogfish in the Gulf of Alaska (Tribuzio et al. 2010) reported the von Bertalanffy function to be the most reasonable for both females and males.

Male spiny dogfish were reported to grow slightly faster than females, but females reach larger sizes, therefore, time-invariant growth was modeled for each gender separately. Stock Synthesis modeling framework uses the following version of the von Bertalanffy function:

$$L_A = L_\infty + (L_1 - L_\infty)e^{-k(A-A_1)}$$

Where L_A is length (cm) at age A, k is the growth coefficient, L_∞ is asymptotic length, and L_1 is the size associated with a minimal reference age.

Given that age data were not used in the assessment (due to concern with extrapolating unreadable annuli along the worn part of the spine, Section 2.1.5.2), the growth parameters in the base model were fixed. All growth parameters (except female L_∞) were fixed at the estimated values from ages generated by Age Method 1, which (unlike those generated by Age Method 2) exhibits consistent pattern between ages estimated from unworn and ages with statistical extrapolation applied. The female L_∞ was treated differently than other parameters because the uncertainty in age data associated with extrapolation was particularly high for females, which is evident from the length at age pattern generated by both ageing methods considered in this assessment (Figs. 13-15). For females, L_∞ was fixed at the value of 109 cm estimated by Taylor and Gallucci (2009). The female L_∞ of 109 cm from Taylor and Gallucci (2009) is consistent with the average size of the 100 largest females in our dataset. All of the parameters used in the assessment are consistent with other growth studies conducted on spiny dogfish in the Northeast Pacific Ocean.

2.3.3. *Maturity and fecundity*

The relationship between female size and maturity was taken from recently published work (Taylor and Gallucci 2009), based on 499 fish collected in Puget Sound in the 2000s (Fig. 20). The logistic function used was:

$$M\% = \frac{1}{1 + e^{\beta(L - L50\%)}}$$

Where $M\%$ is the proportion of mature females in the stock, β = -0.27 is a parameter controlling the rate of increase in maturity and and $L50\%$ = 88.2 cm is the length at 50% maturity.

The fecundity of mature fish was also set equal to values from Taylor and Gallucci (2009), which were calculated from 106 pregnant fish from the maturity study for which counts of embryos were available (Fig. 20). A linear relationship between female length (L) and fecundity (expressed in number of pups) was assumed:

$$Pups = \alpha + \beta L$$

with estimated parameters α = -14.7 and β = 0.214. This relationship results in an increase from 0 pups at the size of 66 cm (when maturity is less than 0.3%) to about 7 pups per litter at 100 cm (when maturity is 97%) and about 15 pups per litter at the largest size of 136 cm.

2.3.4. *Weight-length relationship*

To establish the relationship between weight and length, the following equation was used:

$$W = \alpha(L)^\beta$$

Where W is individual weight (kg), L is total natural length (cm) and α and β are coefficients used as constants. Data from NWSFC shelf-slope survey collected in the years 2007-2010 were used to estimate weight-length parameters by sex. Based on the length and weight observations from 1579 females and 1720 males, the parameters β were estimated as $\alpha = 2.3065 \cdot 10^{-6}$ for females and $3.4911 \cdot 10^{-6}$ and for males, and $\beta = 3.1526$ for females and 3.0349 for males (Fig. 21).

3. Model description

This report describes the latest version of the assessment model that includes changes made during the STAR Panel (these changes are listed in Section 5).

3.1. Assessment program

This assessment model was developed using the Stock Synthesis (SS) modeling program developed by Dr. Richard Methot at the NWFSC (Methot 2005, 2011). The most recent version (v3.21f) distributed on June 16, 2011 was used. This version includes modifications made to specifically accommodate the biology and life history of spiny dogfish. Particularly, it provides a new stock-recruitment option to express the relationship in terms of offspring survival rather than recruitment (Section 3.4.2), which is more reasonable for such low fecund species as spiny dogfish. This SS version also incorporates a new fecundity option when the female fecundity is expressed as a function of length so that the model can easily incorporate the results of the spiny dogfish fecundity study conducted in the 2000s (Taylor and Gallucci 2009).

3.2. General model specifications

This assessment area is limited to coastal waters of the Unites States west coast, off Washington, Oregon and California, bounded by the U.S.-Canadian border on the north and U.S.-Mexican border on the south. The assessment area does not include Puget Sound or any other inland waters. The spiny dogfish population within the assessment area is treated as a single coast-wide U.S. stock, given the migratory nature of the species and the lack of data suggesting the presence of multiple stocks.

As mentioned in the Introduction, the stock included in this assessment very likely has interaction and overlap with dogfish observed off British Columbia. A spatial population dynamics model (Taylor 2008), which included data from a tagging study in the 1940s and from much larger tagging experiments conducted in Canada and inside U.S. waters of Puget Sound, estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. Given this relatively low estimated rate of exchange, it was considered appropriate to proceed with the assessment for the limited area of species range, recognizing that the scope of this assessment does not capture all of the removals and dynamics which very likely bear on the status and trends of the larger, transboundary population.

The modeling period begins in 1916, assuming that in 1915 the stock was in an unfished equilibrium condition. Fishery removals are divided among 8 fleets (6 catch and 2 discard fleets). These fleets are: 1) Bottom trawl, 2) Bottom trawl discard, 2) Midwater trawl, 4) Bycatch in at-sea Pacific hake fishery, 5) Hook-and-line, 6) Hook-and-line discard, 7) Other gears, and 8) Recreational. The time series of removals for each fleet were reconstructed outside the model and entered in the SS data file. Historical catches were reconstructed by state, and then combined into coast-wide fleets, defined based on gear groups. Since discarded catch was included in the model as catch time series, no retention curves were specified in addition to fleet selectivities. Removals associated with research surveys are also treated as fleets. The data for each fleet used in the assessment are summarized in Fig. 2.

This is a sex-specific assessment model. The sex-ratio at birth is assumed to be 1:1. Females and males have separate growth curves and sex-specific weight-at-length parameters. The model assumes a constant natural mortality of 0.064 yr^{-1} for both genders. The length frequency distributions are represented as thirty one 4-cm bins ranging between 12 and 132 cm. Length is expressed as total natural length measured without extending the fish tail. Population length bins are defined at a finer 2-cm scale, ranging between 10 and 136 cm.

3.3. Likelihood components

In the model, likelihood estimates for the various data components were obtained by comparing expected values from the model with the actual observations from sample data based on "goodness of fit" procedures for log likelihood. The likelihood components of the model include: 1) survey abundance indices, 2) mean size of fish in the discard fleets, and 3) fishery and survey length frequency distributions.

3.4. Model parameters

In the assessment, there are parameters of three types, including life history parameters, stock-recruitment parameters and selectivity parameters. These parameters were either fixed or estimated within the model. Reasonable bounds were specified for all parameters. Survey catchability was estimated for each index of abundance; no prior assumptions were made regarding catchability.

3.4.1. Life history parameters

Life history parameters that were fixed in the model included natural mortality and growth for both genders, weight-at-length for males and females, maturity-at-length and fecundity-at-length. The estimates for these fixed parameters were either derived from data available or obtained from the literature, as described in Section 2.3.

3.4.2. Stock-recruitment parameters

The fecundity of dogfish in the Northeast Pacific Ocean has been well studied (Ketchen 1972, Tribuzio 2004, Taylor and Gallucci 2009), with pregnant females having relatively few pups per litter, and with relatively little variability between individuals. Unlike fish producing millions of eggs, the low fecundity of dogfish suggests both low productivity in general and a more direct connection between spawning output and recruitment than for many species.

The spawner-recruit relationship was modeled using a new functional form that was recently added to SS, which allowed a more explicit modeling of pre-recruit survival between the stage during which embryos can be counted in pregnant females to their recruitment as age 0 dogfish (Richard Methot and Mark Maunder, pers.com.). This new method may be useful for a variety of low fecund species, as well as providing additional flexibility in the spawner-recruit relationship that may be explored for any stock. The method is an expansion and improvement on similar approaches previously applied to dogfish (Wood et al. 1979, Taylor 2008), which assumed a linear decline in age 0 survival as a function of population density.

The survival of pre-recruit dogfish at equilibrium is calculated as:

$$S_0 = \frac{R_0}{B_0}$$

Where R_0 is the recruitment at equilibrium, resulting from the exponential of the estimated log(R_0) parameter, and B_0 is the equilibrium spawning output (in units of number of embryos), calculated by projecting the numbers at age forward under natural mortality, starting with R_0 at age 0, then converting to numbers at length for the estimated growth parameters and variability in length at age, and finally applying the maturity and fecundity relationships to get total spawning output.

Recruitment for each year in the time series is then calculated as:

$$R_y = S_y B_y$$

Where B_y is the spawning output in year y, and S_y is the pre-recruit survival given by the equation:

$$S_y = \exp\left(-z_0 + (z_0 - z_{min})\left(1 - \left(\frac{B_y}{B_0}\right)^{\beta}\right)\right)$$

Where

$z_0 = -\log(S_0)$
is the pre-recruit mortality rate at equilibrium,

$z_{min} = z_0\left(1 - z_{frac}\right)$
is the limit of the pre-recruit mortality as depletion approaches 0, parameterized as a function of z_{frac} (which represents the reduction in mortality as a fraction of z_0) so the expression is well defined over a parameter range $0 < z_{frac} < 1$, and,

β is a parameter controlling the shape of density-dependent relationship between spawning depletion and pre-recruit survival.

The steepness (h) of the spawner-recruit curve (defined as recruitment relative to R_0 at a spawning depletion level of 0.2) can be derived from the parameters above according to the relationship

$$h = 0.2\exp\left(z_0 z_{frac}\left(1 - 0.2^{\beta}\right)\right)$$

By modeling the relationship in terms of mortality instead of survival (as in Taylor 2008), annual deviations in recruitment can be modeled (implemented in SS by replacing B_y in the equation above with $B_y e^{r_y}$ where r_y is the deviation in recruitment in year y). Attempts to model recruitment deviations in this assessment indicated that the data did not provide adequate detail to get reasonable estimates. Furthermore, the relatively large size of dogfish pups at birth (20-

30cm, Tribuzio 2004) would suggest that variability in recruitment would be lower than for a species with a larval stage, which is subject to higher mortality rates.

3.4.3. Selectivity parameters

Gear selectivity parameters used in this assessment were specified as a function of size. Age-based selectivity was set to 1.0 for all ages beginning at age 0. Separate size-based selectivity curves were fit to each fishery fleet and survey, for which length composition data were available. Selectivity curves for those fleets that lack length data were "mirrored" to fleets with length data.

A double-normal selectivity curve was used for all fleets. This curve has six parameters, including: 1) peak, which is the length at which selectivity is fully selected, 2) width of plateau on the top, 3) width of the ascending part of the curve, 4) width of the descending part of the curve, 5) selectivity at first size bin, and 6) selectivity at last size bin.

Peaks (parameter 1) and widths of the ascending part of the curves (parameter 3) were estimated by the model for all fleets. The initial selectivity parameters (parameter 5) were fixed so that the smallest bin had a selectivity of 0 for most fleets, except for midwater trawl, at-sea hake bycatch and discard fleets, since those fleets were found to encounter organisms from the smallest data bin (12-15 cm).

Selectivity curves of bottom trawl and hook-and-line fleets were assumed to be asymptotic because examination of length composition data revealed that these fleets are catching the largest fish observed. The selectivities of discard fleets and the recreational were allowed to be dome-shaped, but in initial runs, the estimates were essentially asymptotic, and therefore, these selectivities were made asymptotic by fixing the selectivity at the last size bin (parameter 6) at a large value. We also fixed the width of plateau on the top (parameter 2) and the width of the descending part of the curve (parameter 4) at intermediate values since these parameters are redundant when selectivity is fixed as asymptotic. Selectivity of bottom trawl and hook-and-line fleets during the time of vitamin A fishery (prior to 1950) were assumed to be the same as corresponding discard fleets, since fish of all sizes were retained at the time of that fishery.

Midwater and at-sea hake bycatch fleets were allowed to be dome-shaped. Their selectivity curves were identical due to almost identical length frequency distributions of catch for these fleet (at-sea hake fishery is conducted by midwater trawl as well). It was, therefore, considered appropriate to assume the same selectivities for midwater and at-sea hake fleets and they were set to mirror each other.

The NWFSC shelf-slope survey selectivity curve was also assumed to be asymptotic because this survey covered the entire latitudinal range of the assessment and went deep enough to include the entire depth range of the species. Selectivity curves of AFSC triennial and AFSC slope surveys were estimated to be dome-shaped since they covered only a portion of the latitudinal extent of the assessment and the depth range of the species. Allowing slope surveys to be dome-shaped is further justified biologically by the fact that spiny dogfish does not exhibit ontogenetic shift when older larger individuals are moving to deeper water (as observed in a number of groundfish in the Northeast Pacific Ocean), larger individuals occur in both shelf and slope areas (Fig. 22). Therefore, lack of survey spatial coverage in either shelf or slope areas could potentially lead to not selecting larger organisms in the population.

No length composition data were available for the “Other gear” fleet, NWFSC slope survey and IPHC survey. The Other gear fleet was assumed to have the same selectivity the Hook-and-line discard fleet, since historical records suggest that the set nets (a major component of the Others) were selecting the same-sized fish as hook-and-line gear. This fleet was set to mirror hook-and-line discard rather that hook-and-line fleet because the other gear fleet was primarily in operation at the time of vitamin A fishery and organisms of all sizes were retained. The selectivity for NWFSC slope survey was set to mirror the AFSC slope survey since both surveys used the same type of gear, and had the same depth coverage. Finally, IPHC hook-and-line survey selectivity was also set to mirror that of the Hook-and-line discard fleet since the gear used to conduct the survey is similar to longline gear that is used in some commercial longline fisheries from which the length samples of discarded dogfish are collected.

Different assumptions regarding shape of selectivity curves were explored via sensitivity analysis before and during STAR Panel review (Section 7.1.4).

4. Model selection and evaluation

4.1. Alternate model configurations

A large number of alternative model configurations of different levels of complexity were explored in order to formulate a base model that would realistically describe the population dynamics of this stock and would balance realism and parsimony. A selected number of the most relevant alternate model configurations that were considered but rejected are described in the sensitivity analyses section (Section 7.1). These configurations include alternative assumptions regarding commercial removals, historical discard and discard mortality of spiny dogfish, different assumptions regarding shape of selectivity curves, alternate values for natural mortality (*M*), variation in extend of extra variance added to IPHC survey, and different assumed stock-recruitment relationship (Beverton-Holt model).

We evaluated the alternative models based on overall model fit and convergence criteria. Key assumptions and structural choices were made based on whether the model estimated parameters and outputs make sense and are consistent with information available for the species. The base model reflects the best aspects from these exploratory analyses. It appears to be parameterized sufficiently to fit the observed data, while maintaining reasonable parameter values and parsimonious explanations for the underlying model processes.

4.2. Convergence status

A number of tests were done to verify model convergence. The Hessian matrix for the base model was positive definite. The maximum gradient component for the base model was 0.000028. We also assessed the model’s ability to recover similar likelihood estimates when initialized from dispersed starting points (jitter option in SS). Out of the 25 tests, 16 produced the same result as the base model and the rest produced different results, but with lower likelihood (higher negative log-likelihood). Taken together, this evidence provides every indication that the base model is truly the set of parameter estimates producing the best fit the data.

5. Response to the STAR Panel recommendations

During the STAR Panel review, analysis and evaluation of the base model were performed to explore data sources and better understand model performance. The STAR Panel provided useful recommendations that were incorporated into the base model. Specific changes made to the pre-STAR model during the STAR Panel review included:

1) Not to use age data. In the pre-STAR model, age data were downweighted to 0.1 in the likelihood (compared to values of 1.0 for the other data source) because both ageing methods explored within the assessment raised concerns regarding statistical extrapolation of the unreadable annuli on the worn part of the spines (see Section 2.1.5.2).
2) Keep female L_∞ fixed at the value of 109 cm as estimated by Taylor and Gallucci (2009), and fix the other growth parameters at the values estimated from ages generated by Age Method 1 (instead of estimating those parameters within the model).
3) Use selectivity curves of bottom trawl discard and hook-and-line discard fleets to describe selectivity of bottom trawl and hook-and line fleets respectively during the time of vitamin A fishery (when all sizes of fish were retained).
4) Mirror selectivity of the Other gear fleet to the selectivity hook-and-line discard (instead of hook-and-line) since the other gear fleet contribution was the most during the vitamin A fishery when fish of all sizes were retained.
5) Mirror selectivity of IPHC longline survey to that of hook-and-line discard fleet (instead of hook-and-line fleet).

Comparison of likelihood components, selected parameters and reference points between base and pre-STAR model are provided in Table 7. The comparison of outputs between base and pre-STAR models as well with subsets of changes made during the STAR Panel (changes 1 and 2 in the list above) are provided in Figs. 23-24.

6. Base model results

The list of the explicit parameters used in the base model and their values (either fixed or estimated) is provided in Table 8. The life history parameters estimated within the model are reasonable and consistent with what we know about the species. Both sexes follow the same trajectory in their growth. Males grow slightly faster than females, but with females reaching larger sizes (Fig. 25). Figures 26-29 show weight-at-length relationships by sex, female maturity-at-length, fecundity-at-weight and spawning output-at-length generated based on fixed parameters that were derived from data outside the model. Female fecundity and spawning output are expressed in number of pups (Section 3.4.2).

The base model was able to capture general trends for indices in all surveys, which were either stable or decreasing (Figs. 30-34). The estimated biomass in the 2003 and 2004 NWFSC shelf-slope survey exhibits a significant decline, which is not consistent with the dynamics of *K*-strategy organisms, such as spiny dogfish, with slow growth, late maturation and low fecundity. The most probable explanation for such a decline is that it reflects patchiness in the spatial distribution of spiny dogfish, when survey can encounter either a large school or only diffusely scattered individuals. The NWFSC shelf-slope survey encountered one extremely large haul of spiny dogfish in 2003 and several larger than average hauls in 2004 (Fig. 19), which supports the hypothesis of patchy distribution and extreme variability in survey catches. The model also estimates large variance around those estimates.

The base model fits the length frequency distributions well. The quality of fit varies among years and fleets, which reflects the differences in quantity and quality of data. The Pearson residuals, which reflect the noise in the data both within and among years, did not exhibit any strong trends. In the assessment iterative re-weighting was used to achieve consistency between the input sample sizes and the effective sample sizes for length and age composition samples based on model fit. This reduces the potential for particular data sources to have a disproportionate effect on total model fit. Observed and effective sample sizes for length frequency observations, the model fit to length frequency distributions and Pearson residuals by fleet and gender are shown in Figs. 35-91.

The size selectivity curves from the base model are shown in Figs. 92-104. For the bottom trawl discard and hook-and-line discard fleets, the model estimated higher selectivity for smaller fish than those of corresponding catch fleets (bottom trawl and hook-and-line), which is consistent with the fact that smaller fish are more frequently discarded. The AFSC triennial, AFSC slope and NWFSC slope survey selectivity curves were estimated as dome-shaped, which is consistent with the fact that those survey had only a limited spatial coverage of the assessment area and species range within the assessment area (Table 4).

The time series of total and summary biomass, spawning output, depletion relative to B_0, recruitment, and fishing mortality are presented in Figs. 105-109 and Table 9. The spawning output showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 70% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, and the spawning output started to increase (mostly as a result of maturation of younger dogfish that were not selected by the vitamin A fishery). For the last thirty-five years, spawning output of spiny dogfish has been slowly but steadily declining due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock. Currently, the spawning output is estimated to be at the level of 63% of its unfished level (Fig. 110). Predicted numbers at age from the base case for females and males are provided in Appendix A.

7. Model uncertainty

Parameter uncertainty in the assessment is explicitly captured in the asymptotic confidence intervals estimated within the model and reported throughout this assessment for key parameters and management quantities (Figs. 107, 108, 110). These intervals reflect the uncertainty in the model fits to the data sources in the assessment, but do not include the uncertainty associated with alternative model configurations and fixed parameters. To explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in model assumptions, a variety of sensitivity runs were performed.

7.1. Sensitivity analyses

A large number of configurations of the base model addressing alternative assumptions regarding key model parameters and structural choices were explored via the sensitivity analysis. Only the most relevant ones are reported here. Results of these selected sensitivity runs are summarized in Tables 10-12 and Figs. 111-112, 114-118.

7.1.1. Alternative assumptions about fishery removals

Commercial landings of spiny dogfish are relatively well documented because of dogfish utilization history on the U.S. west coast and unique appearance of this species. However, there is an uncertainty associated with discard estimates used in the model as well as discard mortality rates applied (landings and discard (with associated discard mortality) together comprise the total fishery removals). To explore the model sensitivity to uncertainty in spiny dogfish removals (that include both landings and discard), we ran the model assuming: 1) 50% increase in removals, and 2) 25% decrease in removals, in all the fleets, except for at-sea hake bycatch since it is 100% observed by A-SHOP. Although these runs differed in the absolute estimate of B_0 and current biomass (Fig. 111), the trends in spawning depletion as well as estimated depletion levels varied only slightly (Fig. 112, Table 10).

7.1.2. Alternative assumptions about historical discard

No information is currently available about the historical discard during the period between 1950 (when vitamin A fishery ended) and 1975 (when the export fish food fishery began). We could locate only one document on coastal historical dogfish discard, which is a one-trawler, one-trip snapshot. This document confirms that discard did take place, but it does not provide enough information to estimate the magnitude of discard for the entire fleet. Given the limitations of the historical discard data, in the base model, the relationship for predicting the discard derived from WCGOP data was assumed for the entire period after the vitamin A fishery. An alternative assumption about historical discard was explored when a minimum threshold applied to historical discard (i.e. discard was not allowed to drop below a specified amount); this minimum threshold was calculated as an average of the 1950-1974 discard (Fig. 113). The results show that the model is only slightly sensitive to this assumption, and neither spawning output nor spawning depletion noticeably changed when alternative historical discard time series was assumed (Figs. 114-115, Table 10).

7.1.3. Alternative assumptions about discard mortality

We also explored the model sensitivity to the alternative assumptions regarding dogfish discard mortality. In the base model, 100% discard mortality was assumed for trawl discard fleet and 50% for hook-and-line discard. In the alternative runs, we assumed both discard fleets to have: 1) 100% discard mortality, and 2) 50% discard mortality. We also ran the model assuming 6% mortality for hook-and-line discard fleet and 5% for bottom trawl discard fleet. Those values are used by the Integrated Fisheries Management Plan (IFMP) for Pacific Canadian groundfish fisheries, except for the fact that IFMP uses 5% discard mortality for the first two hours of a trawl fishing event with 5% for each additional hour (no historical data on tow length were available for this assessment). The runs with both fleets having 100% and 50% did not produce large differences in comparison with the base model in the sense of depletion level, but the run with the lowest discard mortality rates produced more depleted stock that estimated by the base model. In general, most of the model results in this sensitivity and others show a slight declining trend in the most recent years. The model with the lowest discard mortality has the lowest total mortality in the past 30 years compared to the peak in the 1940s. Therefore, for this model to produce a slight decline in recent years, the status of the stock in the 1970s, when the recent fishery restarted, has to be lower so that a smaller increase in total mortality (with little additional mortality from discard) can be enough to cause the stock to stop rebuilding.

7.1.4. Alternative assumptions about gear selectivity

In the base model, a few selectivity curves were fixed to be asymptotic (see Section 3.4.3). Prior to the STAR Panel, we conducted a number of runs to explore model sensitivity to assumptions regarding shape of fleets' selectivity curves. Those runs resulted in a range of outputs, but the one with no selectivity curves fixed as asymptotic produced the most extreme result when the depletion level was estimated to be at 100%. Given the low productivity of the stock and the intense period of fishing in the 1940s, this result seems implausible.

7.1.5. Alternative assumptions about extra variance for the IPHC survey

Prior to STAR Panel, a sensitivity analysis was also conducted on the base-case addition of 0.1 to the standard deviation, in log space, for the IPHC survey biomass estimate. In one alternative, no extra variance was added and in the other, the model was allowed to freely estimate it. Model results were not sensitive to either alternative formulation. The estimated parameter value was 0.204, compared to 0.1 in the base case. Estimates of B_0 and depletion level from the models with the low and high estimates of the parameter bracketed the base model estimates of B_0 and depletion.

7.1.6. Alternative assumptions of spawner-recruit relationship

Sensitivities were conducted to explore alternative assumptions about the spawner-recruit relationships. The relationship used in this model is parameterized in terms pre-recruit survival (Section 3.4.2). The parameters controlling the relationship, which may be estimated or fixed, are equilibrium recruitment (R_0), a parameter controlling the potential decrease in pre-recruit mortality as spawning output is reduced (z_{frac}), and a parameter controlling the shape of the mortality-depletion relationship (β). This is unlike the Beverton-Holt spawner-recruit relationship, which is parameterized in terms of R_0 and steepeness (h), representing the recruitment at a spawning depletion of 0.2, as a fraction of R_0.

The base model uses the survival-based relationship with z_{frac} = 0.4 and β = 1.0. Five sensitivities were conducted for the survival-based relationships, exploring alternative values of z_{frac} fixed at 0.2 and 0.6, as well as estimated, and alternative values of β = 0.5 or 2.0. Four sensitivities were conducted using a Beverton-Holt spawner-recruit relationship instead of the survival-based relationship. These had h fixed at 0.284, 0.3, and 0.4, as well as estimated. The value of h = 0.284 was chosen to match the steepness of the base model, calculated as a derived quantity rather than a parameter input. In all models, the R_0 parameter was estimated.

Comparisons of model output are shown in Figs. 116-118 and Tables 11-12. All models showed a similar pattern in depletion, but the extent of decline in the 1940s and the scale of the trajectory since then vary among cases. In the cases where the z_{frac} parameter in the survival-based spawner-recruitment relationship and h in the Beverton-Holt relationship estimated, they both hit the lower boundary: z_{frac} = 0 and h = 0. These values are associated with a biologically unrealistic stock with no surplus-production and the increases in spawning output from the 1950s through 1970s in these cases are entirely the result of maturation of younger dogfish that were not selected by the 1940s target fishery, as opposed to density-dependent increases in recruitment. The model with Beverton-Holt spawner-recruit relationship with h = 0.284 set to match the result of the base model produced very similar results to those from base model, both in terms of population trajectories and yield. Sensitivities with parameters associated with higher productivity than the base model (z_{frac} = 0.6, β = 2.0, and a Beverton-Holt relationship with with h = 0.3 or 0.4) had higher equilibrium biomass estimates, and thus were less depleted and had higher current status. Those sensitivities with parameters associated with less productive stocks (z_{frac} = 0 or 0.2, β = 0.5, and a Beverton-Holt relationship with with h = 0.2) showed greater depletion and lower equilibrium yield.

Over the range of depletion values estimated in these sensitivities, none of the values for pre-recruit survival (Fig. 118, bottom row) were above 1.0. However, one advantage of the new survival-based spawner-recruit curve is that it allows these values to be contained within a biologically reasonable range. Projections with Beverton-Holt relationships indicate that pre-recruit survival increases to about 0.9 for h=0.4 as spawning depletion approaches 0. With h=0.6, the limit of pre-recruit survival is about 2.0, a value associated with recruitment of 2 age 0 recruits for every estimated embryo in the spawning output. Such patterns could only occur if either fecundity was very strongly density dependent or a large fraction of recruitments came from areas outside the area modeled in this study.

7.2. Retrospective analyses

A retrospective analysis was conducted where we re-ran the model sequentially removing data from the last 3 years. A 3-year retrospective analysis was conducted by running the model using data only through 2007 ("Retrospective in 2008"), a 2-year retrospective analysis was conducted by running the model using data only through 2008 ("Retrospective in 2009") and a 1-year retrospective analysis was conducted by running the model using data only through 2009 ("Retrospective in 2010") (Figs. 119-120). Much of the data in this assessment is from recent years, so a large change in result would be expected for this retrospective analysis. For example, slight changes in selectivities were observed for selected fleets in some of the retrospective runs; these changes, when put together, could be translated into changes in overall dynamics and model output. Also, the index form the IPHC longline survey showed a general decline over the years 1999-2006 which has not continued in subsequent years. Likewise, the first two years of the NWFSC shelf-slope survey showed the highest abundance. All these factors contribute to the retrospectives with the most data removed producing estimates of a more depleted stock with greater recent declines in abundance.

7.3. Likelihood profile analyses

A likelihood profile was conducted over a range of values of natural mortality between M = 0.050 and M = 0.075 (Figs. 121-122). The profile showed that the length composition data had the greatest change in likelihood over this range of M values with the best fit to the length data occurring at M = 0.054. The indices of abundance fit best at higher M values with equally good fit for $M \geq 0.064$. The likelihood contribution from mean body weight showed little change over the profiled values of M. The estimates of B_0 and depletion were very sensitivity to the choice of

M, with lower mortality values leading to lower estimates of equilibrium spawning output and lower status in 2011. As *M* is increased above 0.065, the B_0 estimates increase quickly and with $M > 0.070$ the 2011 status is estimated to be at 100% of B_0. Although the profile is illustrative of the influence of natural mortality on estimates of population scale and stock status, none of the data sources in the model are assumed to provide information sufficient to estimate *M*.

8. Reference points

Unfished spawning stock output for spiny dogfish is estimated to be 70,724 thousands of fish (95% confidence interval: 35,598-105,850). The stock is declared overfished if the current spawning output is estimated to be below 25% of unfished level. The management target for spiny dogfish is defined as 40% of the unfished spawning output ($SB_{40\%}$), which is estimated by the model to be 28,290 thousand of fish (95% confidence interval: 14,239-42,340), which corresponds to an exploitation rate of 0.006. This harvest rate provides an equilibrium yield of 831 mt at $SB_{40\%}$ (95% confidence interval: 421-1241 mt). The model estimate of maximum sustainable yield (MSY) is 848 mt (95% confidence interval: 430-1267 mt). The estimated spawning stock output at MSY is 33,229 thousands of fish (95% confidence interval: 16,723-49,736). The exploitation rate corresponding to the estimated SPR_{MSY} of F79.26% is 0.0053.

Because of this extremely low productivity and other reproductive characteristics of the stock, fishing at the target SPR of 45% is expected to severely reduce the spawning output over the long term. Conversely, fishing at a rate that would maintain spawning output near 40% of the unfished level would require a target SPR of about 77%. The Council's Scientific and Statistical Committee should consider the appropriateness of using the current proxy harvest rate for spiny dogfish.

The summary of spiny dogfish reference points from the base model is shown in Table 13. The equilibrium yield curve developed based on reference point values is shown in Fig. 134.

9. Status of the stock

The assessment shows that the stock of spiny dogfish off the continental U.S. Pacific Coast is currently at 63% of its unexploited level and, therefore, not overfished (Fig. 110). Historically, the abundance of spiny dogfish has always been above the management target of $SB_{40\%}$. Time series of estimated spawning potential ratio (SPR) with current SPR target of 0.45 (Fig. 124) demonstrate that currently harvest does not exceed current overfishing proxy. The assessment identified a period, which is during the vitamin A fishery in the 1940s, when the exploitation rate exceeded the current FMSY proxy harvest rate (Fig. 124). Time series of estimated spawning potential ratio (SPR) relative to its target of 0.45 versus estimated spawning output relative to its target of $SB_{40\%}$ also demonstrate that currently stock is not overfished and overfishing is not occurring (Fig. 125).

Time series of total and summary biomass as well as spawning output, recruitment and fishing mortality are shown in Figs. 105-109. Recent trends in estimated spiny dogfish exploitation and stock level from the assessment model are presented in Table 14.

Historically, the spawning output of spiny dogfish showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 70% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, and the spawning output started to increase (mostly as a result of maturation of younger dogfish that were not selected by the vitamin A fishery). For the last thirty five years, spawning output of spiny dogfish has been slowly but steadily declining due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock.

10. Decision table

Three states of nature were defined based on the alternative time series of removals and natural mortality values. The middle (base case) scenario has catch time series and natural mortality (0.064) as used in the base model. For the "low" and "high" states of nature, the base model was first modified by decreasing the entire time series of removals by 25% and increasing by 50% for low and high catch scenarios respectively. The low and high catch scenario models were further modified by subtracting one standard deviation from the 2011 spawning output value from the low catch model and adding one standard deviation to the 2011 spawning output value from the high catch model. The natural mortality for low state of nature (0.061) was selected to match one standard deviation below the 2011 spawning output for low catch scenario. The natural mortality for high state of nature (0.066) was selected to match one standard deviation above the 2011 spawning output estimate for high catch scenario. The fourth state of nature based on the retrospective analysis that excluded the last three years of the time series was added to allow for decision table to broaden the uncertainty in the assessment estimates. The net effect is to add more pessimistic state of nature, in which the spawning depletion falls below the management target of $SB_{40\%}$ in recent years. Comparison of spawning output and spawning depletion of four states of nature is provided in Figs. 126-127. The comparison of likelihood component values, selected parameters and reference points of three states of nature defined based on time series of removals and natural mortality is also given in Table 15.

Twelve-year forecasts for each state of nature were calculated based on removals at SPR 45% for the base model. Twelve-year forecasts were also produced with future catch fixed at the 2011-2012 OFL-based value provided by the Groundfish Management Team (GMT) and calculated as 28.4% of the total Other Fish ACL (the percentage is derived from the dogfish contribution to Other Fish OFL). Finally, twelve-year forecasts for each state of nature were calculated based on removals at SPR 77% for the base model, the level identified by the model as associated with the $SB_{40\%}$ target biomass level. Under the low state of nature, the catch at SPR 45% is projected to reduce the spawning stock output to 34.81 % of the unfished level within 12 years. In all other scenarios covered by the decision table, the spawning output remains above the 40% target level throughout the 12-year projection period. The highest level predicted in the 12 year projections is 75.65%, which occurs when the SPR 77% catch series is applied to the high state of nature. In general, there is little change in stock size over the 12 year projections for any of the combinations of state of nature and removals. Decision table with difference forecast options described above for four states of nature is provided in Table 16.

11. Regional management consideration

Spiny dogfish is a migratory species found in the U.S. west coast from Alaska to Southern California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts.

The stock included in this assessment (from the U.S.-Canada border on the north to U.S.-Mexico border on the south) very likely has substantial interaction and overlap with dogfish observed off British Columbia. From a seasonal perspective, this is particularly important, because spring aggregations of dogfish that have been targeted off Washington may well have migrated to areas north of the border by the time that trawl surveys have commenced off the US coast. In a population sense, it must be acknowledged that the scope of this assessment does not capture all of the removals and dynamics which very likely bear on the status and trends of the larger, transboundary population.

It was considered appropriate to proceed with the assessment for the limited area of U.S. west coast based on the recent estimated annual directed (not seasonal) movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada (Taylor 2008). Nevertheless, it is extremely important to pursue collaborative efforts between U.S. and Canada to more accurately describe the dynamics and access the status of stock, especially given the vulnerability of the stock, which exhibits slow growth, the longest gestation period known for sharks and is the latest maturing of all elasmobranchs.

12. Research and data needs

In this assessment, several critical assumptions were made based on limited supporting data and research. There are several research and data needs which, if satisfied could improve the assessment. These research and data needs include:

1) The ageing method for dogfish requires further research. Double reads indicate that the method of counting annuli on the unworn portion of dogfish dorsal spines is reasonably precise and has been validated using both oxytetracycline marking and bomb radiocarbon. However, more research is needed on the topic of unreadable annuli that are missing due to wear on the spines of older dogfish. Cheng (2011) has proposed important improvements to the statistical methods applied to these calculations, but the differences in patterns of age at length between worn and unworn spines resulting from those calculations suggests that addition research is needed. Improving estimates of the statistical uncertainty associated with the age extrapolation methods, including that proposed in Cheng (2011) would also be valuable. Tribuzio et al. (2010) explored a variety of refinements to the age estimation and growth for dogfish in Alaska that could be applied for west coast dogfish. Ideally, an alternative method of ageing dogfish that does not rely on the highly uncertainty estimation of ages missing from worn spines may be necessary before age information can be a reliable data source in dogfish stock assessments. Future assessment could also benefit from additional age readings of dogfish spines that have not yet been examined, including thousands of samples collected in the NWFSC shelf-slope survey from 2004-2009.

2) The move to full observer coverage in 2011 will improve estimate of dogfish discards for the west coast. However, there is considerable uncertainty in both the historic discard amounts, especially prior to the commencement of the West Coast Groundfish Observer

Program. Even more important is the need to improve estimates of discard mortality. Studies of this topic on the east coast used shorter tow durations than those in common fishing operations in these waters, and thus are likely to produce understimates of discard mortality (NEFSC, 2006). Data on tow duration could also be incorporated into future models to better refine discard mortality estimates from the trawl fishery.

3) Ongoing research using acoustic tags on dogfish released in central Puget Sound in the summer show regular seasonal movements to coastal waters during the winter and returns to Puget Sound in the subsequent summers (Andrews, pers.com.). This suggests that biomass sampled by summertime surveys (including all those from AFSC, NWFSC, and IPHC used in this analysis) may not be representative of the population size and distribution available to the fishery in other seasons. If the movements are very regular, the surveys may still provide a reliable relative index of abundance, but any differences in movement patterns due to climate or prey availability could impact these indices. Further research into how to account for such movement patterns should be conducted to inform future dogfish stock assessments. Acoustic or satellite tagging of dogfish in coastal waters could provide valuable insight into movement patterns along the coast and benefit future assessments.

4) There are high densities of dogfish close to the U.S./Canada border, at the mouth of the Strait of Juan de Fuca which connects the outside coastal waters with the inside waters of Puget Sound and the Strait of Georgia. This distribution, combined with potential seasonal or directed movement patterns for dogfish suggest that U.S. and Canada should explore the possibility of a joint stock assessment in future years. The data used in these assessment are far more comprehensive than that used by Taylor (2008), but the spatial modeling approach used in that analysis might be considered as a starting point for spatial considerations in a future international assessment.

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TABLES

Table 1. Chronology of the regulatory history of spiny dogfish by the Pacific Fishery Management Council.

Year	Harvest Specifications (mt) for the Other Fish Complex		Management Measures	Comments
	ABC/OFL a/	OY/ACL a/		
1982-2005	14,700	14,700	All sectors: not limited.	Spiny dogfish managed under the Other Fish complex since FMP implementation.
2006	14,600	7,300	All sectors: not limited in period 1; 200,000 lbs. spiny dogfish/2 mo. in period 2; 150,000 lbs. spiny dogfish/2 mo. in period 3; 100,000 lbs. spiny dogfish/2 mo. in periods 4-6.	Reduction in ABC in 2005 due to removal of the California substock of cabezon from the Other Fish complex. 50% precautionary OY reduction implemented in 2005 to accommodate uncertainty associated with managing unassessed stocks. Trip limit for spiny dogfish first implemented in March 2006.
2007-2008	14,600	7,300	All sectors: 200,000 lbs. spiny dogfish/2 mo. in periods 1 and 2; 150,000 lbs. spiny dogfish/2 mo. in period 3; 100,000 lbs. spiny dogfish/2 mo. in periods 4-6.	
2009-2010	11,200	5,600	All sectors: 200,000 lbs. spiny dogfish/2 mo. in periods 1 and 2; 150,000 lbs. spiny dogfish/2 mo. in period 3; 100,000 lbs. spiny dogfish/2 mo. in periods 4-6.	Reduction in ABC in 2009 due to removal of longnose skate from the Other Fish complex. 50% precautionary OY reduction is maintained.
2011	11,150	5,575	LE trawl: 60,000 lbs. spiny dogfish/mo. in periods 1-6. LE and OA fixed gear: 200,000 lbs. spiny dogfish/2 mo. in periods 1 and 2; 150,000 lbs. spiny dogfish/2 mo. in period 3; 100,000 lbs. spiny dogfish/2 mo. in periods 4-6.	Reduction in OFL in 2011 due to removal of the Oregon substock of cabezon from the Other Fish complex. 50% precautionary reduction to the ACL is maintained; however, a scientific uncertainty buffer is specified as an ABC of 7,742 mt is implemented under the new Amendment 23 framework (see footnote a).

a/ The acceptable biological catch (ABC) specification prior to 2011 represents the MSY harvest level and the optimum yield (OY) represents the annual total catch limit. Implementation of Amendment 23 in 2011 changed these definitions to the overfishing limit (OFL) as the MSY harvest level and the annual catch limit (ACL) as the annual total catch limit. Additionally, the definition of ABC changed under Amendment 23 to a level of harvest less than or equal to the OFL to accommodate the scientific uncertainty associated with estimating the OFL.

Table 2. Time series of reconstructed spiny dogfish removals (in metric tons) by fleet (BT=bottom trawl, BTD=bottom trawl discard, MDT=midwater trawl, ASH=at-sea hake fishery bycatch, HKL=hook-and-line, HKLD=hook-and-line discard, OTH=others, REC=recreational).

Year	BT	BTD	MDT	ASH	HKL	HKLD	OTH	REC	TOTAL
1916	0	0	0	0	0	0	0	0	0
1917	1	0	0	0	0	0	0	0	1
1918	1	0	0	0	0	0	0	0	1
1919	2	0	0	0	0	0	0	0	2
1920	2	0	0	0	0	0	0	0	3
1921	3	0	0	0	0	0	0	0	3
1922	4	0	0	0	0	0	0	0	4
1923	4	0	0	0	1	0	0	0	5
1924	5	0	0	0	1	0	0	0	5
1925	5	0	0	0	1	0	0	0	6
1926	6	0	0	0	1	0	0	0	7
1927	7	0	0	0	1	0	0	0	7
1928	7	0	0	0	1	0	0	0	8
1929	8	0	0	0	1	0	0	0	9
1930	8	0	0	0	1	0	0	0	9
1931	9	0	0	0	1	0	0	0	10
1932	20	0	0	0	2	0	0	0	23
1933	19	0	0	0	2	0	0	0	21
1934	20	0	0	0	2	0	0	0	23
1935	39	0	0	0	5	0	0	0	44
1936	21	0	0	0	3	0	0	0	23
1937	57	0	0	0	7	0	0	0	64
1938	334	0	0	0	40	0	0	0	374
1939	610	0	0	0	74	0	0	0	684
1940	975	0	0	0	96	0	0	0	1,072
1941	5,287	0	0	0	710	0	1,255	0	7,252
1942	4,635	0	0	0	131	0	1,393	0	6,160
1943	3,036	0	0	0	161	0	5,025	0	8,221
1944	9,644	0	0	0	2,797	0	4,435	0	16,876
1945	5,766	0	0	0	969	0	2,477	0	9,212
1946	4,503	0	0	0	328	0	4,338	0	9,170
1947	4,145	0	0	0	170	0	1,920	0	6,235
1948	4,452	0	0	0	10	0	1,056	0	5,519
1949	3,946	0	0	0	205	0	896	0	5,047
1950	366	921	0	0	82	0	659	0	2,028
1951	462	852	0	0	0	0	436	0	1,750
1952	818	543	0	0	0	0	188	0	1,550

Table 2 (continued). Time series of reconstructed spiny dogfish removals (in metric tons) by fleet (BT=bottom trawl, BTD=bottom trawl discard, MDT=midwater trawl, ASH=at-sea hake fishery bycatch, HKL=hook-and-line, HKLD=hook-and-line discard, OTH=others, REC=recreational).

Year	BT	BTD	MDT	ASH	HKL	HKLD	OTH	REC	TOTAL
1953	363	923	0	0	0	0	152	0	1,438
1954	348	933	0	0	0	0	0	0	1,280
1955	367	920	0	0	0	0	0	0	1,287
1956	219	988	0	0	0	0	0	0	1,207
1957	825	537	0	0	0	0	0	0	1,362
1958	195	989	0	0	0	0	0	0	1,184
1959	156	979	0	0	0	0	0	0	1,135
1960	73	848	0	0	0	0	0	0	921
1961	40	674	0	0	0	0	0	0	714
1962	16	396	0	0	0	0	0	0	412
1963	17	408	0	0	0	0	0	0	425
1964	19	444	0	0	0	0	0	0	463
1965	18	420	0	0	0	0	0	0	437
1966	20	461	0	0	0	0	0	0	481
1967	13	333	0	0	0	0	0	0	346
1968	22	479	0	0	0	0	0	0	500
1969	30	585	0	0	0	0	1	0	616
1970	11	303	0	0	0	0	1	0	315
1971	3	104	0	0	1	4	8	0	120
1972	3	104	0	0	1	2	1	0	110
1973	2	73	0	0	1	3	0	0	80
1974	12	325	0	0	0	0	0	0	338
1975	22	478	0	0	0	0	7	0	506
1976	62	804	0	0	0	0	7	0	873
1977	200	989	0	12	2	6	94	0	1,304
1978	174	986	0	8	33	73	178	0	1,451
1979	167	984	0	20	117	131	212	1	1,632
1980	93	905	0	76	66	109	101	0	1,351
1981	228	986	0	167	13	35	15	33	1,477
1982	95	908	0	130	24	58	11	46	1,271
1983	25	520	0	64	6	17	24	17	675
1984	240	983	0	65	31	71	8	16	1,414
1985	196	989	0	23	101	126	1	52	1,489
1986	83	878	0	123	29	67	5	62	1,246
1987	91	899	0	138	49	93	23	8	1,302
1988	134	964	0	108	62	106	2	48	1,424

Table 2 (continued). Time series of reconstructed spiny dogfish removals (in metric tons) by fleet (BT=bottom trawl, BTD=bottom trawl discard, MDT=midwater trawl, ASH=at-sea hake fishery bycatch, HKL=hook-and-line, HKLD=hook-and-line discard, OTH=others, REC=recreational).

Year	BT	BTD	MDT	ASH	HKL	HKLD	OTH	REC	TOTAL
1989	84	881	0	55	207	129	1	24	1,381
1990	341	936	0	112	135	133	3	25	1,686
1991	694	657	0	159	208	129	1	25	1,873
1992	880	486	43	385	177	133	1	25	2,129
1993	843	521	8	74	416	66	3	25	1,956
1994	1,030	345	25	53	337	95	0	11	1,896
1995	358	926	0	198	7	22	1	20	1,532
1996	193	989	4	401	54	98	0	18	1,758
1997	336	940	3	328	85	120	0	5	1,817
1998	410	891	50	275	1	3	2	1	1,632
1999	430	876	32	470	44	88	4	11	1,955
2000	285	966	36	117	321	100	5	10	1,841
2001	333	941	13	237	216	128	2	9	1,879
2002	437	856	29	299	409	114	0	15	2,159
2003	194	807	8	271	237	57	9	11	1,593
2004	129	1,114	38	613	235	100	5	3	2,238
2005	129	1,517	71	355	233	78	7	4	2,396
2006	117	906	106	59	191	178	6	4	1,567
2007	63	658	98	155	217	167	0	6	1,364
2008	43	994	158	673	281	135	15	3	2,300
2009	78	587	76	164	55	181	1	4	1,147
2010	42	691	111	278	10	28	0	2	1,163

Table 3. Summary of sampling efforts used to generate length-frequency distributions for the assessment model by fishing fleet (BT=bottom trawl, BTD=bottom trawl discard, MDT=midwater trawl, ASH=at-sea hake fishery bycatch, HKL=hook-and-line, 5HKLD=hook-and-line discard, OTH=others, REC=recreational).

	BT		**BTD**		**MDT**		**HKL**		**HKLD**		**ASH**		**REC**
Year	*N trips*	*N fish*	*N trips*	*N fish*	*N trips*	*N fish*	*N trips*	*N fish*	*N trips*	*N fish*	*N hauls*	*N fish*	*N fish*
1993													15
1994													14
1995													16
1996													18
1997													6
1999													27
2000													12
2001													6
2002													9
2003							4	100	5	3775			13
2004	1	25	11	208			2	93	3	1,313			17
2005					3	200							27
2006	3	250	685	1,620	8	492	10	721	435	994			66
2007	5	422	512	1,202	15	976	8	659	465	1,190	748	2,883	46
2008	2	2	235	571	3	150	15	785	22	51	1,312	15,657	31
2009	7	151	965	2,297	4	181	5	250	33	77	663	4,236	32
2010					11	588					1,134	8,384	13

Table 4. Latitudinal and depth ranges by year of four NOAA Fisheries' trawl surveys used in the assessment.

Survey	Year	Latitudes	Depths (fm)
AFSC triennial	1977	34° 00'- Border	50-250
	1980	36° 48'- 49° 15'	30-200
	1983	36° 48'- 49° 15'	30-200
	1986	36° 48'- Border	30-200
	1989	34° 30'- 49° 40'	30-200
	1992	34° 30'- 49° 40'	30-200
	1995	34° 30'- 49° 40'	30-275
	1998	34° 30'- 49° 40'	30-275
	2001	34° 30'- 49° 40'	30-275
	2004	34° 30'- Border	30-275
AFSC slope	1988	44° 05'- 45° 30'	100-700
	1990	44° 30'- 40° 30'	100-700
	1991	38° 20'- 40° 30'	100-700
	1992	45° 30'- Border	100-700
	1993	43° 00'- 45° 30'	100-700
	1995	40° 30'- 43° 00'	100-700
	1996	43° 00'- Border	100-700
	1997	34° 00'- Border	100-700
	1999	34° 00'- Border	100-700
	2000	34° 00'- Border	100-700
	2001	34° 00'- Border	100-700
NWFSC shelf-slope	2003	32° 34'- 48° 27'	30-700
	2004	32° 34'- 48° 27'	30-700
	2005	32° 34'- 48° 27'	30-700
	2006	32° 34'- 48° 27'	30-700
	2007	32° 34'- 48° 27'	30-700
	2008	32° 34'- 48° 27'	30-700
	2009	32° 34'- 48° 27'	30-700
	2010	32° 34'- 48° 27'	30-700
NWFSC slope	1999	34° 50'- 48° 10'	100-700
	2000	34° 50'- 48° 10'	100-700
	2001	34° 50'- 48° 10'	100-700
	2002	34° 50'- 48° 10'	100-700

Table 5. Estimated indices of abundance and standard errors of the natural log of biomass for the surveys used in the assessment.

	AFSC triennial		AFSC slope		NWFSC slope		NWFSC shelf-slope		IPHC survey	
Year	**Index (mt)**	**SE(log)**	**Index (mt)**	**SE(log)**	**Index (mt)**	**SE(log)**	**Index (mt)**	**SE(log)**	**Index (fish)**	**SE(log)**
1980	18,274	0.15189								
1983	47,555	0.11806								
1986	19,401	0.07917								
1989	47,852	0.09294								
1992	43,344	0.12244								
1997			170,735	0.20884						
1998	36,857	0.08843					18,304	0.29483		
1999			95,279	0.22599			30,482	0.37383	0.04661	0.04043
2000			151,996	0.30558			4,836	0.26391		
2001	19,207	0.13030	25,889	0.27446			1,339	0.28979	0.03154	0.06015
2002							3,104	0.22464	0.03046	0.06380
2003					381,759	0.16046			0.03383	0.05858
2004	19,592	0.13025			159,889	0.10816			0.02192	0.06942
2005					69,961	0.08574			0.04115	0.04518
2006					52,321	0.09868			0.02761	0.06088
2007					45,089	0.10646			0.05917	0.04518
2008					38,536	0.08955			0.04034	0.05285
2009					12,661	0.09604			0.03501	0.04847
2010					36,688	0.09744			0.03109	0.04796

Table 6. Summary of sampling effort used to generate survey length-frequency distributions used in the assessment.

	AFSC triennial		**AFSC slope**		**NWFSC shelf-slope**	
Year	*N tows*	*N fish*	*N tows*	*N fish*	*N tows*	*N fish*
1997			62	3,009		
1998	6	98				
1999			87	1,872		
2000			36	1,454		
2001	146	1,626	37	671		
2002						
2003					176	3,785
2004	126	2,410			159	2,480
2005					248	3,559
2006					223	3,881
2007					224	2,461
2008					247	2,825
2009					203	1,652
2010					225	1,723

Table 7. Comparison base model with pre-STAR (changed made during the STAR panel are summarized in Section 5)

	Base model	**pre-STAR base model**
Negative log-likelihood		
TOTAL	1,203.63	1,635.11
Survey indices	-1.86	-1.92
Length data	1,054.89	1,056.77
Age data	0.00	429.70
Parameters		
$\log(R_0)$	10.07	9.83
Z_{frac}	0.4	0.4
Beta	1	1
Natural mortality (females)	0.064	0.064
Natural mortality (males)	0.064	0.064
L_1 (females)	25.25	25.25
L_∞ (females)	109.10	109.10
L_1 (males)	25.25	25.25
L_∞ (males)	86.12	86.12
von Bertalanffy k (females)	0.026	0.026
von Bertalanffy k (males)	0.052	0.052
Reference points		
SB_0 (1000s fish)	70,724	55,344
2011 depletion	63.15%	53.01%
2010 SPR ratio	0.21	0.29

Table 8. List of parameter values used in the base model.

Parameter		Value	Min	Max	Fixed	Estimated (phase)
Natural Mortality						
Females		0.064			x	
Males		0.064			x	
Growth						
Females	L_1	25			x	
	L_∞	109			x	
	K	0.026			x	
	CV in size at age A1	0.123			x	
	CV in size at age A2	0.240			x	
	L_1	25			x	
Males	L_∞	86			x	
	K	0.052			x	
	CV in size at age A1	0.192			x	
	CV in size at age A2	0.057			x	
Biological parameters						
	Maturity logistic inflection	2.31E-06			x	
	Maturity slope	3.1526			x	
	Fecundity at length intercept	88.2			x	
	Fecundity at leangth slope	-0.27			x	
Weight at length						
Females	Coefficient	2.31E-06			x	
	Exponent	3.1526			x	
Males	Coefficient	3.49E-06			x	
	Exponent	3.0349			x	
Stock-Recruitment						
	$\log(R_0)$	10.0704	8	18		x (1)
	Z_{frac}	0.4			x	
	Beta	1			x	
Survey catchability (*Q*)						
	AFSC triennial early survey	0.22				x (3)
	AFSC triennial late survey	0.16				x (3)
	AFSC slope survey	0.55				x (3)
	NWFSC shelf slope survey	0.28				x (3)
	NWFSC slope survey	0.04				x (3)
	IHPC survey	3.46E-07				x (3)

Table 8 (continued). List of parameter values used in the base model.

Parameter	Value	Min	Max	Fixed	Estimated (phase)
Size selectivity parameters bottom trawl					
Peak	101	20	120		x (1)
Top	-1			x	
Ascending slope	6	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-5			x	
Selectivity at last bin	9			x	
Size selectivity parameters bottom trawl discard					
Peak	74	20	120		x (1)
Top	-1			x	
Ascending slope	6	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-3			x	
Selectivity at last bin	9			x	
Size selectivity parameters midwater trawl					
Peak	57	20	120		x (1)
Top	1	-6	4		x (3)
Ascending slope	5	-1	9		x (3)
Descending slope	4	-1	9		x (3)
Selectivity at fist bin	-6	-9	9		x (3)
Selectivity at last bin	-999			x	
Size selectivity parameters at-sea hake bycatch					
First size bin (mirror to midwater)	0			x	
Last size bin (mirror to midwater)	0			x	
Size selectivity parameters hook-and-line					
Peak	105	20	120		x (1)
Top	-1			x	
Ascending slope	6	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-5			x	
Selectivity at last bin	9			x	
Size selectivity parameters hook-and-line discard					
Peak	67	20	120		x (1)
Top	-1			x	
Ascending slope	5	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-5			x	
Selectivity at last bin	9			x	

Table 8 (continued). List of parameter values used in the base model.

Parameter	**Value**	**Min**	**Max**	**Fixed**	**Estimated (phase)**
Size selectivity parameters other gears					
First size bin (mirror to hook-and-line discard)	0			x	
Last size bin (mirror to hook-and-line discard)	0			x	
Size selectivity parameters recreational					
Peak	110	20	120		x (1)
Top	-1			x	
Ascending slope	6	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-5			x	
Selectivity at last bin	9			x	
Size selectivity parameters AFSC triennial survey					
Peak	58	25	100		x (1)
Top	-9	-9	3		x (3)
Ascending slope	7	-4	12		x (3)
Descending slope	6	-2	15		x (3)
Selectivity at fist bin	-5			x	
Selectivity at last bin	-999			x	
Size selectivity parameters AFSC slope survey					
Peak	59	25	100		x (1)
Top	-1	-9	3		x (3)
Ascending slope	6	-4	12		x (3)
Descending slope	5	-2	15		x (3)
Selectivity at fist bin	-5			x	
Selectivity at last bin	-999			x	
Size selectivity parameters NWFSC shelf-slope survey					
Peak	57	20	120		x (1)
Top	-1			x	
Ascending slope	7	-1	9		x (3)
Descending slope	5			x	
Selectivity at fist bin	-5			x	
Selectivity at last bin	9			x	
Size selectivity parameters NWFSC slope survey					
First size bin (mirror to AFSC slope)	0			x	
Last size bin (mirror to AFSC slope)	0			x	
Size selectivity parameters IHPC longline survey					
First size bin (mirror to hook-and-line discard)	0			x	
Last size bin (mirror to hook-and-line discard)	0			x	

Table 9. Time series of estimated total and summary biomass (mt), spawning output (1,000s fish), depletion, recruitment (1,000s fish) and exploitation rate.

Year	Total biomass	Summary biomass	Spawning output	Depletion	Recruirment	Exploitation rate
1916	305,690	304,105	70,724	100.00%	23,634	0.0000
1917	305,690	304,105	70,724	100.00%	23,634	0.0000
1918	305,690	304,105	70,724	100.00%	23,634	0.0000
1919	305,688	304,103	70,723	100.00%	23,634	0.0000
1920	305,687	304,102	70,723	100.00%	23,634	0.0000
1921	305,684	304,099	70,722	100.00%	23,634	0.0000
1922	305,681	304,096	70,721	100.00%	23,633	0.0000
1923	305,678	304,093	70,720	99.99%	23,633	0.0000
1924	305,674	304,089	70,719	99.99%	23,633	0.0000
1925	305,669	304,084	70,717	99.99%	23,633	0.0000
1926	305,664	304,079	70,716	99.99%	23,632	0.0000
1927	305,658	304,074	70,714	99.99%	23,632	0.0000
1928	305,652	304,068	70,712	99.98%	23,632	0.0000
1929	305,646	304,061	70,710	99.98%	23,631	0.0000
1930	305,639	304,054	70,708	99.98%	23,631	0.0000
1931	305,631	304,046	70,705	99.97%	23,630	0.0000
1932	305,623	304,038	70,703	99.97%	23,630	0.0001
1933	305,603	304,019	70,697	99.96%	23,629	0.0001
1934	305,586	304,001	70,691	99.95%	23,628	0.0001
1935	305,567	303,982	70,685	99.95%	23,627	0.0001
1936	305,529	303,945	70,673	99.93%	23,624	0.0001
1937	305,511	303,926	70,667	99.92%	23,623	0.0002
1938	305,455	303,871	70,651	99.90%	23,620	0.0012
1939	305,116	303,533	70,549	99.75%	23,601	0.0023
1940	304,499	302,918	70,364	99.49%	23,566	0.0035
1941	303,538	301,961	70,075	99.08%	23,511	0.0240
1942	296,921	295,370	68,106	96.30%	23,132	0.0209
1943	291,452	289,923	66,449	93.96%	22,802	0.0284
1944	284,228	282,729	64,240	90.83%	22,348	0.0597
1945	269,224	267,791	59,738	84.47%	21,370	0.0344
1946	261,549	260,153	57,338	81.07%	20,819	0.0352
1947	254,069	252,711	54,977	77.74%	20,256	0.0247
1948	249,397	248,064	53,426	75.54%	19,874	0.0222
1949	245,437	244,126	52,090	73.65%	19,539	0.0207
1950	241,949	240,659	50,899	71.97%	19,233	0.0084
1951	241,313	240,031	50,452	71.34%	19,117	0.0073
1952	240,915	239,639	50,083	70.81%	19,021	0.0065
1953	240,720	239,451	49,736	70.32%	18,930	0.0060
1954	240,507	239,242	49,508	70.00%	18,870	0.0054
1955	240,386	239,123	49,344	69.77%	18,826	0.0054
1956	240,210	238,950	49,198	69.56%	18,788	0.0051
1957	240,032	238,774	49,116	69.45%	18,766	0.0057
1958	239,767	238,511	48,930	69.19%	18,716	0.0050

Table 9. Time series of estimated total and summary biomass (mt), spawning output (1,000s fish), depletion, recruitment (1,000s fish) and exploitation rate.

Year	Total biomass	Summary biomass	Spawning output	Depletion	Recruirment	Exploitation rate
1959	239,513	238,259	48,906	69.15%	18,710	0.0048
1960	239,253	237,998	48,920	69.17%	18,714	0.0039
1961	239,131	237,875	49,018	69.31%	18,740	0.0030
1962	239,152	237,892	49,190	69.55%	18,785	0.0017
1963	239,405	238,140	49,454	69.93%	18,856	0.0018
1964	239,605	238,335	49,730	70.32%	18,928	0.0019
1965	239,735	238,461	50,008	70.71%	19,001	0.0018
1966	239,860	238,581	50,301	71.12%	19,078	0.0020
1967	239,920	238,636	50,588	71.53%	19,153	0.0015
1968	240,084	238,794	50,913	71.99%	19,237	0.0021
1969	240,090	238,795	51,196	72.39%	19,310	0.0026
1970	239,982	238,683	51,444	72.74%	19,374	0.0013
1971	240,144	238,839	51,763	73.19%	19,455	0.0005
1972	240,478	239,167	52,122	73.70%	19,547	0.0005
1973	240,814	239,497	52,470	74.19%	19,635	0.0003
1974	241,176	239,853	52,811	74.67%	19,721	0.0014
1975	241,300	239,973	53,066	75.03%	19,785	0.0021
1976	241,277	239,947	53,257	75.30%	19,832	0.0036
1977	240,934	239,603	53,327	75.40%	19,850	0.0054
1978	240,238	238,908	53,245	75.29%	19,829	0.0061
1979	239,436	238,109	53,103	75.09%	19,794	0.0069
1980	238,514	237,190	52,883	74.77%	19,739	0.0057
1981	237,856	236,535	52,737	74.57%	19,702	0.0062
1982	237,121	235,803	52,530	74.28%	19,650	0.0054
1983	236,584	235,269	52,374	74.05%	19,611	0.0029
1984	236,596	235,281	52,377	74.06%	19,611	0.0060
1985	235,978	234,667	52,139	73.72%	19,551	0.0063
1986	235,328	234,022	51,859	73.33%	19,480	0.0053
1987	234,884	233,581	51,664	73.05%	19,430	0.0056
1988	234,393	233,094	51,452	72.75%	19,376	0.0061
1989	233,821	232,527	51,188	72.38%	19,308	0.0059
1990	233,319	232,029	50,919	72.00%	19,238	0.0073
1991	232,573	231,289	50,549	71.47%	19,142	0.0081
1992	231,742	230,467	50,075	70.80%	19,019	0.0092
1993	230,703	229,437	49,532	70.04%	18,876	0.0085
1994	229,899	228,642	49,003	69.29%	18,736	0.0083
1995	229,173	227,926	48,494	68.57%	18,600	0.0067
1996	228,602	227,359	48,243	68.21%	18,532	0.0077
1997	227,788	226,551	47,965	67.82%	18,457	0.0080
1998	226,947	225,715	47,655	67.38%	18,373	0.0072
1999	226,267	225,039	47,406	67.03%	18,306	0.0087
2000	225,289	224,068	47,079	66.57%	18,216	0.0082
2001	224,463	223,247	46,756	66.11%	18,128	0.0084

Table 9. Time series of estimated total and summary biomass (mt), spawning output (1,000s fish), depletion, recruitment (1,000s fish) and exploitation rate.

Year	Total biomass	Summary biomass	Spawning output	Depletion	Recruirment	Exploitation rate
2002	223,580	222,370	46,450	65.68%	18,043	0.0097
2003	222,491	221,289	46,042	65.10%	17,930	0.0072
2004	221,848	220,649	45,849	64.83%	17,876	0.0101
2005	220,571	219,379	45,527	64.37%	17,786	0.0109
2006	219,159	217,973	45,168	63.86%	17,685	0.0072
2007	218,515	217,331	45,022	63.66%	17,644	0.0063
2008	218,039	216,857	44,939	63.54%	17,620	0.0106
2009	216,672	215,496	44,638	63.12%	17,535	0.0053
2010	216,357	215,181	44,641	63.12%	17,536	0.0054
2011	215,988	214,812	44,660	63.15%	17,541	NA

Table 10. Sensitivities to changes in time series of removals and assumptions regarding historical discard.

	Base model	**50% catch increase**	**25% catch decrease**	**Alternative historical discard**
Negative log-likelihood				
TOTAL	1,203.63	1,203.60	1,203.67	1,203.66
Survey indices	-1.86	-1.86	-1.87	-1.86
Length data	1,054.89	1,054.85	1,054.92	1,054.92
Parameters				
$\log(R_0)$	10.07	10.46	9.80	10.08
Z_{frac}	0.4	0.4	0.4	0.4
Beta	1	1	1	1
Natural mortality (females)	0.064	0.064	0.064	0.064
Natural mortality (males)	0.064	0.064	0.064	0.064
L_1 (females)	25.25	25.25	25.25	25.25
L_∞ (females)	109.10	109.10	109.10	109.10
L_1 (males)	25.25	25.25	25.25	25.25
L_∞ (males)	86.12	86.12	86.12	86.12
von Bertalanffy k (females)	0.026	0.026	0.026	0.026
von Bertalanffy k (males)	0.052	0.052	0.052	0.052
Reference points				
SB_0 (1000s fish)	70,724	104,070	54,079	71,501
2011 depletion	63.15%	63.12%	63.20%	62.85%
2010 SPR ratio	0.21	0.20	0.22	0.21

Table 11. Sensitivities to changes in spawner-recruit relationship for survival-based relationships (bold values for steepness are quantities derived from survival-based spawner-recruitment rather than parameters).

	Base model: Z_{frac}=0.4, beta=1	**Z_{frac}=0.2, beta=1**	**Z_{frac}=0.6, beta=1**	**Z_{frac}=0 (estimated), beta=1**	**Z_{frac}=0.4, beta=0.5**	**Z_{frac}=0.4, beta=2.0**
Negative log-likelihood						
TOTAL	1,203.63	1,202.92	1,204.10	1,202.35	1,203.10	1,204.11
Survey indices	-1.86	-1.80	-1.87	-1.60	-1.82	-1.87
Length data	1,054.89	1,054.14	1,055.35	1,053.39	1,054.33	1,055.36
Parameters						
$\log(R_0)$	10.07	9.93	10.20	9.84	9.96	10.23
Z_{frac}	0.4	0.2	0.6	0	0.4	0.4
Beta	1.0	1.0	1.0	1.0	0.5	2.0
Steepness (h)	**0.28**	**0.24**	**0.34**	**0.20**	**0.25**	**0.30**
S_0	0.33	0.33	0.33	0.33	0.33	0.33
$Z_0 = \log(S_0)$	1.10	1.10	1.10	1.10	1.10	1.10
Natural mortality (females)	0.064	0.064	0.064	0.064	0.064	0.064
Natural mortality (males)	0.064	0.064	0.064	0.064	0.064	0.064
L_1 (females)	25.25	25.52	25.23	25.49	25.46	25.20
L_∞ (females)	109.10	109.10	109.10	109.10	109.10	109.10
L_1 (males)	25.25	25.52	25.23	25.49	25.46	25.20
L_∞ (males)	86.12	86.12	86.12	86.12	86.12	86.12
von Bertalanffy k (females)	0.026	0.026	0.026	0.026	0.026	0.026
von Bertalanffy k (males)	0.052	0.052	0.052	0.051	0.052	0.052
Reference points						
SB_0 (1000s fish)	70,724	61,493	80,803	55,966	63,334	82,863
2011 depletion	63.15%	52.78%	71.73%	43.43%	54.58%	74.53%
2010 SPR ratio	0.21	0.27	0.17	0.35	0.26	0.16

Table 12. Sensitivities to changes in spawner-recruit relationship for Beverton-Holt relationships (bold values for steepness are quantities derived from survival-based spawner-recruitment rather than parameters).

	Base model: Zfrac=0.4, beta=1	**Beverton-Holt, h=0.2 (estimated)**	**Beverton-Holt, h=0.284**	**Beverton-Holt, h=0.3**	**Beverton-Holt, h=0.4**
Negative log-likelihood					
TOTAL	1,203.63	1,203.16	1,203.57	1,203.73	1,205.09
Survey indices	-1.86	-1.57	-1.86	-1.87	-1.87
Length data	1,054.89	1,054.17	1,054.82	1,054.98	1,056.34
Parameters					
$\log(R_0)$	10.07	9.82	10.05	10.09	10.20
Z_{frac}	0.4	NA	NA	NA	NA
Beta	1	NA	NA	NA	NA
Steepness (h)	**0.28**	0.20	0.28	0.30	0.40
S_0	0.33	0.33	0.33	0.33	0.33
$Z_0 = \log(S_0)$	1.10	1.10	1.10	1.10	1.10
Natural mortality (females)	0.064	0.064	0.064	0.064	0.064
Natural mortality (males)	0.064	0.064	0.064	0.064	0.064
L_1 (females)	25.25	25.52	25.23	25.49	25.46
L_∞ (females)	109.10	109.10	109.10	109.10	109.10
L_1 (males)	25.25	25.52	25.23	25.49	25.46
L_∞ (males)	86.12	86.12	86.12	86.12	86.12
von Bertalanffy k (females)	0.026	0.026	0.026	0.026	0.026
von Bertalanffy k (males)	0.052	0.052	0.052	0.051	0.052
Reference points					
SB_0 (1000s fish)	70,724	54,879	69,500	72,169	80,437
2011 depletion	63.15%	42.32%	61.54%	63.98%	71.92%
2010 SPR ratio	0.21	0.36	0.22	0.20	0.17

Table 13. Summary of spiny dogfish reference points from the assessment model.

	Point estimate	**95% confidence interval**
Unfished Spawning Stock Output (SB_0) (1000s fish)	70,724	35,598-105,849
Unfished Summary Age 1+ Biomass (B_0) (mt)	304,105	NA
Unfished Recruitment (R_0) at age 0	23,634	11,895-35,372
Reference points based on SB40%		
MSY Proxy Spawning Stock Output ($SB_{40\%}$) (1000s fish)	28,290	14,239-42,340
SPR resulting in $SB_{40\%}$ ($SPR_{SB40\%}$)	76.87%	74.71%-79.03%
Exploitation rate resulting in $SB_{40\%}$	0.60%	NA
Yield with $SPRSB_{40\%}$ at $SB_{40\%}$ (mt)	831	421-1241
Reference points based on estimated MSY values		
Spawning Stock Output at MSY (SB_{MSY}) (1000s fish)	33,229	16,723-49,736
SPR_{MSY}	79.26%	77.20%-81.32%
Exploitation Rate corresponding to SPR_{MSY}	0.53%	NA
MSY (mt)	848	430-1267

Table 14. Summary of recent trends in estimated spiny dogfish exploitation and stock level from the assessment model.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Landings (mt)[a]	1,190	730	1,023	801	483	539	1,172	378	444	NA
Estimated Discards (mt)	970	863	1,215	1,595	1,084	825	1,128	768	719	NA
Estimated Total Catch (mt)	2,159	1,593	2,238	2,396	1,567	1,364	2,300	1,147	1,163	NA
ABC/OFL[b] Other Fish Complex	14,700	14,700	14,700	14,700	14,600	14,600	14,600	11,200	11,200	11,150
OY/ACL[b] Other Fish Complex	14,700	14,700	14,700	14,700	7,300	7,300	7,300	5,600	5,600	5,575
SPR	66.32%	73.20%	64.92%	63.08%	73.37%	76.09%	63.64%	79.31%	78.97%	NA
Exploitation Rate (total catch/summary biomass)	0.00971	0.00720	0.01014	0.01092	0.00719	0.00628	0.01061	0.00532	0.00540	
Summary Age 1+ Biomass (B) (mt)	222,370	221,289	220,649	219,379	217,973	217,331	216,857	215,496	215,181	214,812
Spawning Stock Output (SB) (1000s fish)	46,450	46,042	45,849	45,527	45,168	45,022	44,939	44,638	44,641	44,660
Uncertainty in Spawning Stock Output estimate	10,760-82,140	10,352-81,730	10,155-81,542	9,837-81,215	9,484-80,850	9,333-80,711	9,240-80,636	8,943-80,331	8,932-80,349	8,937-80,383
Recruitment at age 0	18,043	17,930	17,876	17,786	17,685	17,644	17,620	17,535	17,536	17,541
Uncertainty in Recruitment estimate	5,591-30,494	5,456-30,402	5,391-30,360	5,285-30,286	5,166-30,203	5,115-30,172	5,084-30,155	4,983-30,086	4,980-30,091	4,982-30,099
Depletion (SB/SB_0)	65.68%	65.10%	64.83%	64.37%	63.86%	63.66%	63.54%	63.12%	63.12%	63.15%
Uncertainty in Depletion estimate									43.98%-82.26%	44.00%-82.30%

Table 15. Comparison of likelihood components, selected parameters and reference points of three states of nature defined based on time series of removals and natural mortality.

	Low catch, low M	**Base model**	**High catch, high M**
Negative log-likelihood			
TOTAL	1,203.68	1,203.63	1,204.35
Survey indices	-1.82	-1.86	-1.87
Length data	1,054.88	1,054.89	1,055.61
Parameters			
$\log(R_0)$	0.4	0.4	0.4
Z_{frac}	1	1	1
Natural mortality (females)	0.064	0.064	0.064
Natural mortality (males)	0.064	0.064	0.064
L_1 (females)	25.23	25.25	25.52
L_∞ (females)	109.10	109.10	109.10
L_1 (males)	25.23	25.25	25.52
L_∞ (males)	86.12	86.12	86.12
von Bertalanffy k (females)	0.026	0.026	0.026
von Bertalanffy k (males)	0.052	0.052	0.052
Reference points			
SB_0 (1000s fish)	4,149	7,072	14,286
2011 depletion	49.27%	63.15%	74.11%
2010 SPR ratio	0.34	0.21	0.23

Table 16. Decision table of 12-year projections for alternative states of nature defined based on the alternative time series of removals and natural mortality of spiny dogfish.

			Retrospective run (data from the last three years removed)		Low M, low removals		**Base model**		High M, high removals	
Forecast	Year	Total removals (mt)	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion	Spawning output (1,000s)	Depletion
Forecast catch calculated from 45% SPR applied to base model	2011	3,041	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	3,010	13,622	33.08%	19,827	47.79%	44,130	62.40%	105,499	73.85%
	2013	2,980	13,122	31.86%	19,228	46.34%	43,615	61.67%	105,144	73.60%
	2014	2,950	12,631	30.67%	18,644	44.93%	43,113	60.96%	104,802	73.36%
	2015	2,921	12,150	29.50%	18,074	43.56%	42,624	60.27%	104,472	73.13%
	2016	2,893	11,678	28.36%	17,518	42.22%	42,147	59.59%	104,152	72.91%
	2017	2,866	11,214	27.23%	16,975	40.91%	41,682	58.94%	103,841	72.69%
	2018	2,839	10,757	26.12%	16,444	39.63%	41,228	58.29%	103,538	72.48%
	2019	2,813	10,307	25.03%	15,926	38.38%	40,783	57.67%	103,243	72.27%
	2020	2,787	9,865	23.95%	15,420	37.16%	40,349	57.05%	102,953	72.07%
	2021	2,763	9,430	22.90%	14,926	35.97%	39,924	56.45%	102,669	71.87%
	2022	2,738	9,002	21.86%	14,444	34.81%	39,508	55.86%	102,391	71.67%
2011-2012 OFL-derived catch	2011	1,584	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	1,584	13,977	33.94%	20,226	48.75%	44,530	62.96%	105,899	74.13%
	2013	1,584	13,822	33.56%	20,013	48.23%	44,402	62.78%	105,933	74.15%
	2014	1,584	13,666	33.18%	19,802	47.72%	44,277	62.61%	105,968	74.18%
	2015	1,584	13,509	32.80%	19,593	47.22%	44,153	62.43%	106,003	74.20%
	2016	1,584	13,350	32.42%	19,385	46.72%	44,030	62.26%	106,037	74.23%
	2017	1,584	13,189	32.03%	19,179	46.22%	43,907	62.08%	106,069	74.25%
	2018	1,584	13,025	31.63%	18,972	45.72%	43,783	61.91%	106,098	74.27%
	2019	1,584	12,858	31.22%	18,766	45.23%	43,659	61.73%	106,122	74.29%
	2020	1,584	12,688	30.81%	18,560	44.73%	43,533	61.55%	106,142	74.30%
	2021	1,584	12,513	30.38%	18,354	44.23%	43,405	61.37%	106,156	74.31%
	2022	1,584	12,334	29.95%	18,147	43.74%	43,275	61.19%	106,164	74.32%
Forecast catch calculated from 77% SPR applied to base model	2011	928	14,133	34.32%	20,442	49.27%	44,660	63.15%	105,868	74.11%
	2012	928	14,138	34.33%	20,406	49.18%	44,530	62.96%	105,899	74.13%
	2013	928	14,143	34.34%	20,373	49.10%	44,402	62.78%	105,933	74.15%
	2014	928	14,148	34.35%	20,341	49.02%	44,277	62.61%	105,968	74.18%
	2015	928	14,152	34.36%	20,309	48.95%	44,153	62.43%	106,003	74.20%
	2016	928	14,154	34.37%	20,278	48.87%	44,030	62.26%	106,037	74.23%
	2017	928	14,153	34.37%	20,247	48.79%	43,907	62.08%	106,069	74.25%
	2018	927	14,149	34.36%	20,214	48.72%	43,783	61.91%	106,098	74.27%
	2019	927	14,142	34.34%	20,182	48.64%	43,659	61.73%	106,122	74.29%
	2020	926	14,130	34.31%	20,147	48.56%	43,533	61.55%	106,142	74.30%
	2021	926	14,113	34.27%	20,111	48.47%	43,405	61.37%	106,156	74.31%
	2022	925	14,091	34.22%	20,073	48.38%	43,275	61.19%	106,164	74.32%

FIGURES

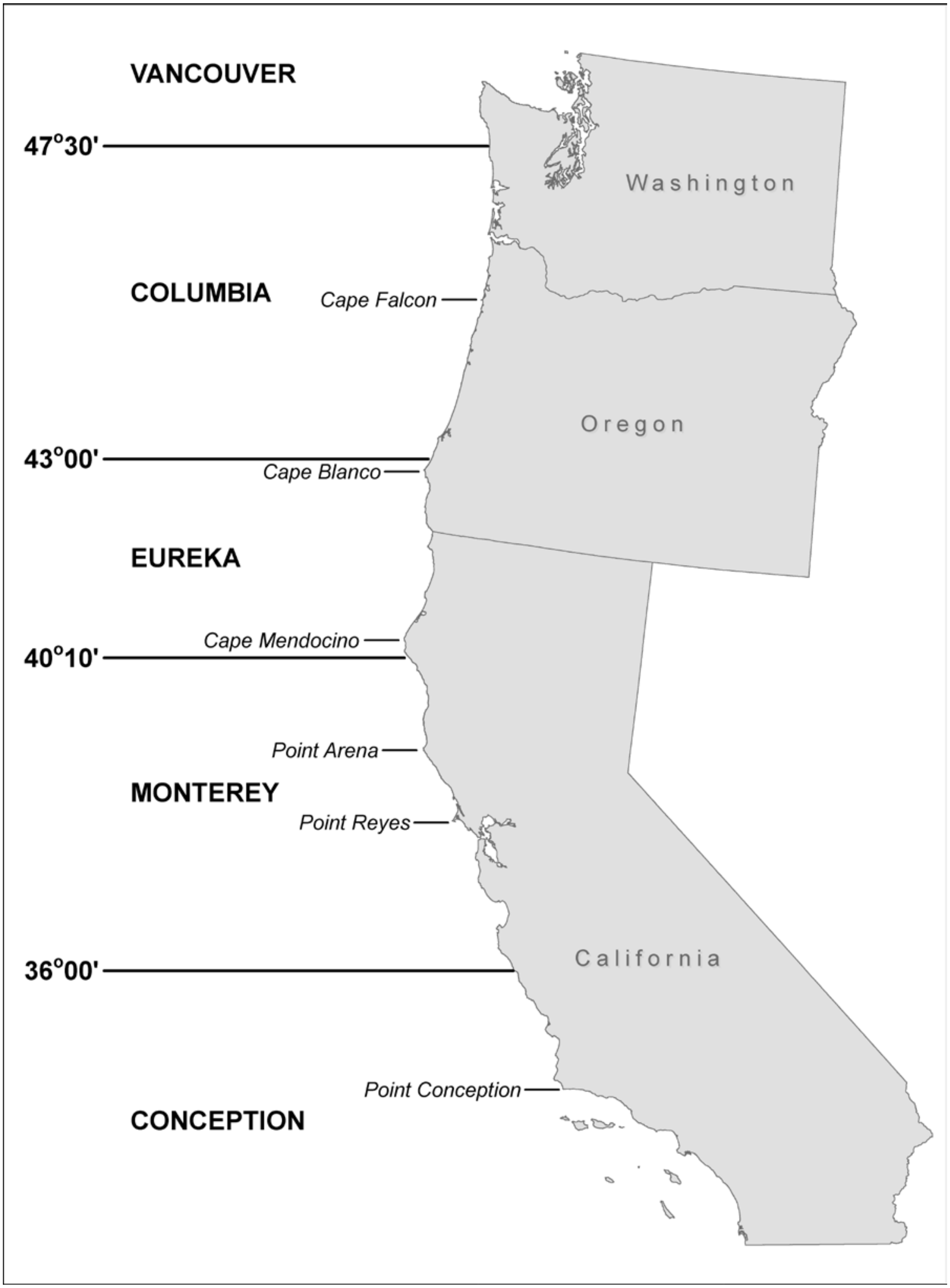

Figure 1. A map of the assessment area that includes coastal waters off three U.S. west coast states and five International North Pacific Fisheries Commission (INPFC) areas.

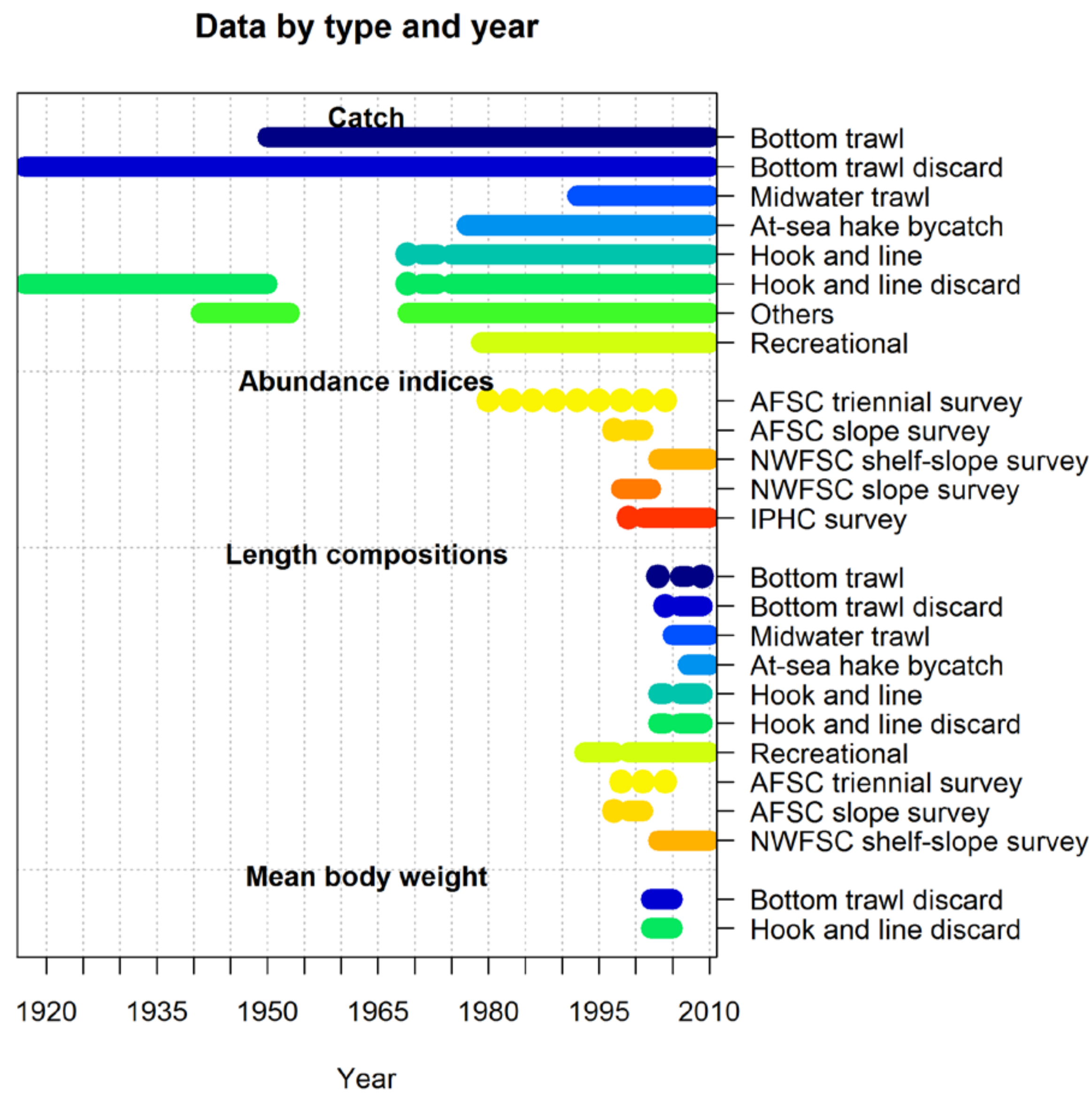

Figure 2. The summary of fishery-dependent and fishery-independent data used in the assessment.

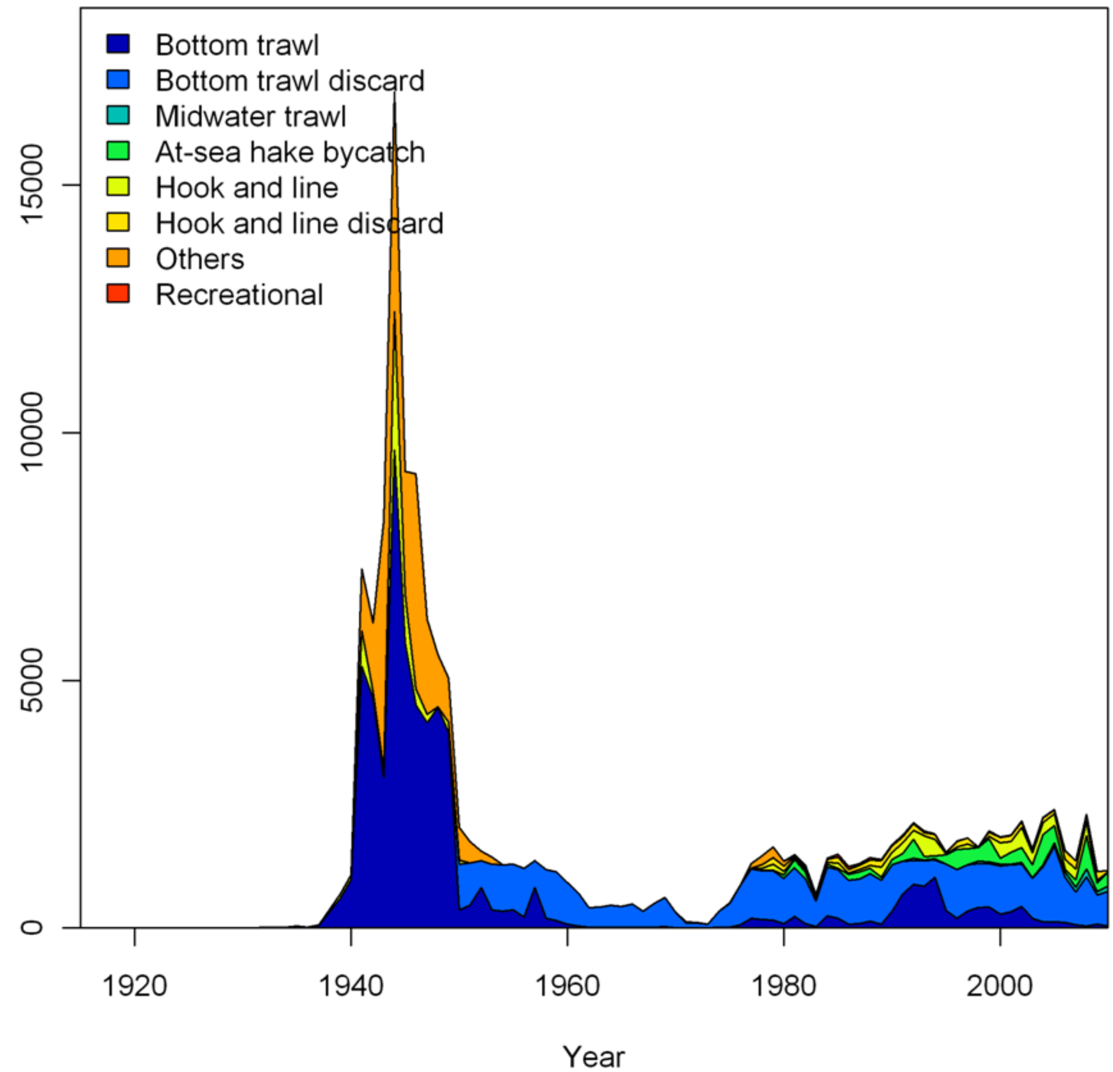

Figure 3. The reconstructed time series of spiny dogfish removals (mt) by fleet.

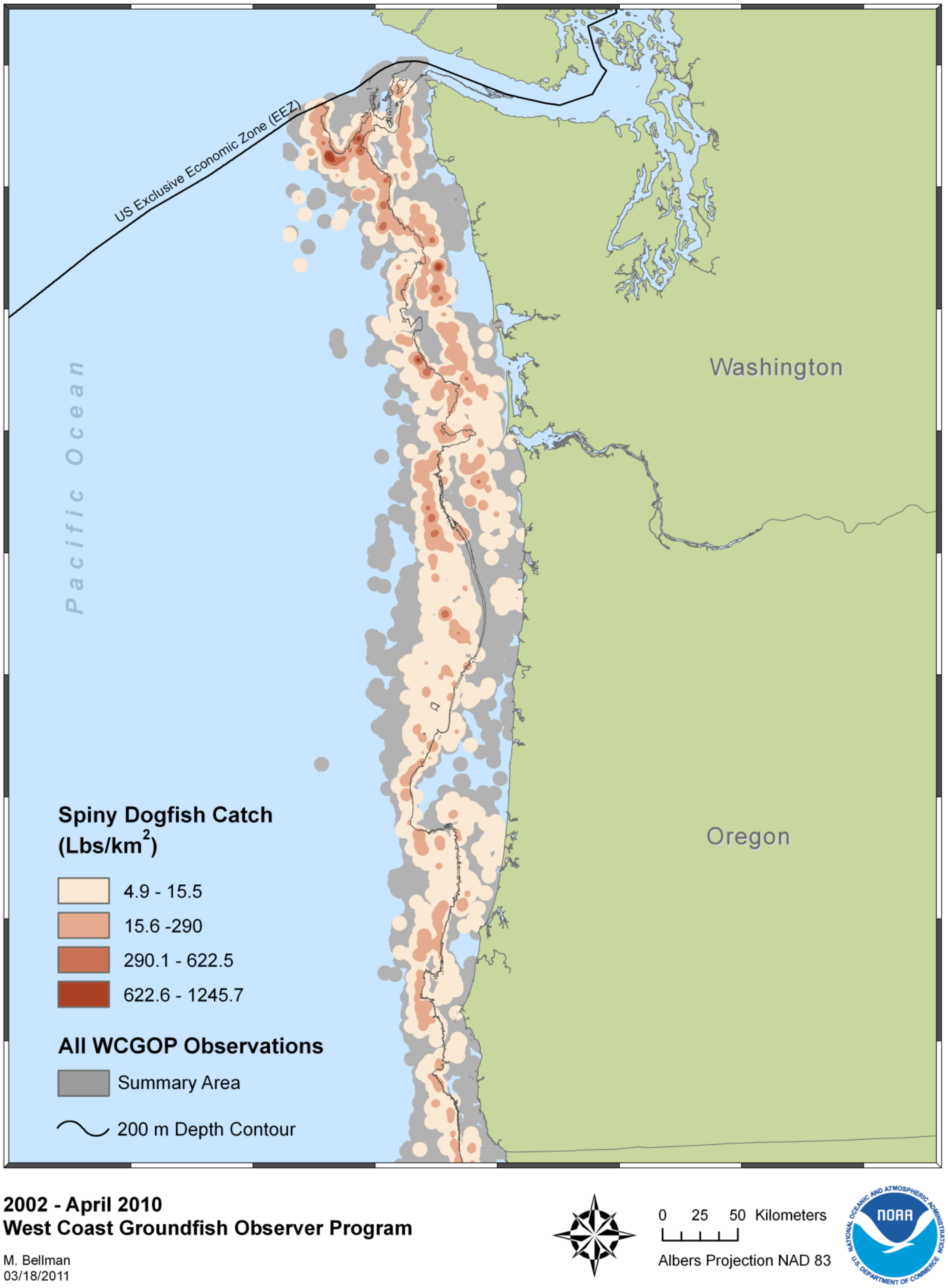

Figure 4. Spatial distribution of spiny dogfish shark catch (lbs/km^2) observed by the West Coast Groundfish Observer Program from 2002 – April 2010 and the summary area of all observed fishing events.

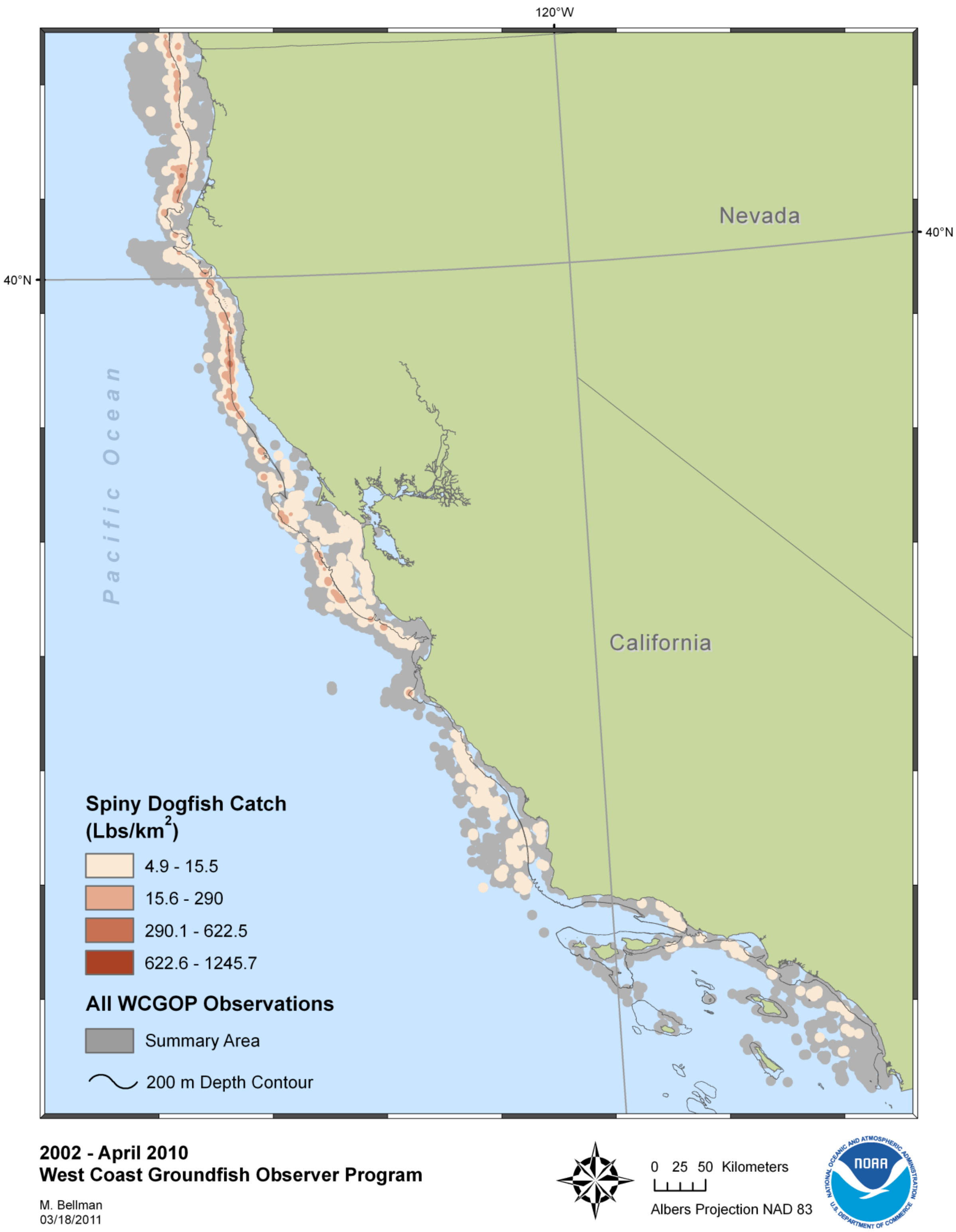

Figure 4 (continued). Spatial distribution of spiny dogfish shark catch (lbs/km^2) observed by the West Coast Groundfish Observer Program from 2002 – April 2010 and the summary area of all observed fishing events.

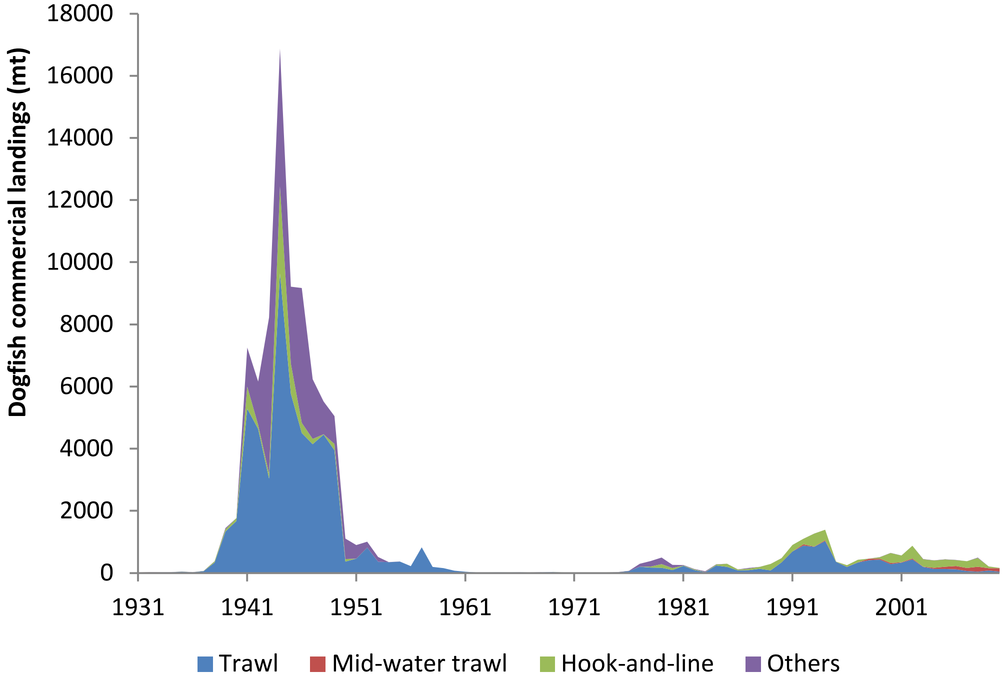

Figure 5. Commercial landings of spiny dogfish by fleet.

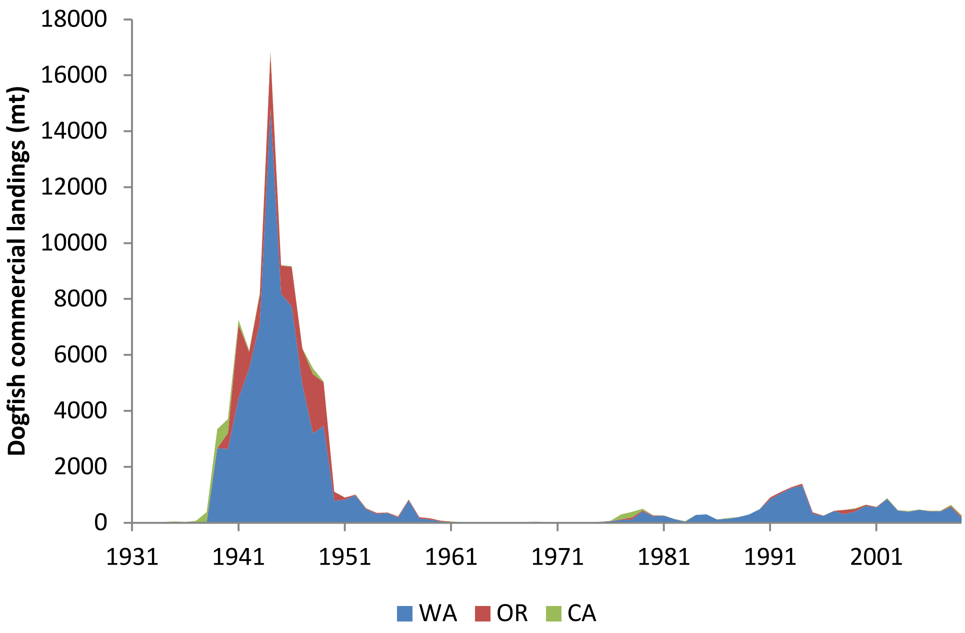

Figure 6. Commercial landings of spiny dogfish by state.

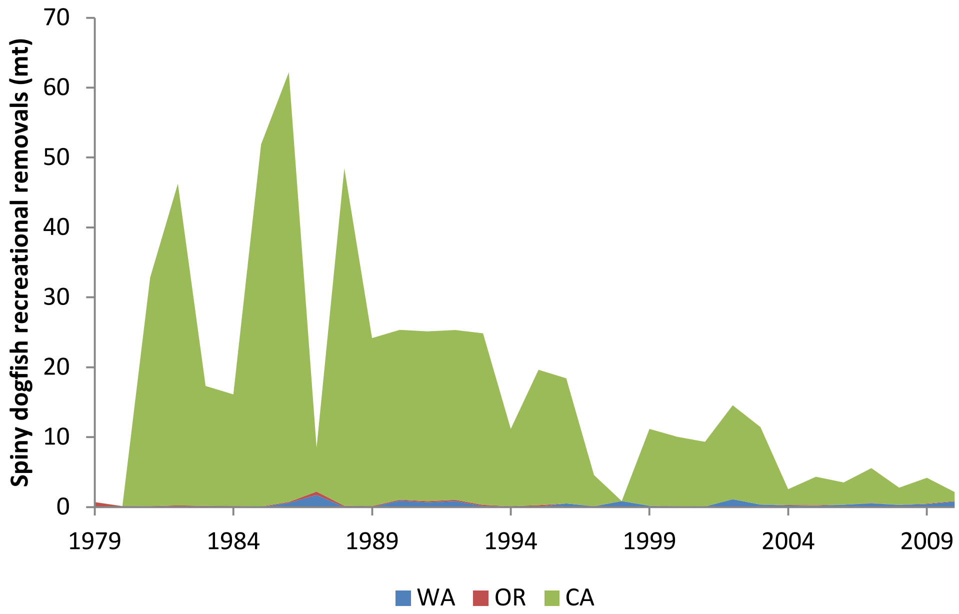

Figure 7. Recreational removals of spiny dogfish by state.

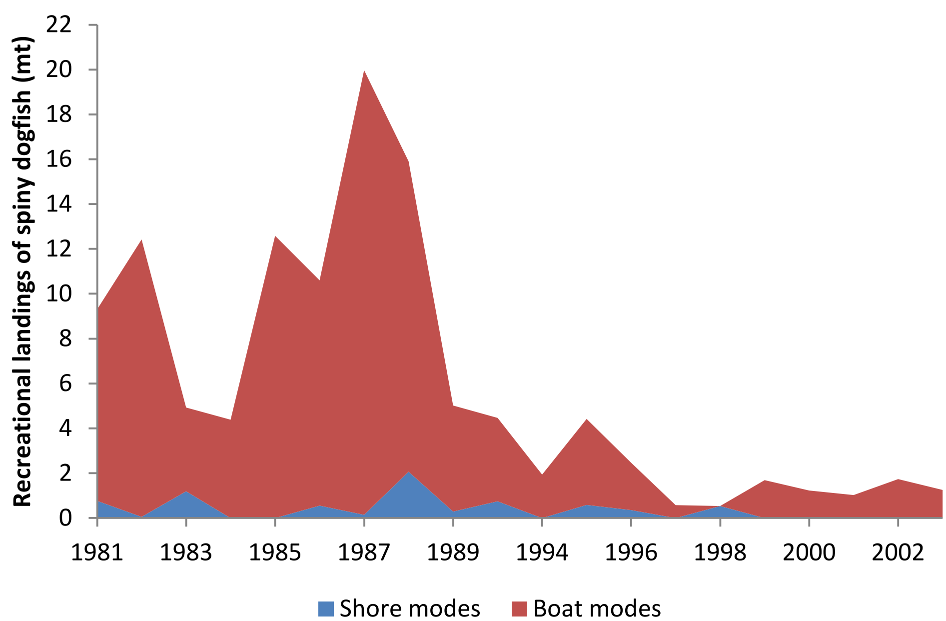

Figure 8. Recreational landings of spiny dogfish by fishing mode.

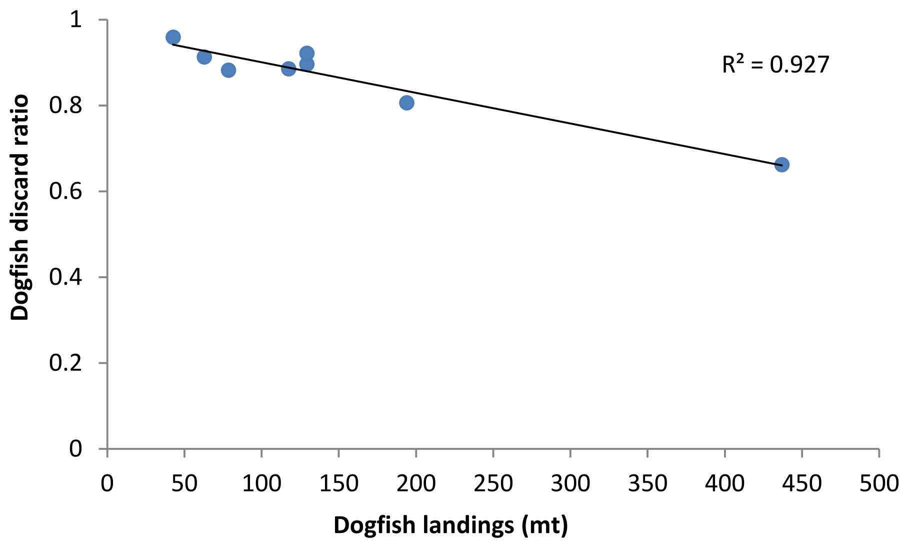

Figure 9. Relationship between spiny dogfish landings and discard ratio for bottom trawl fleet.

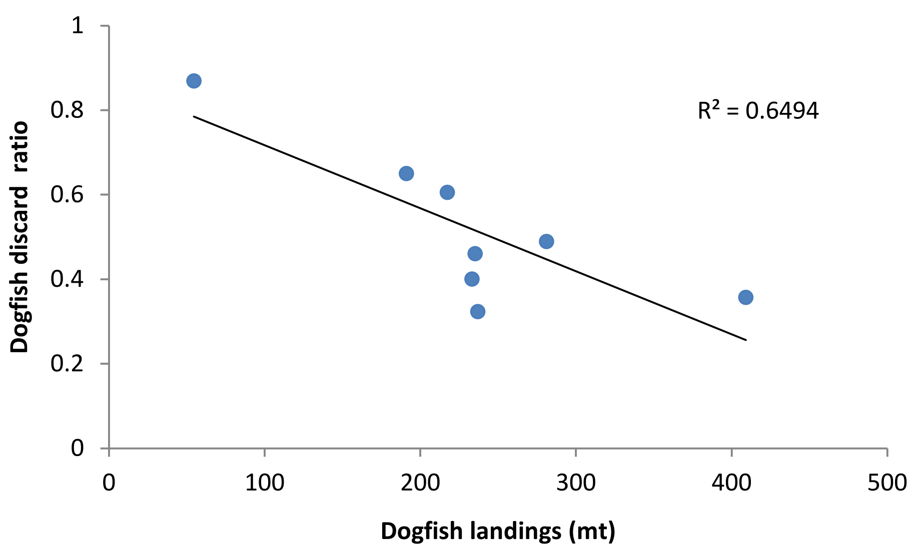

Figure 10. Relationship between spiny dogfish landings and discard ratio for hook-and-line fleet.

Figure 11. Spiny dogfish bycatch within at-sea Pacific hake fishery.

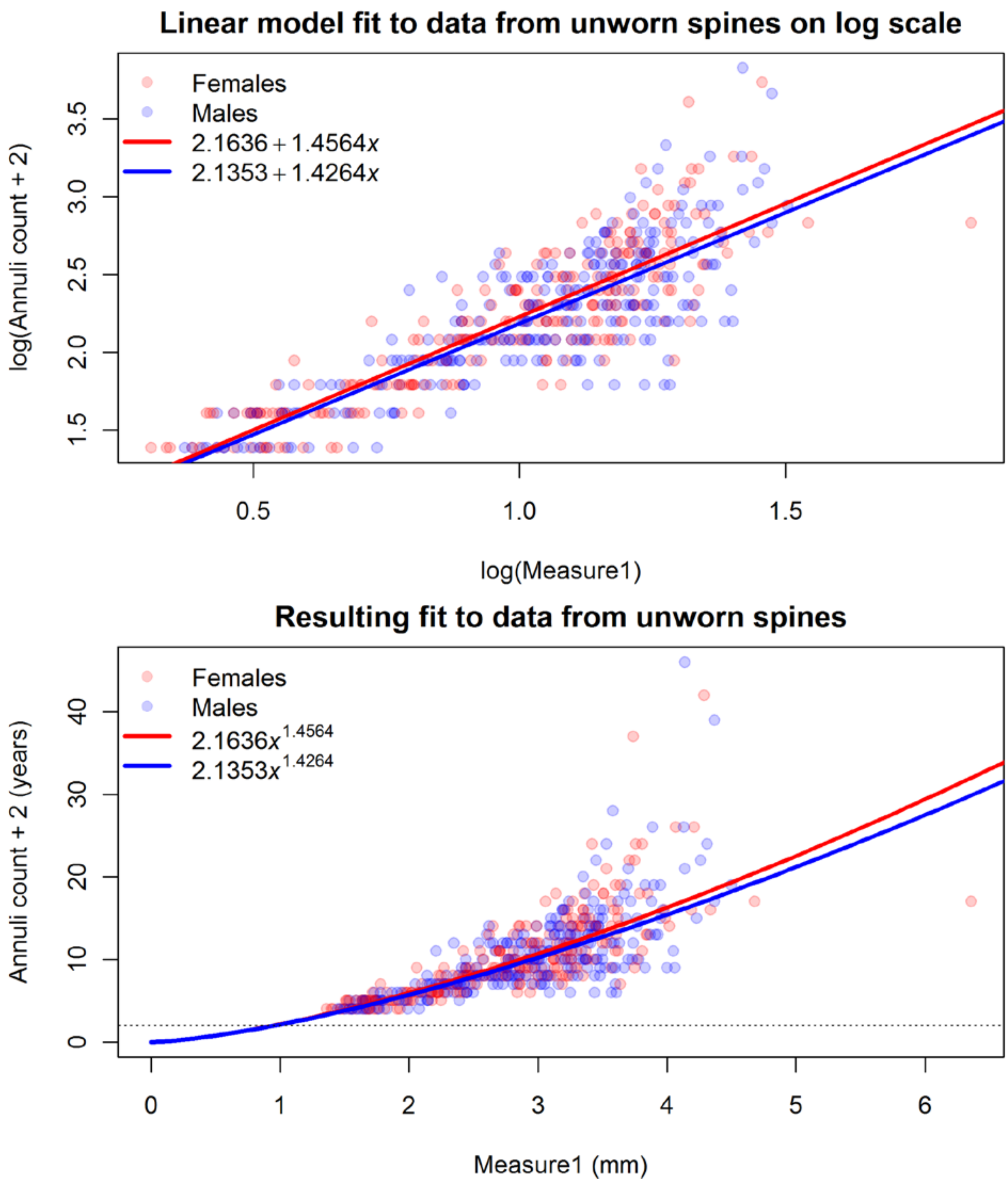

Figure 12. Estimated extrapolation function for missing ages in Age Method 1 fit to data from unworn spines on a log scale (top) and untransformed (bottom). The dotted horizontal line in the lower figure corresponds to a count of 0 annuli, and indicates that the estimated spine diameter at birth is about 1 mm.

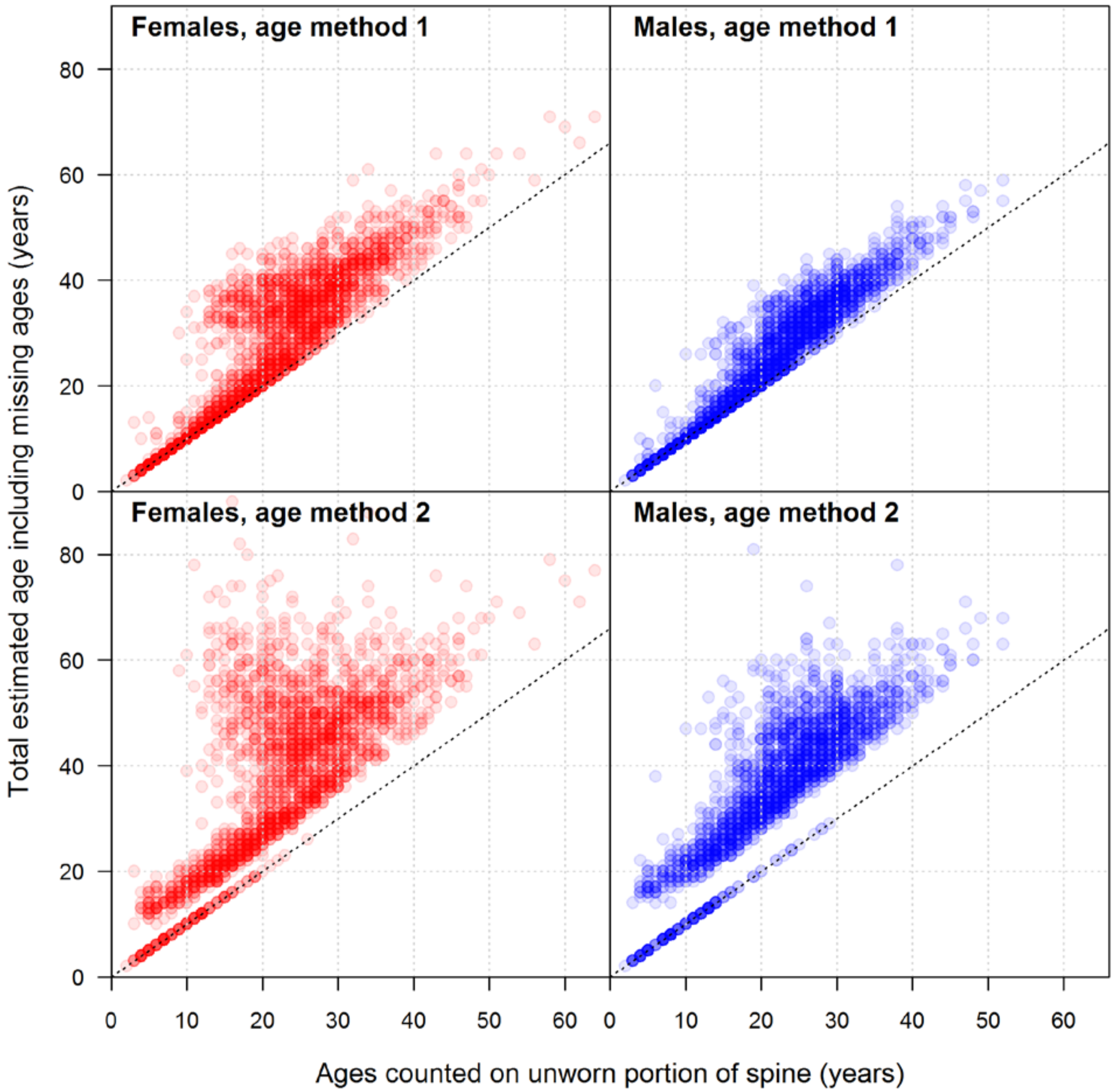

Figure 13. Total estimated age vs. the number of ages countable on the spine for males and females from each method of age determination.

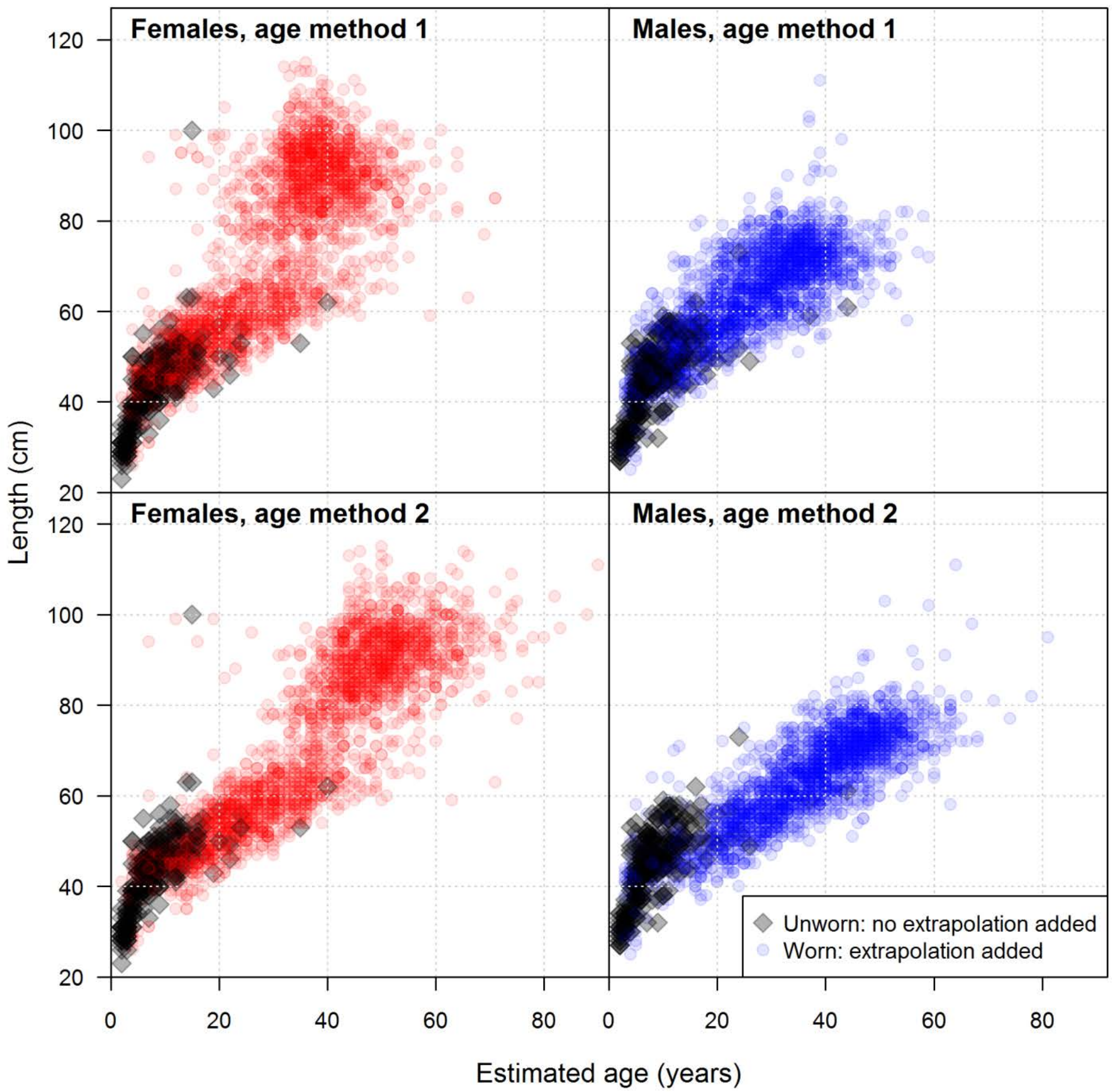

Figure 14. Age vs. length for males and females from each method of age determination.

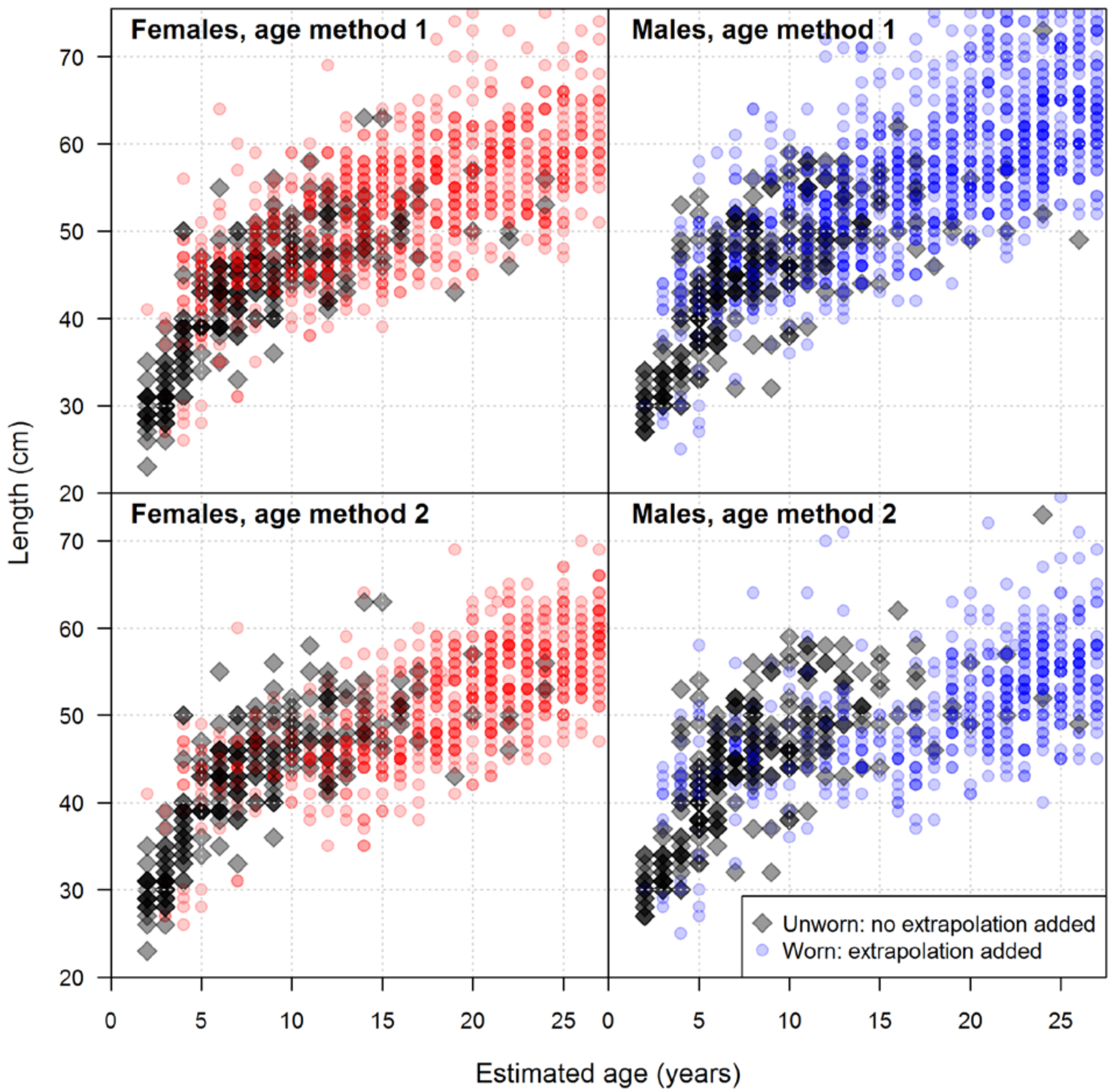

Figure 15. A closer view of age vs. length as in the figure above, with range restricted to younger fish to better illustrate differences between age at length for unworn and worn spines in Method 2.

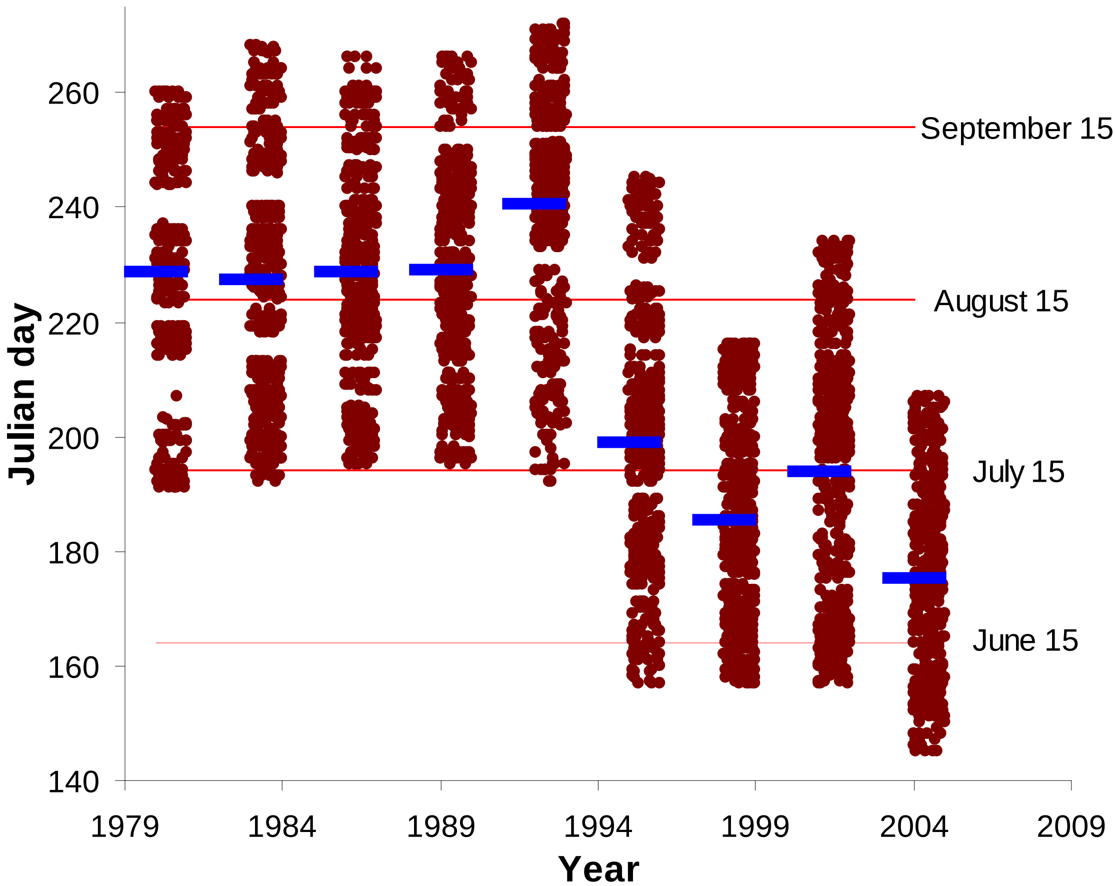

Figure 16. Timing of the AFSC triennial survey (1980-2004): solid bars represent the mean date for each survey year, points - individual hauls dates, jittered to allow better delineation of the distribution of individual points.

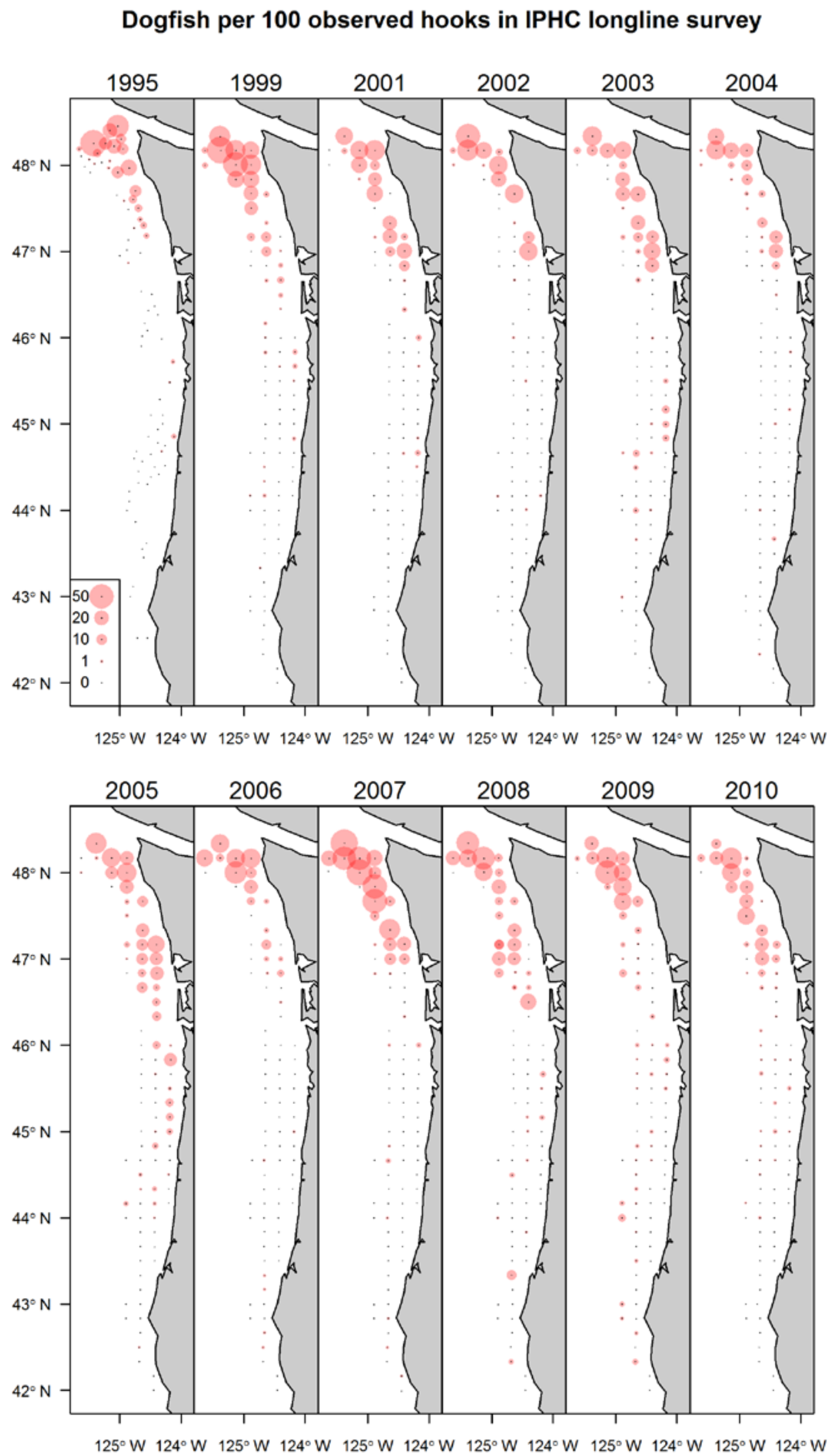

Figure 17. Spatial distribution of spiny dogfish catches by year within the International Pacific Halibut Commission (IPHC) hook-and-line survey (expressed as the number of dogfish per 100 observed hooks).

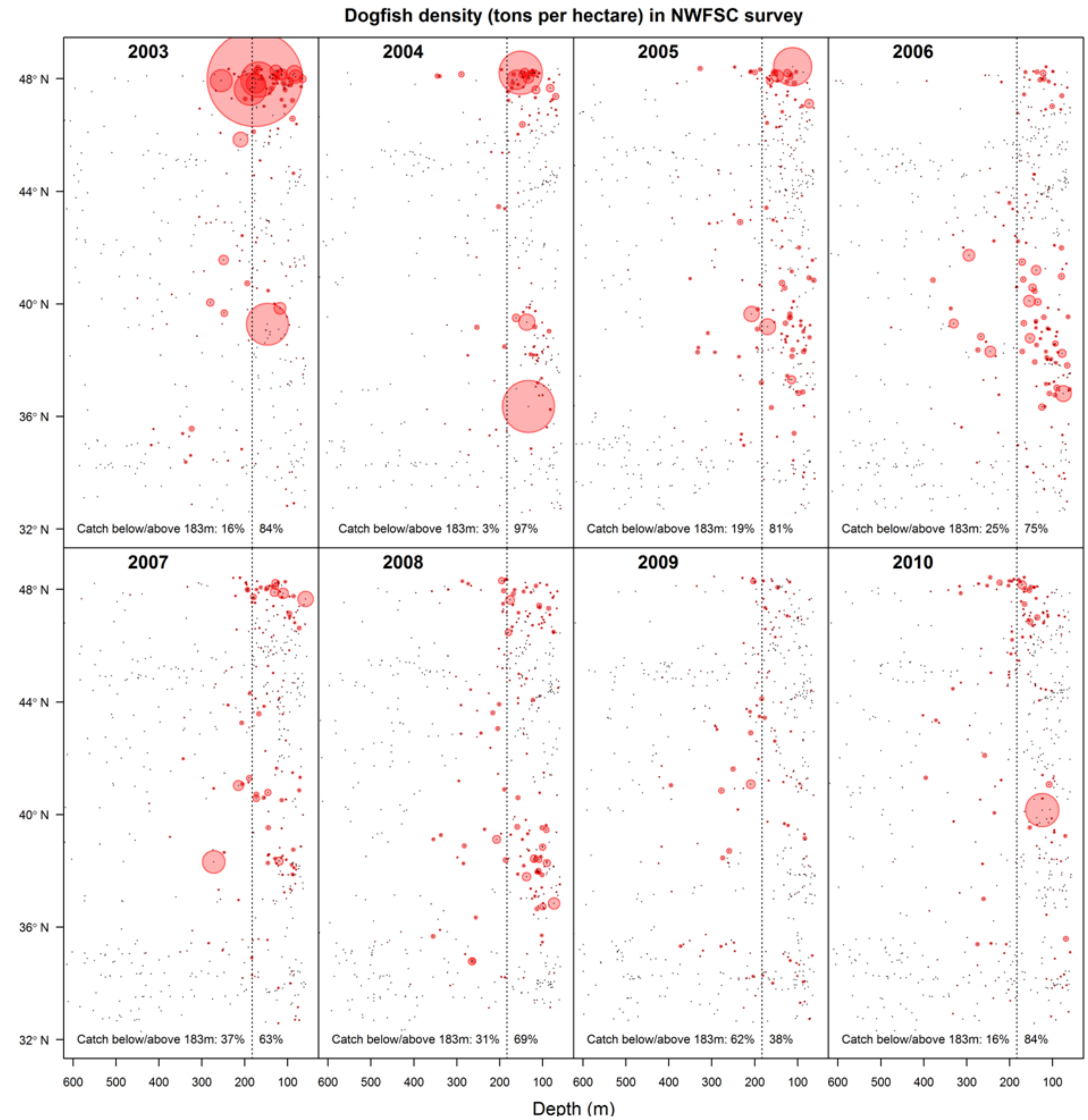

Figure 18. Distribution of spiny dogfish catch observed by the NWFSC shelf-slope survey (2003-2010) by latitude and depth.

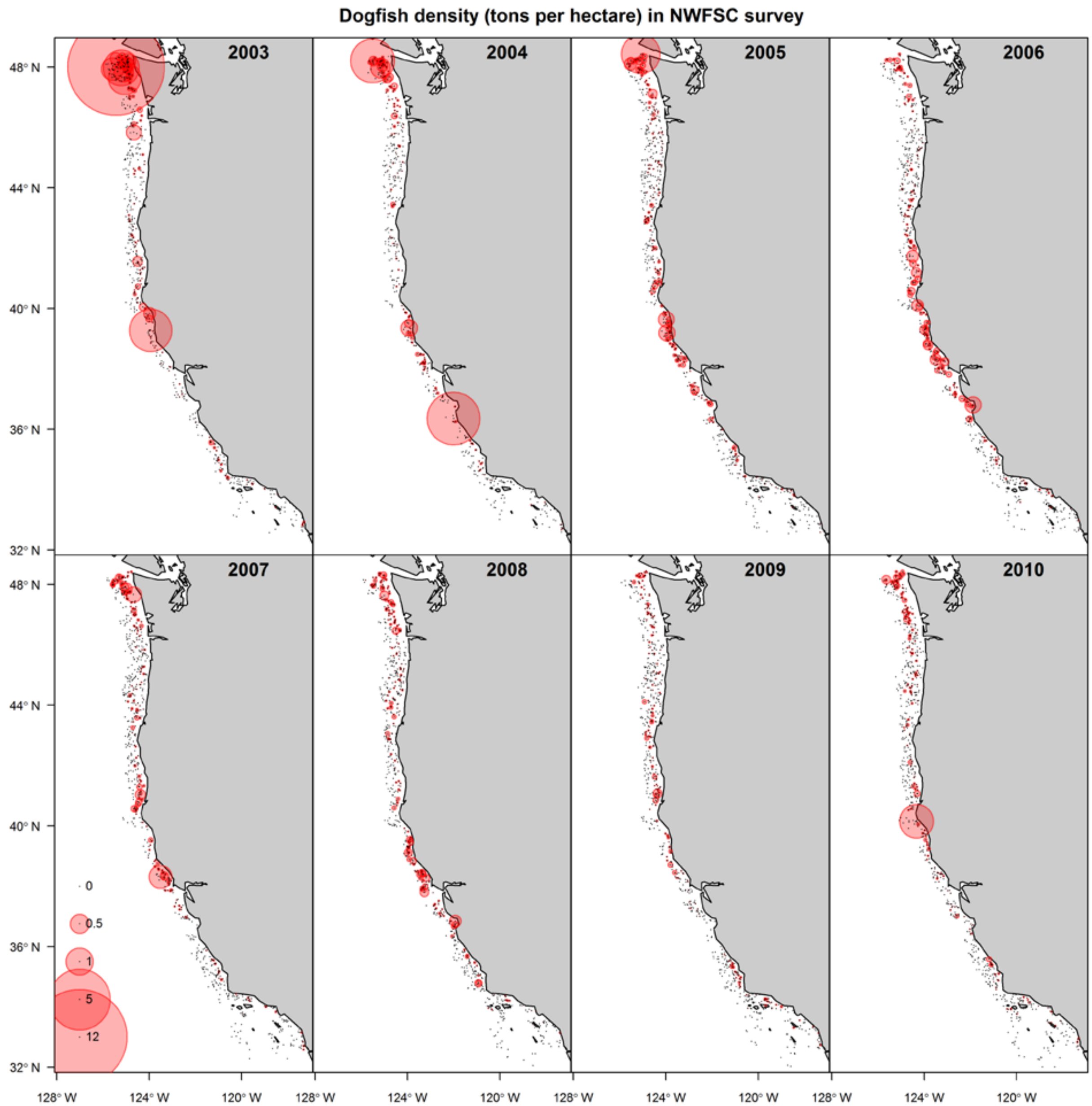

Figure 19. Distribution of spiny dogfish shark catch observed by the NWFSC shelf-slope survey (2003-2010) by latitude.

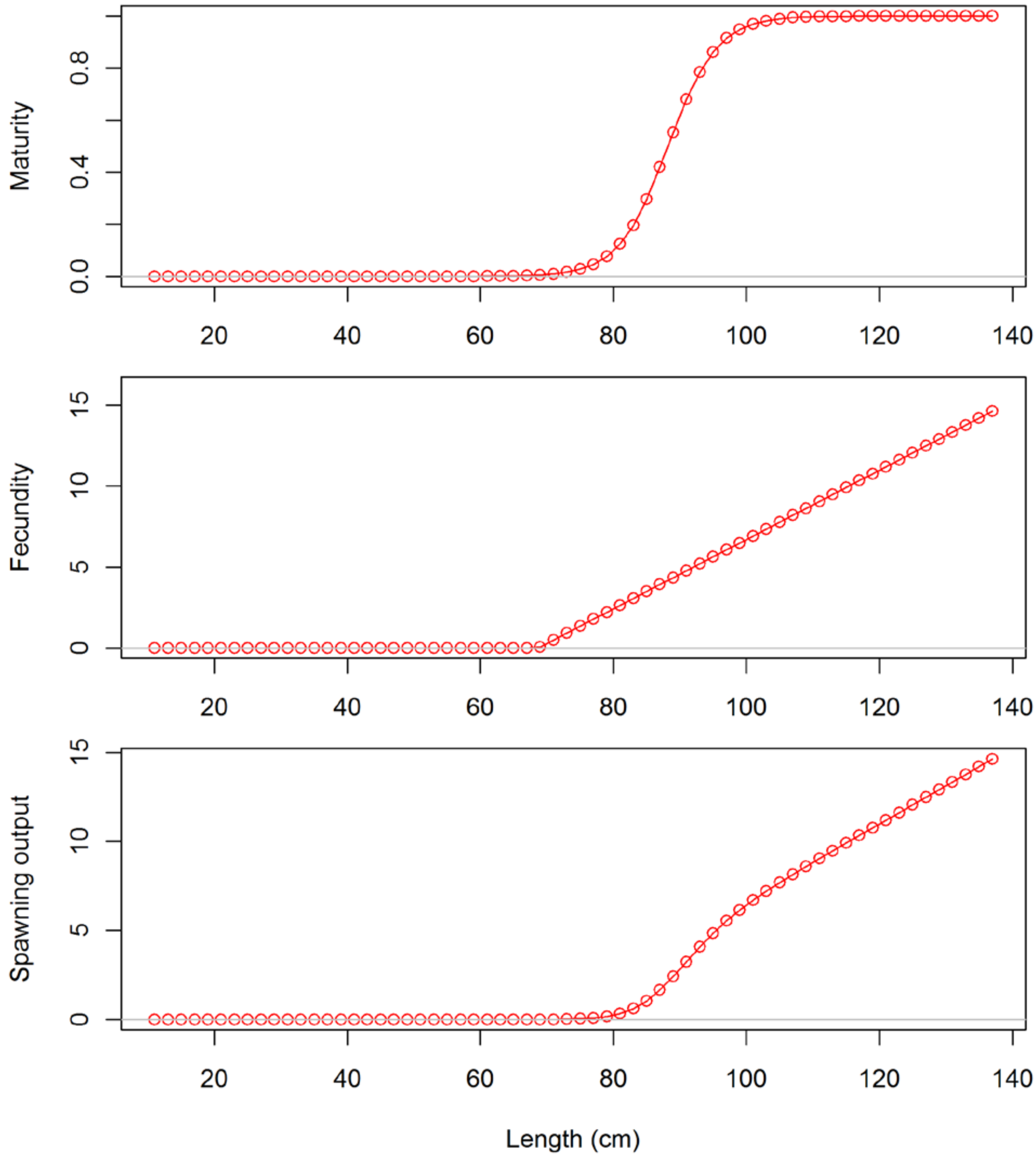

Figure 20. Published relationships used in the model for female maturity (top), fecundity (middle), and spawning output (product of maturity and fecundity, bottom) as a function of length.

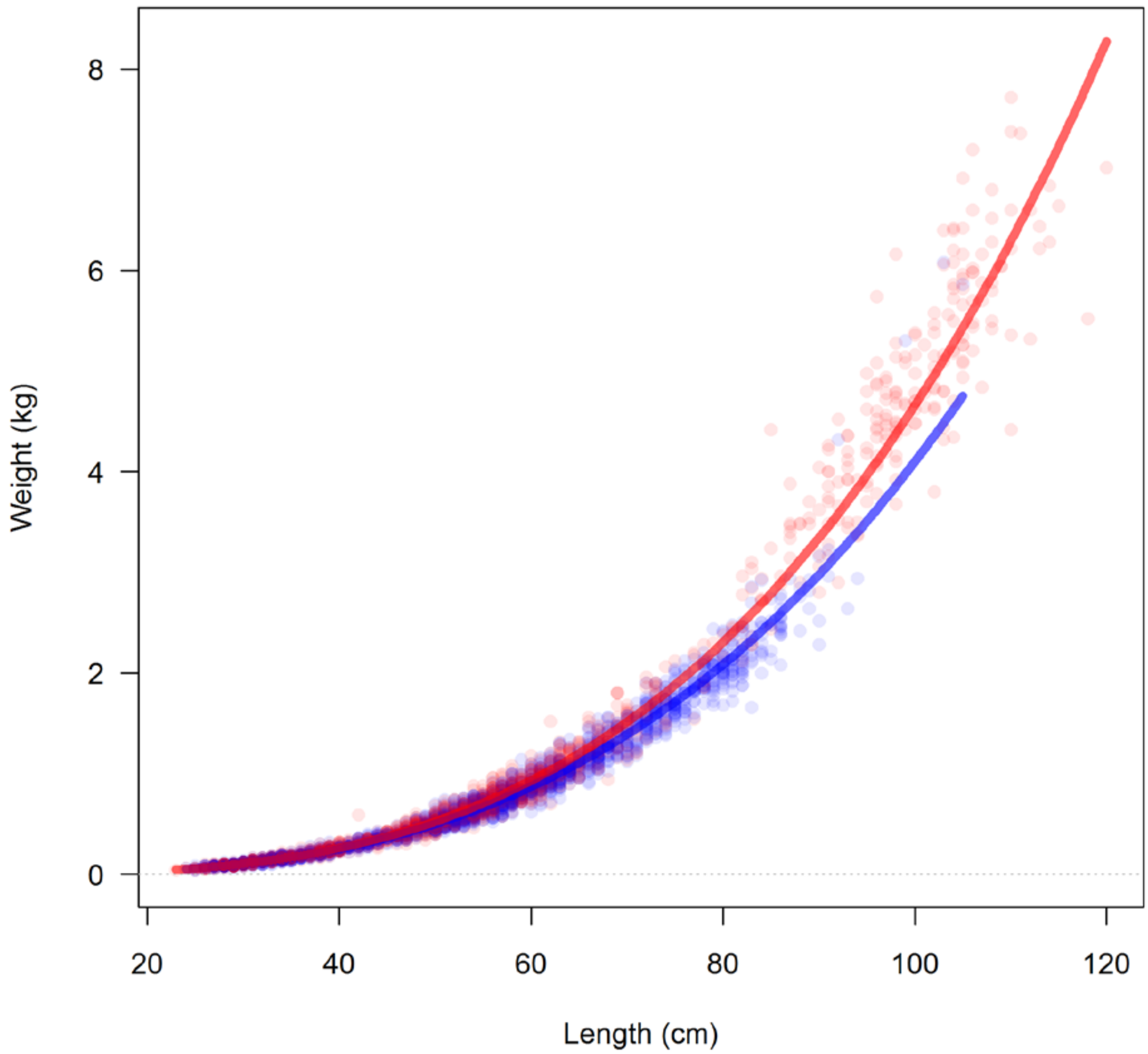

Figure 21. Weight-length relationships for females (red) and males (blue) shown with fit to the data from the NWFSC shelf-slope survey samples (shaded points).

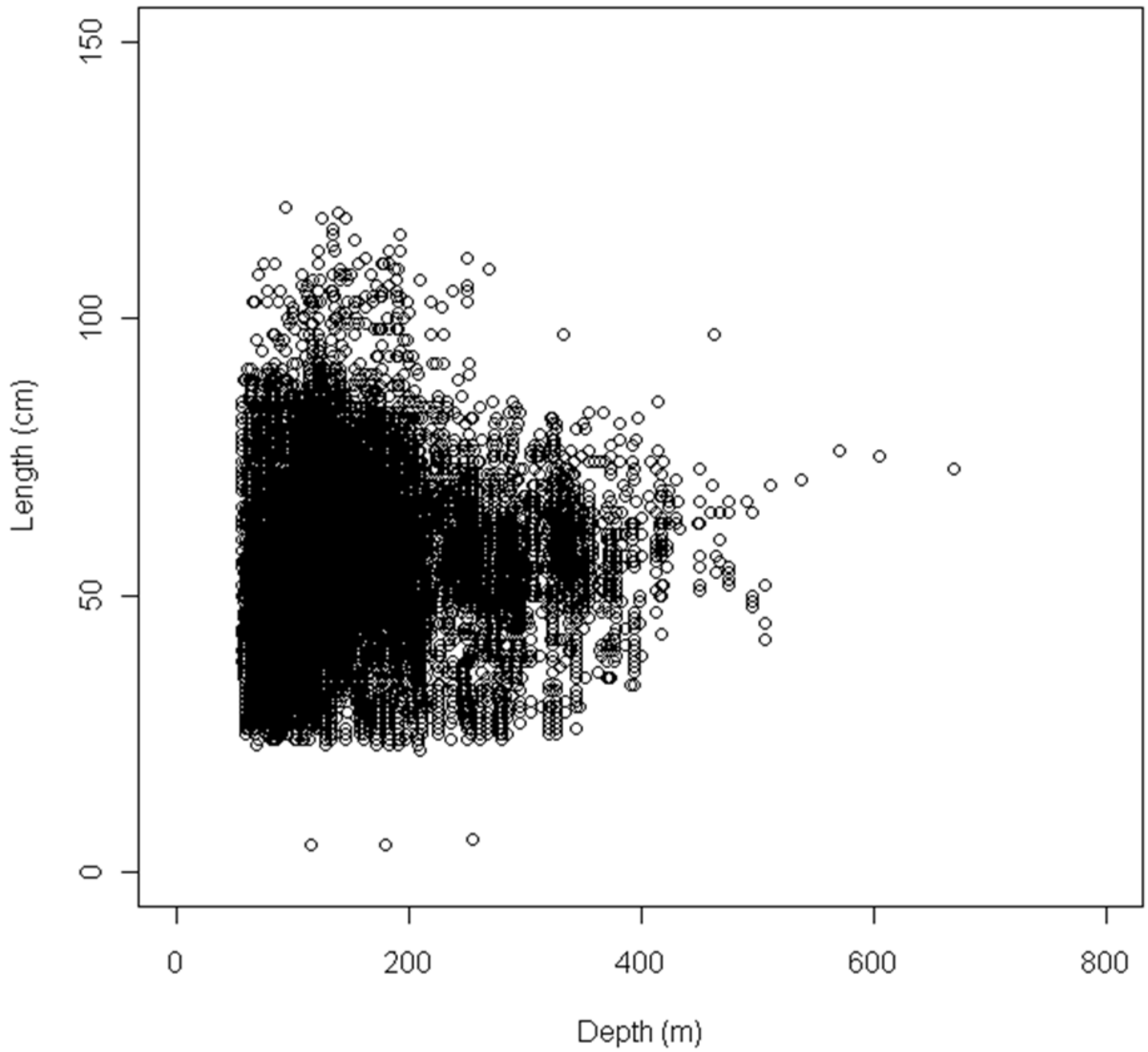

Figure 22. Relationship of spiny dogfish length and depth in the NWFSC shelf-slope survey.

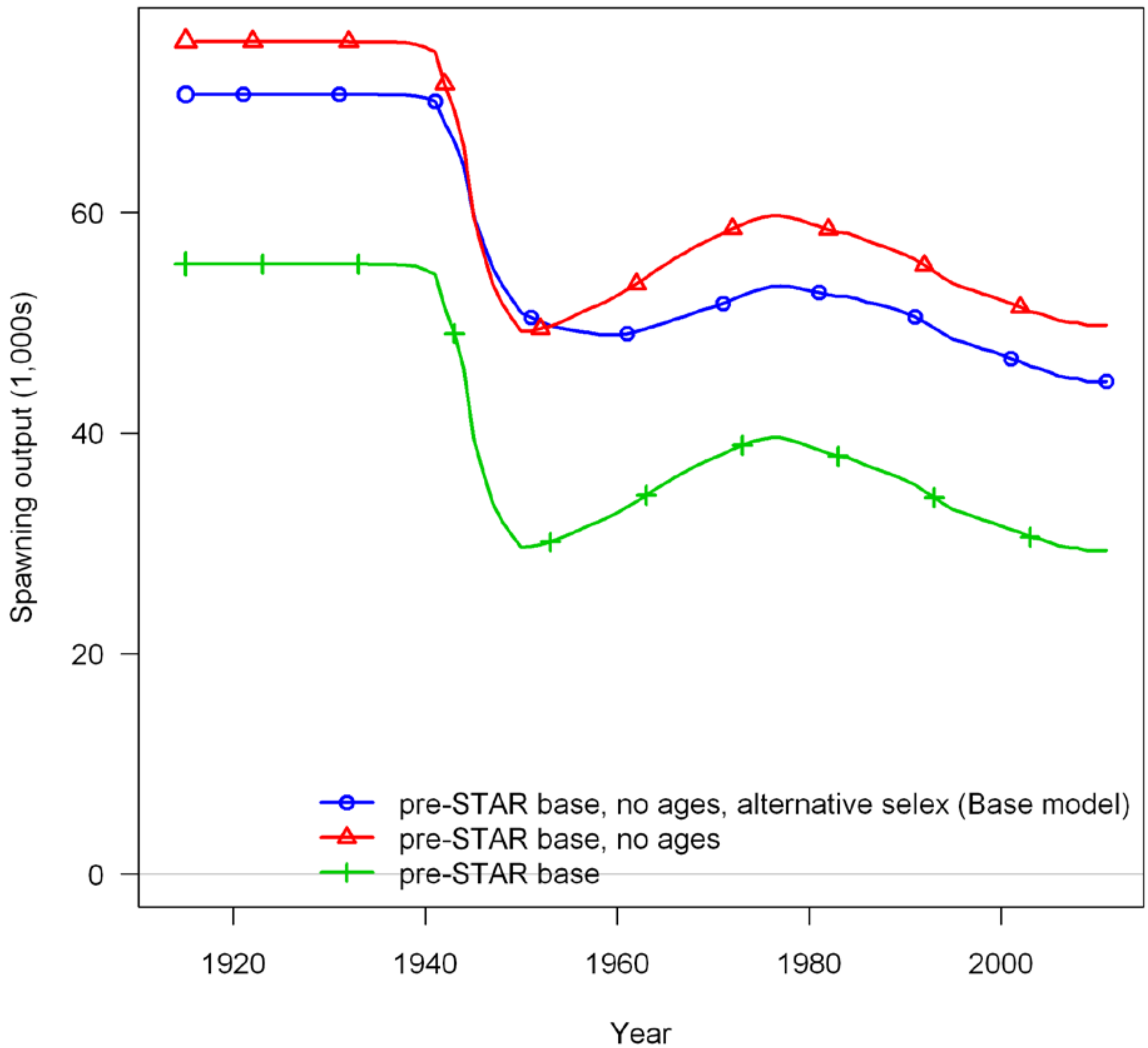

Figure 23. Comparison of spawning output time series for pre-STAR base model and changes made during STAP panel review.

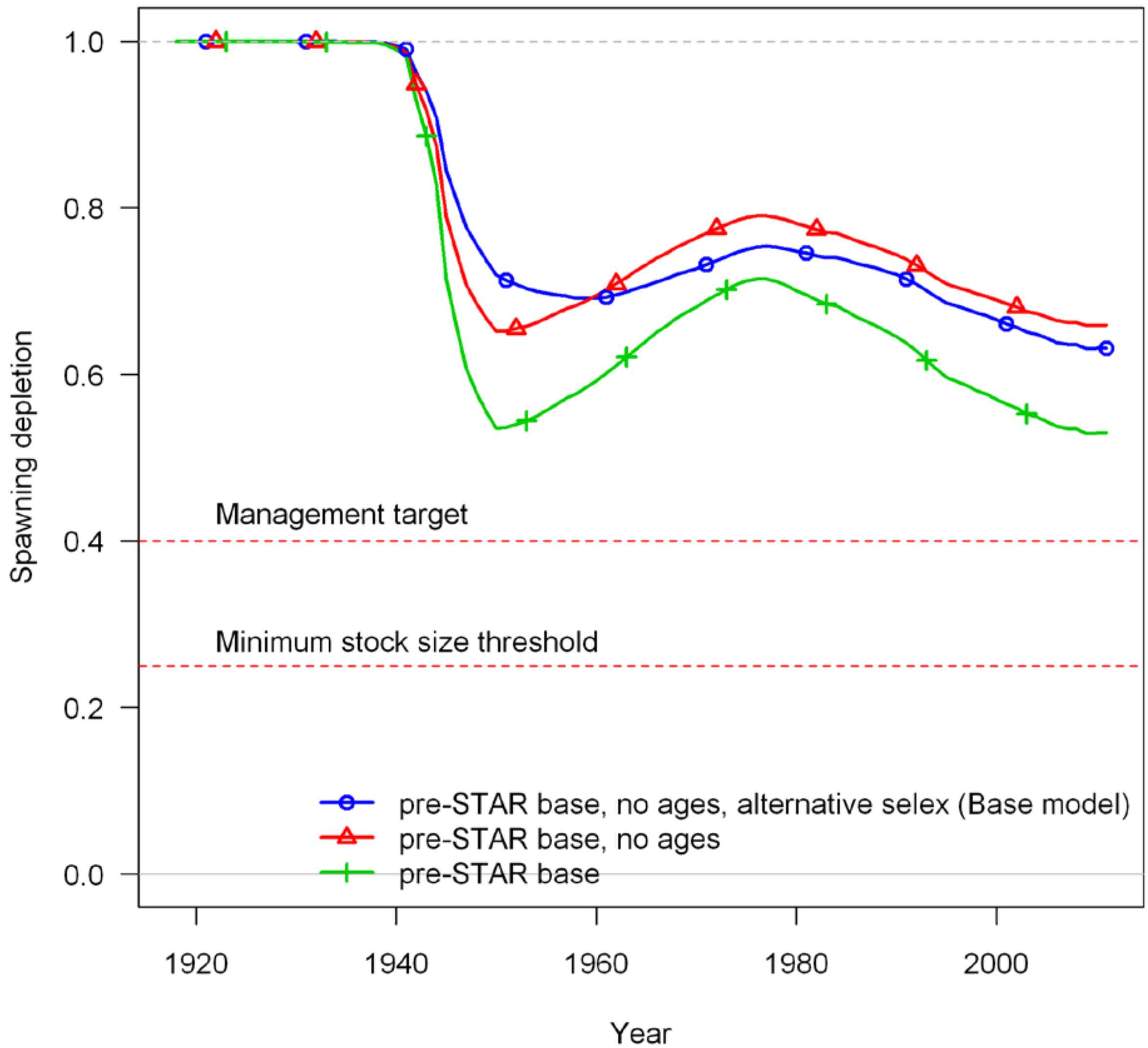

Figure 24. Comparison of spawning depletion time series for pre-STAR base model and changes made during STAP panel review.

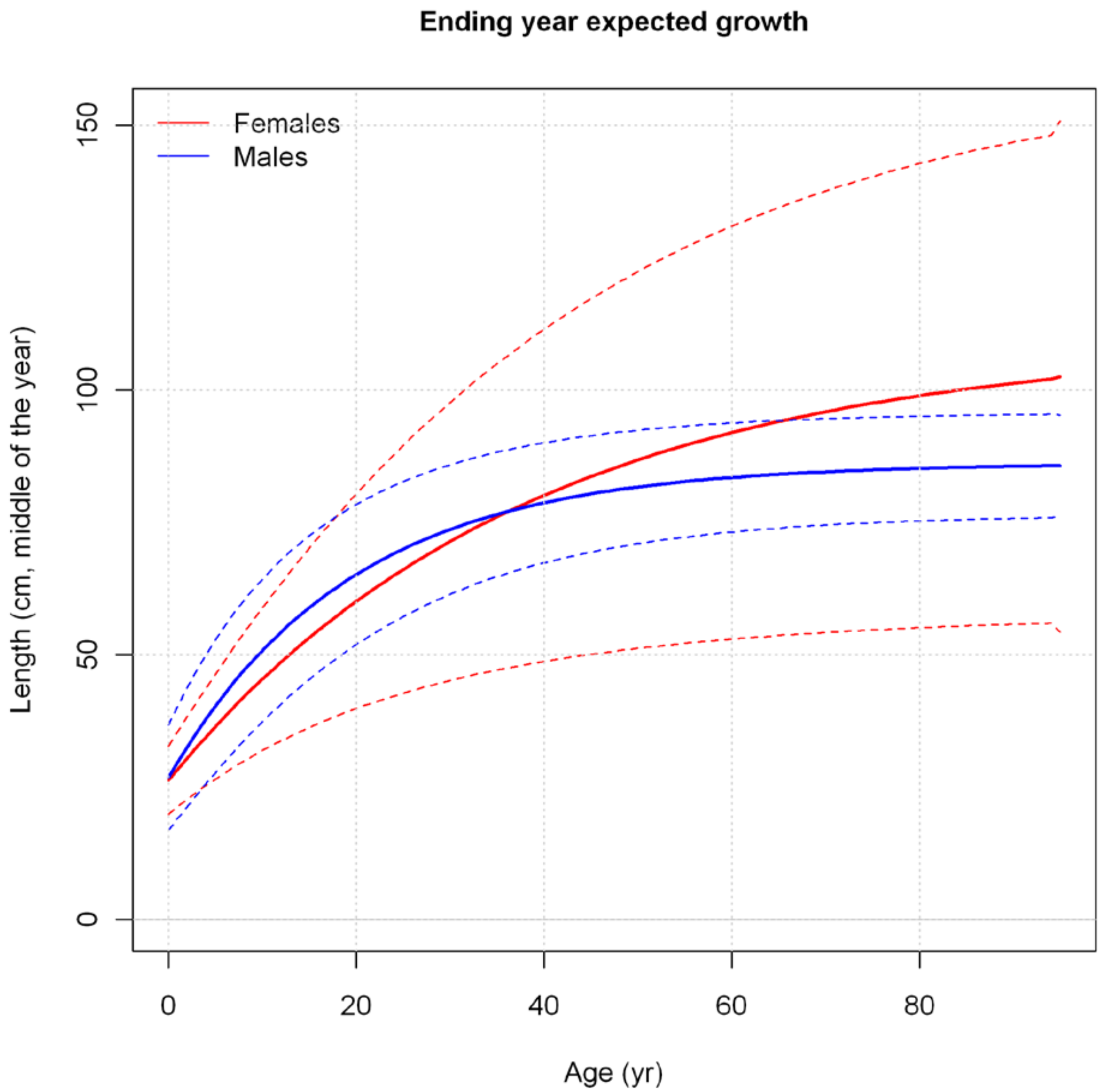

Figure 25. Growth curves for females and males of spiny dogfish shark used in the base model.

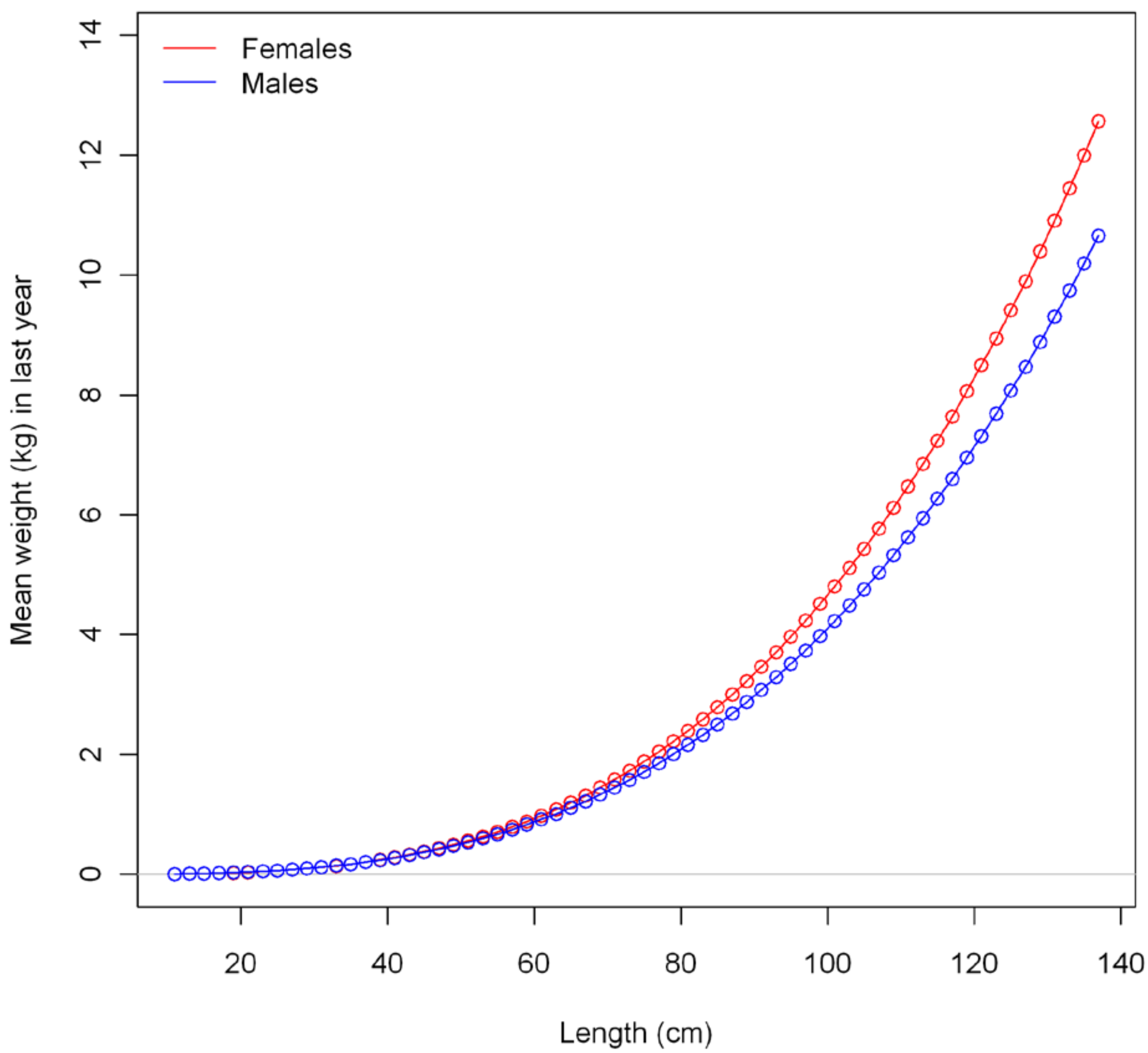

Figure 26. Weight-at-length relationship for females and males of spiny dogfish used in the base model.

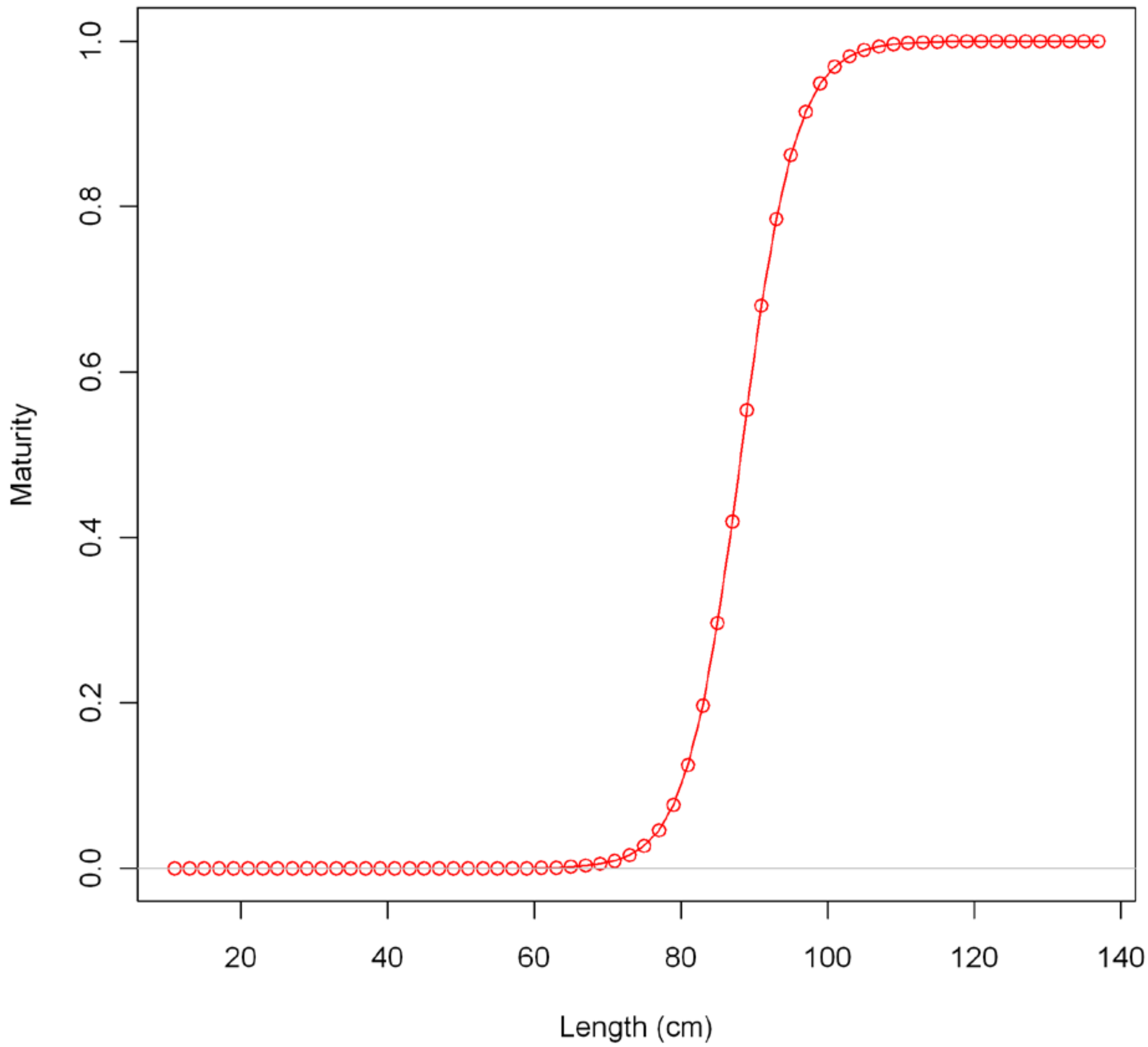

Figure 27. Spiny dogfish female maturity-at-length relationship used in the base model.

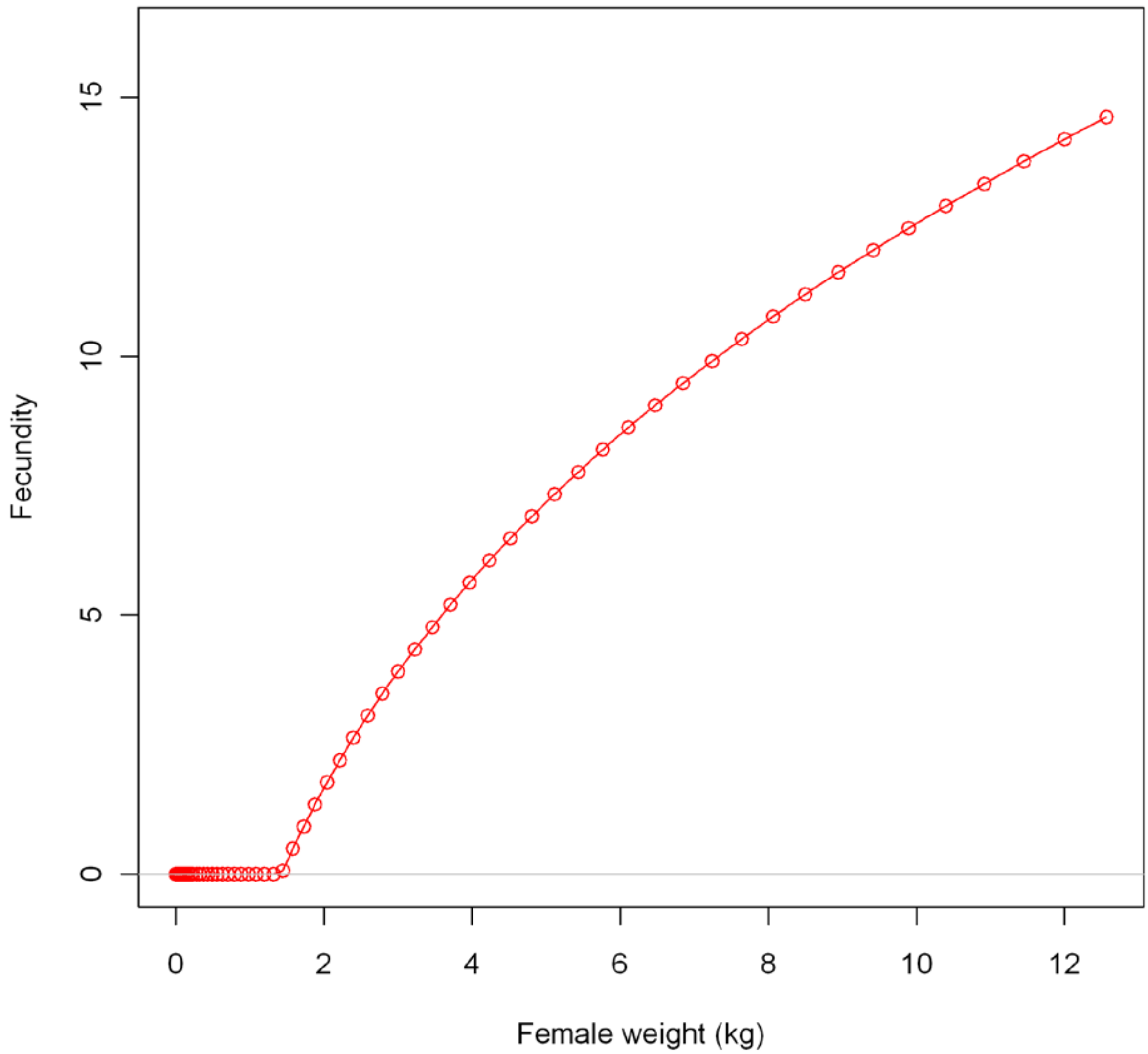

Figure 28. Spiny dogfish female fecundity-at-weight relationship used in the base model.

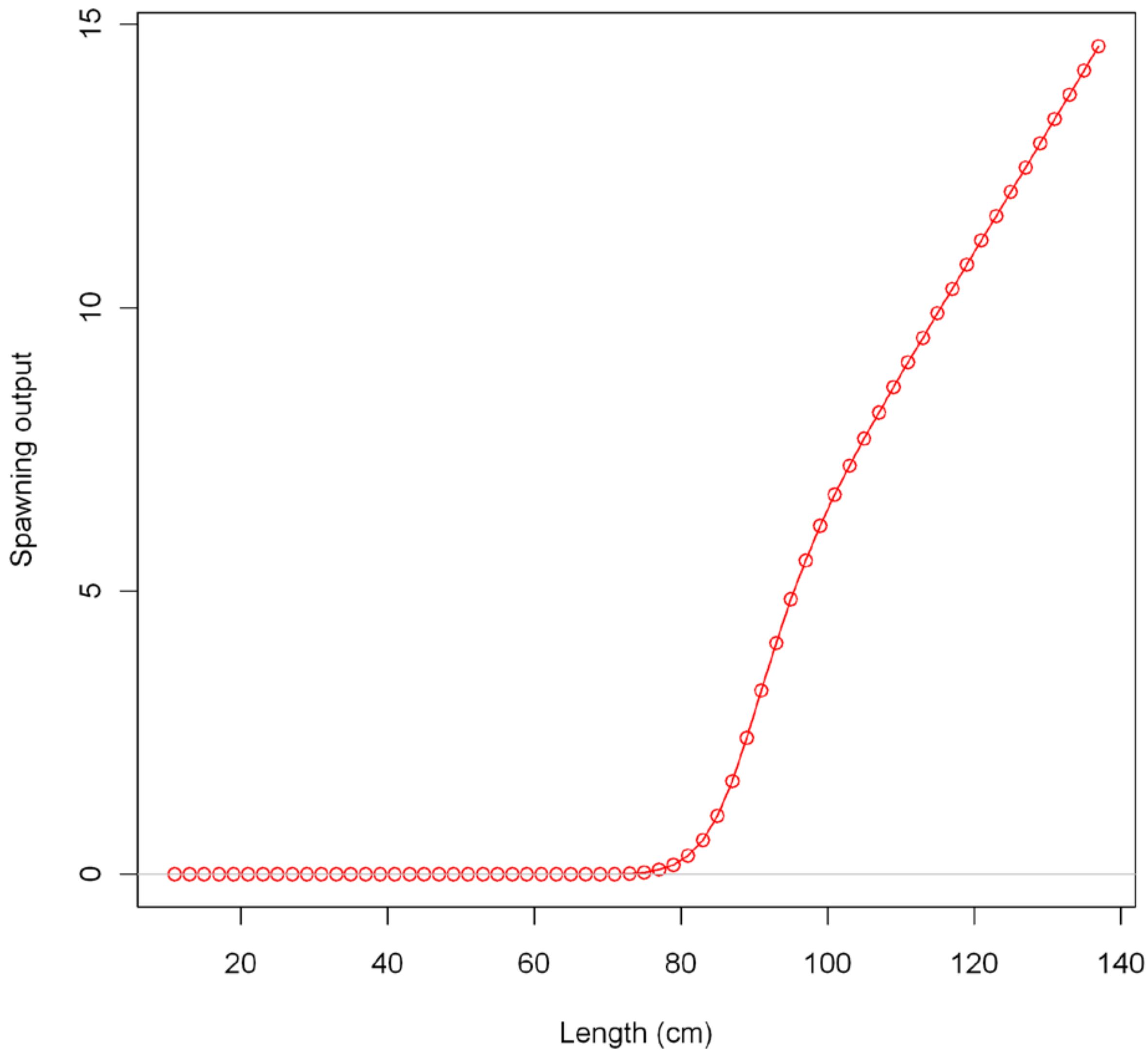

Figure 29. Spiny dogfish female spawning output-at-length relationship used in the base model.

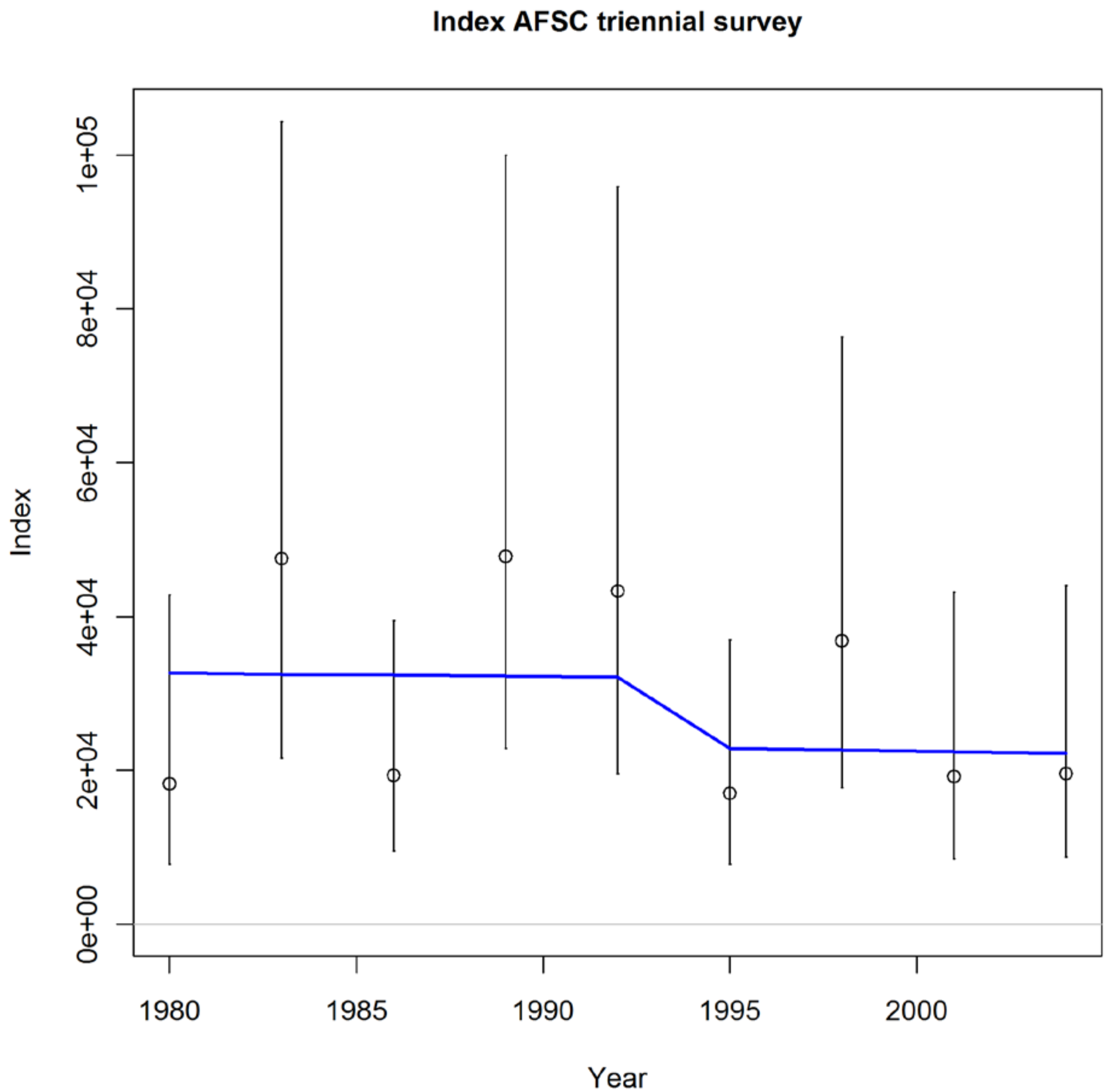

Figure 30. Observed and expected values of spiny dogfish biomass index (mt) for the AFSC triennial survey.

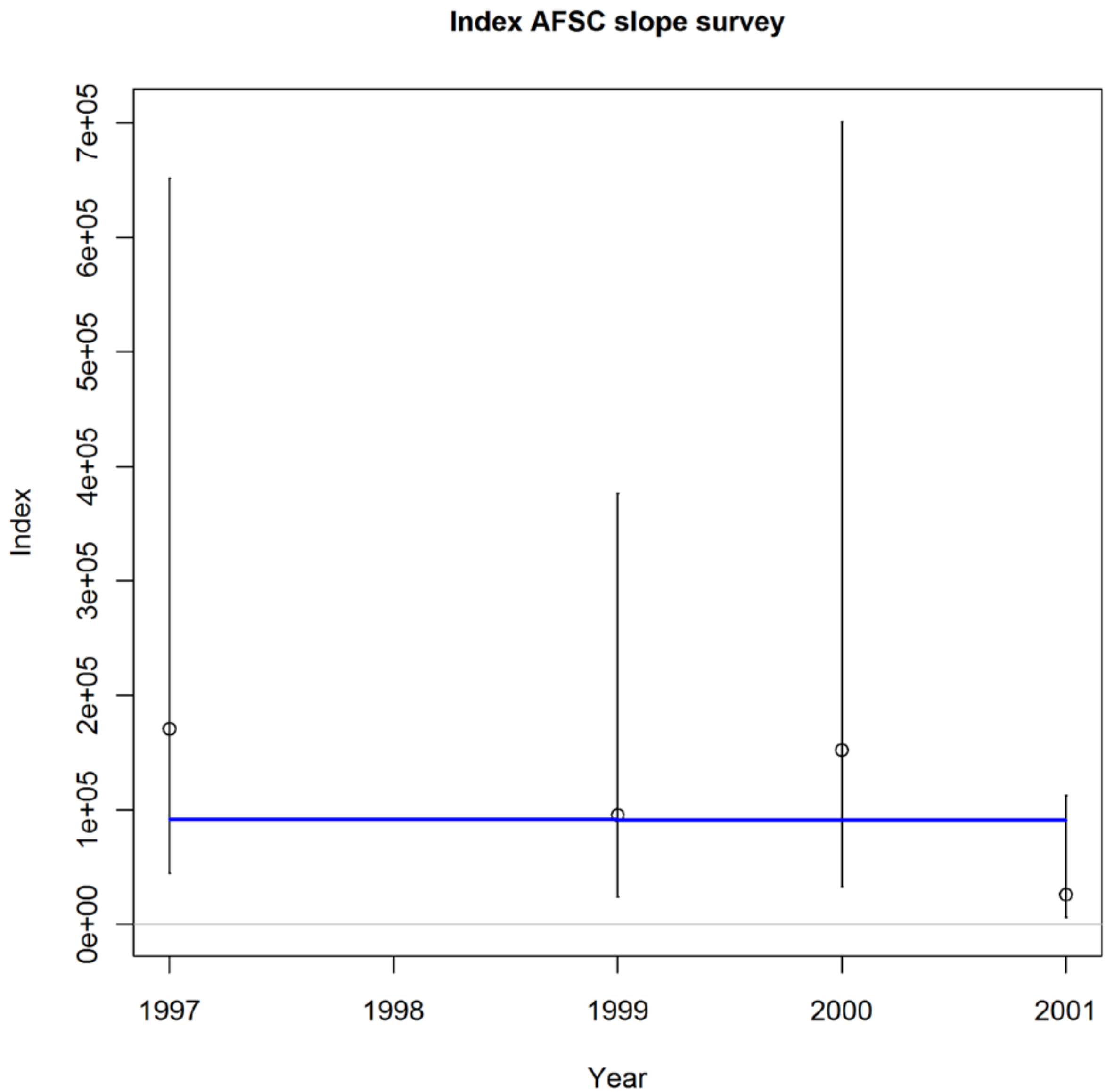

Figure 31. Observed and expected values of spiny dogfish biomass index (mt) for the AFSC slope survey.

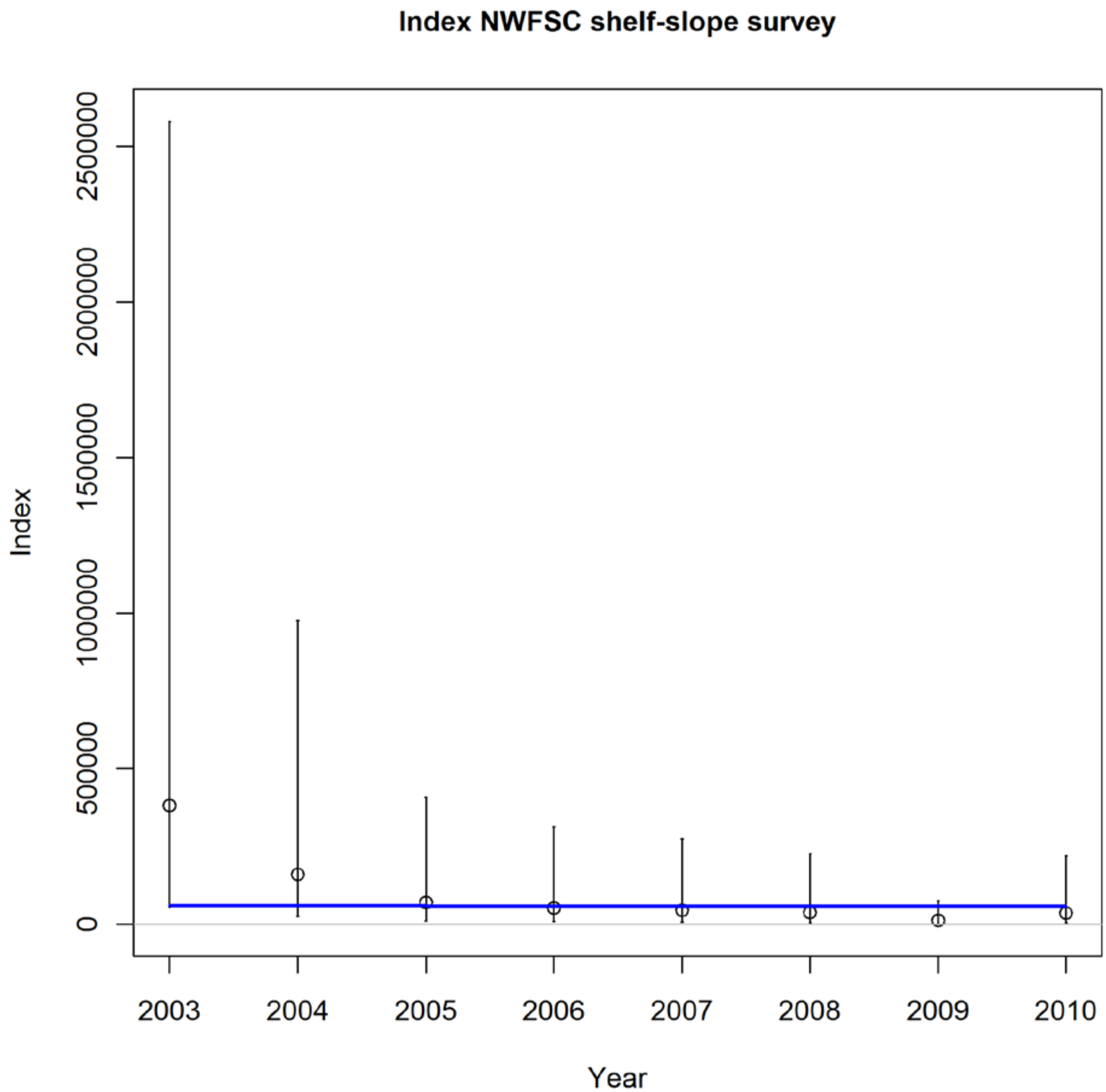

Figure 32. Observed and expected values of spiny dogfish biomass index (mt) for the NWFSC shelf-slope survey.

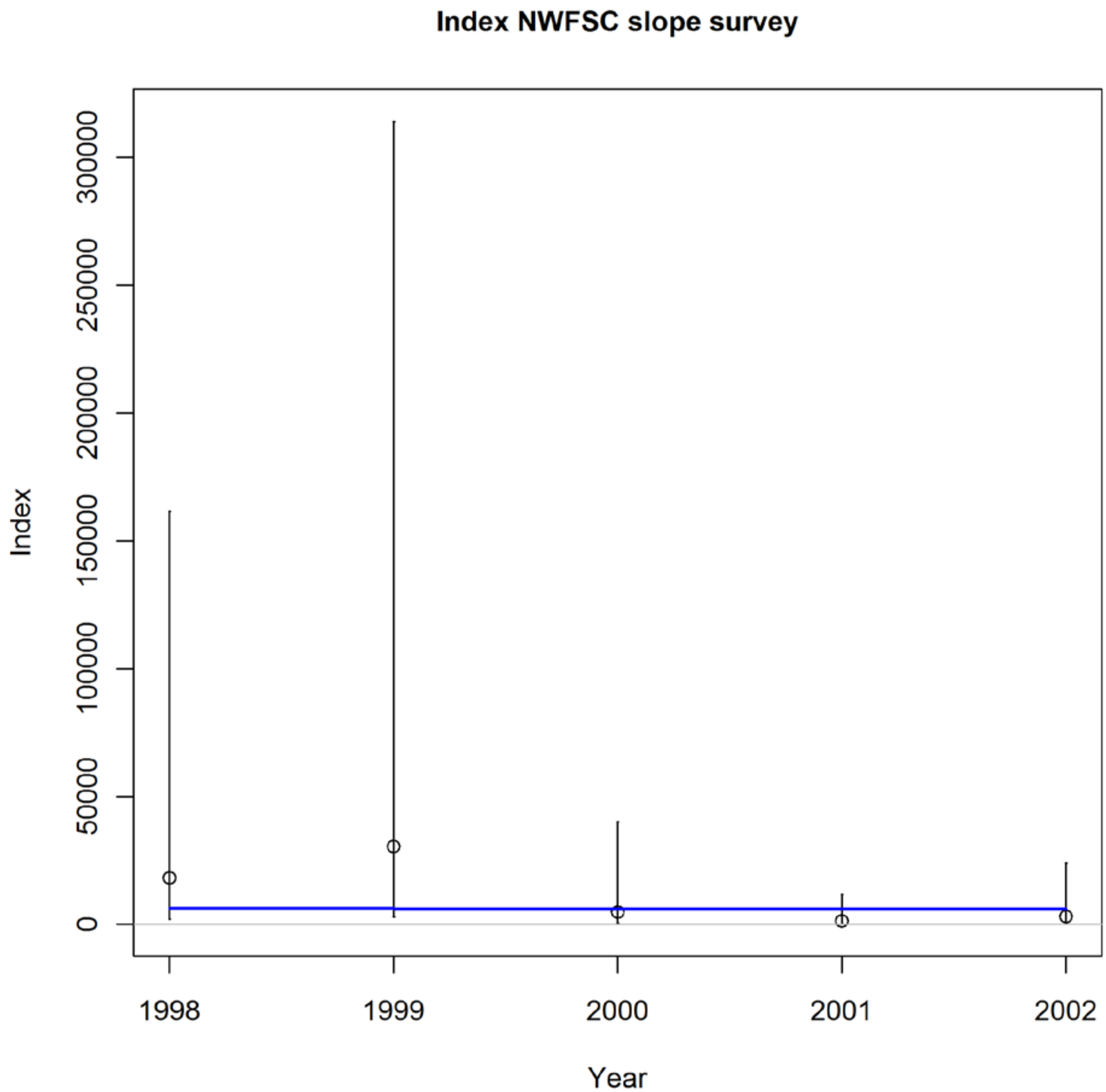

Figure 33. Observed and expected values of spiny dogfish biomass index (mt) for the NWFSC slope survey.

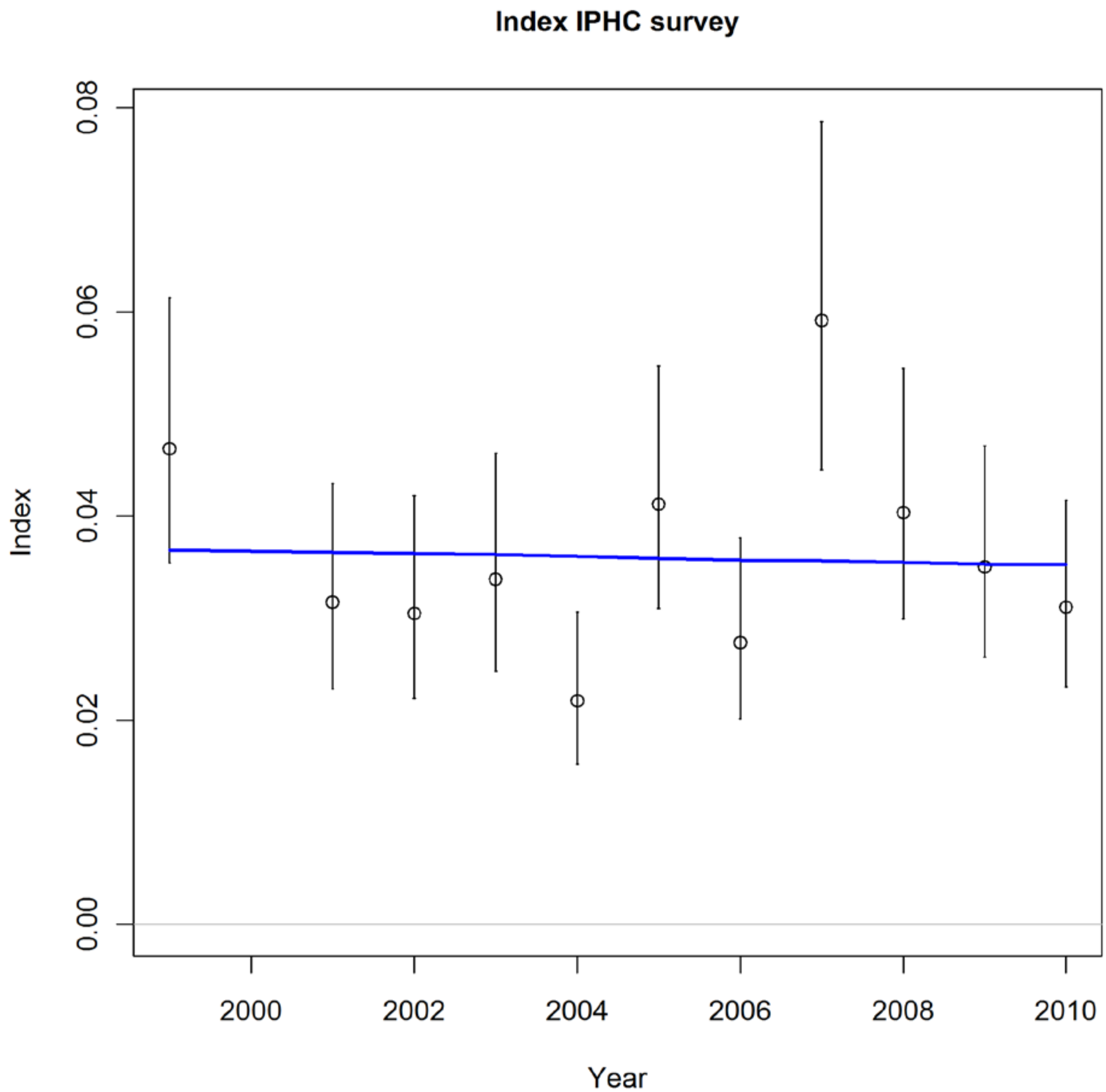

Figure 34. Observed and expected values of spiny dogfish abundance index (number of fish) for the IPHC longline survey.

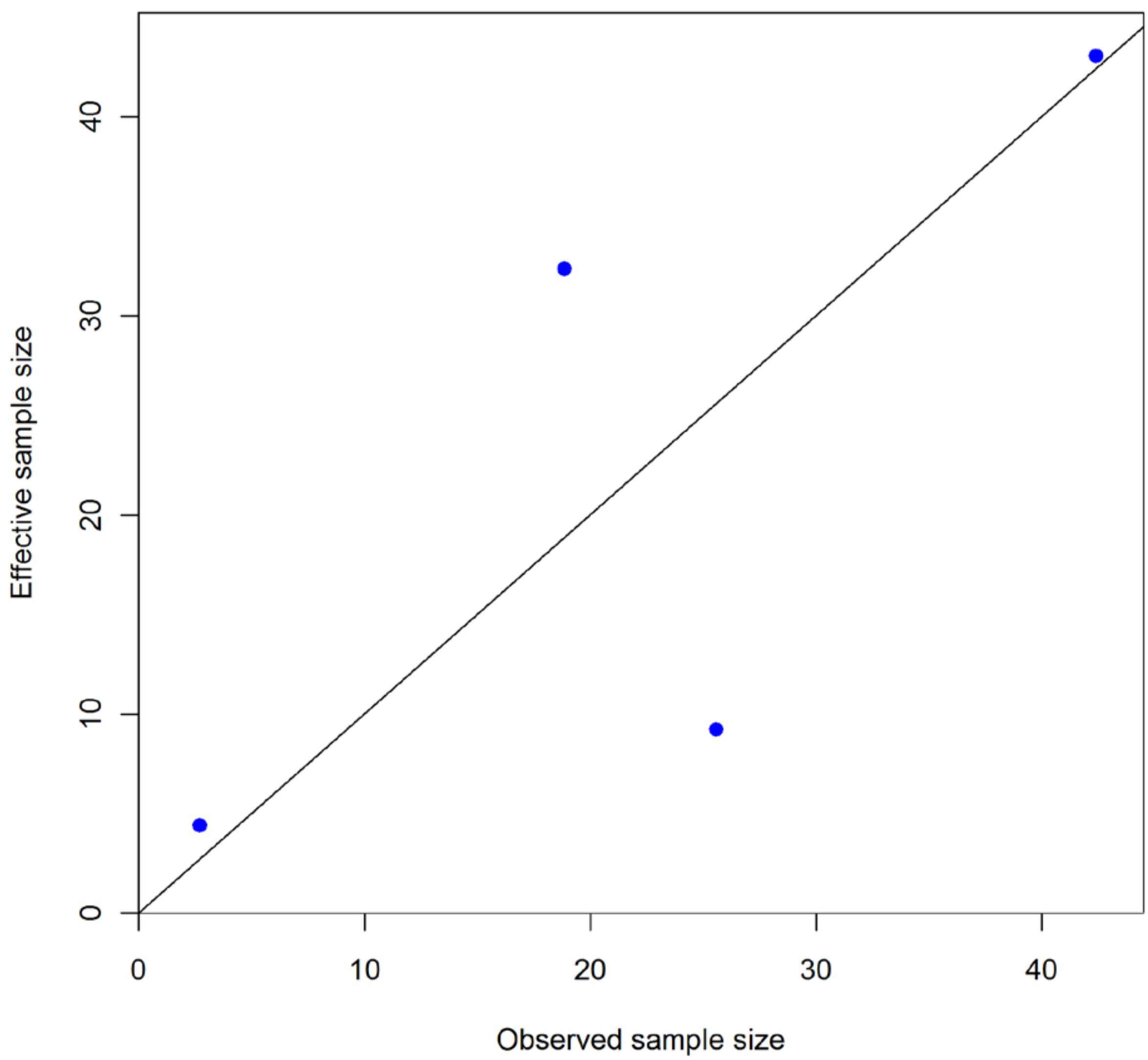

Figure 35. Observed and effective sample sizes for the sex-specific bottom trawl fishery length-frequency observations.

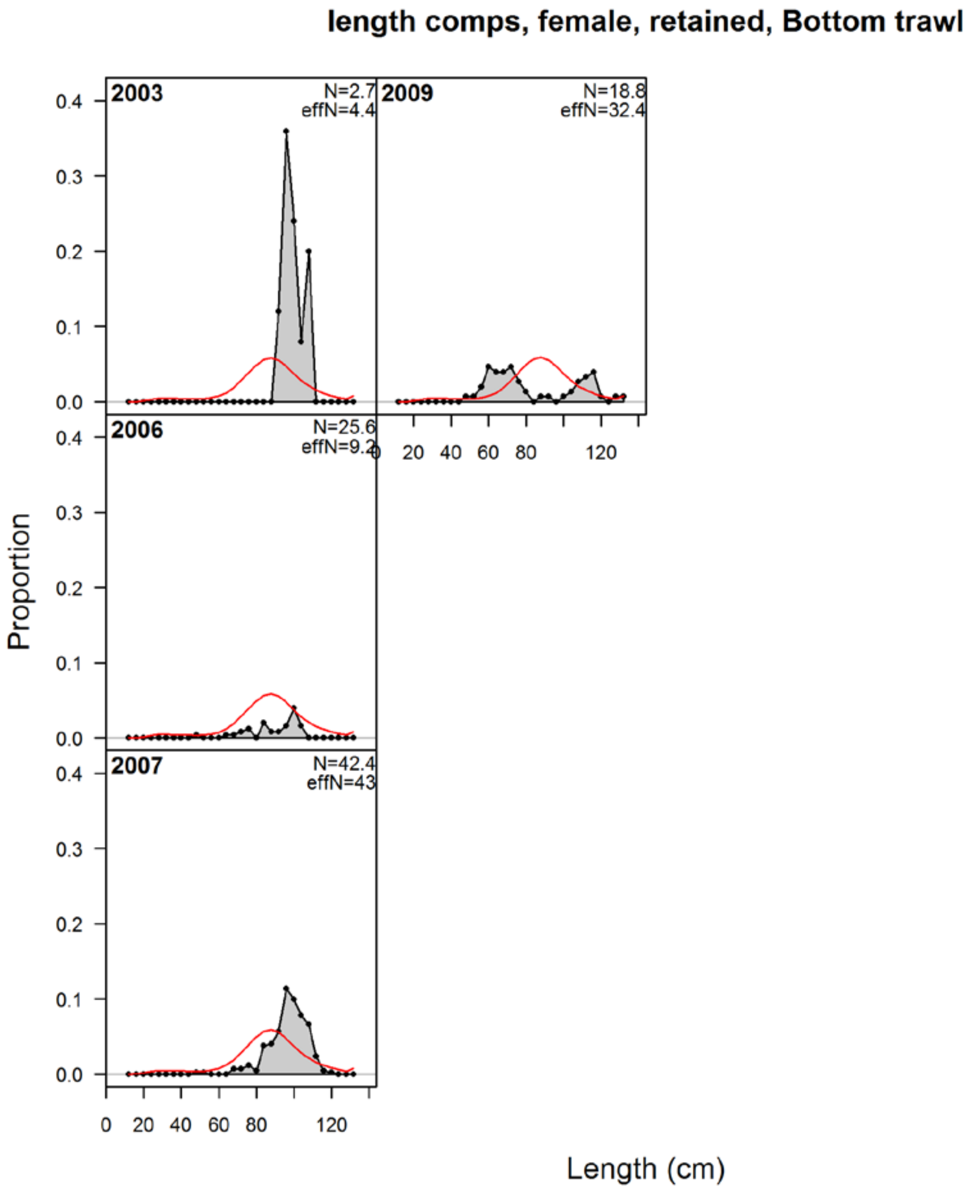

Figure 36. Fit to length-frequency distributions of female spiny dogfish for the bottom trawl fleet.

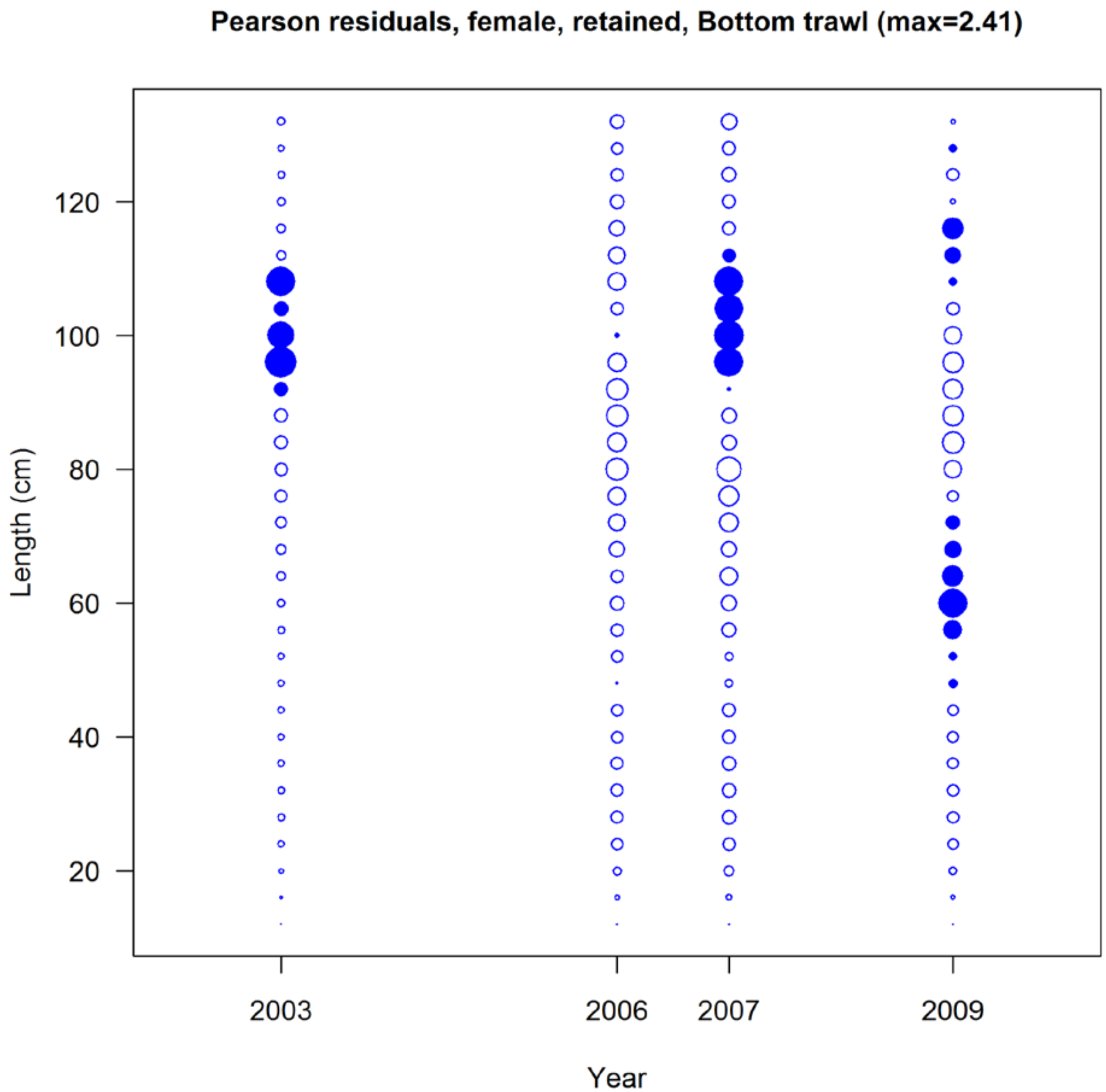

Figure 37. Pearson residuals for the fit of the female length-frequency distributions for the bottom trawl fleet.

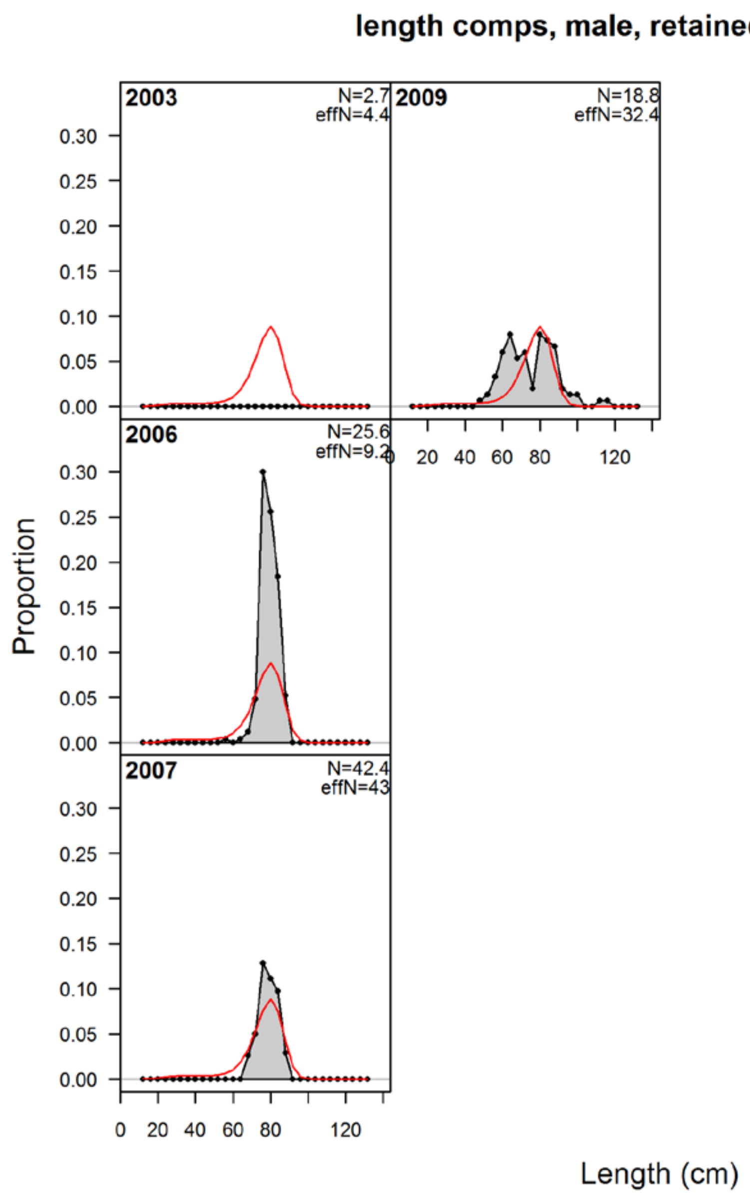

Figure 38. Fit to length-frequency distributions of male spiny dogfish for the bottom trawl fleet.

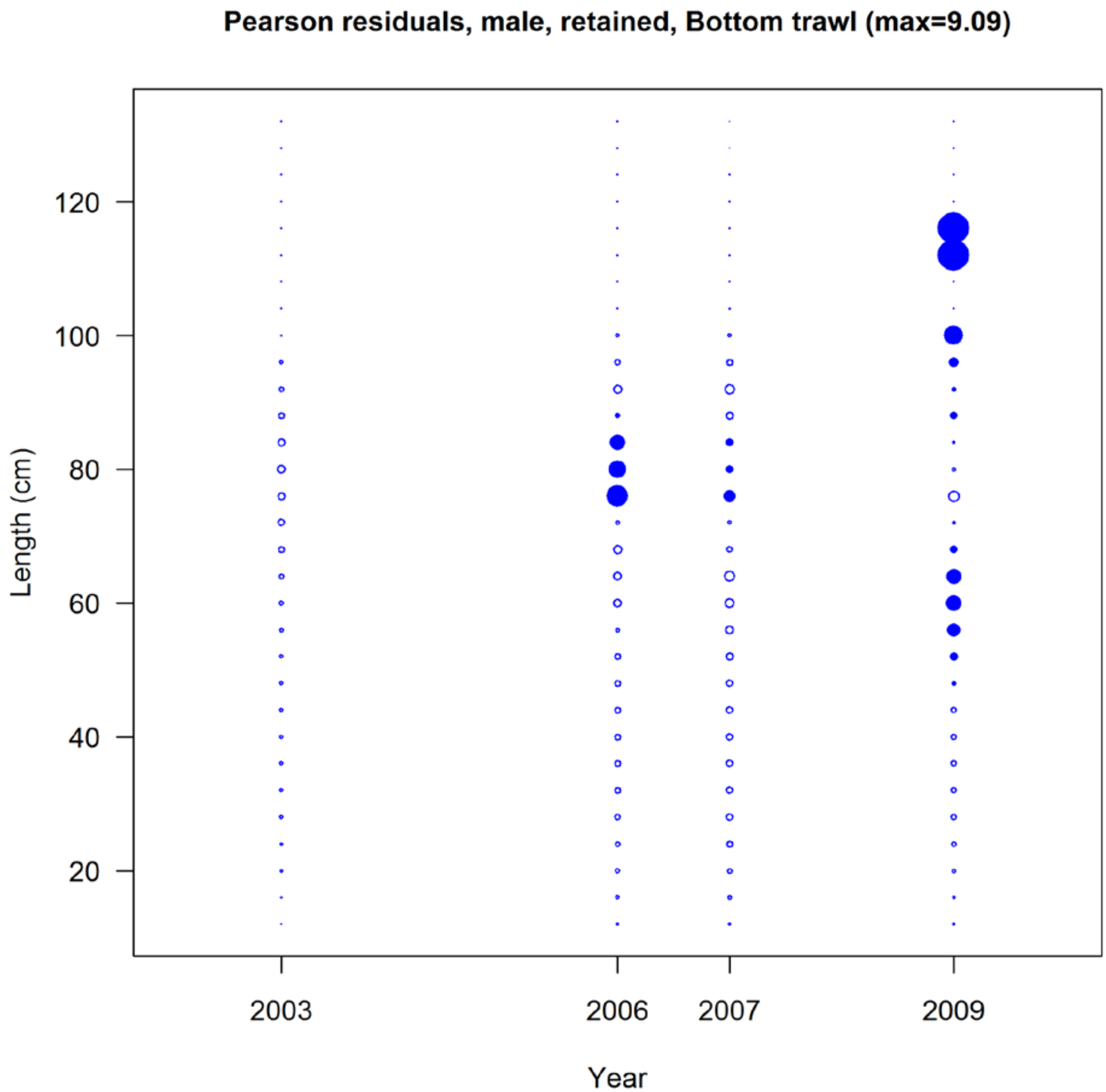

Figure 39. Pearson residuals for the fit of the male length-frequency distributions for the bottom trawl fleet.

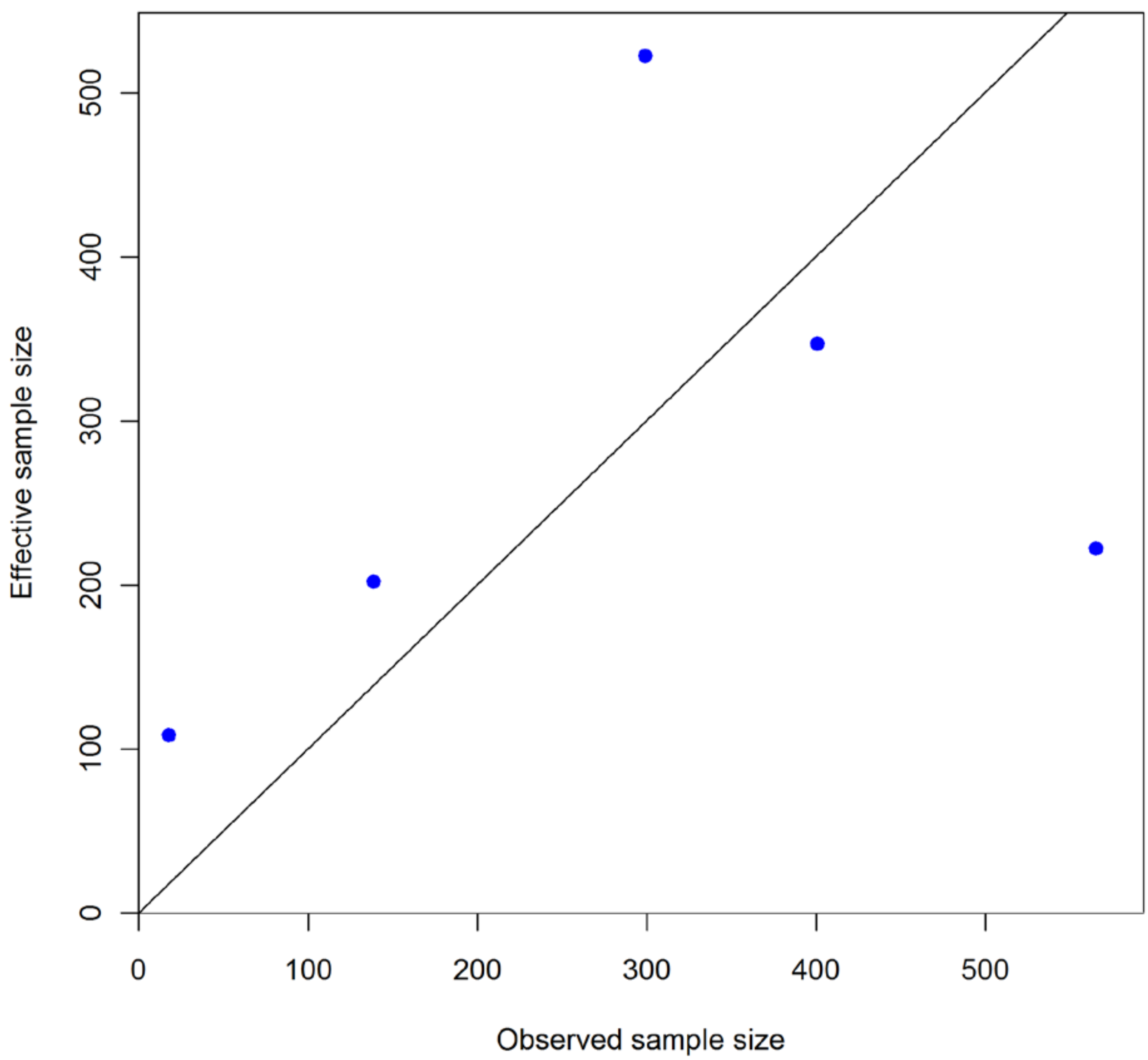

Figure 40. Observed and effective sample sizes for the sex-specific bottom trawl discard fleet length-frequency observations.

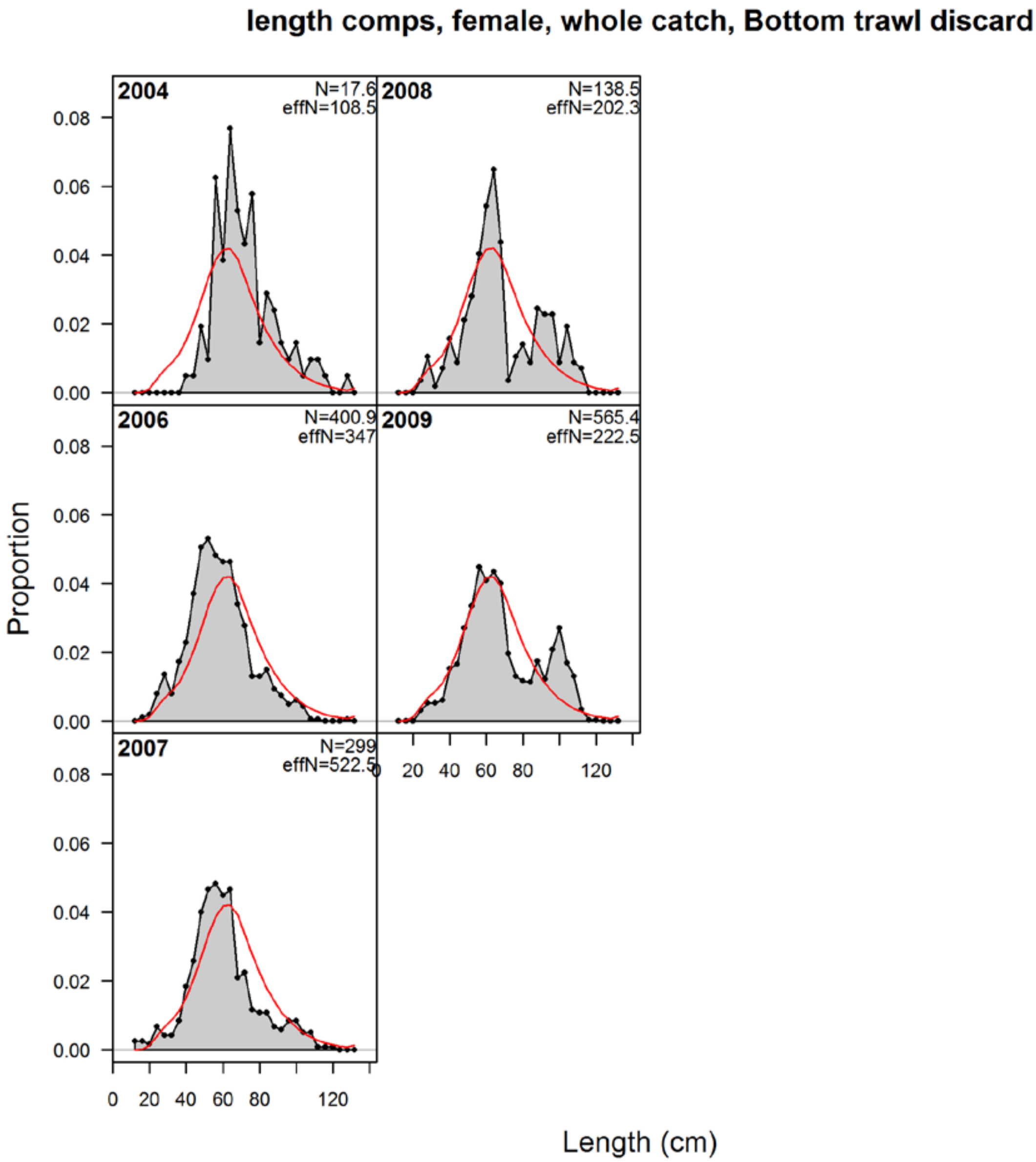

Figure 41. Fit to length-frequency distributions of female spiny dogfish for the bottom trawl discard fleet.

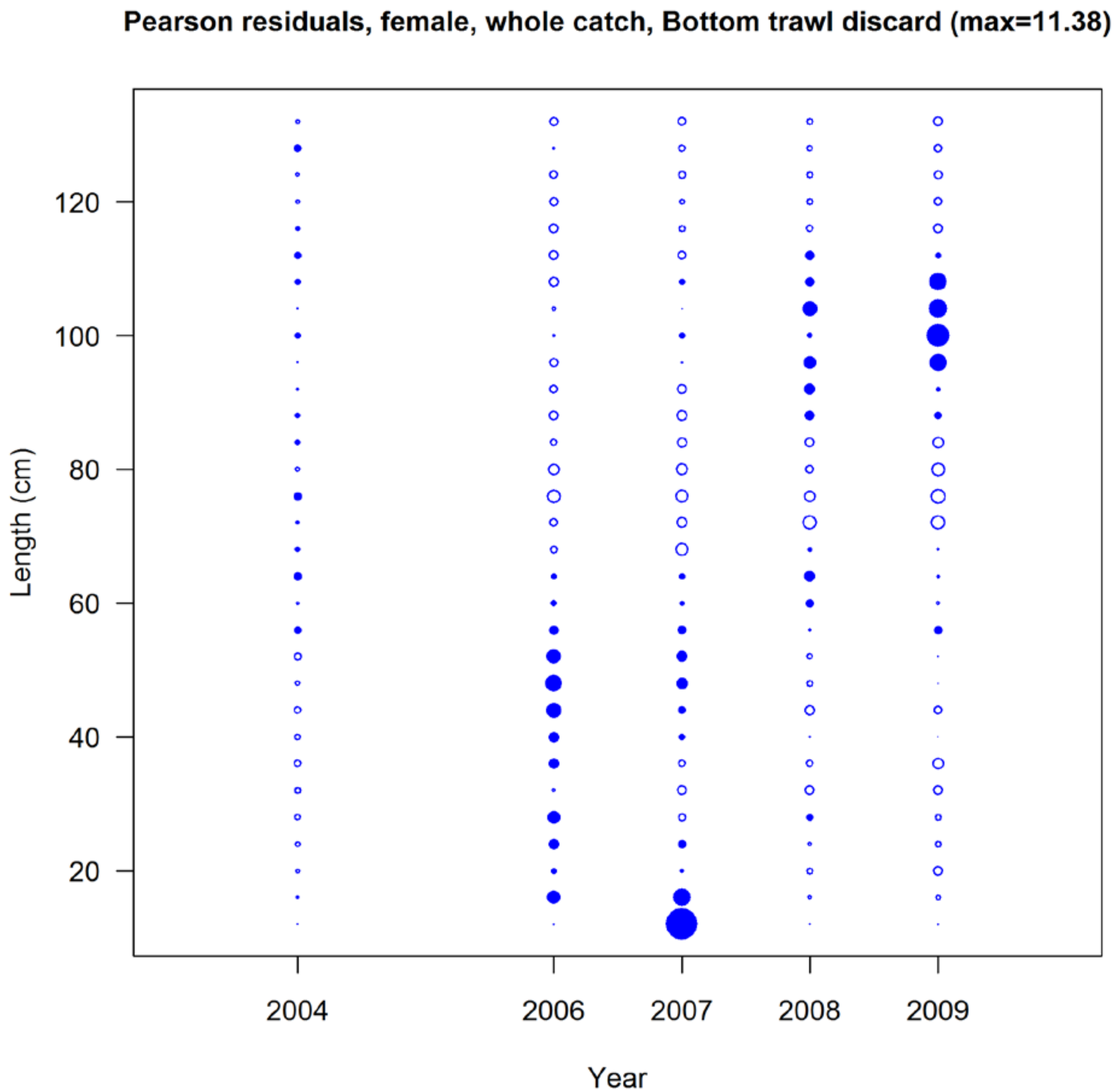

Figure 42. Pearson residuals for the fit of the female length-frequency distributions for the bottom trawl discard fleet.

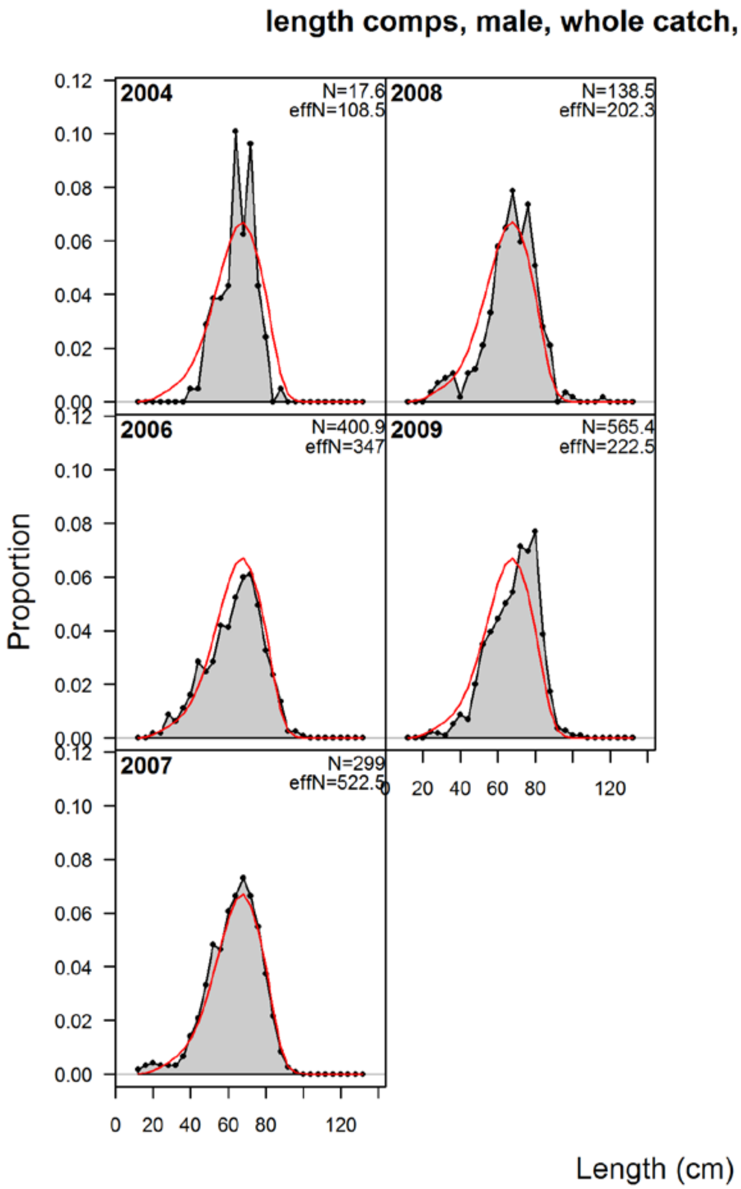

Figure 43. Fit to length-frequency distributions of male spiny dogfish for the bottom trawl discard fleet.

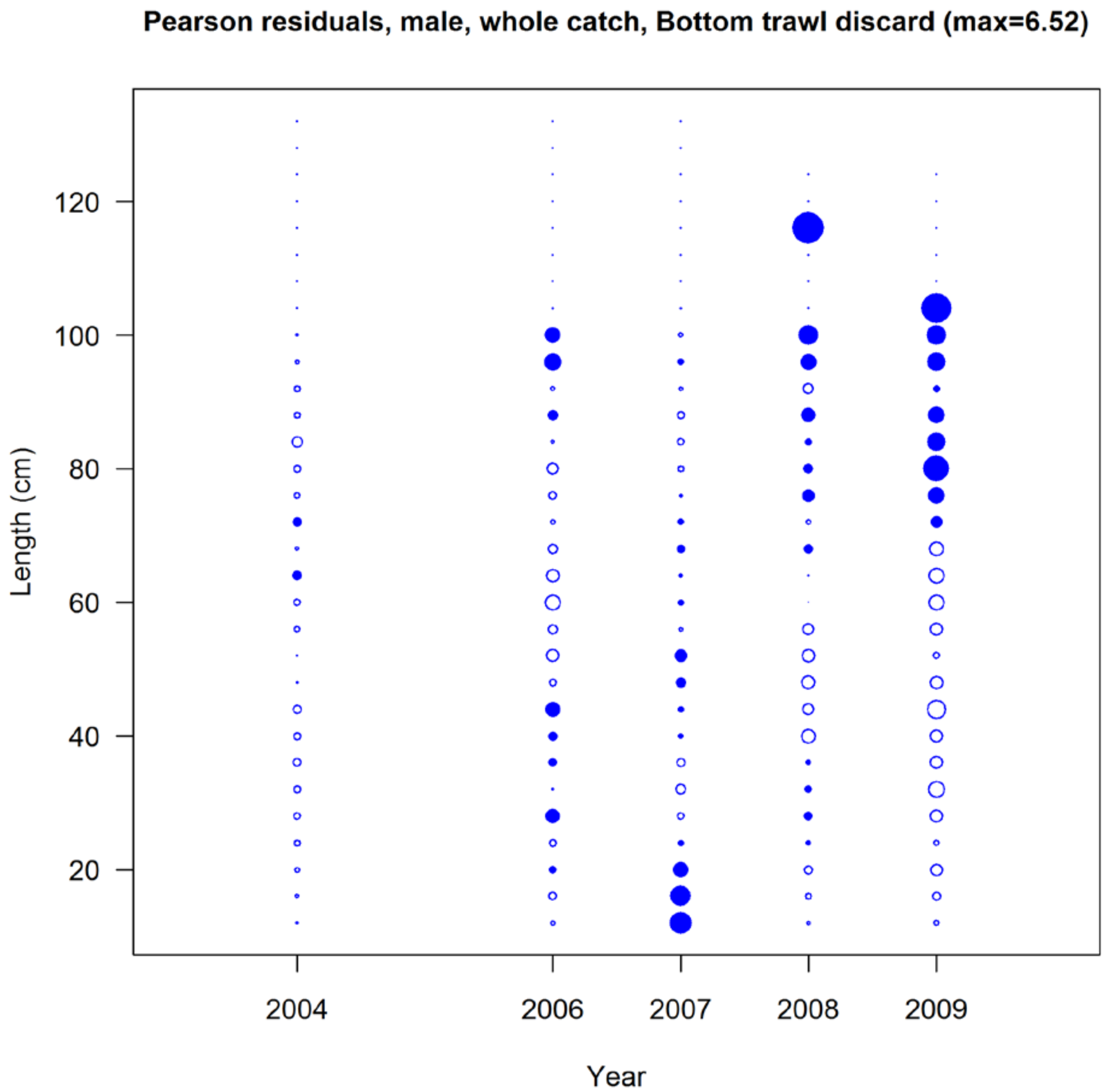

Figure 44. Pearson residuals for the fit of the male length-frequency distributions for the bottom trawl discard fleet.

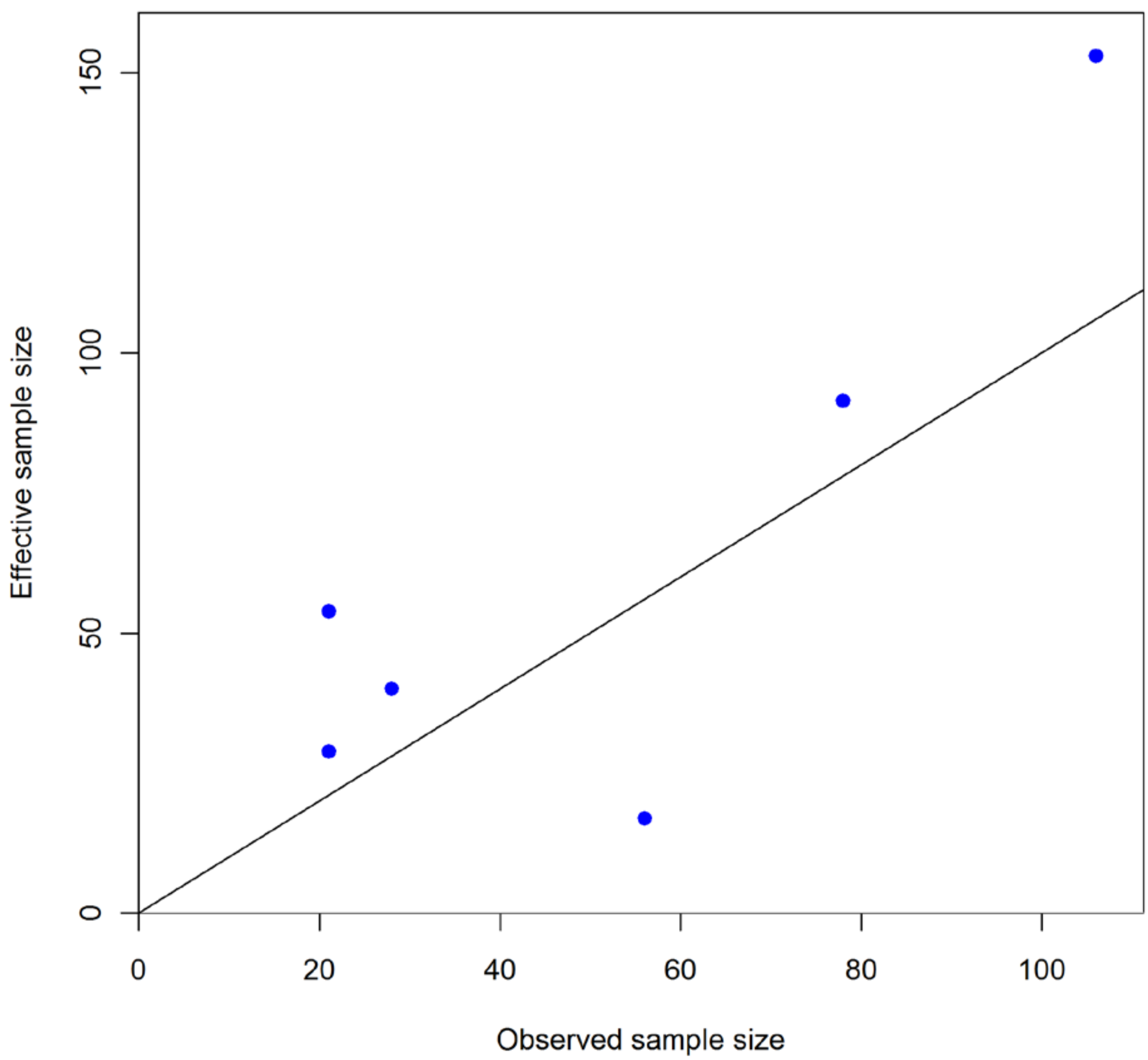

Figure 45. Observed and effective sample sizes for the sex-specific midwater trawl fleet length-frequency observations.

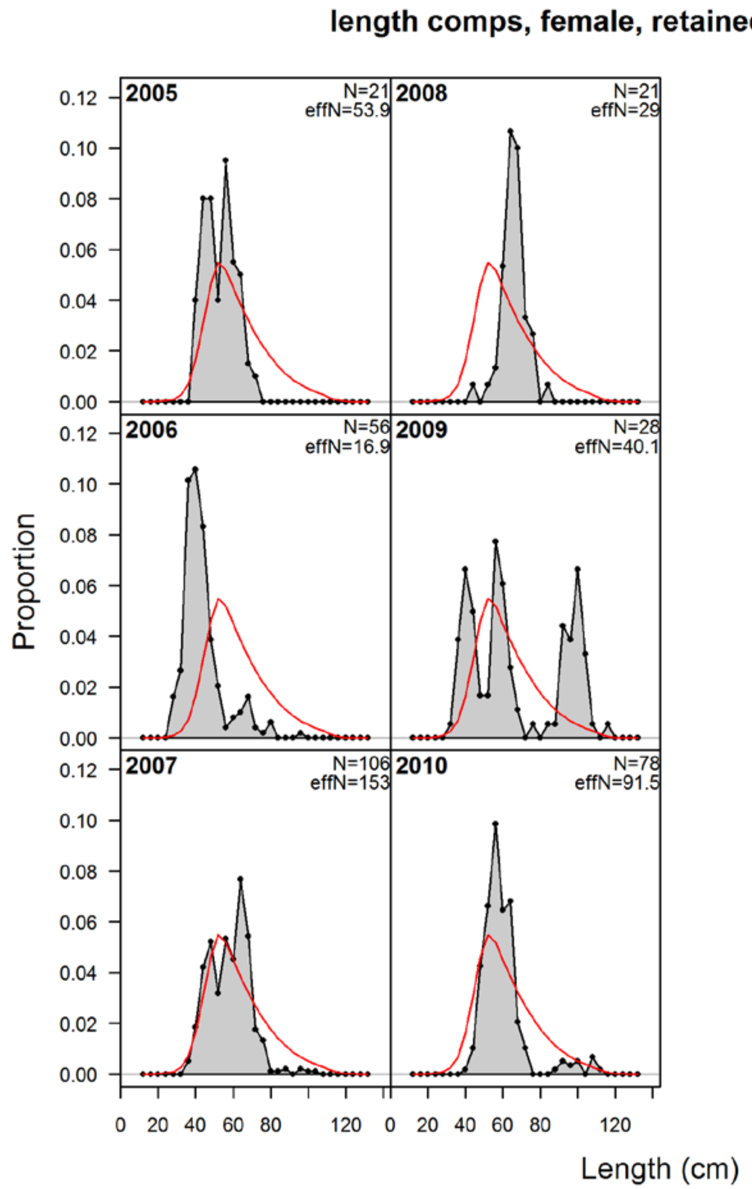

Figure 46. Fit to length-frequency distributions of female spiny dogfish for the midwater trawl fleet.

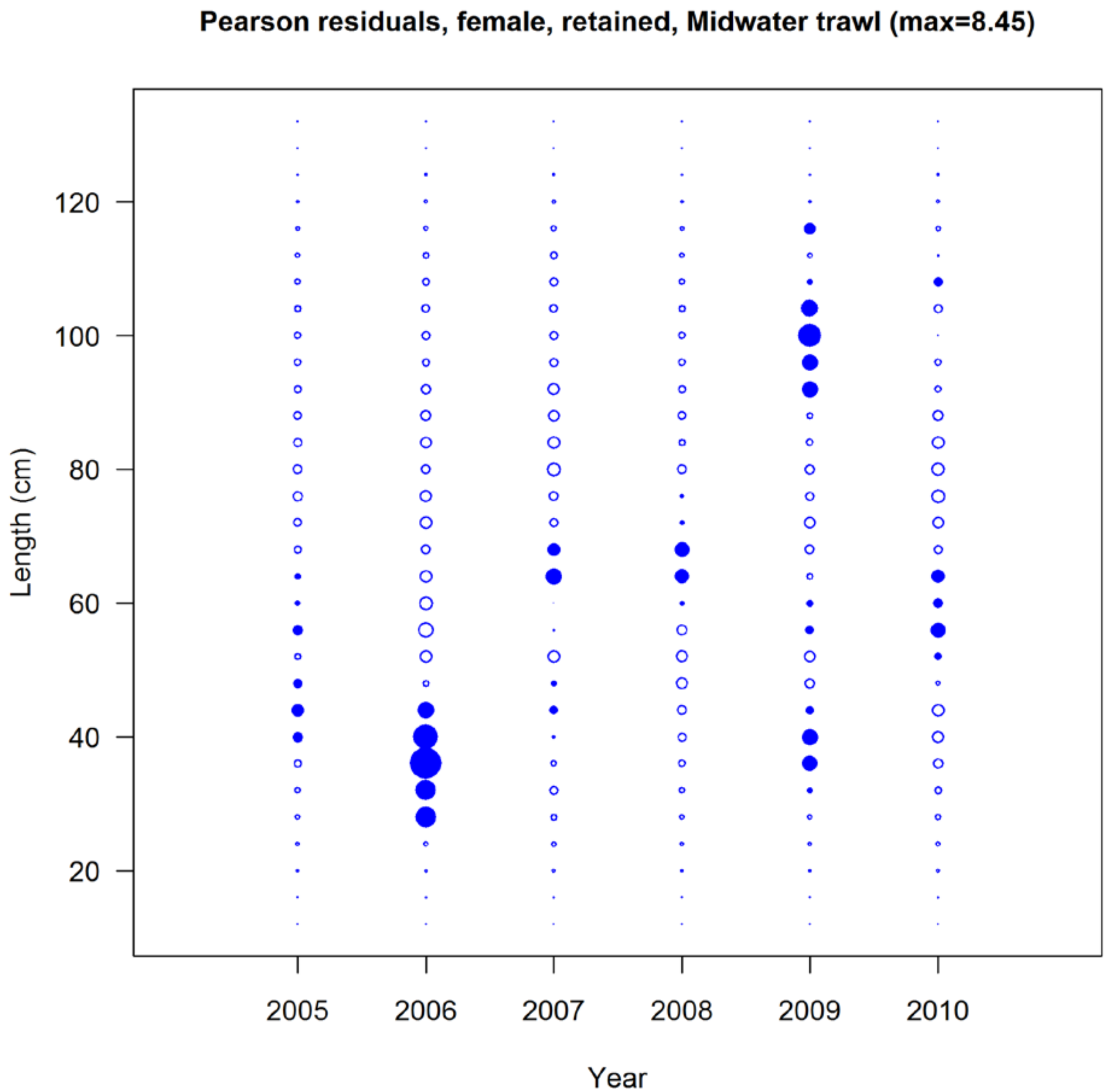

Figure 47. Pearson residuals for the fit of the female length-frequency distributions for the midwater trawl fleet.

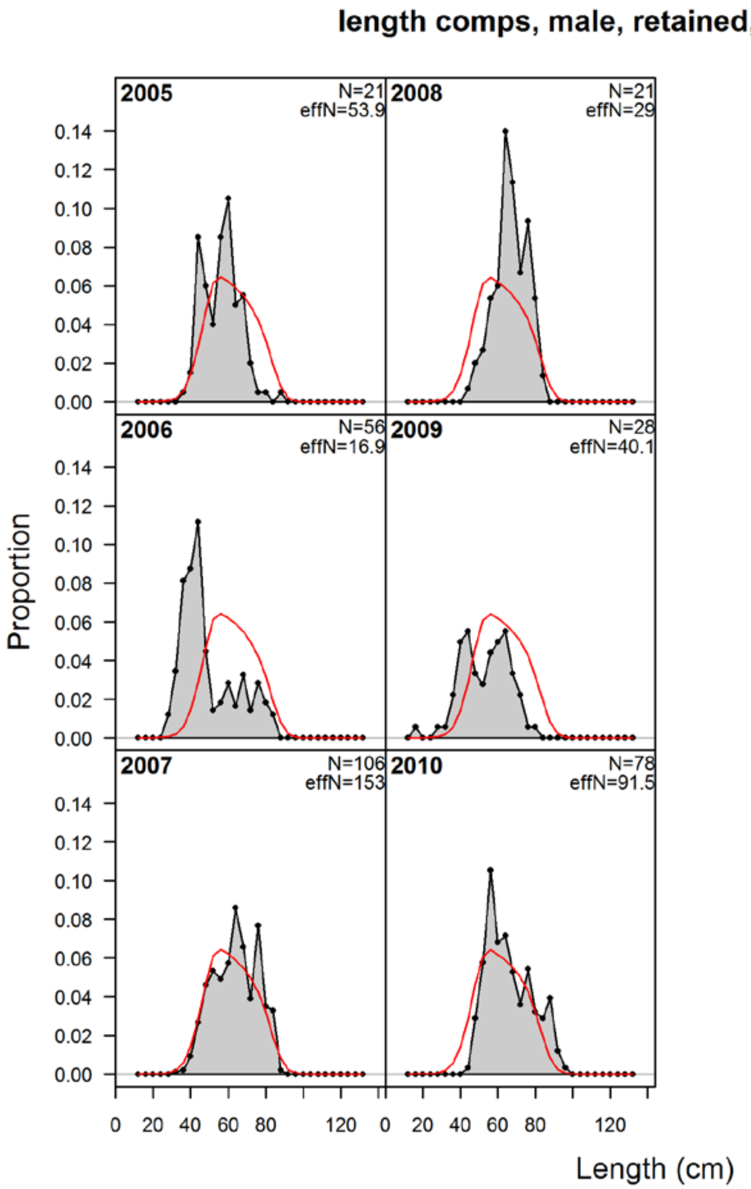

Figure 48. Fit to length-frequency distributions of male spiny dogfish for the midwater trawl fleet.

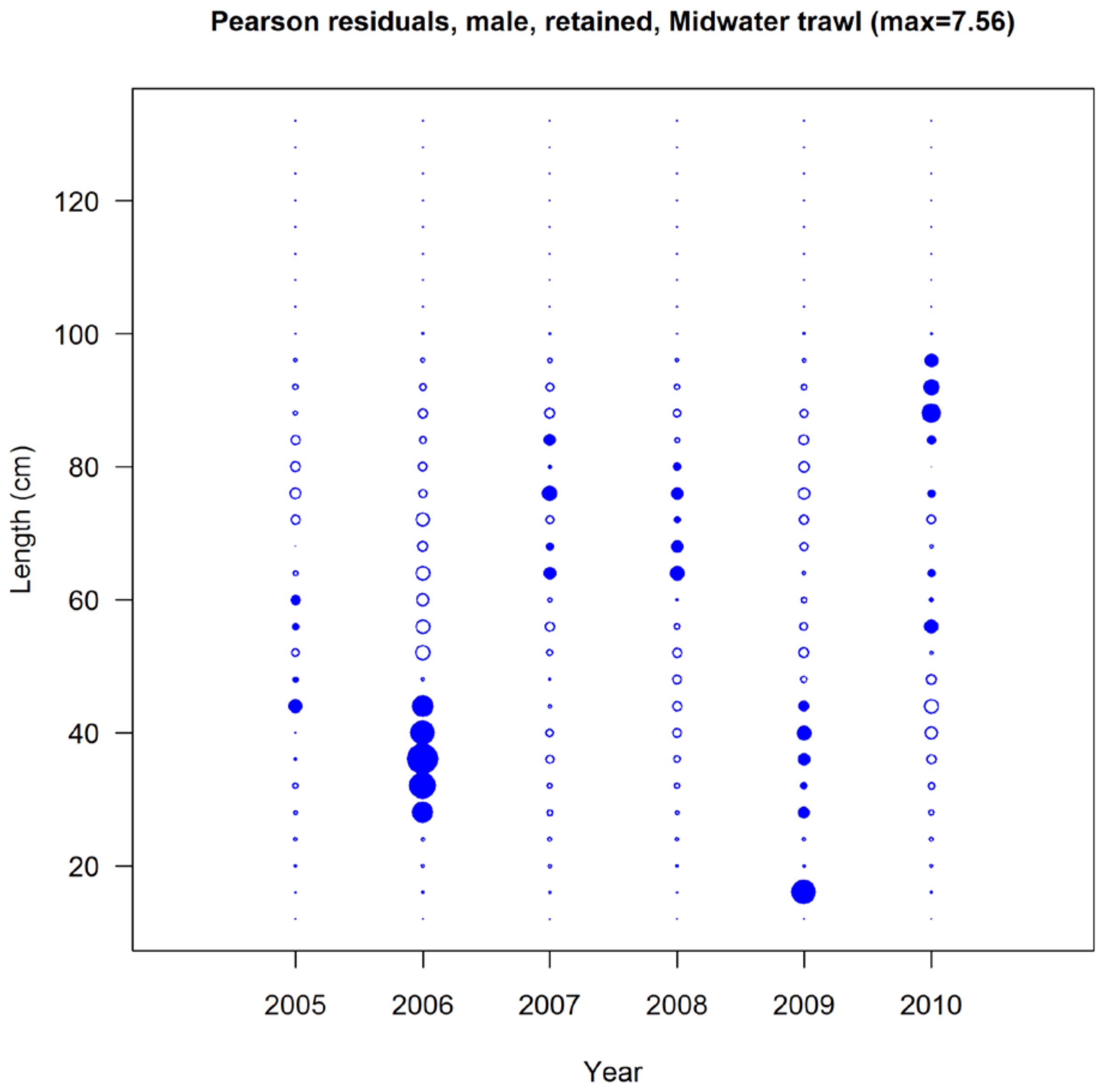

Figure 49. Pearson residuals for the fit of the male length-frequency distributions for the midwater trawl fleet.

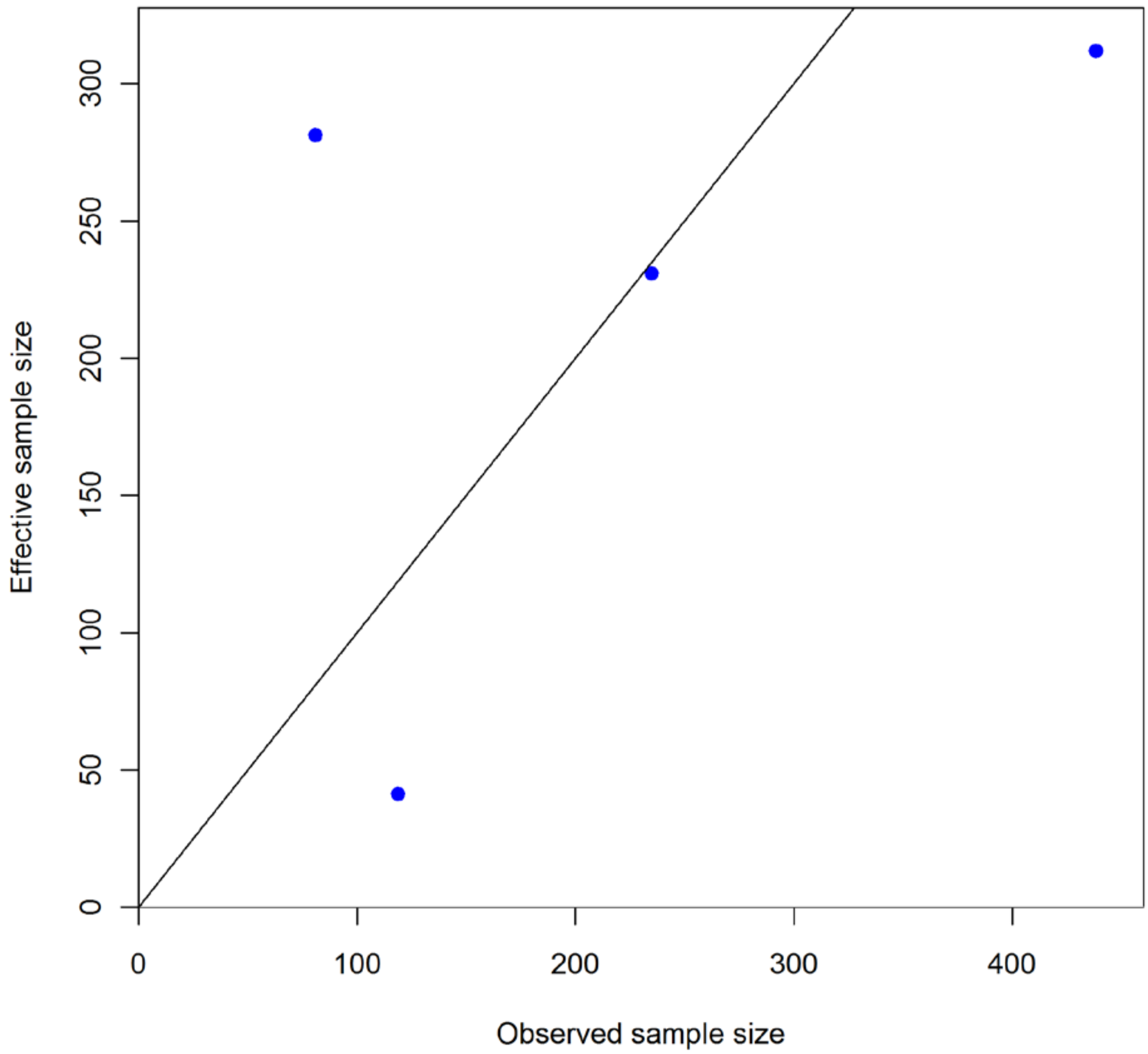

Figure 50. Observed and effective sample sizes for the sex-specific at-sea hake bycatch fleet length-frequency observations.

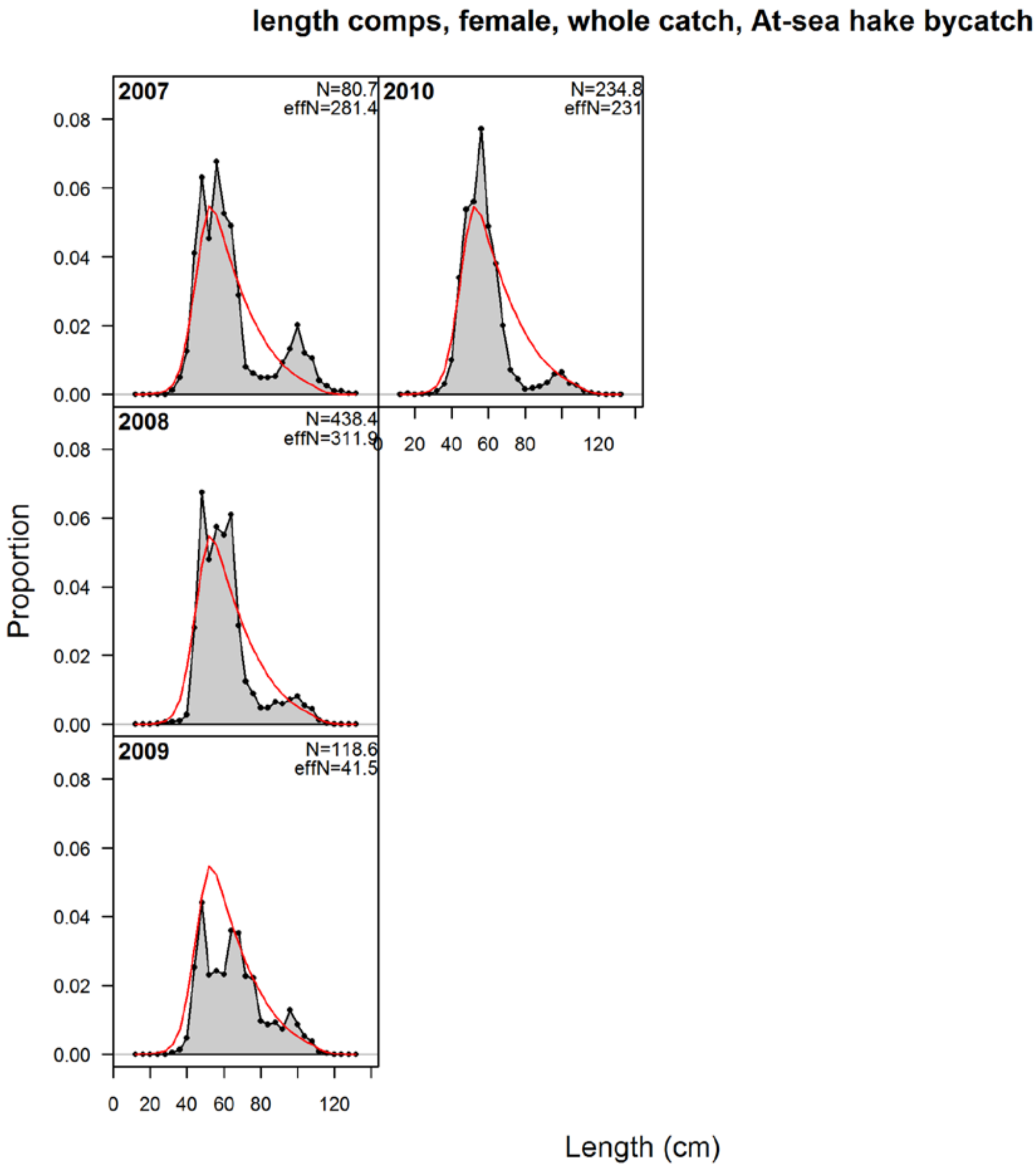

Figure 51. Fit to length-frequency distributions of female spiny dogfish for the at-sea hake bycatch fleet.

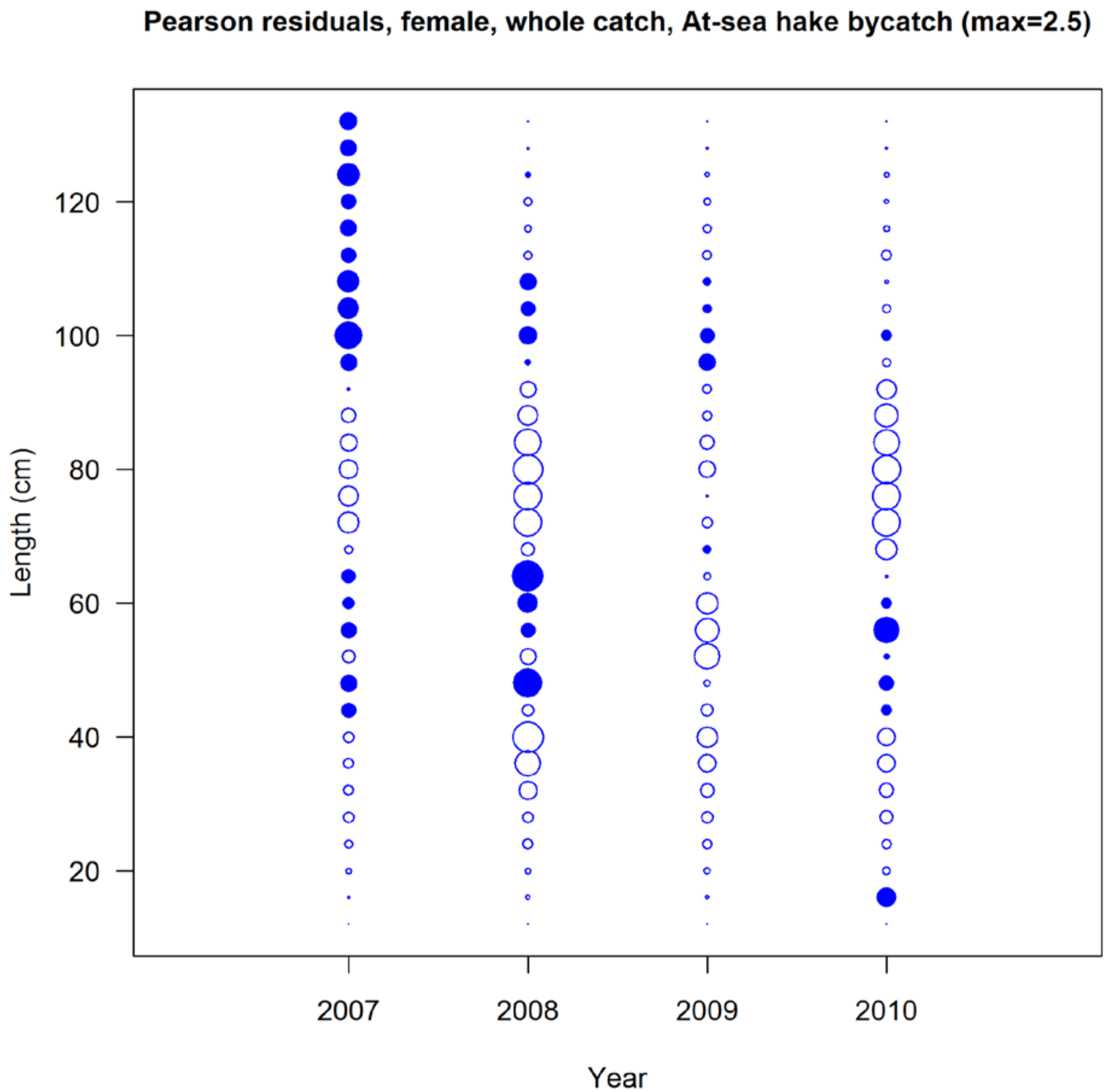

Figure 52. Pearson residuals for the fit of the female length-frequency distributions for the at-se hake bycatch fleet.

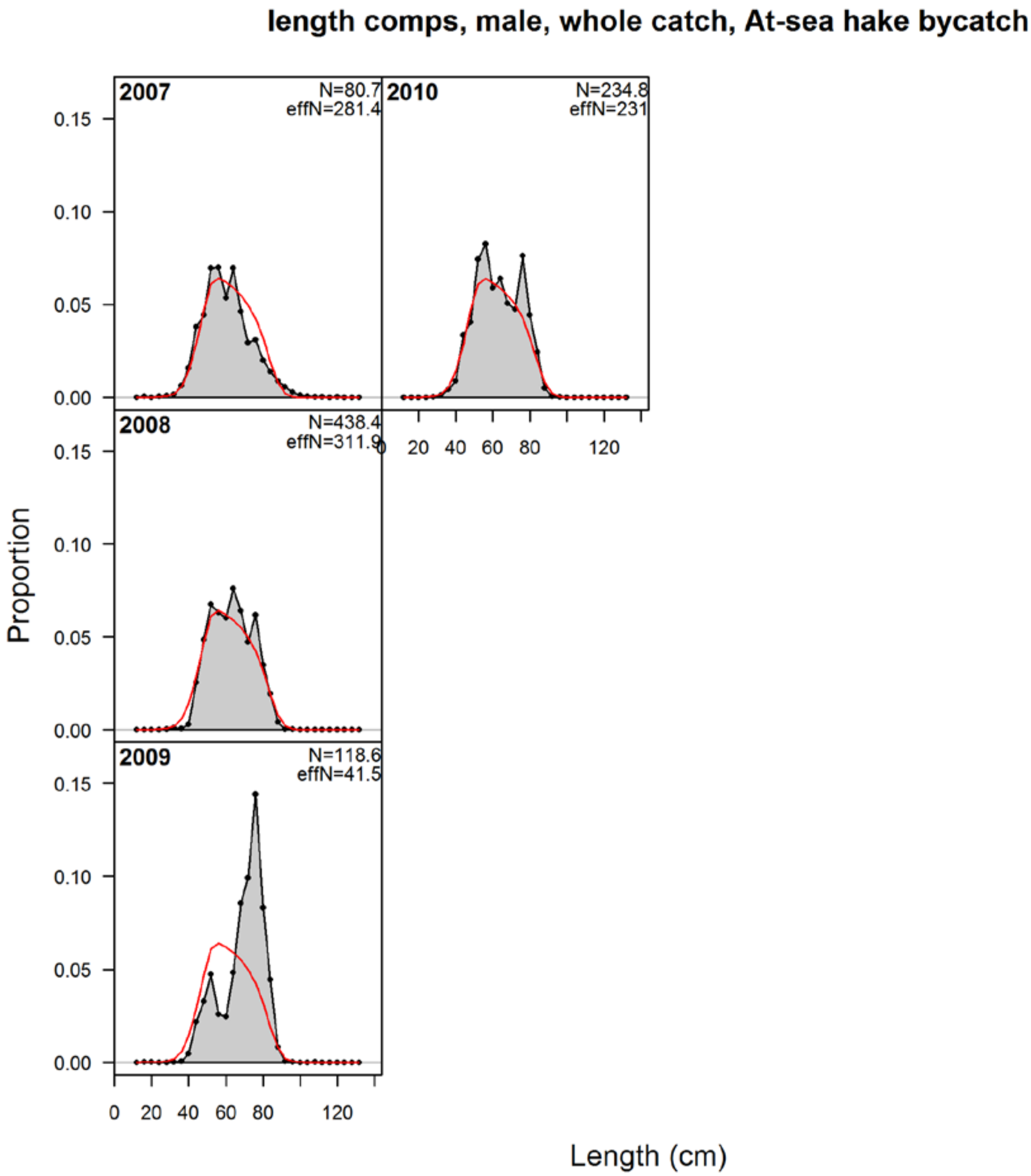

Figure 53. Fit to length-frequency distributions of male spiny dogfish for the at-sea hake bycatch fleet.

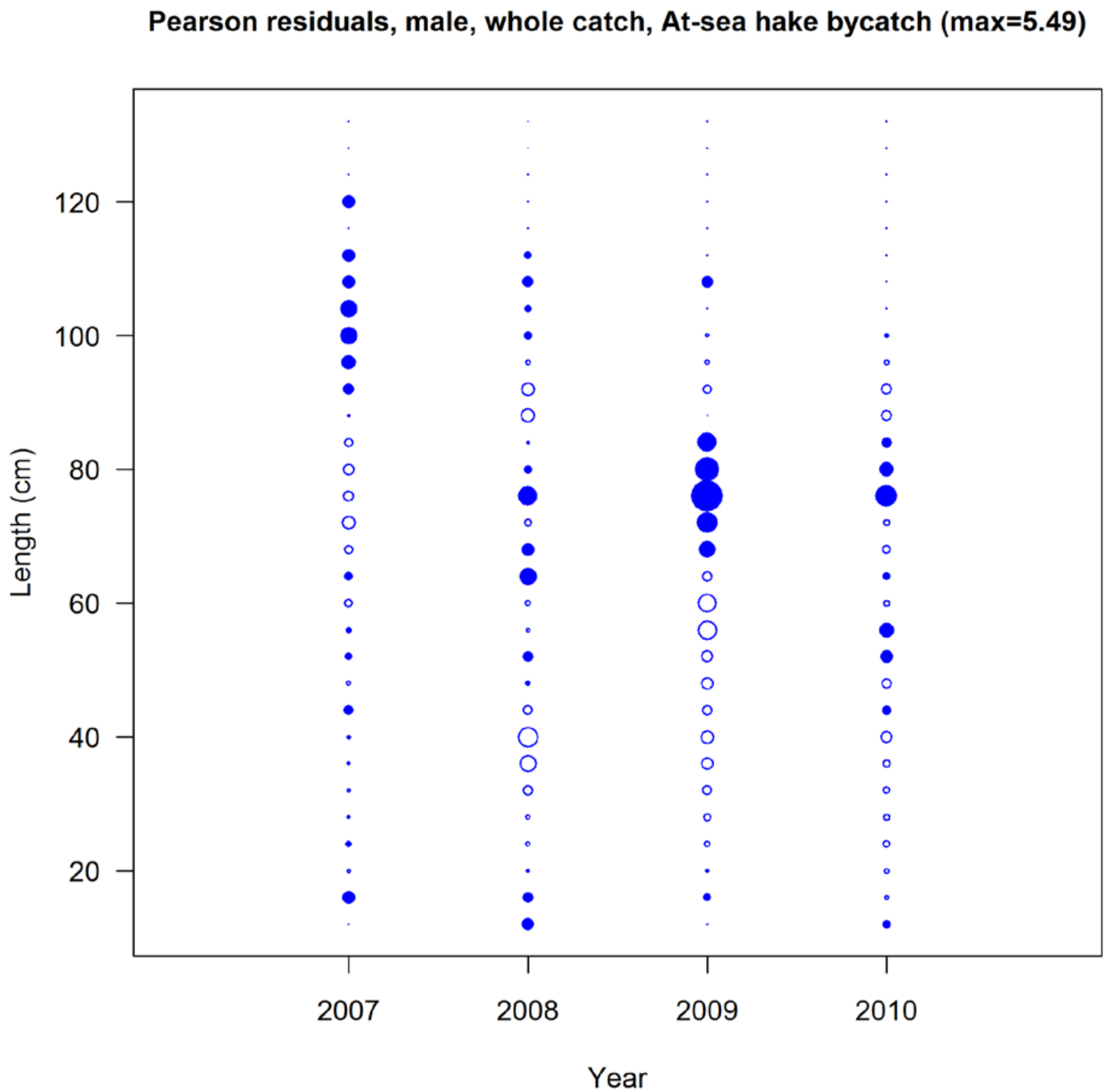

Figure 54. Pearson residuals for the fit of the male length-frequency distributions for the at-sea hake bycatch fleet.

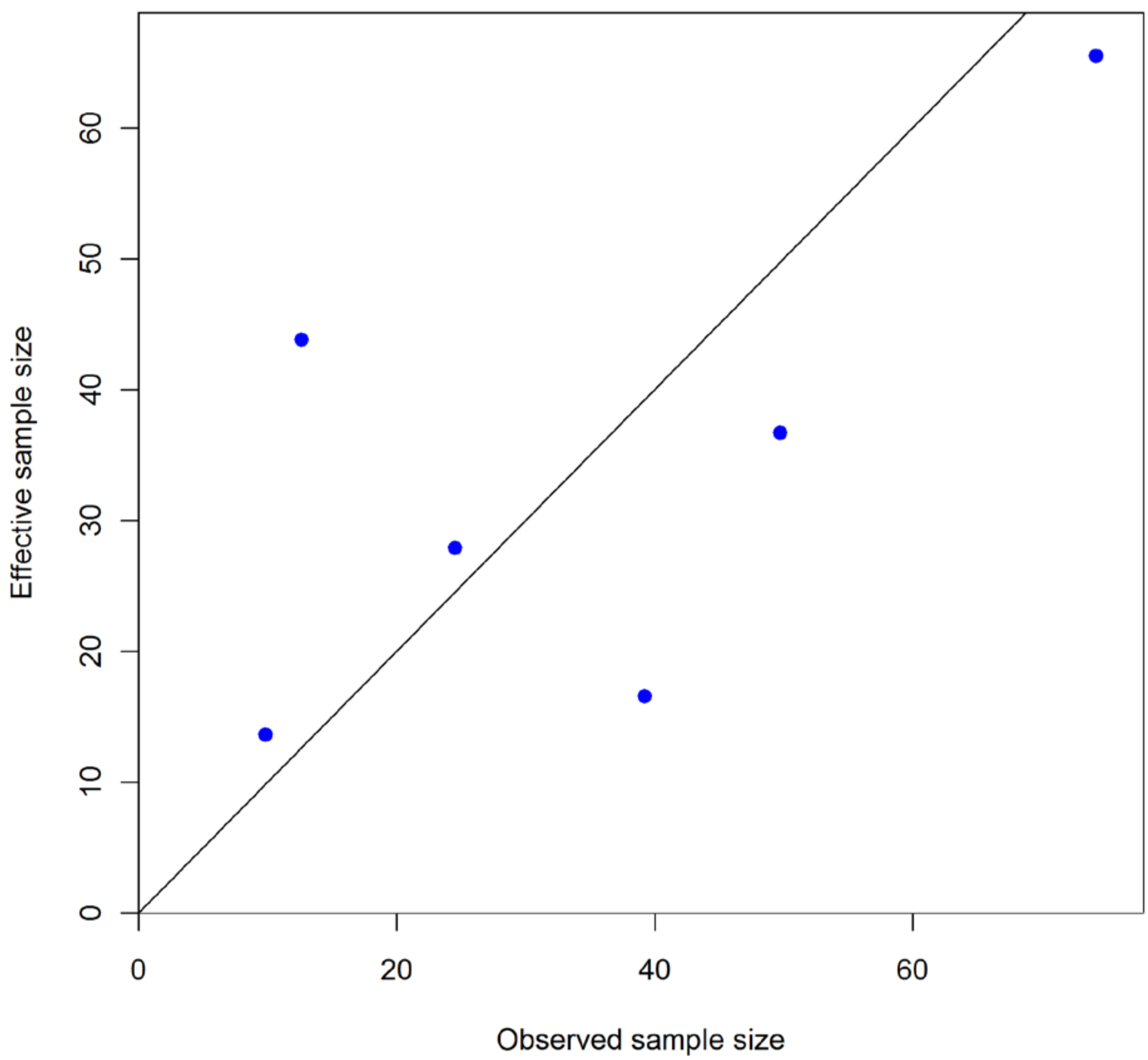

Figure 55. Observed and effective sample sizes for the sex-specific hook-and-line fleet length-frequency observations.

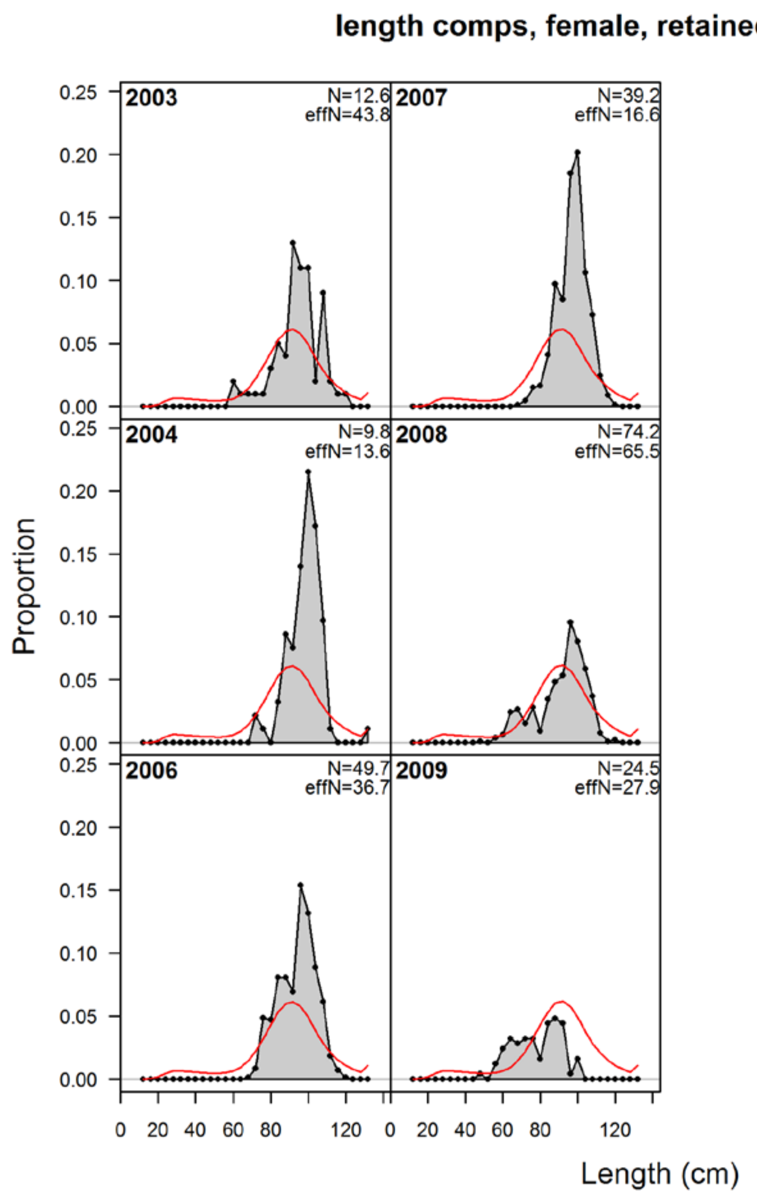

Figure 56. Fit to length-frequency distributions of female spiny dogfish for the hook-and-line fleet.

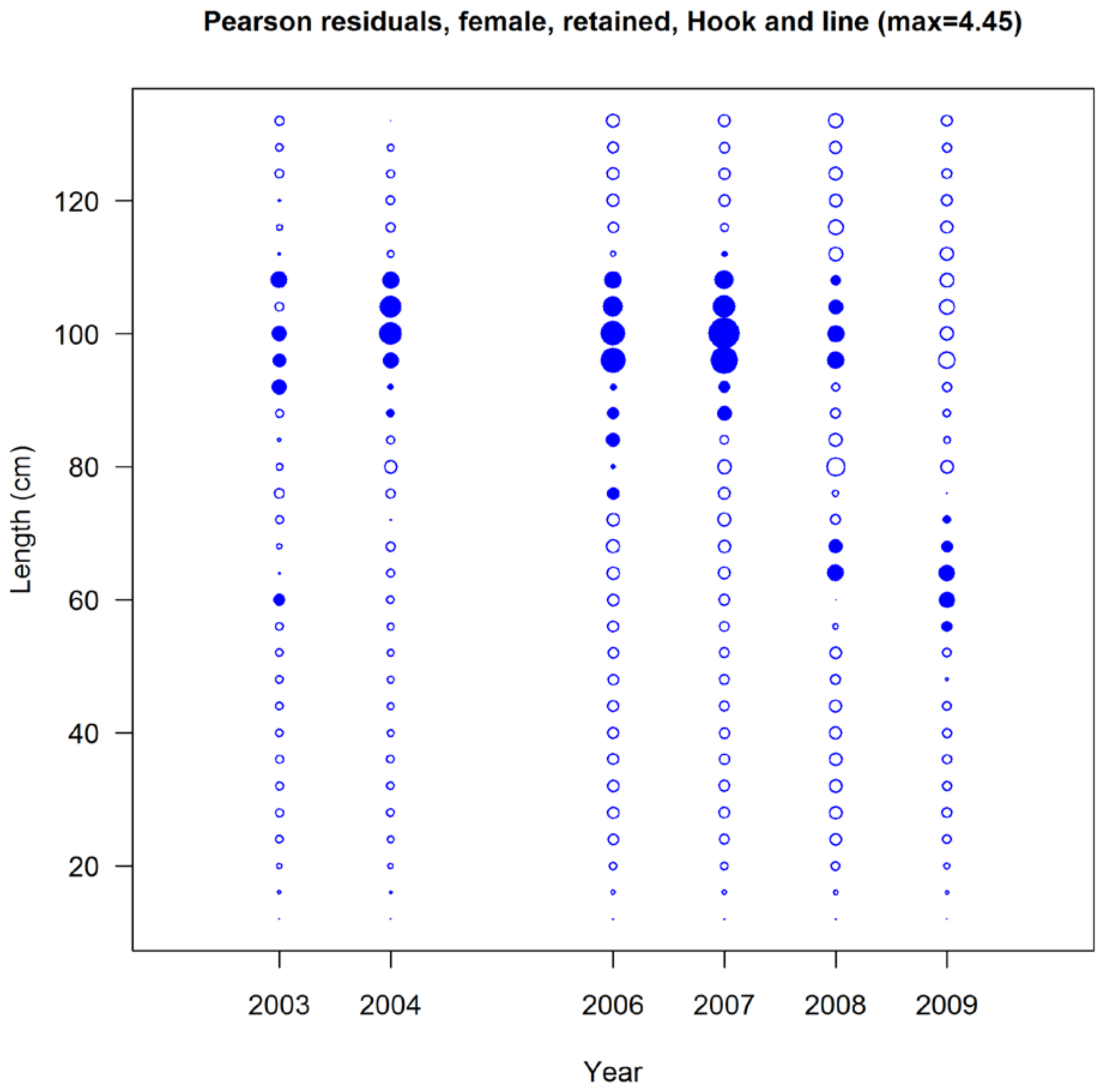

Figure 57. Pearson residuals for the fit of the female length-frequency distributions for the hook-and-line fleet.

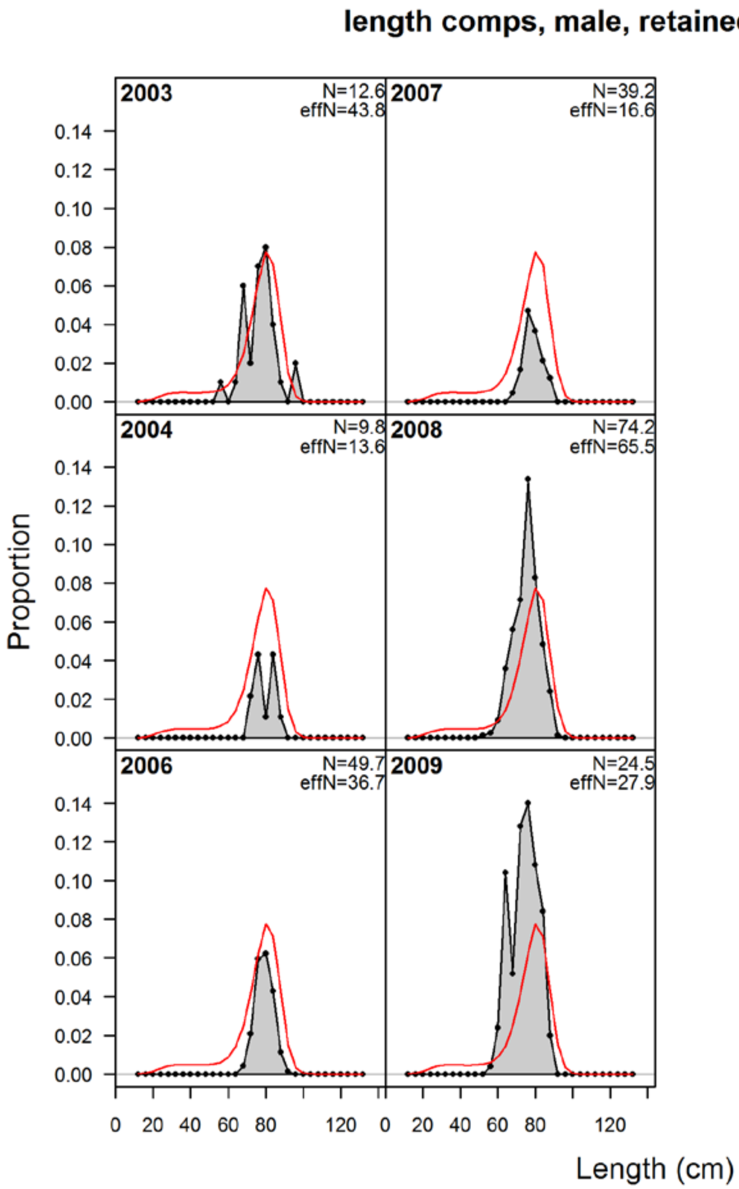

Figure 58. Fit to length-frequency distributions of male spiny dogfish for the hook-and-line fleet.

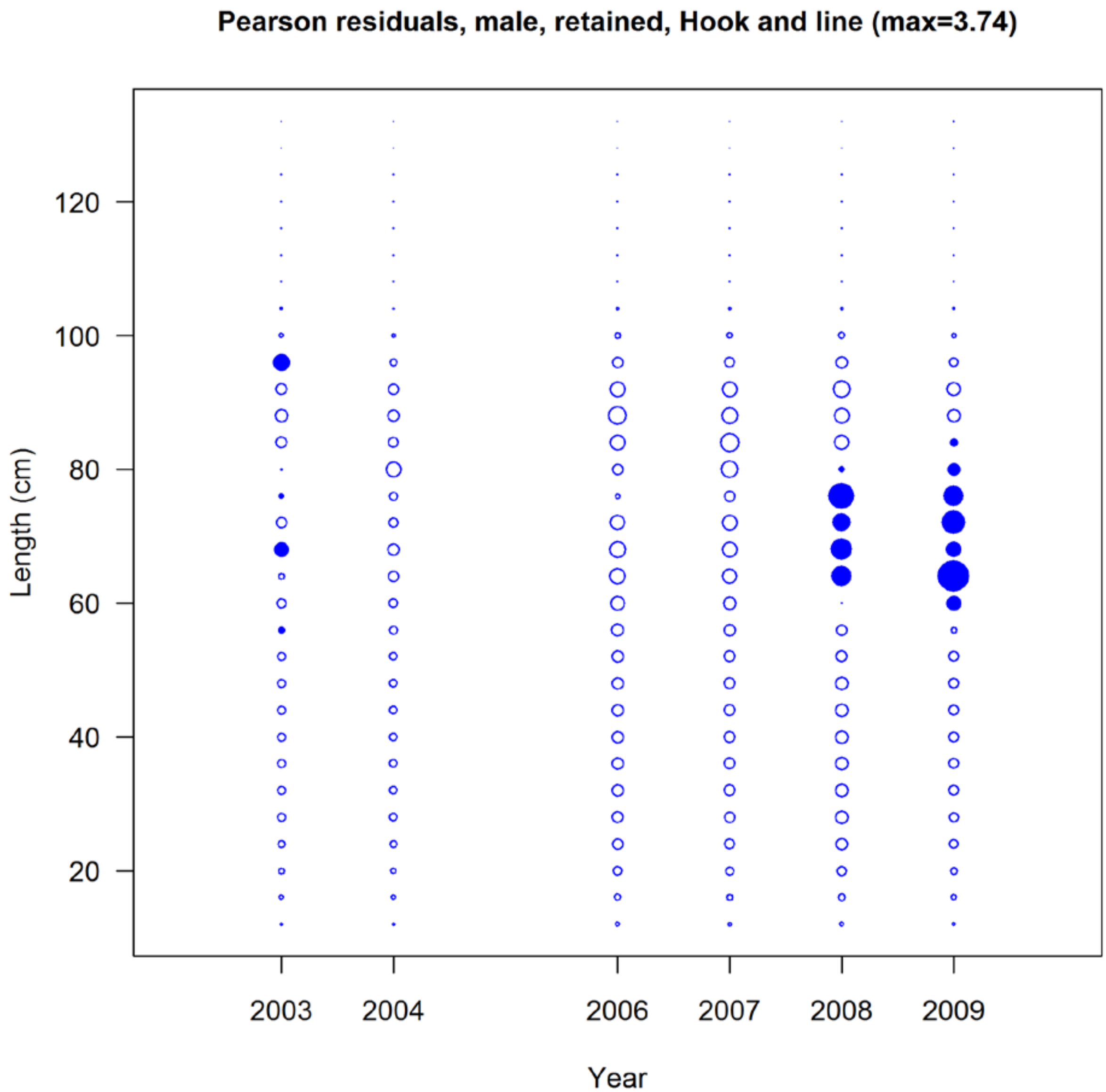

Figure 59. Pearson residuals for the fit of the male length-frequency distributions for the hook-and-line fleet.

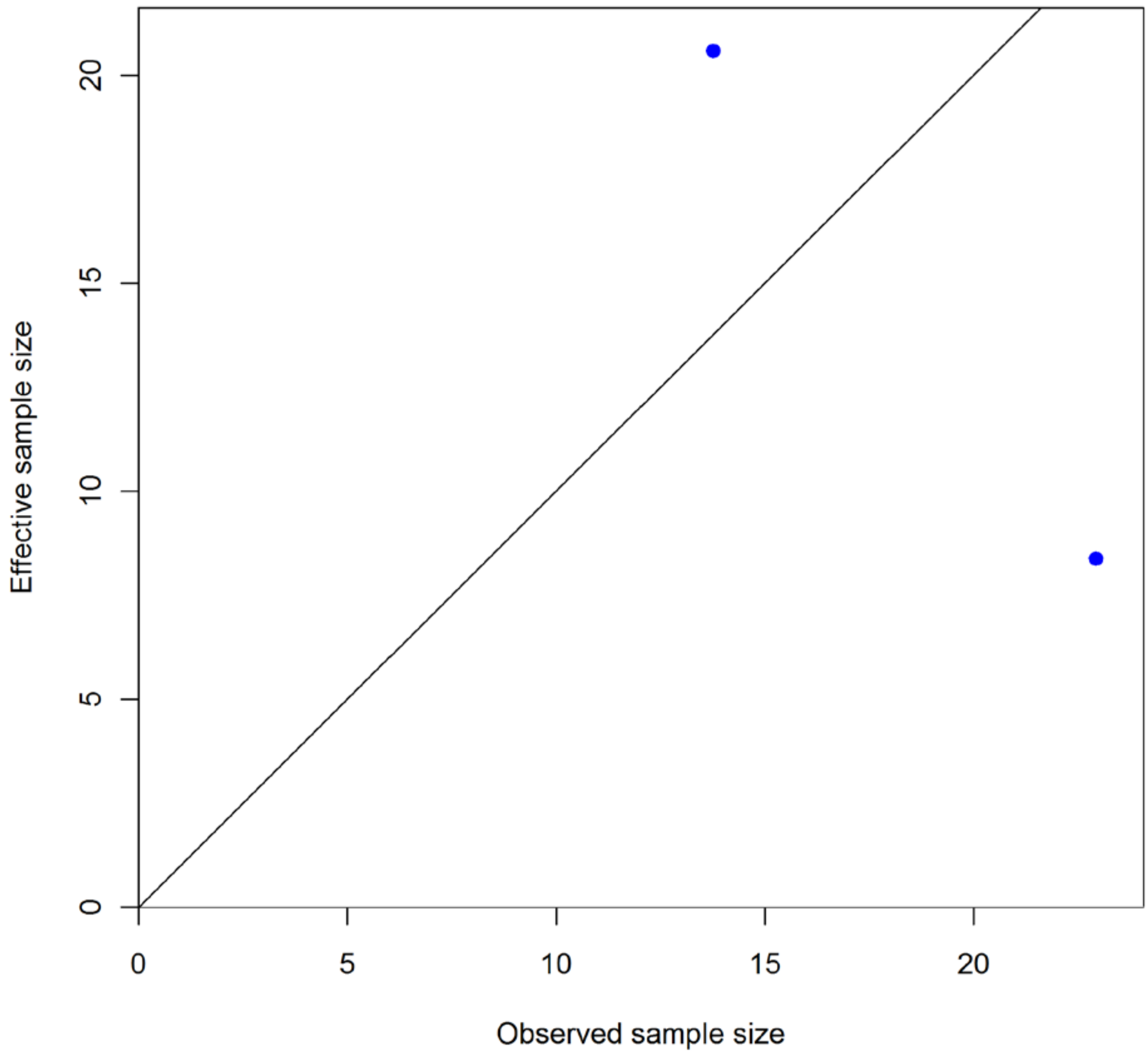

Figure 60. Observed and effective sample sizes for the hook-and-line discard fleet length-frequency observations (the data were collected during EFP fishery).

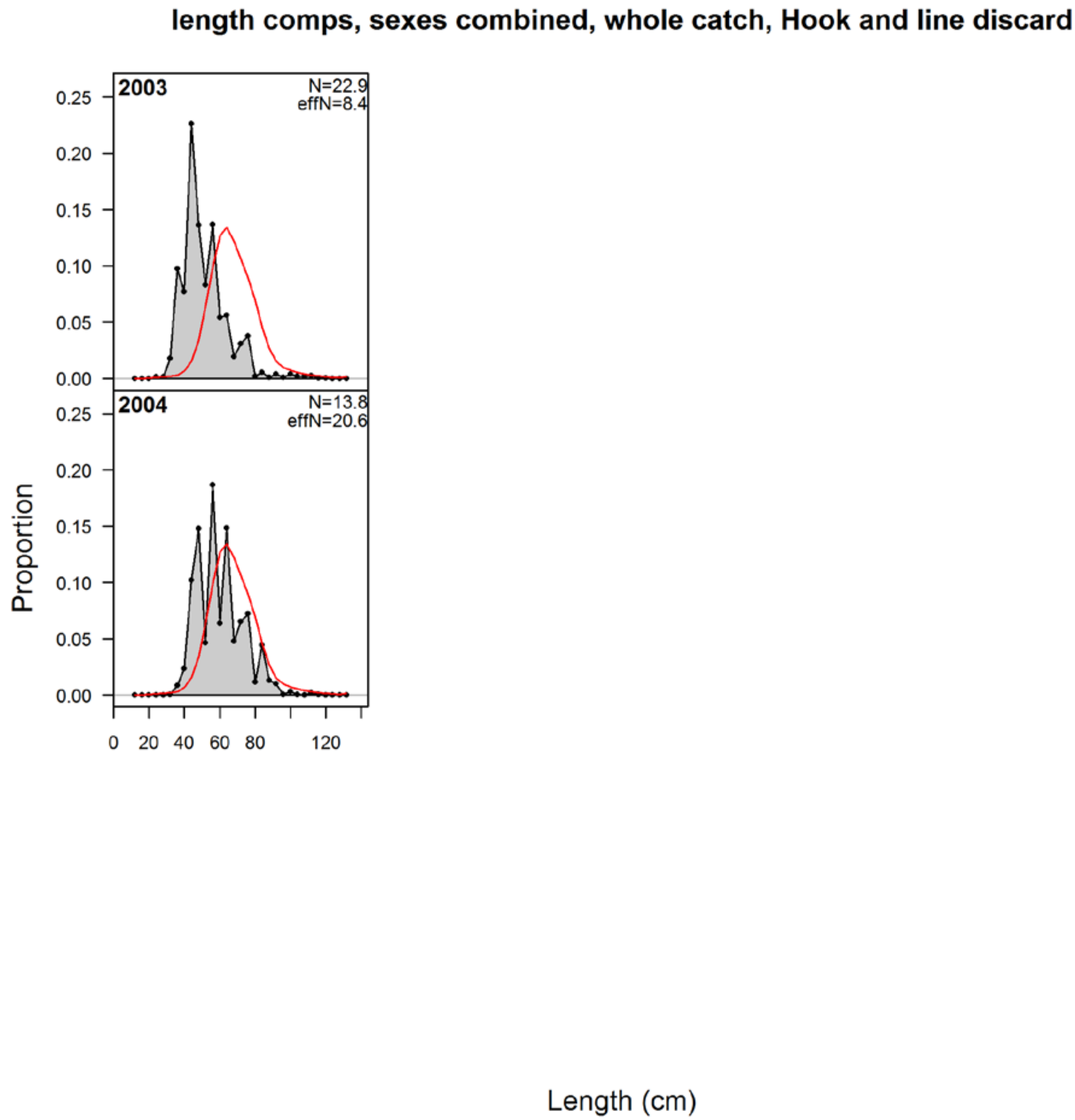

Figure 61. Fit to length-frequency distributions of spiny dogfish (both sexes combined) for the hook-and-line discard fleet (the data were collected during EFP fishery).

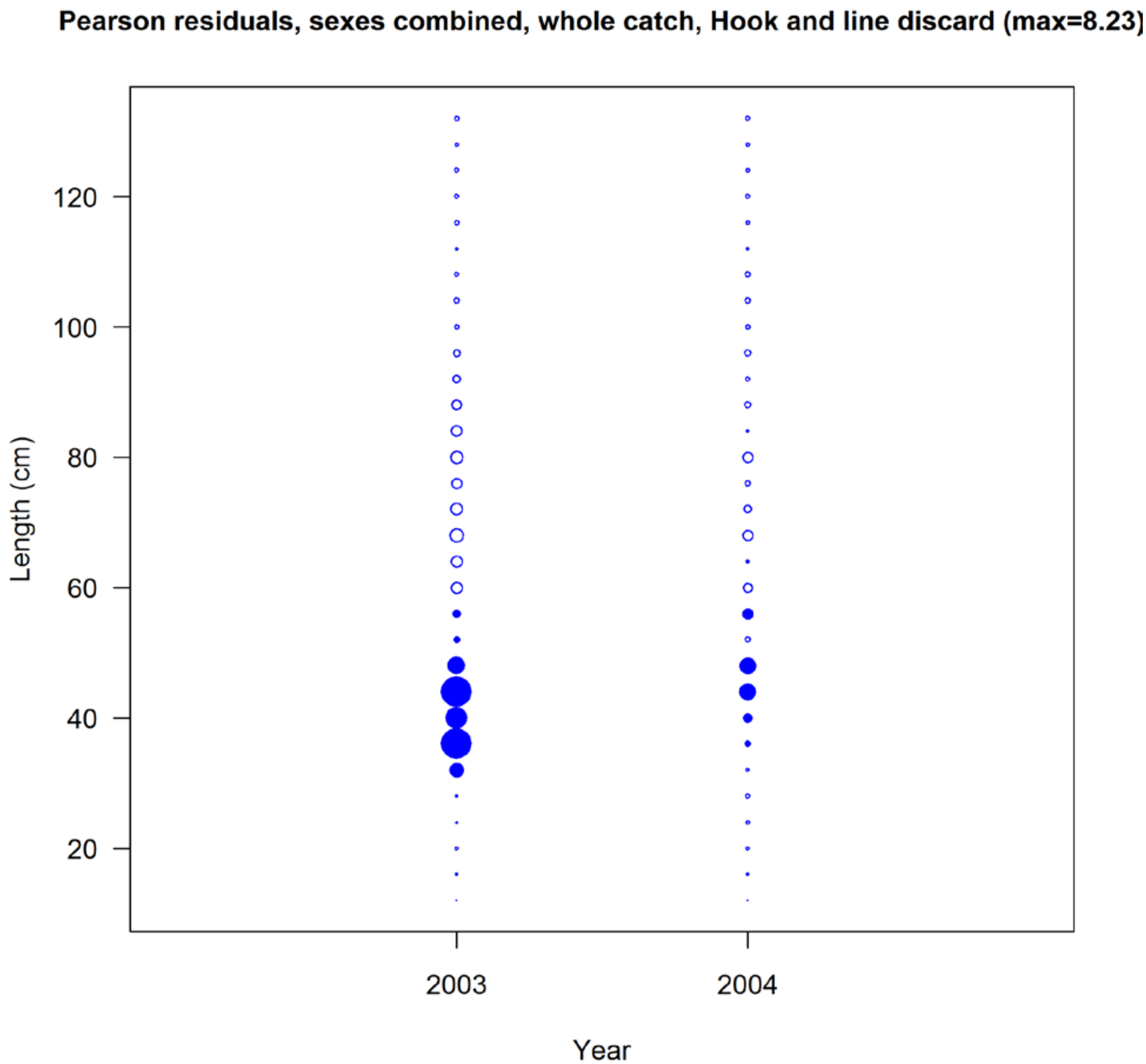

Figure 62. Pearson residuals for the fit of the length-frequency distributions (both sexes combined) for the hook-and-line discard fleet (the data were collected during EFP fishery).

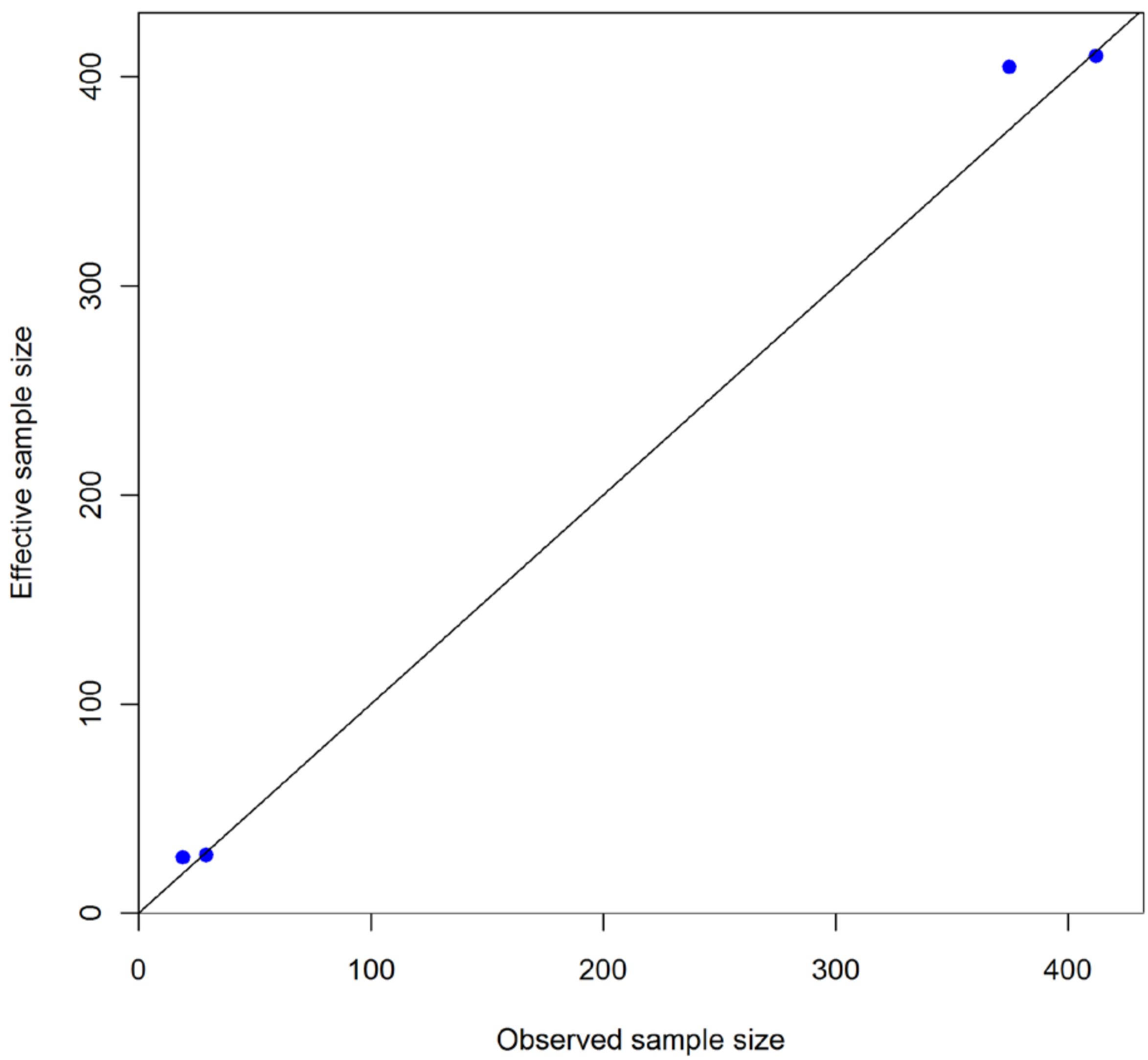

Figure 63. Observed and effective sample sizes for the sex-specific hook-and-line discard fleet length-frequency observations.

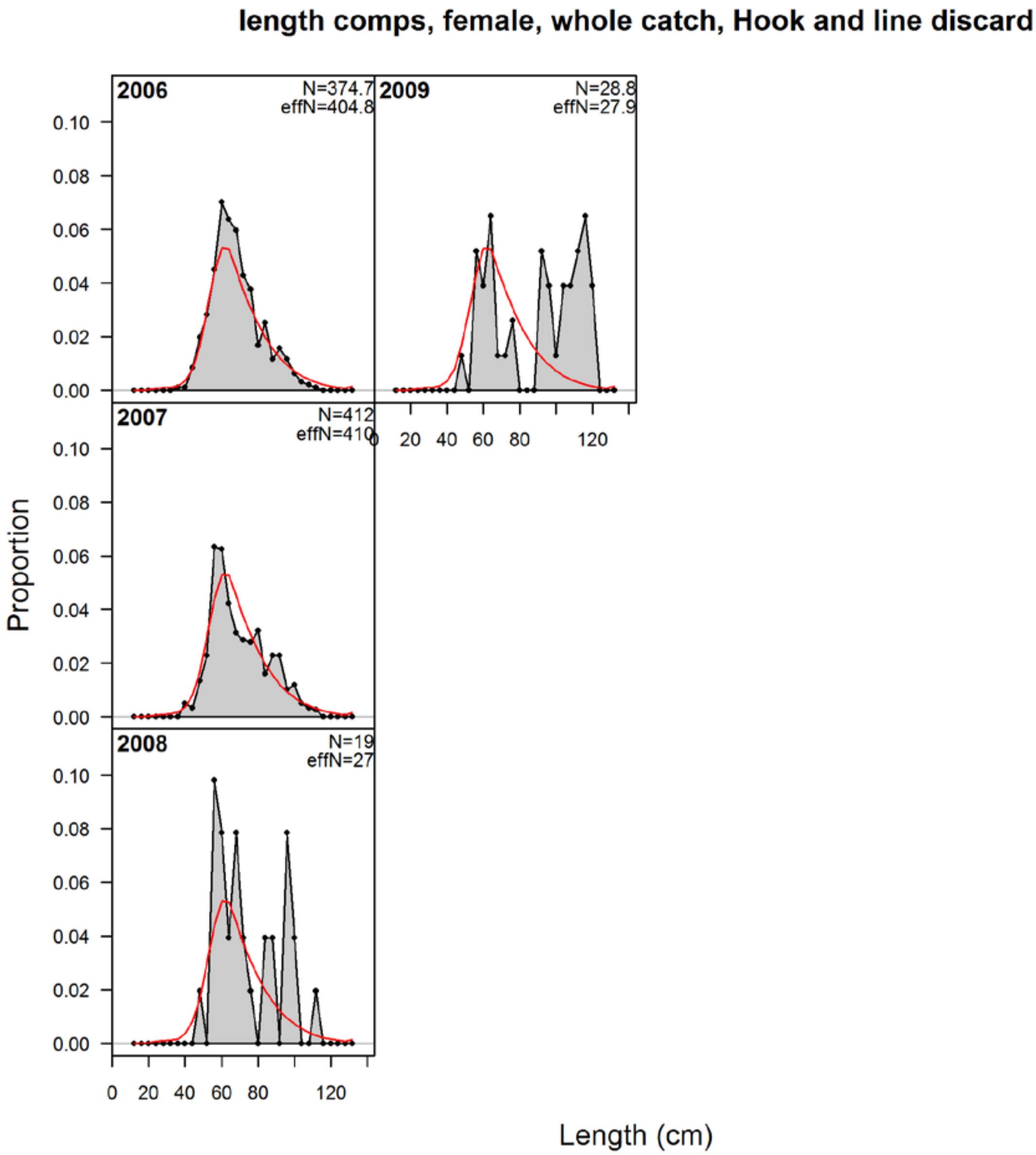

Figure 64. Fit to female length-frequency distributions of spiny dogfish for the hook-and-line discard fleet.

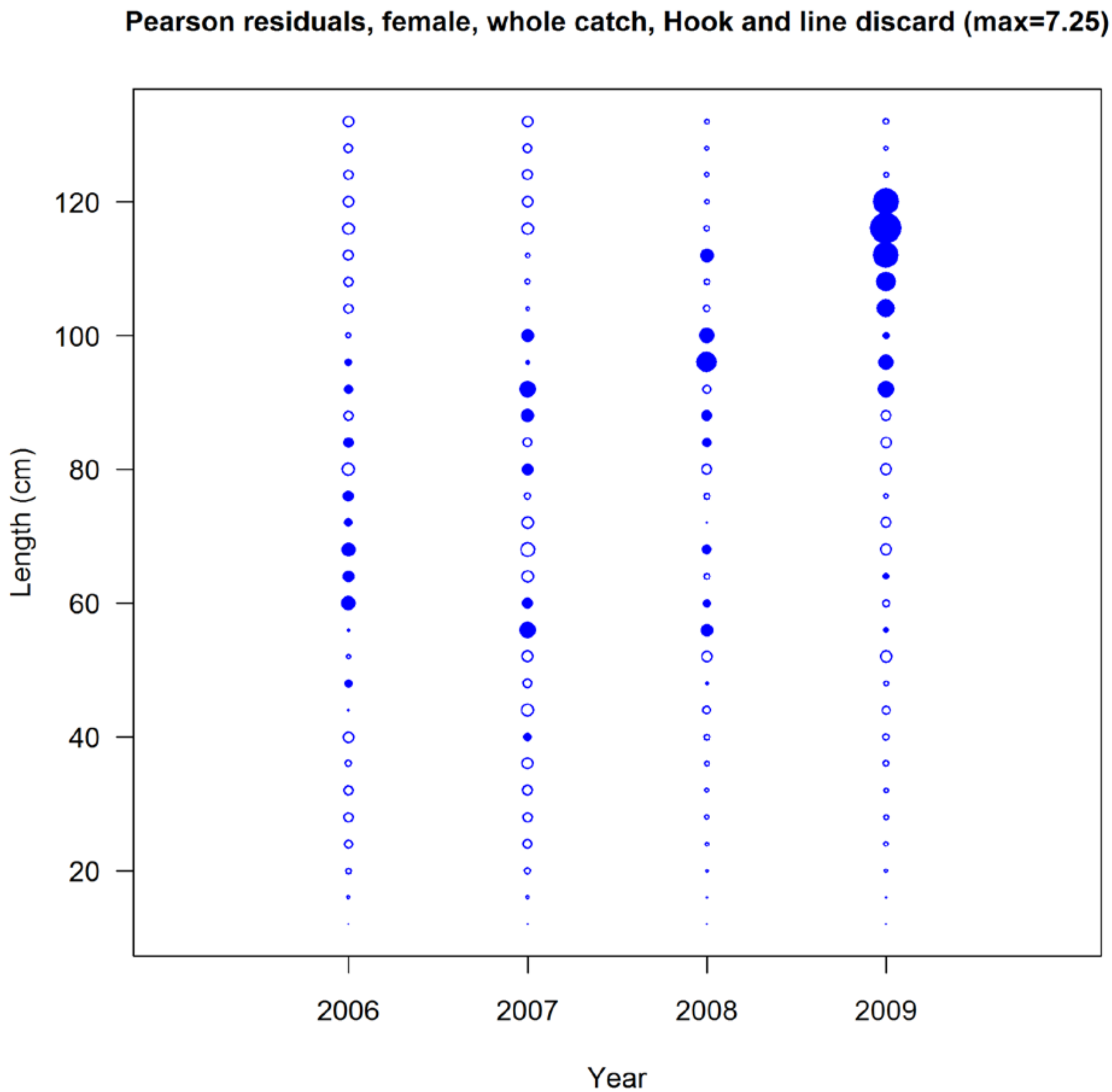

Figure 65. Pearson residuals for the fit of the female length-frequency distributions for the hook-and-line discard fleet.

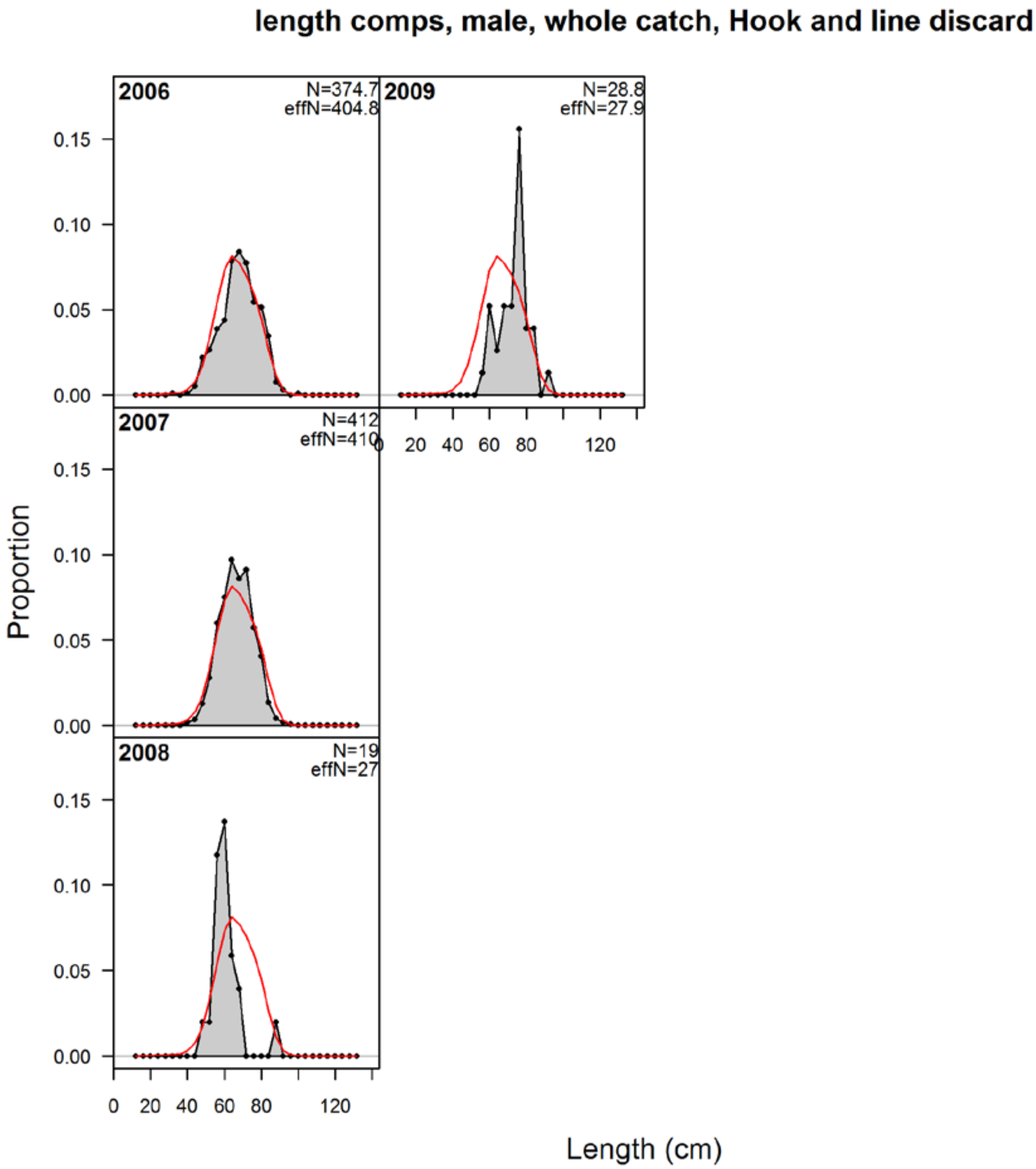

Figure 66. Fit to male length-frequency distributions of spiny dogfish for the hook-and-line discard fleet.

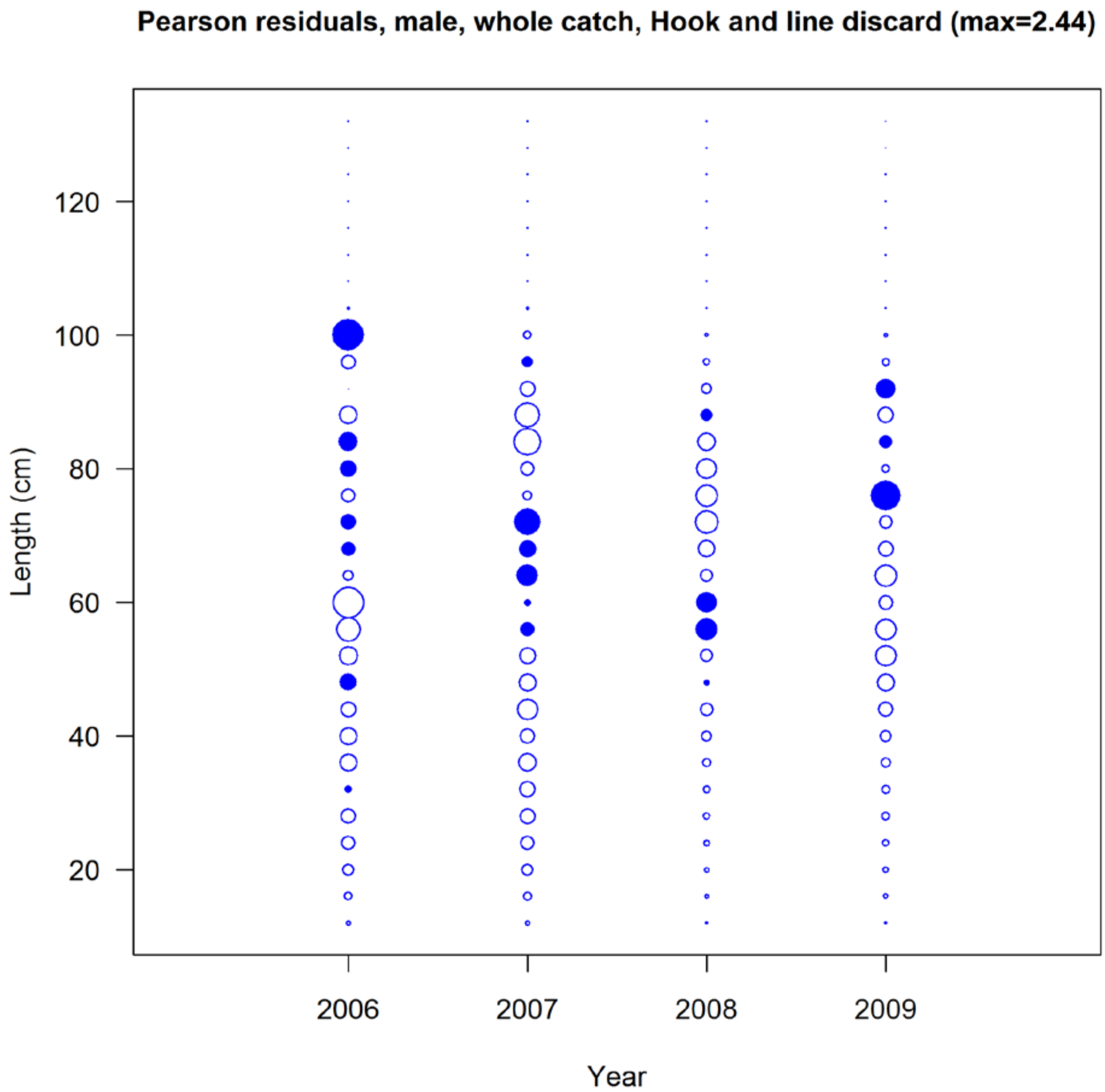

Figure 67. Pearson residuals for the fit of the male length-frequency distributions for the hook-and-line discard fleet.

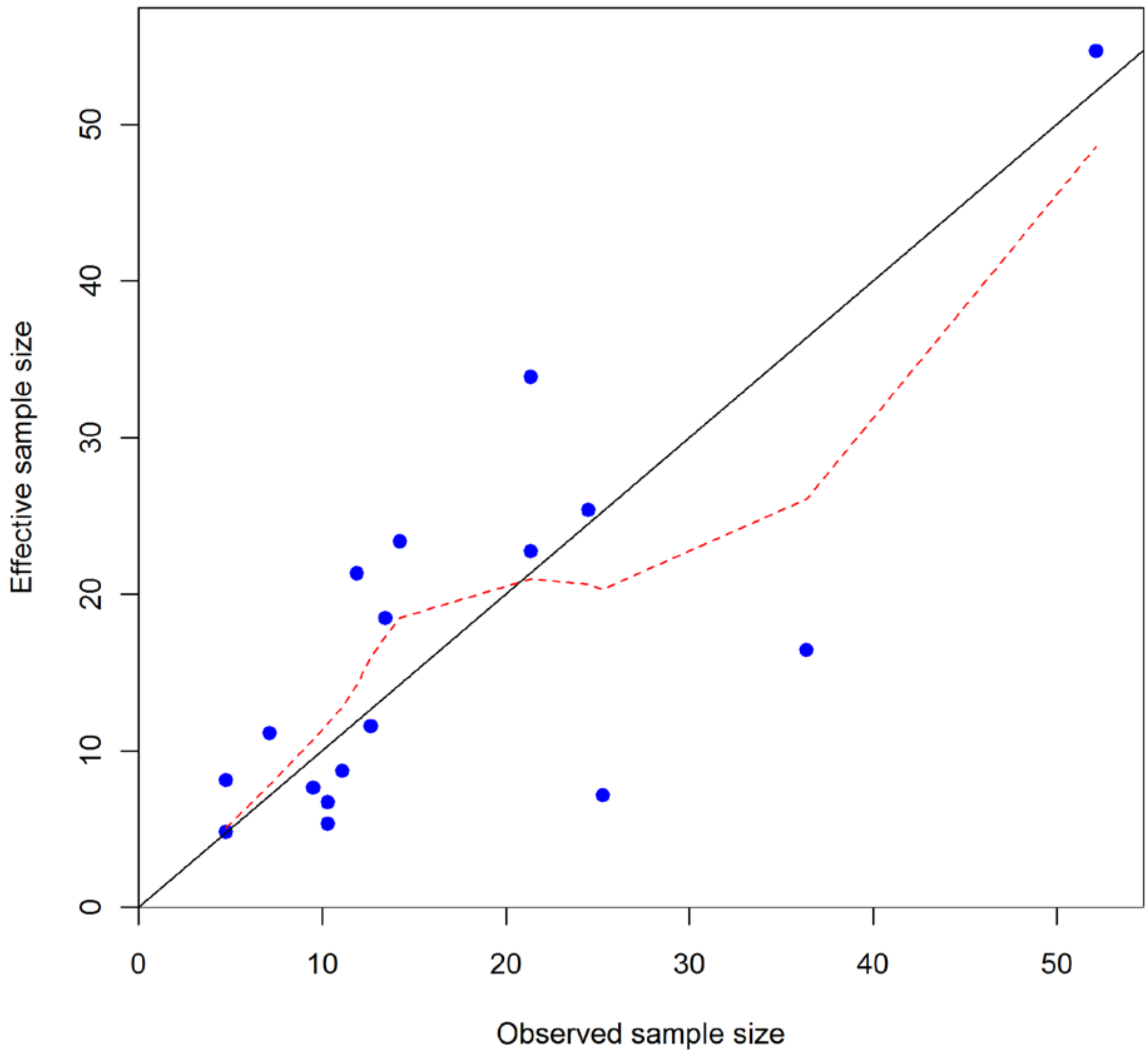

Figure 68. Observed and effective sample sizes for the recreational fleet length-frequency observations.

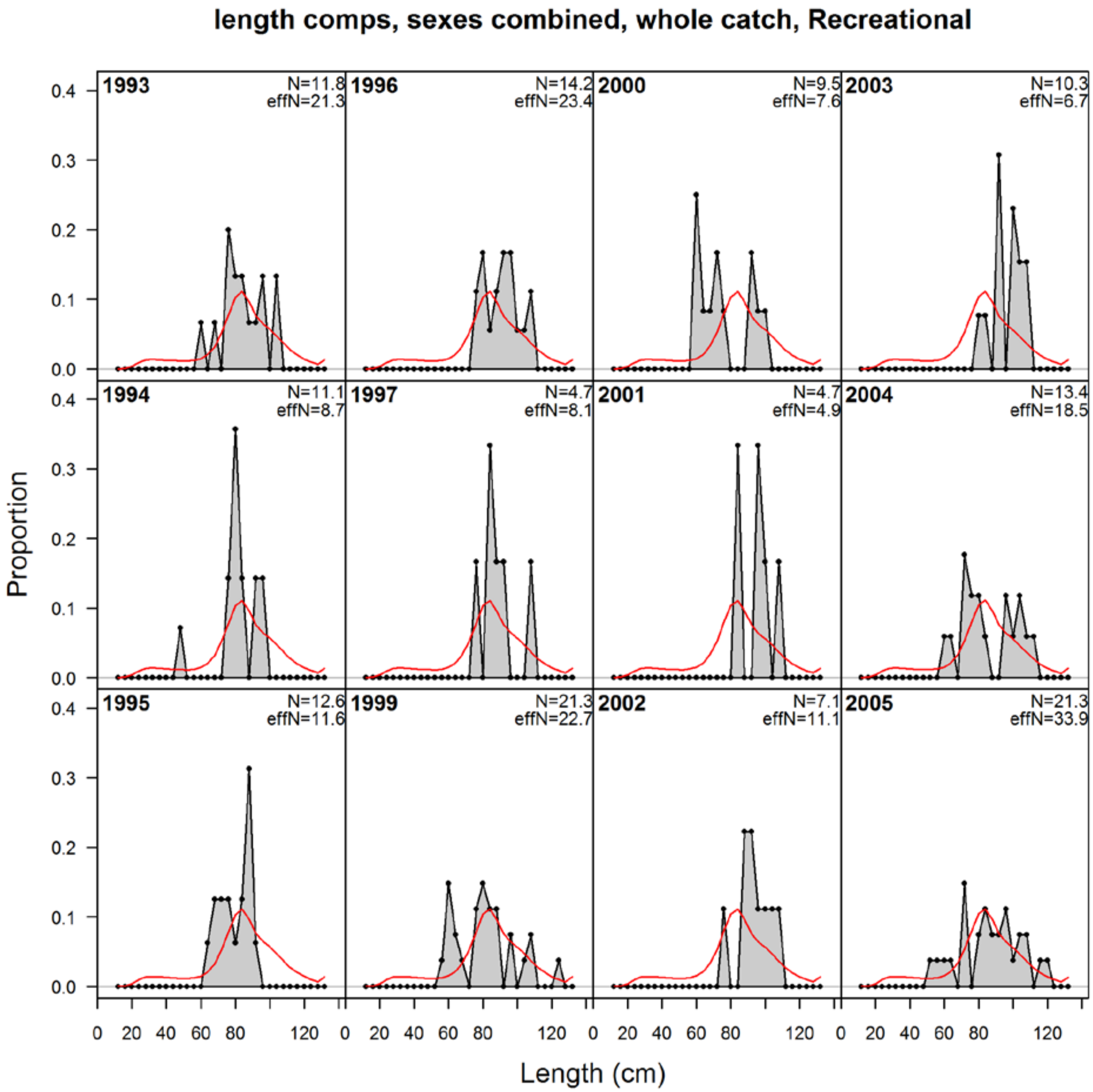

Figure 69. Fit to length-frequency distributions of spiny dogfish (both genders combined) for the recreational fleet.

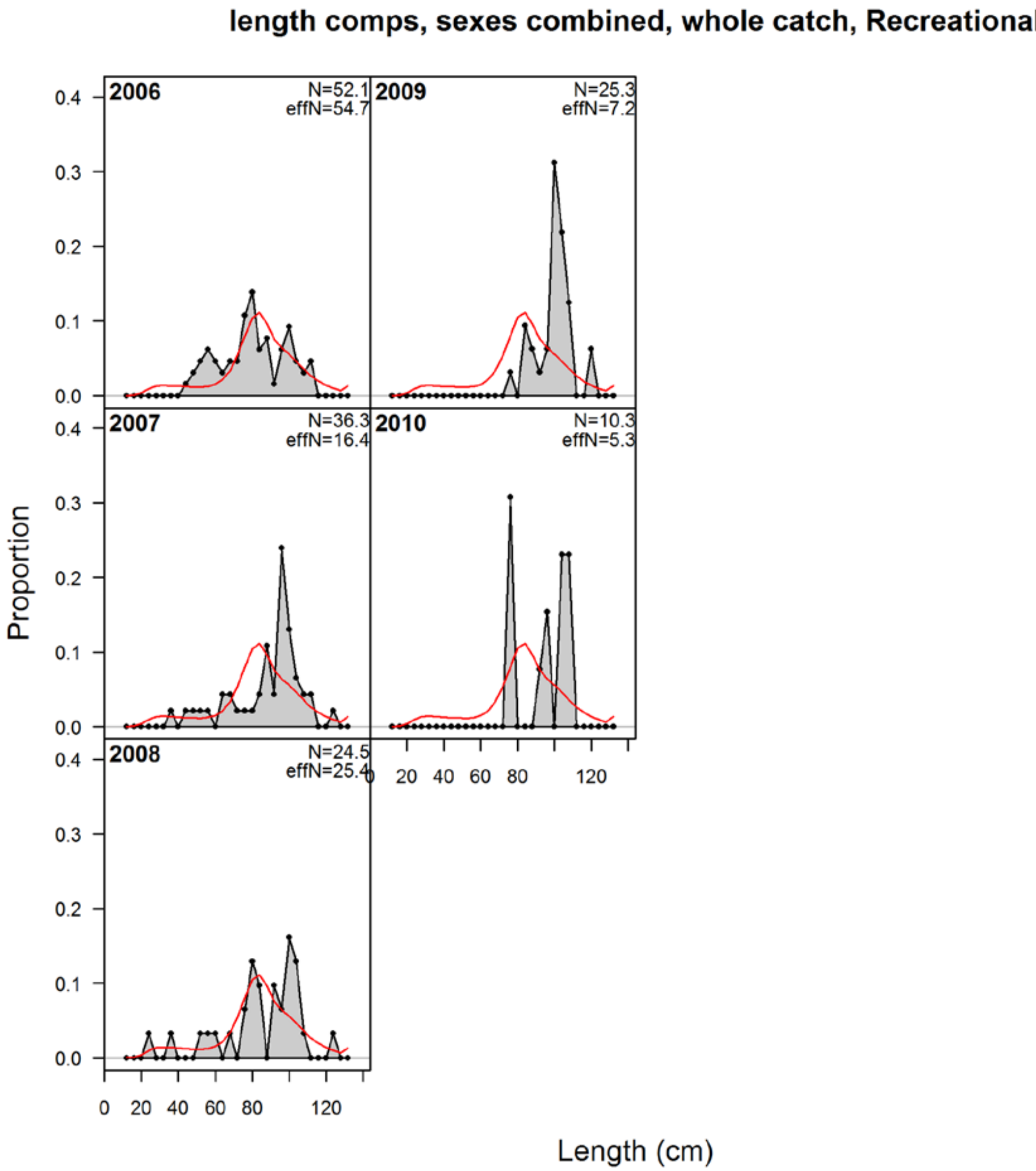

Figure 69 (continued). Fit to length-frequency distributions of spiny dogfish (both genders combined) for the recreational fleet.

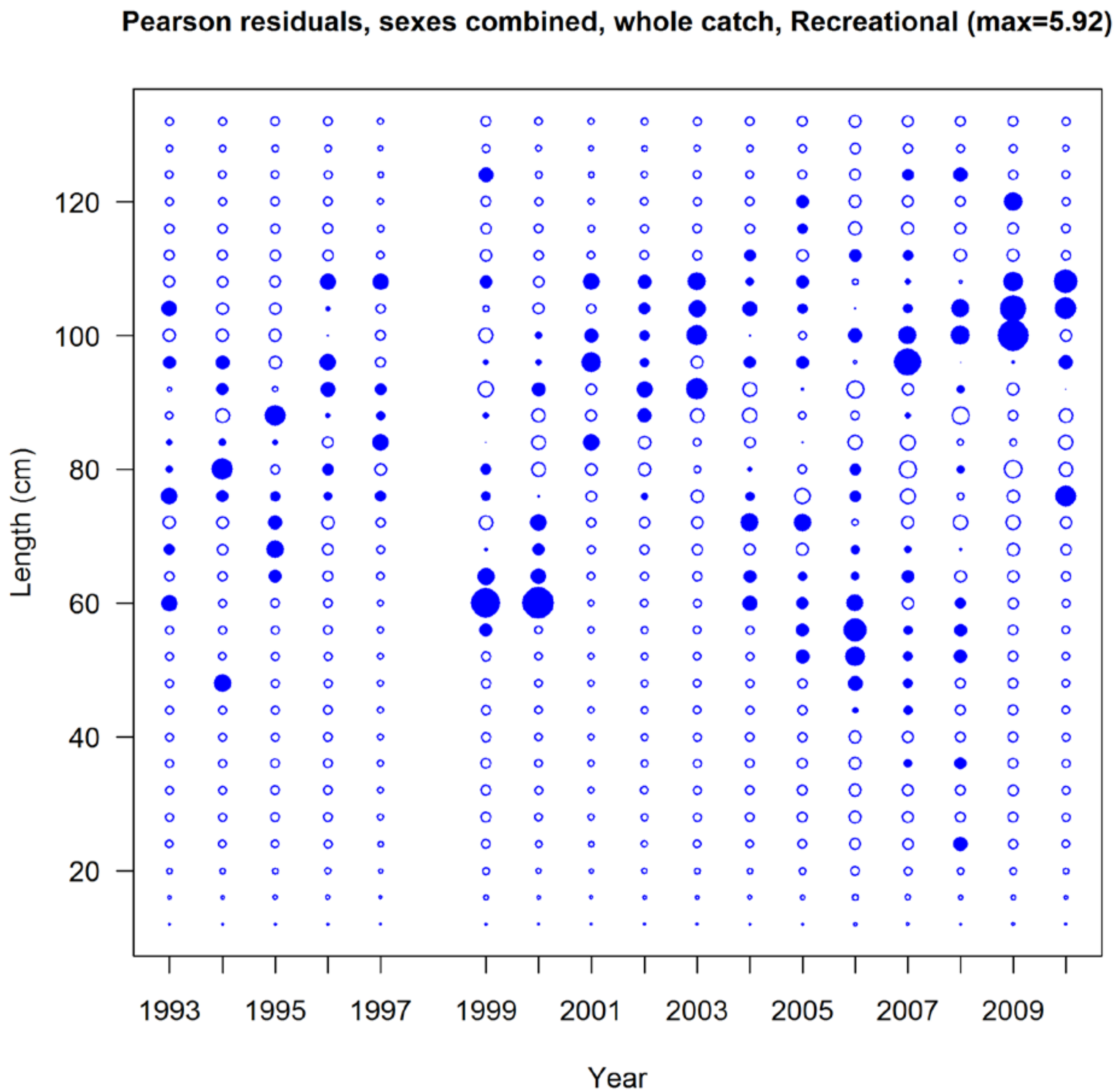

Figure 70. Pearson residuals for the fit of the length-frequency distributions (both genders combined) for the recreational fleet.

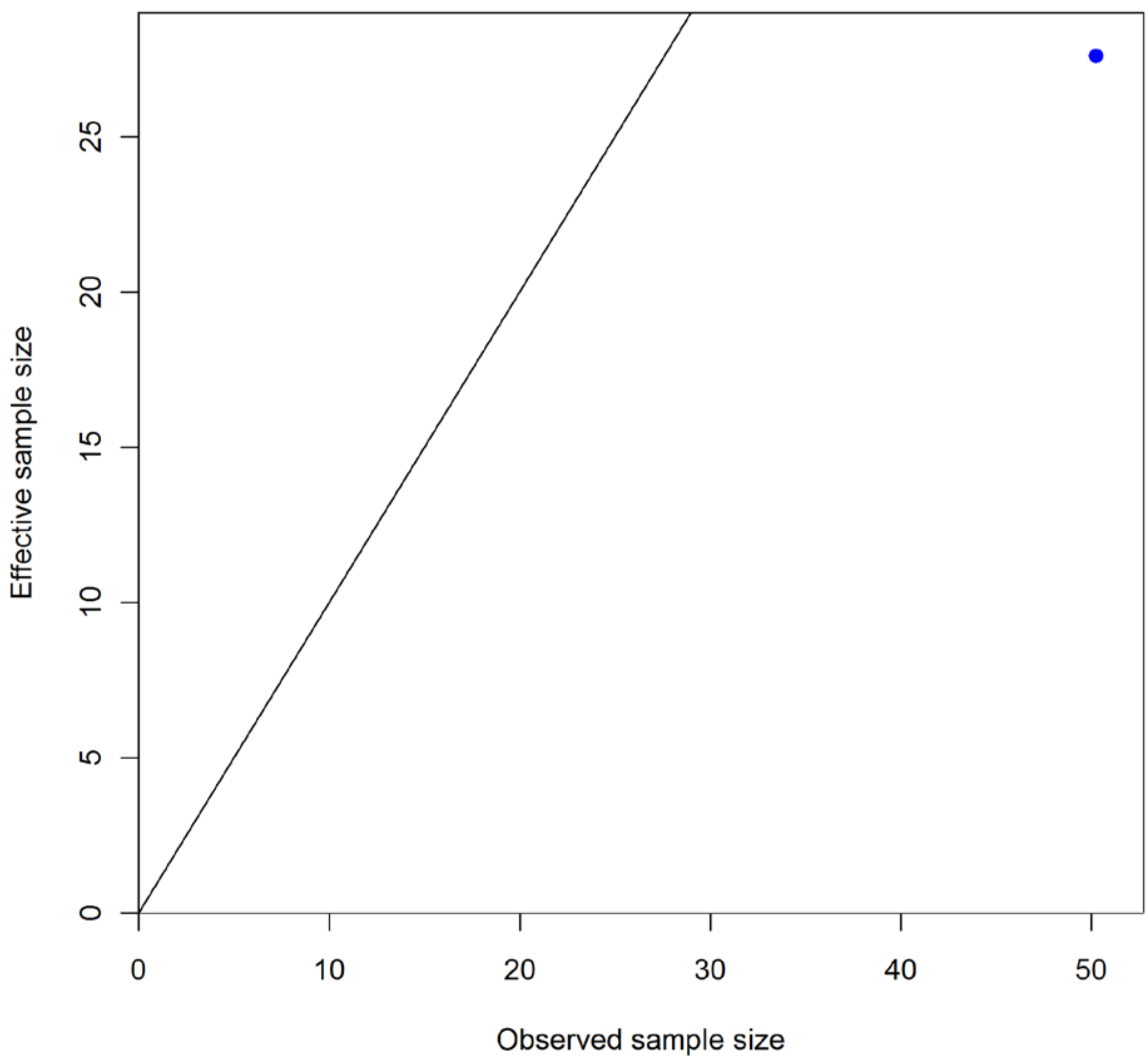

Figure 71. Observed and effective sample sizes for the AFSC triennial survey length-frequency observations.

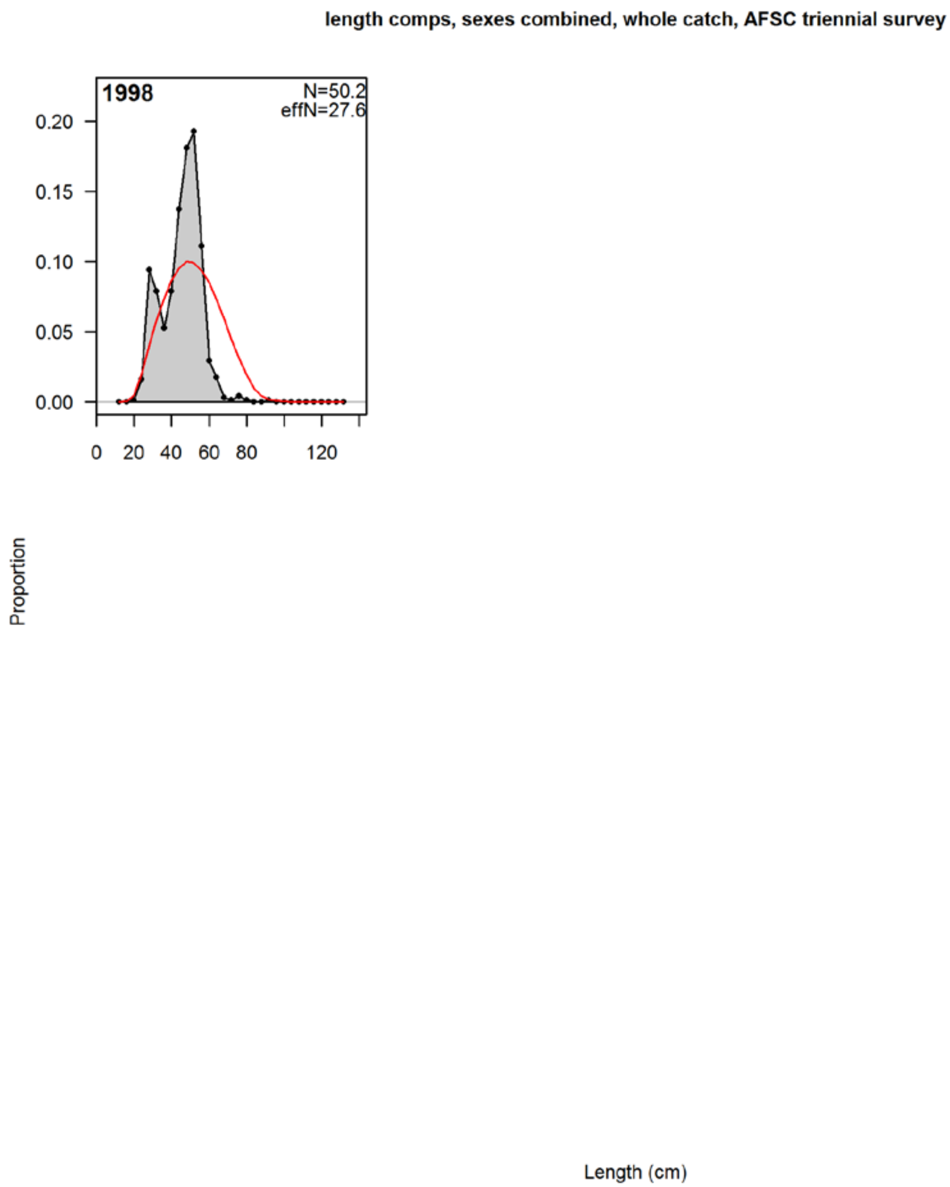

Figure 72. Fit to length-frequency distributions of spiny dogfish (both genders combined) for the AFSC triennial survey.

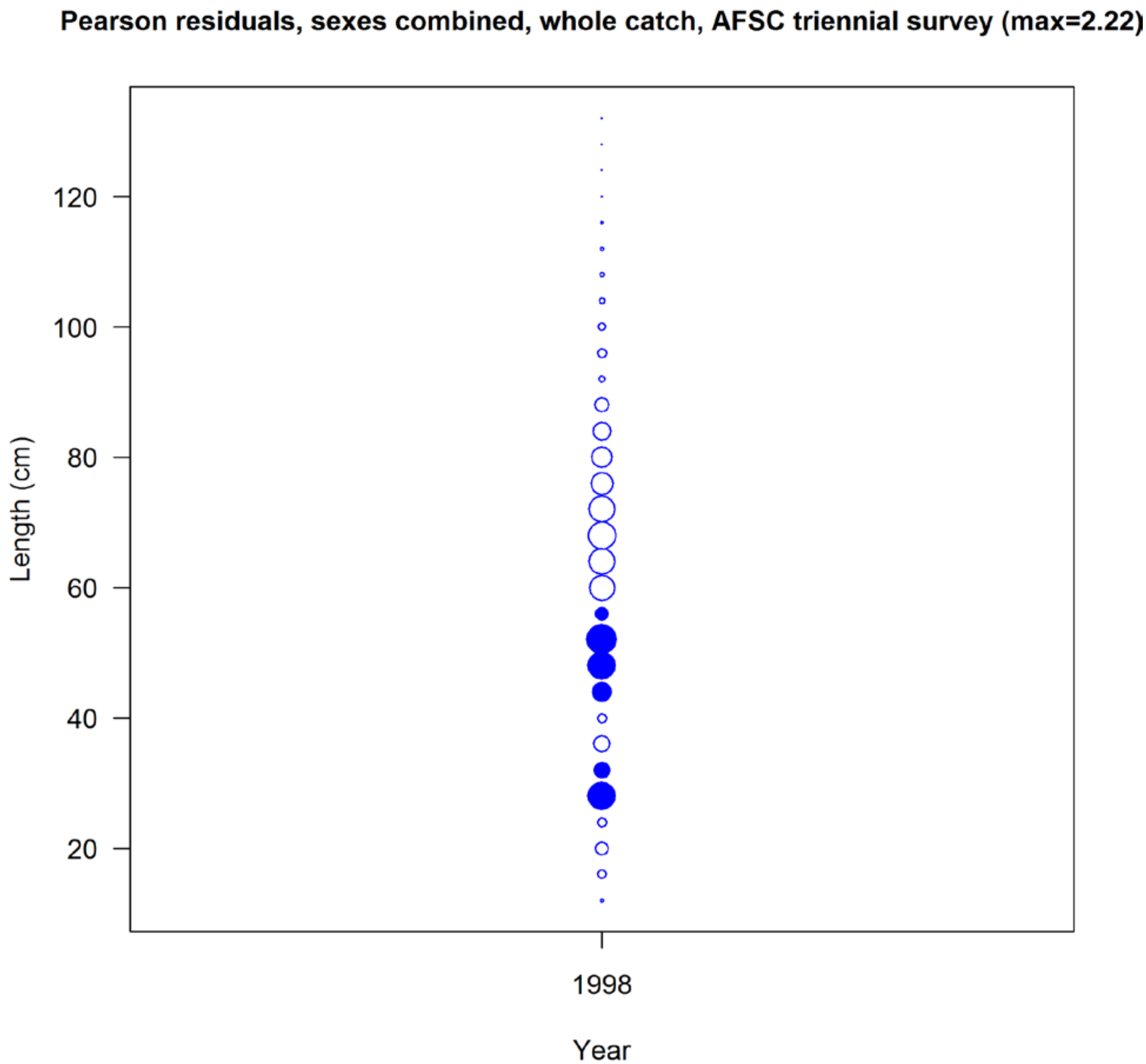

Figure 73. Pearson residuals for the fit of the length-frequency distributions (both genders combined) for the AFSC triennial survey.

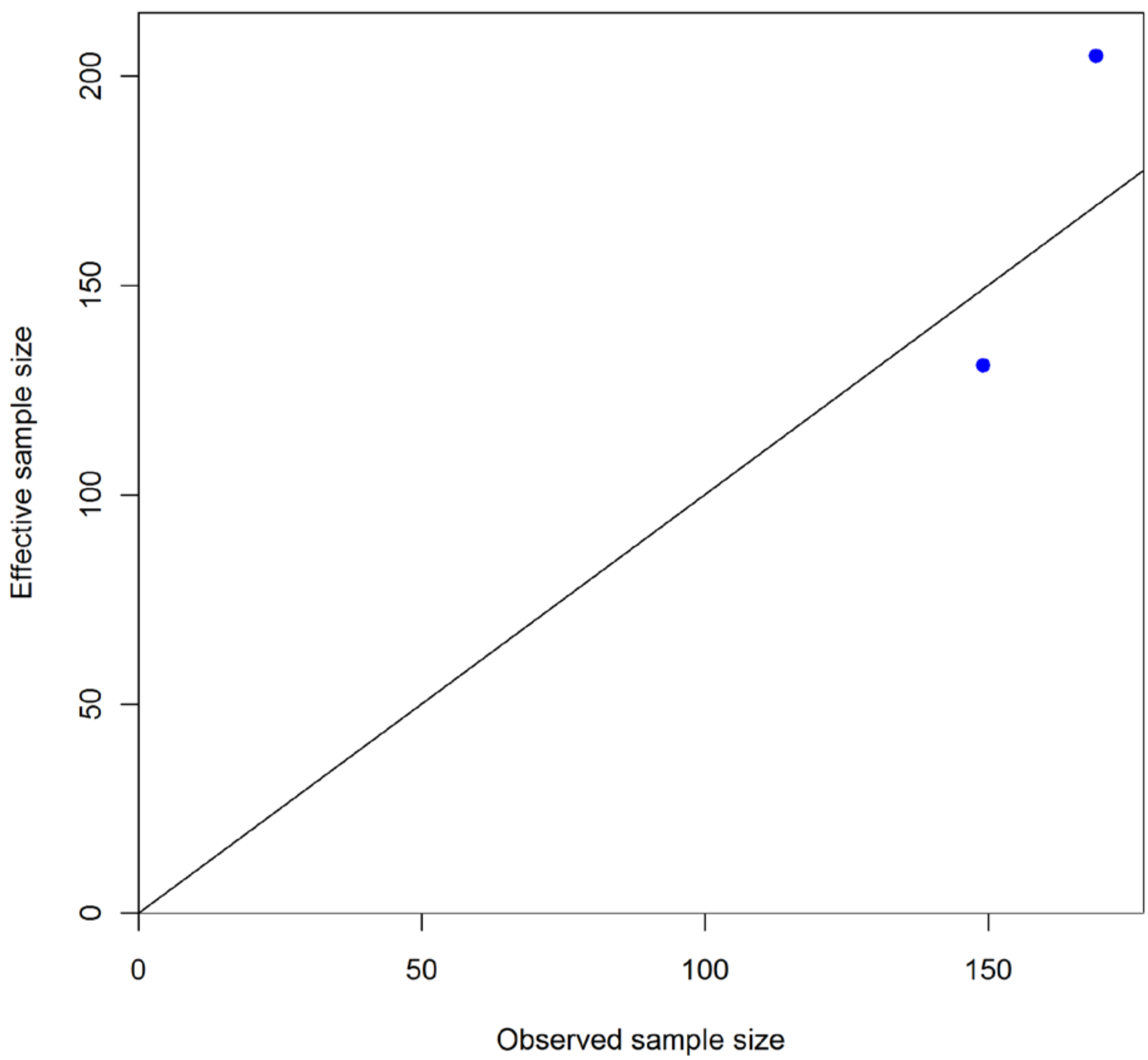

Figure 74. Observed and effective sample sizes for the sex-specific AFSC triennial survey length-frequency observations.

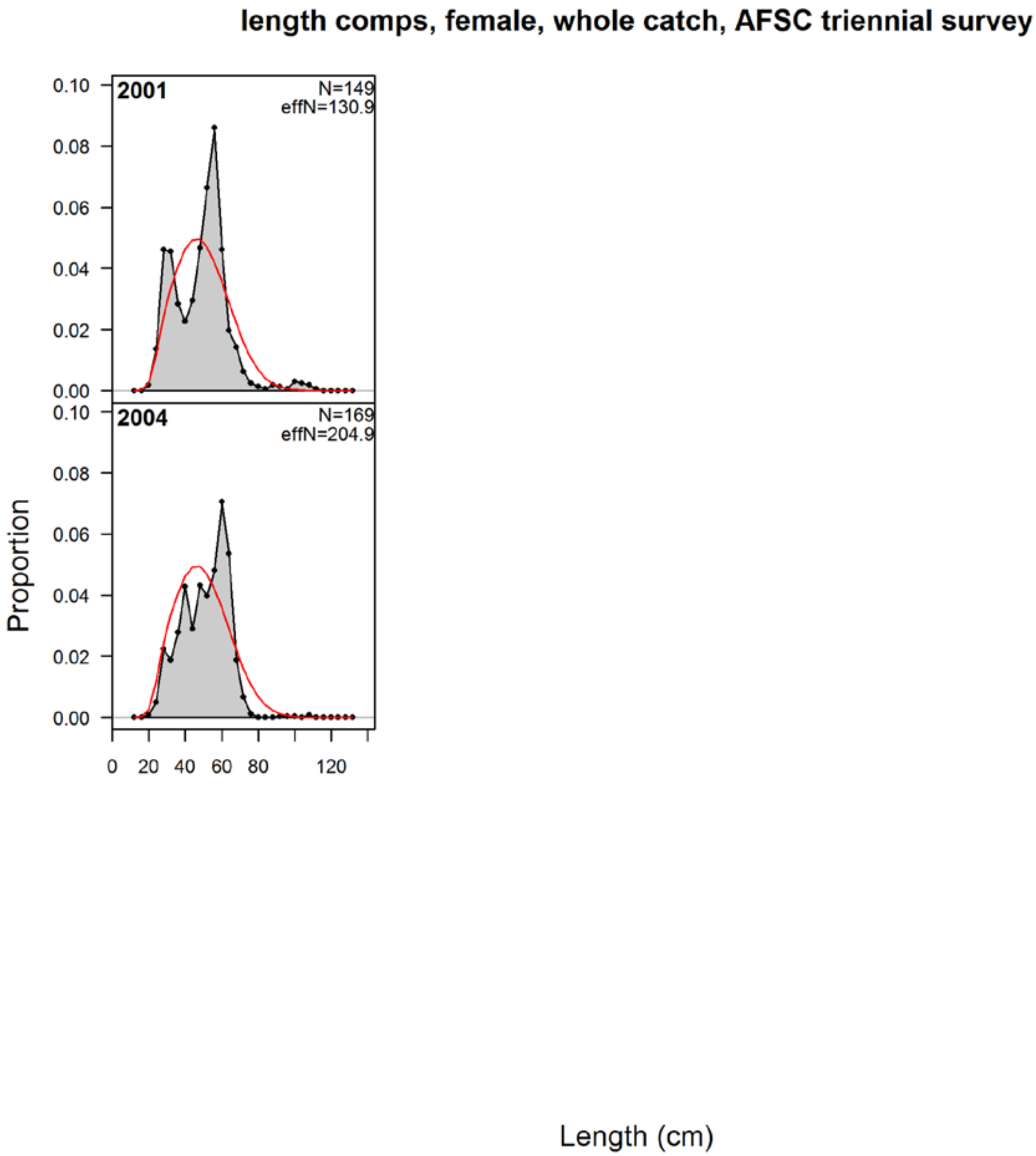

Figure 75. Fit to female length-frequency distributions of spiny dogfish for the AFSC triennial survey.

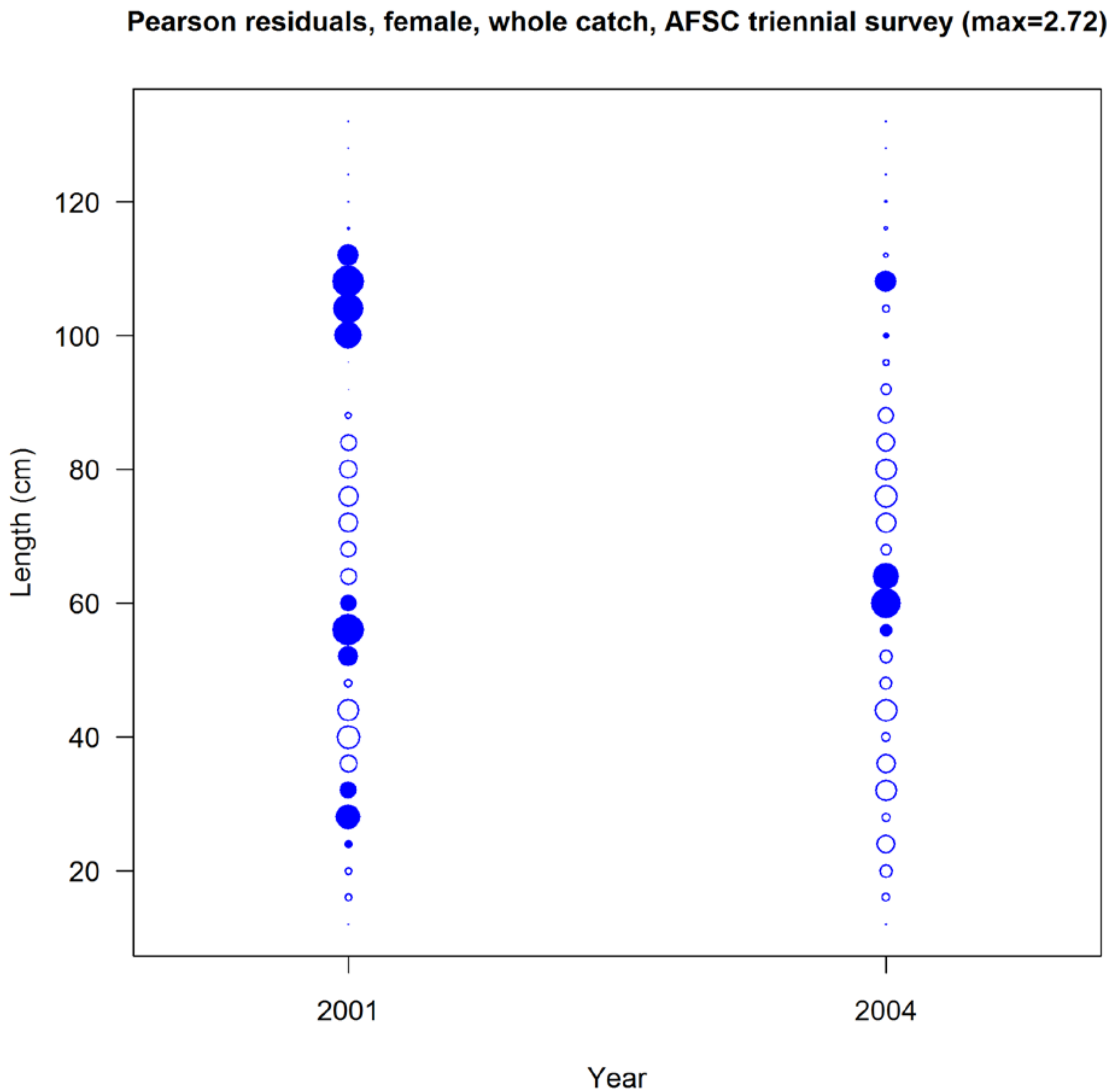

Figure 76. Pearson residuals for the fit of the female length-frequency distributions for the AFSC triennial survey.

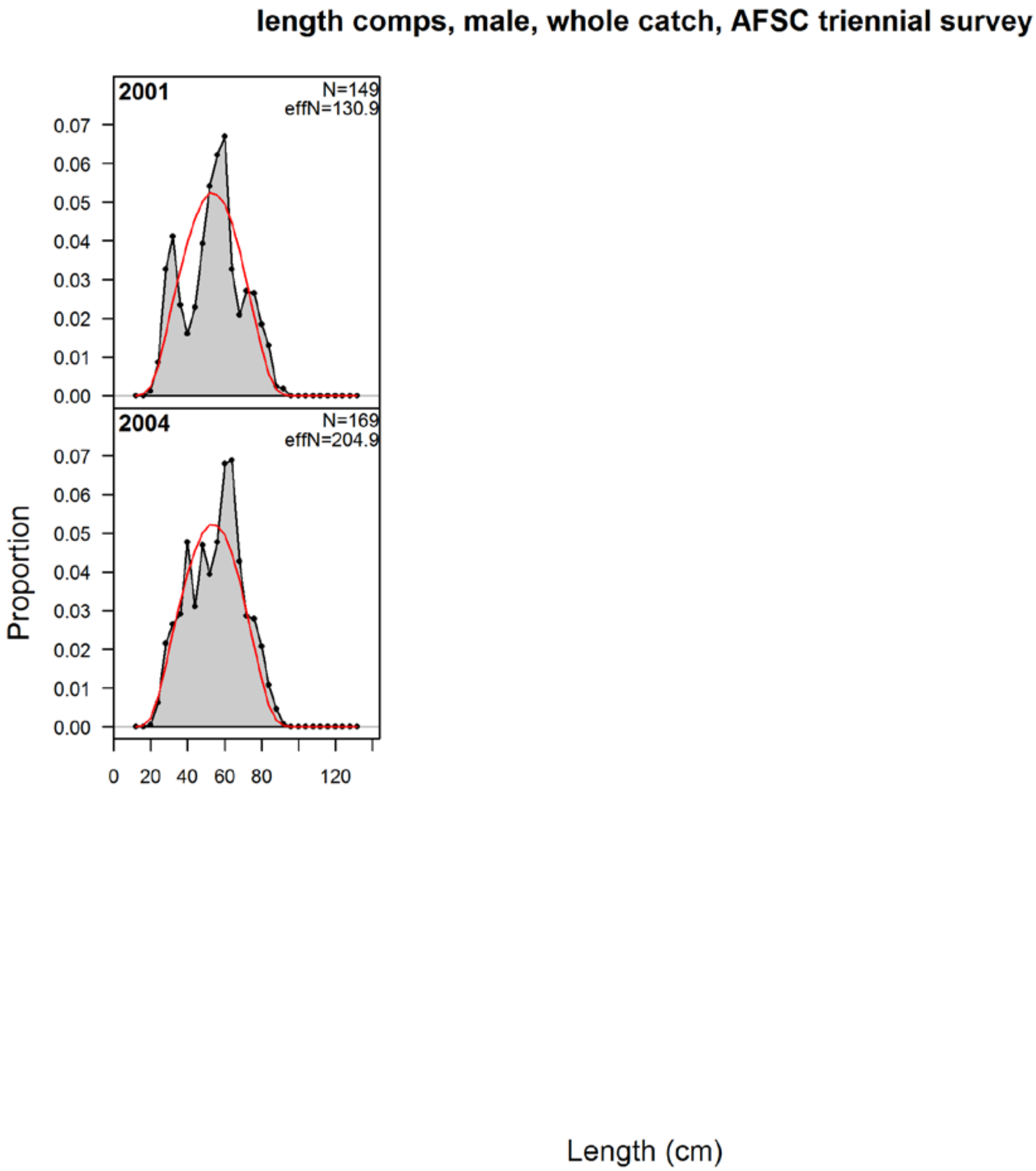

Figure 77. Fit to male length-frequency distributions of spiny dogfish for the AFSC triennial survey.

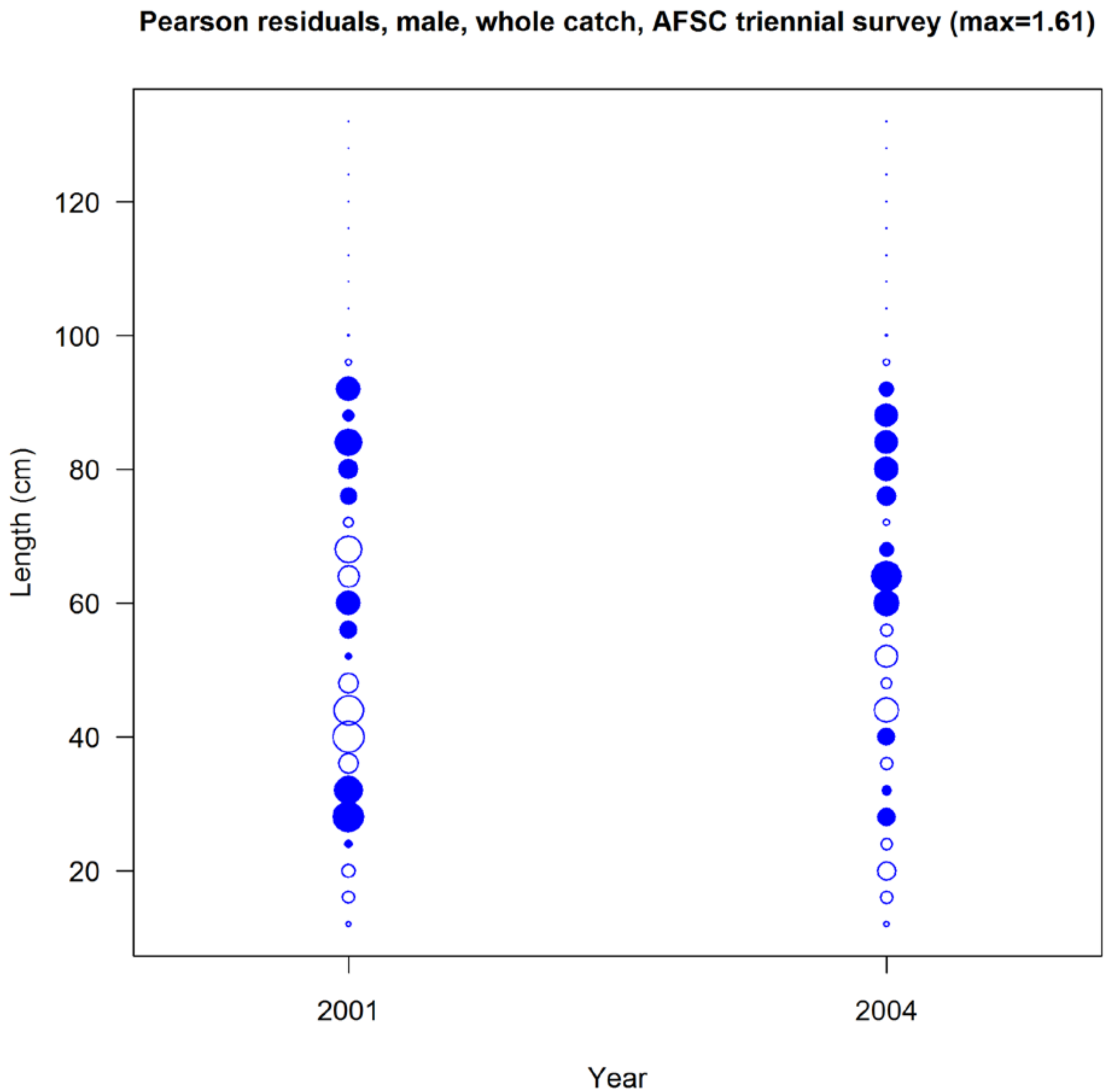

Figure 78. Pearson residuals for the fit of the male length-frequency distributions for the AFSC triennial survey.

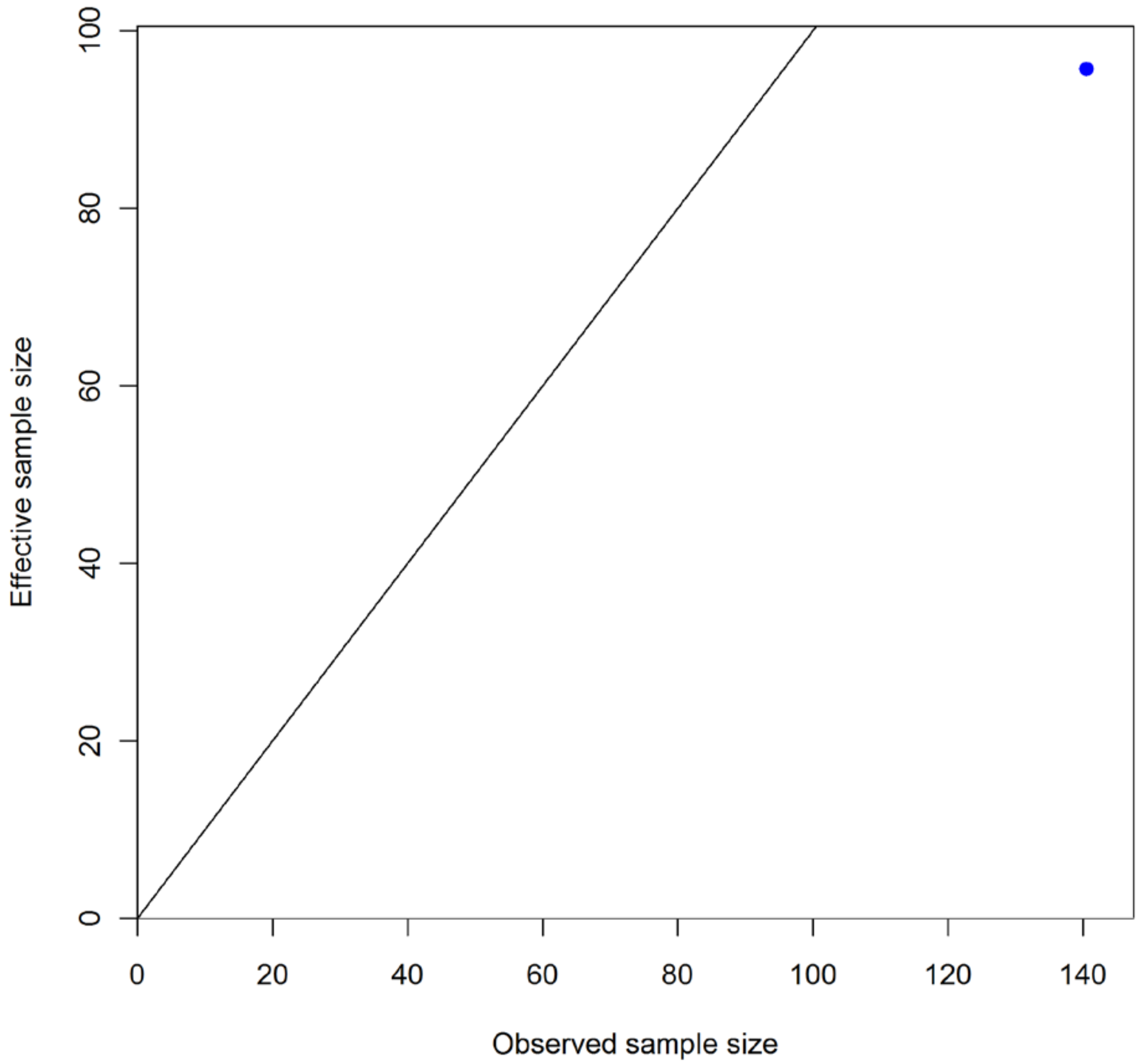

Figure 79. Observed and effective sample sizes for the AFSC slope survey length-frequency observations.

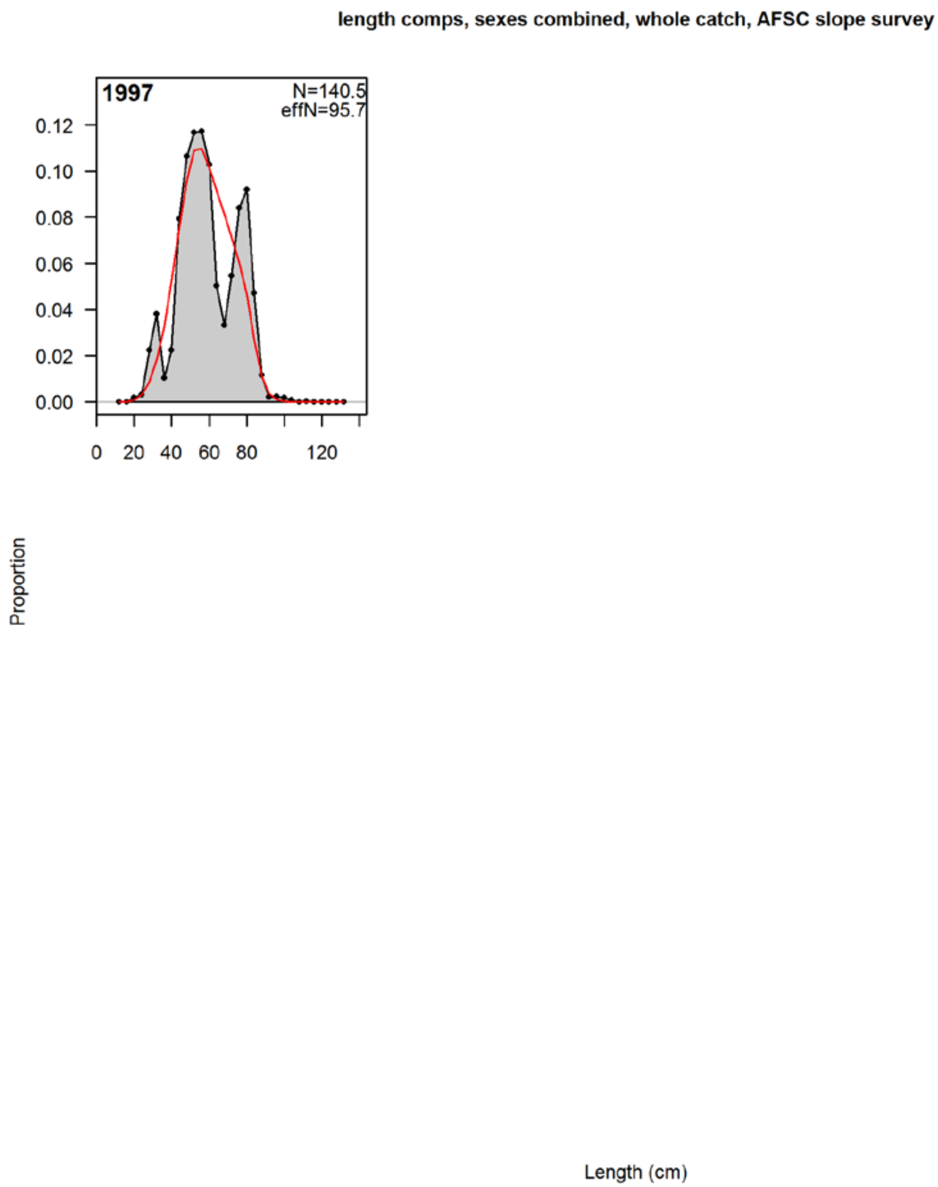

Figure 80. Fit to length-frequency distributions (both genders combined) of spiny dogfish for the AFSC slope survey.

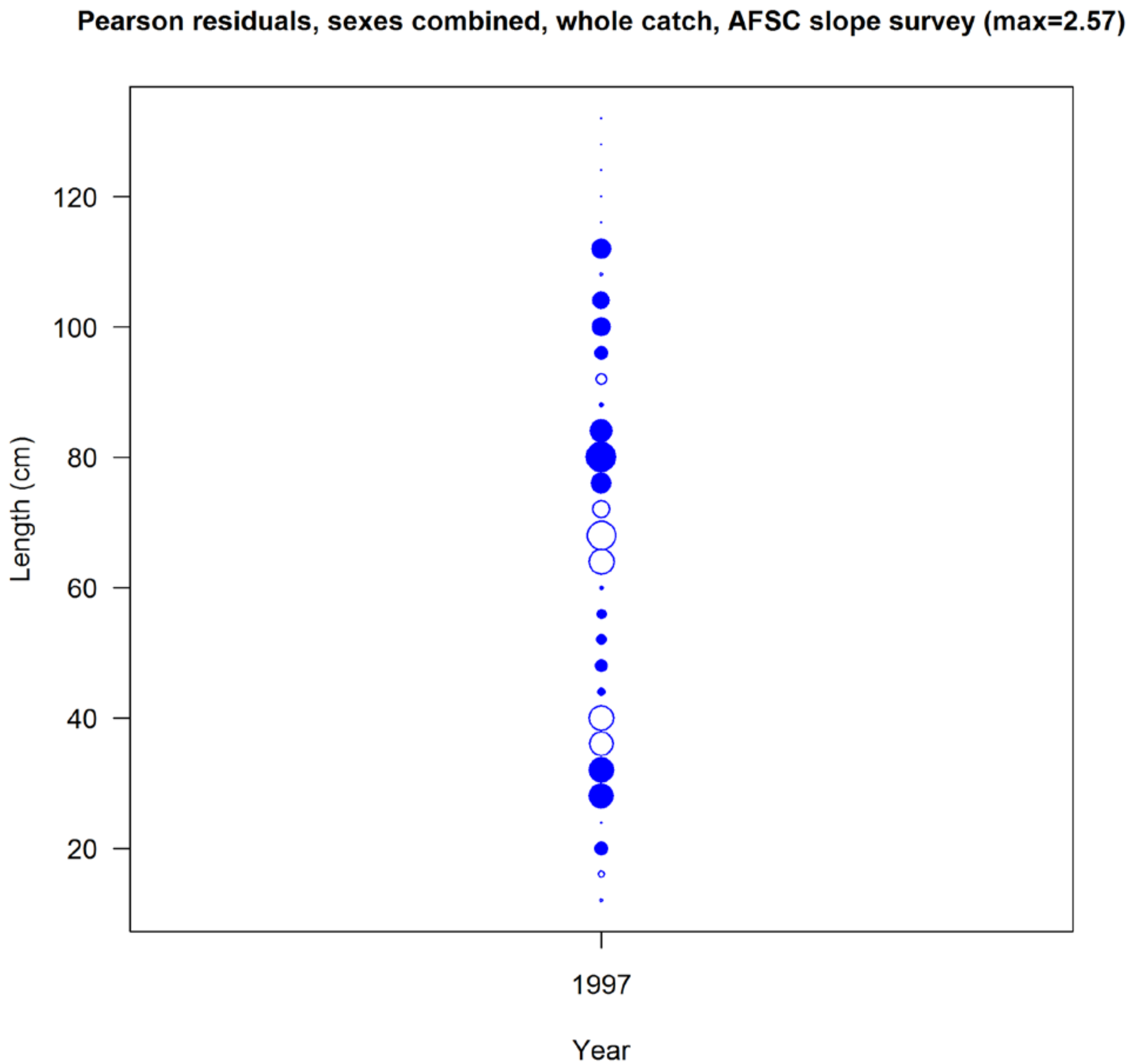

Figure 81. Pearson residuals for the fit of the length-frequency distributions (both genders combined) for the AFSC slope survey.

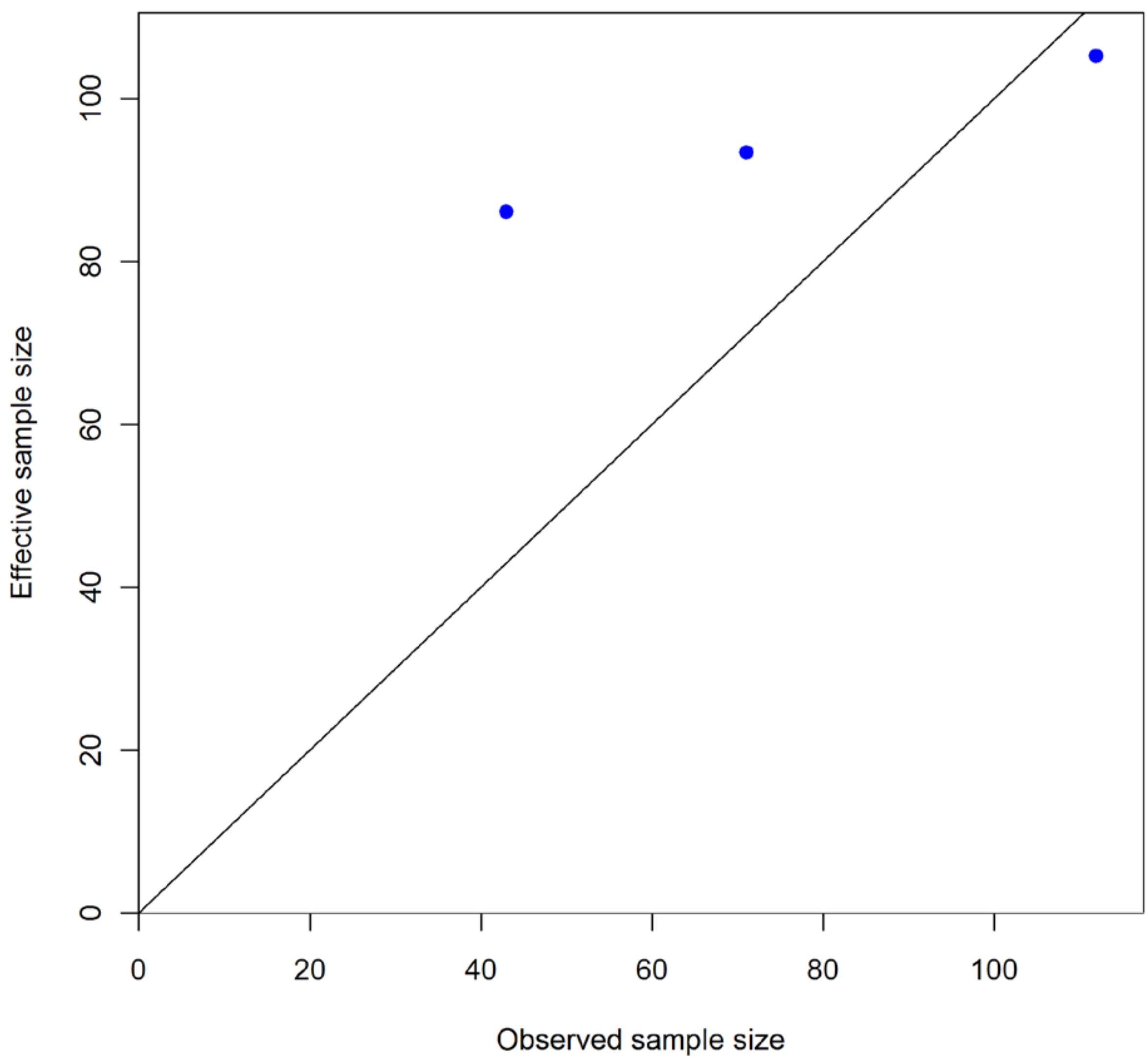

Figure 82. Observed and effective sample sizes for the sex-specific AFSC slope survey length-frequency observations.

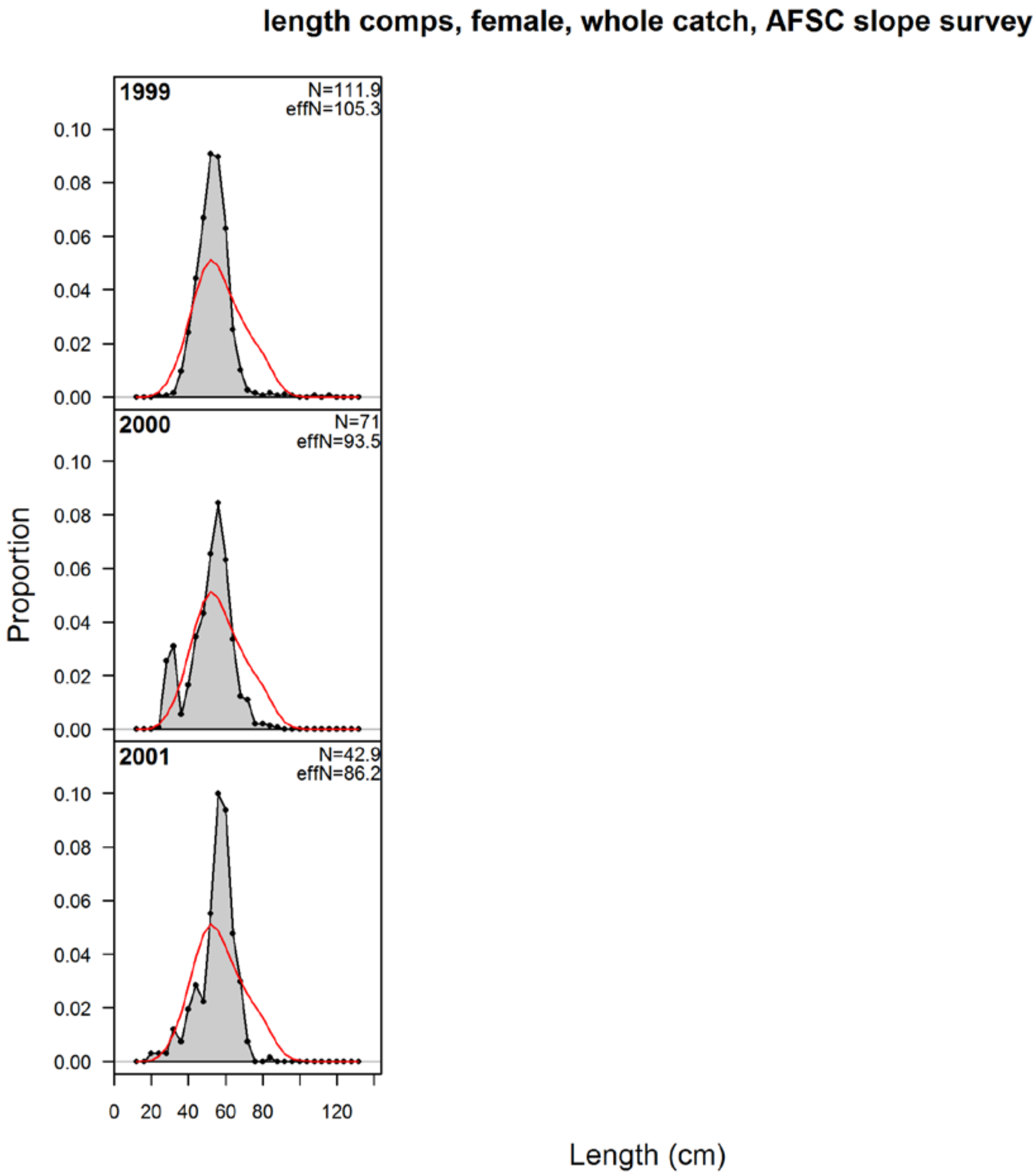

Figure 83. Fit to female length-frequency distributions of spiny dogfish for the AFSC slope survey.

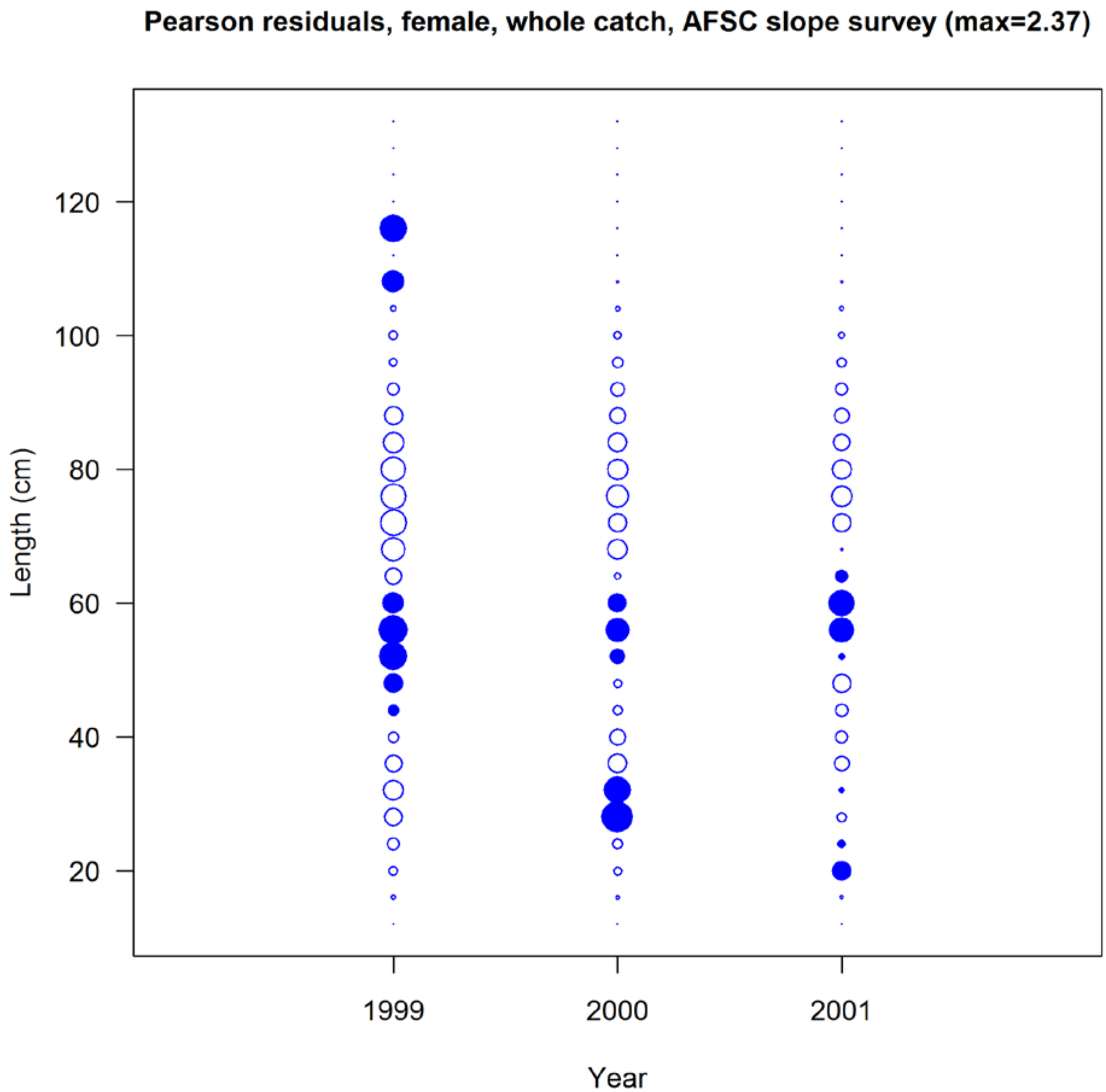

Figure 84. Pearson residuals for the fit of the female length-frequency distributions for the AFSC slope survey.

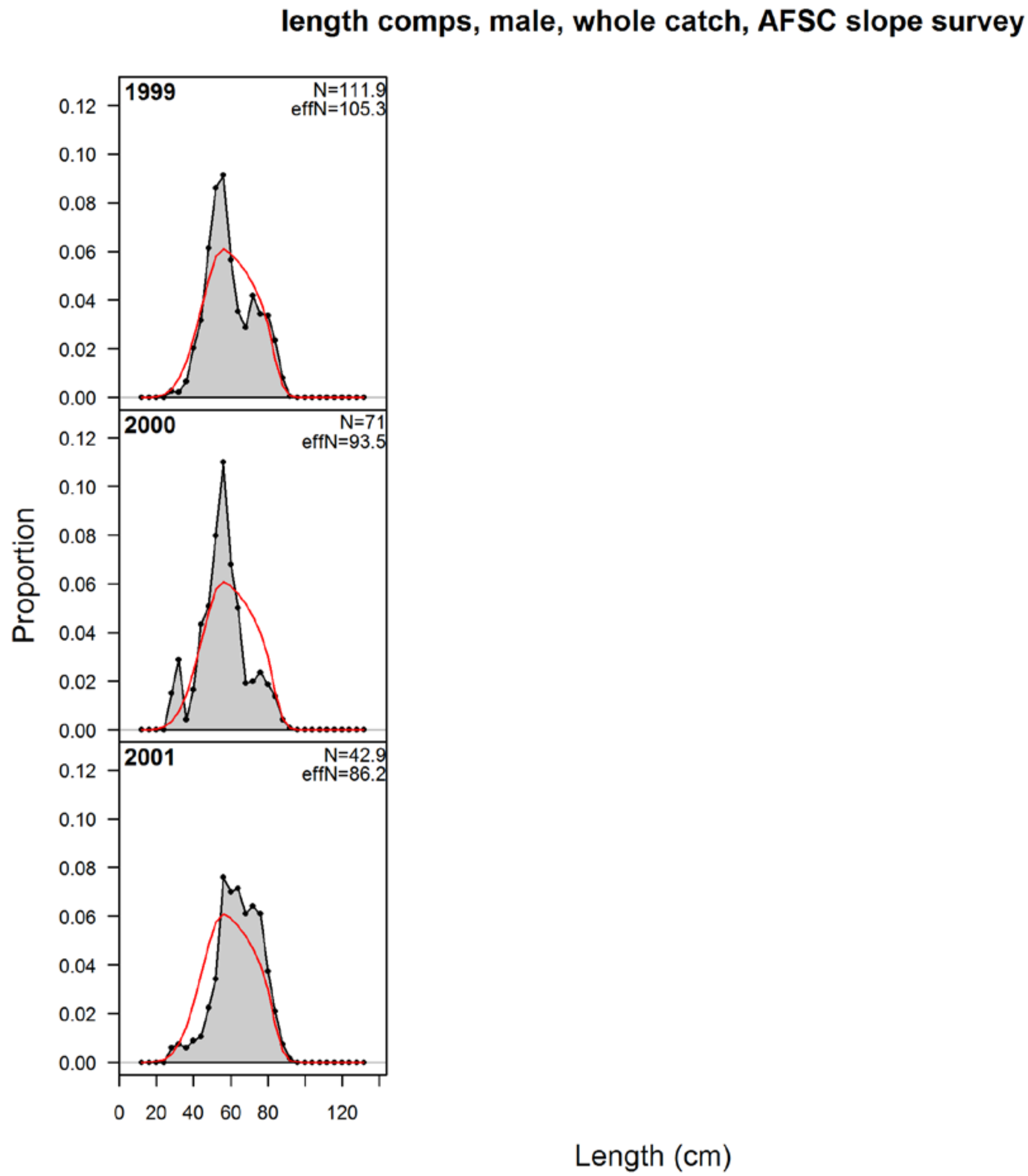

Figure 85. Fit to male length-frequency distributions of spiny dogfish for the AFSC slope survey.

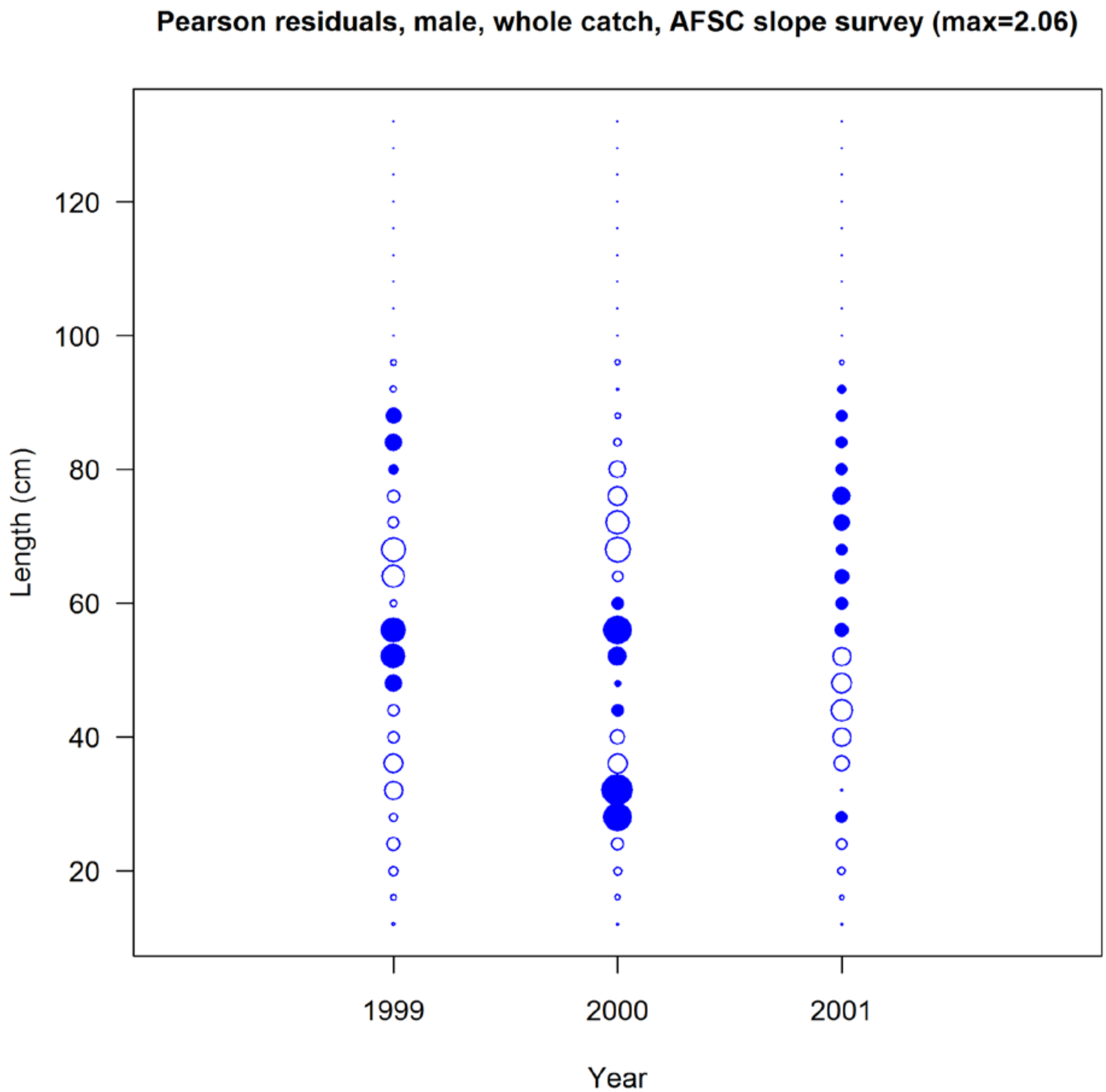

Figure 86. Pearson residuals for the fit of the male length-frequency distributions for the AFSC slope survey.

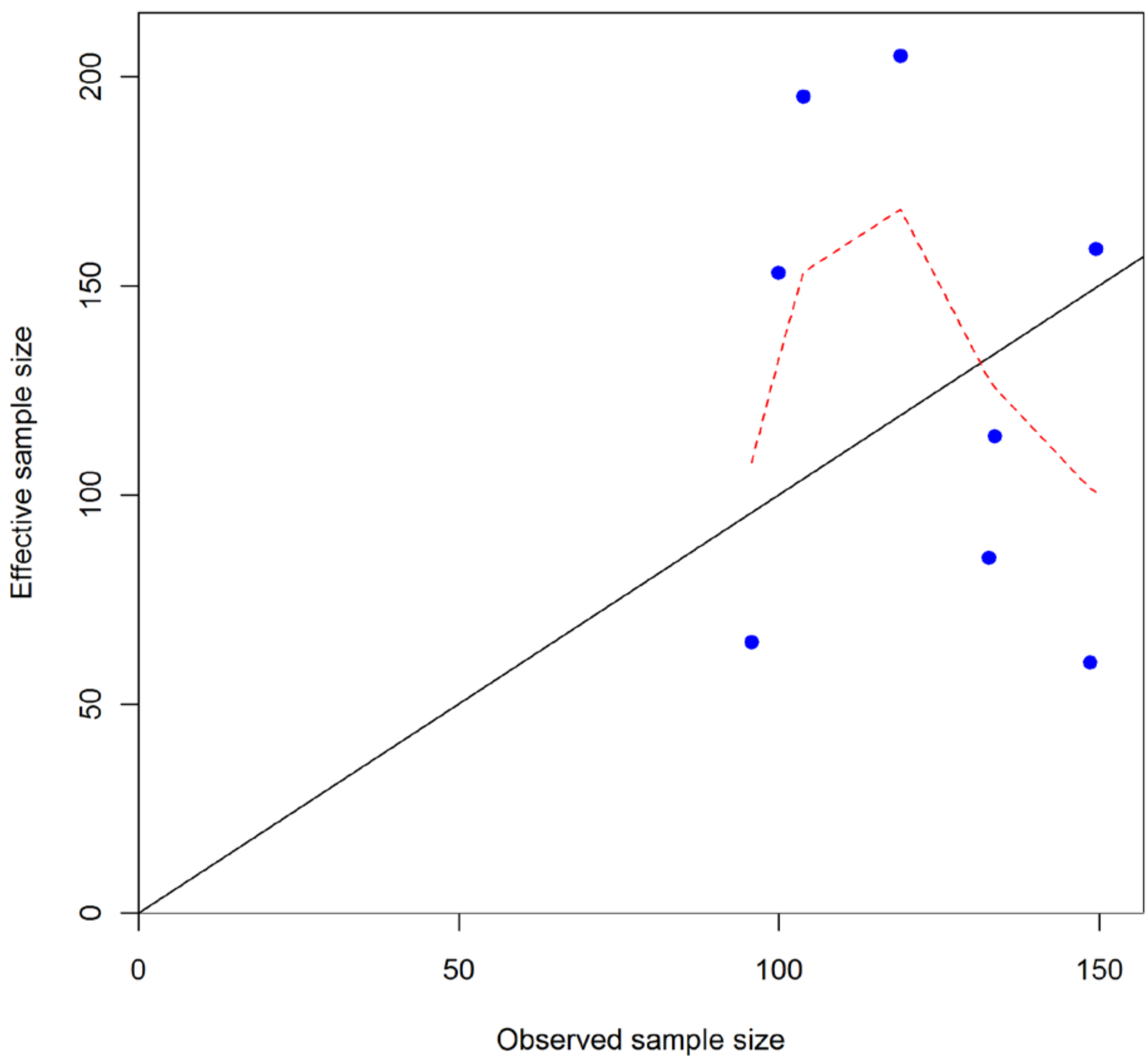

Figure 87. Observed and effective sample sizes for the sex-specific NWFSC shelf-slope survey length-frequency observations.

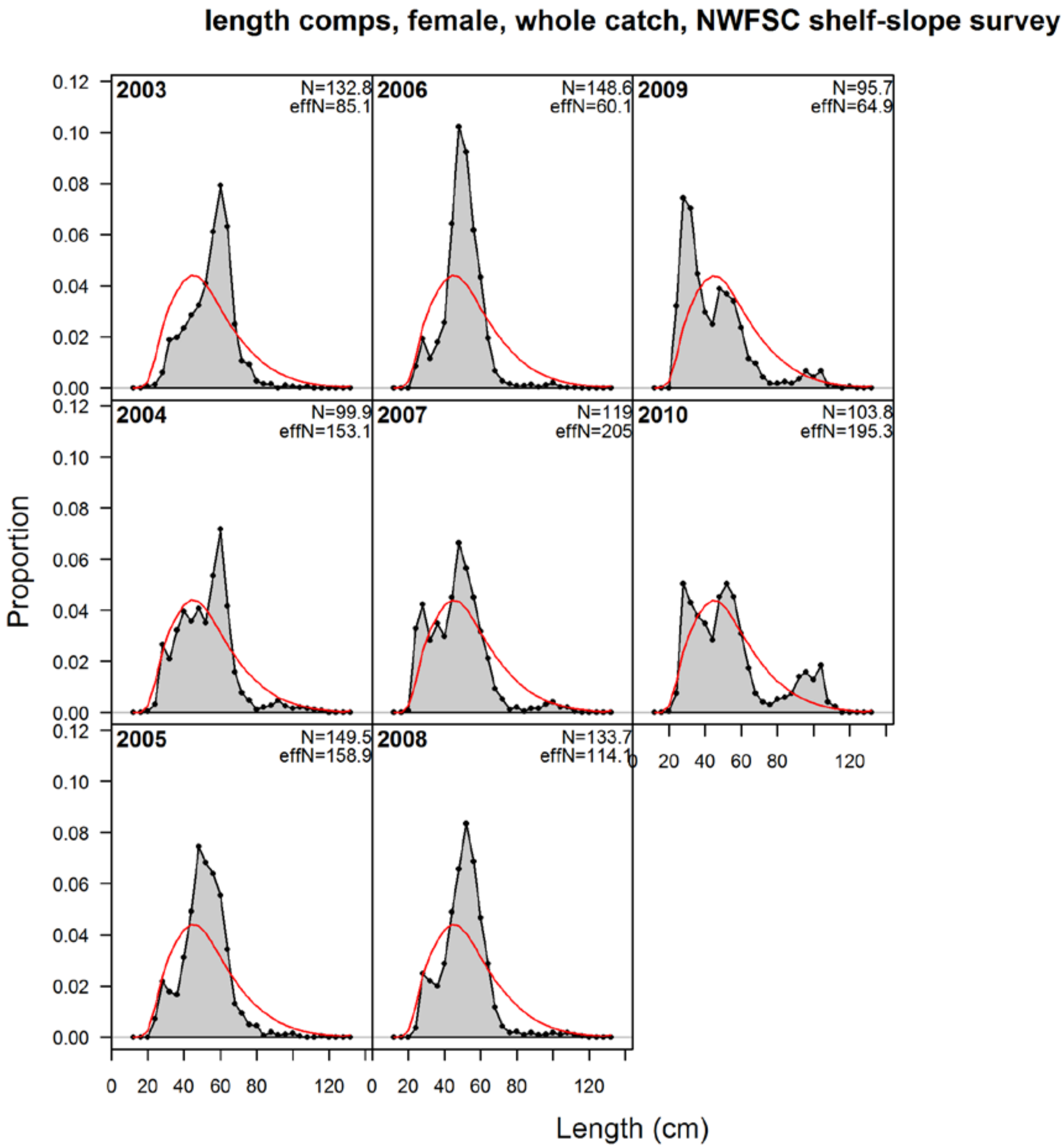

Figure 88. Fit to female length-frequency distributions of spiny dogfish for the NWFSC shelf-slope survey.

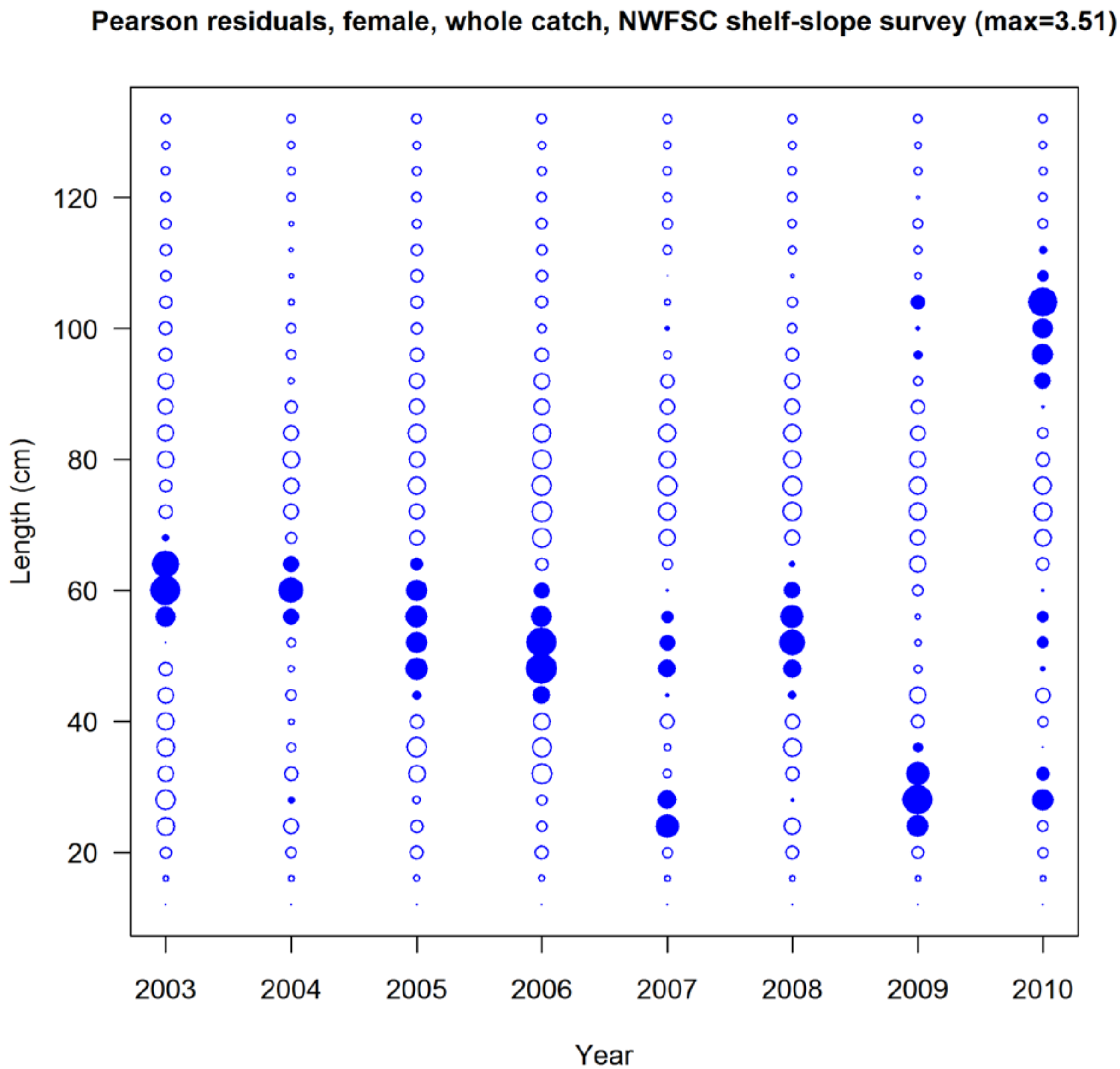

Figure 89. Pearson residuals for the fit of the female length-frequency distributions for the NWFSC shelf-slope survey.

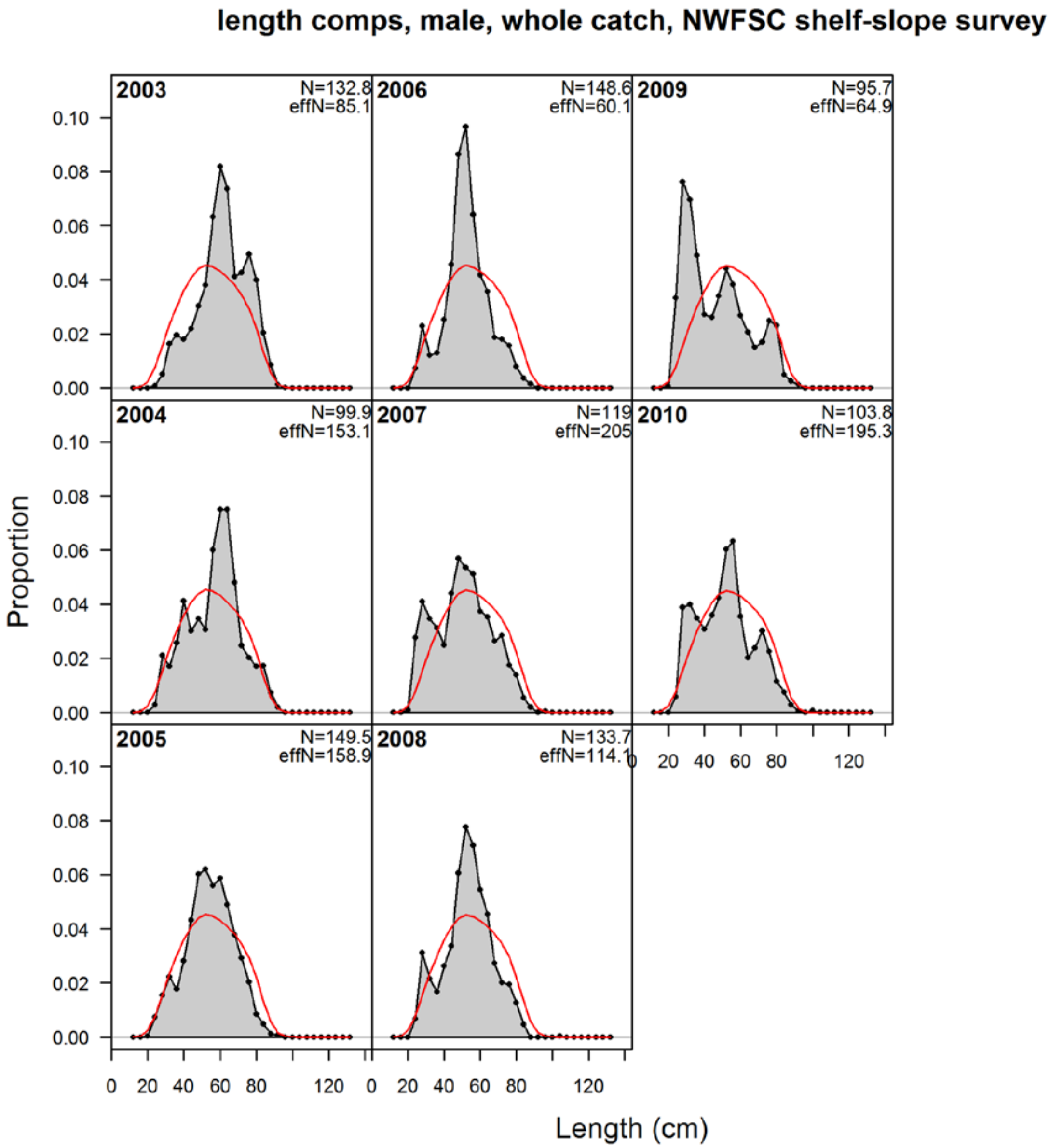

Figure 90. Fit to male length-frequency distributions of spiny dogfish for the NWFSC shelf-slope survey.

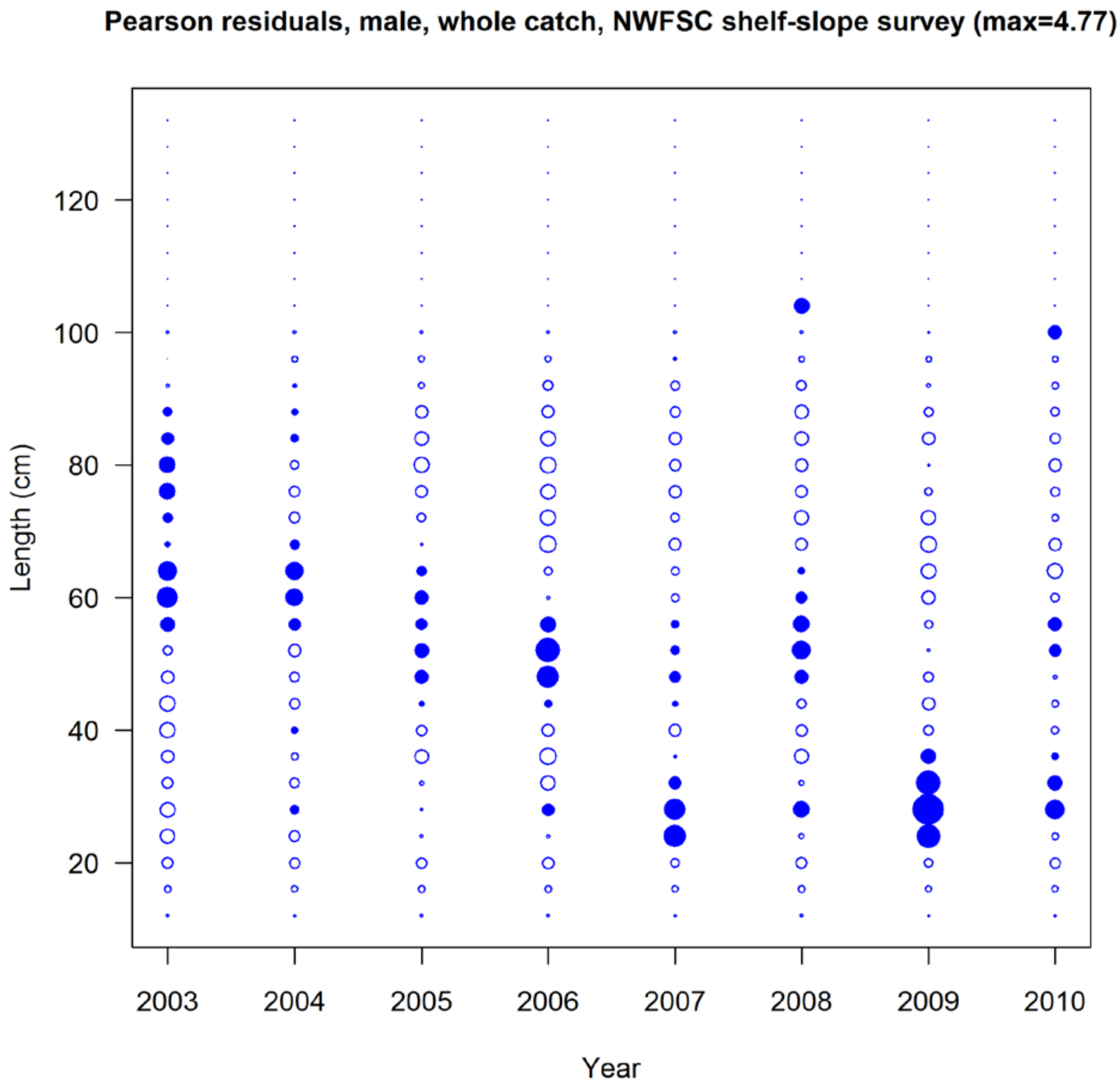

Figure 91. Pearson residuals for the fit of the male length-frequency distributions for the NWFSC shelf-slope survey.

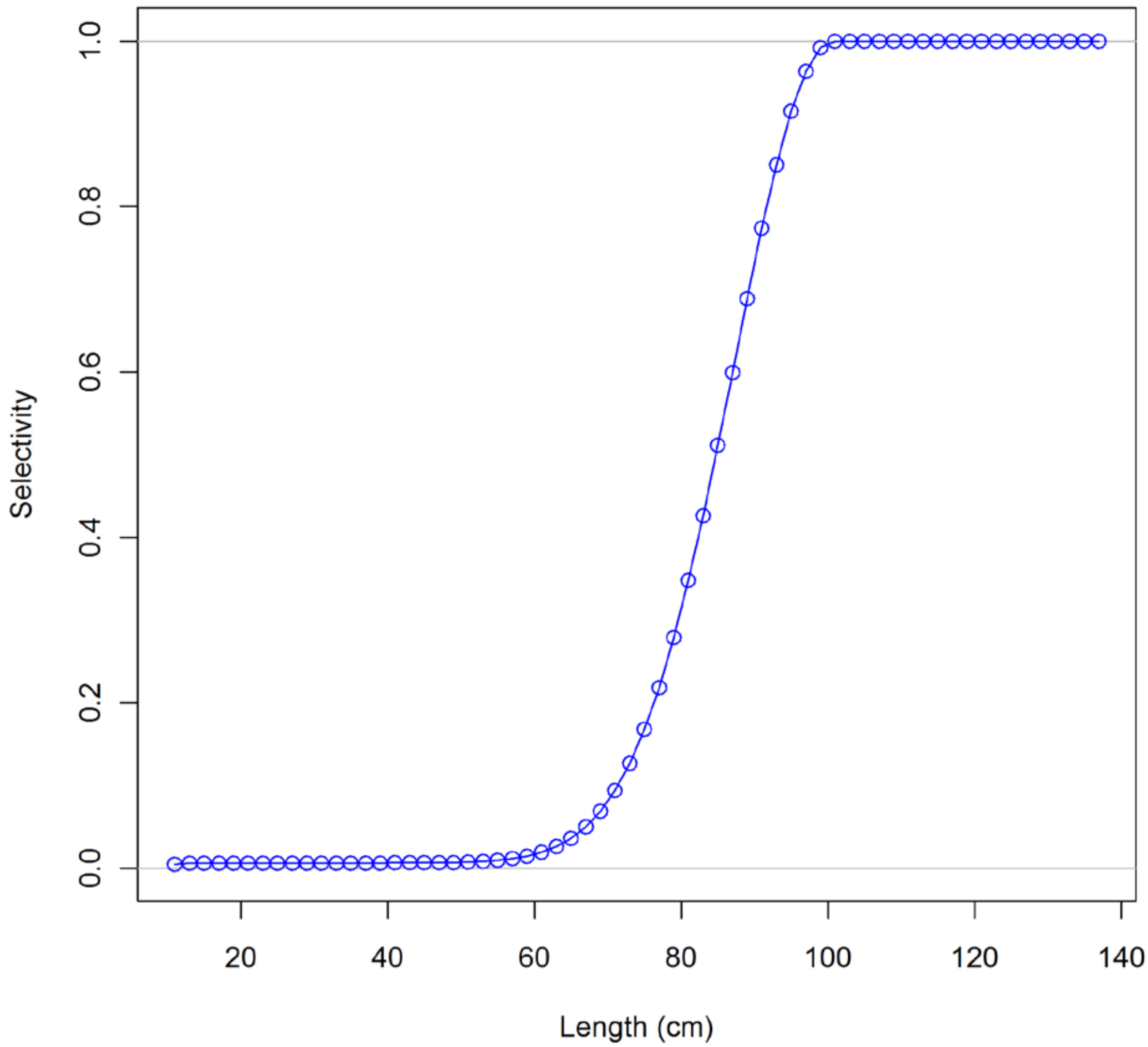

Figure 92. Length-based selectivity curve estimated for the bottom trawl fleet.

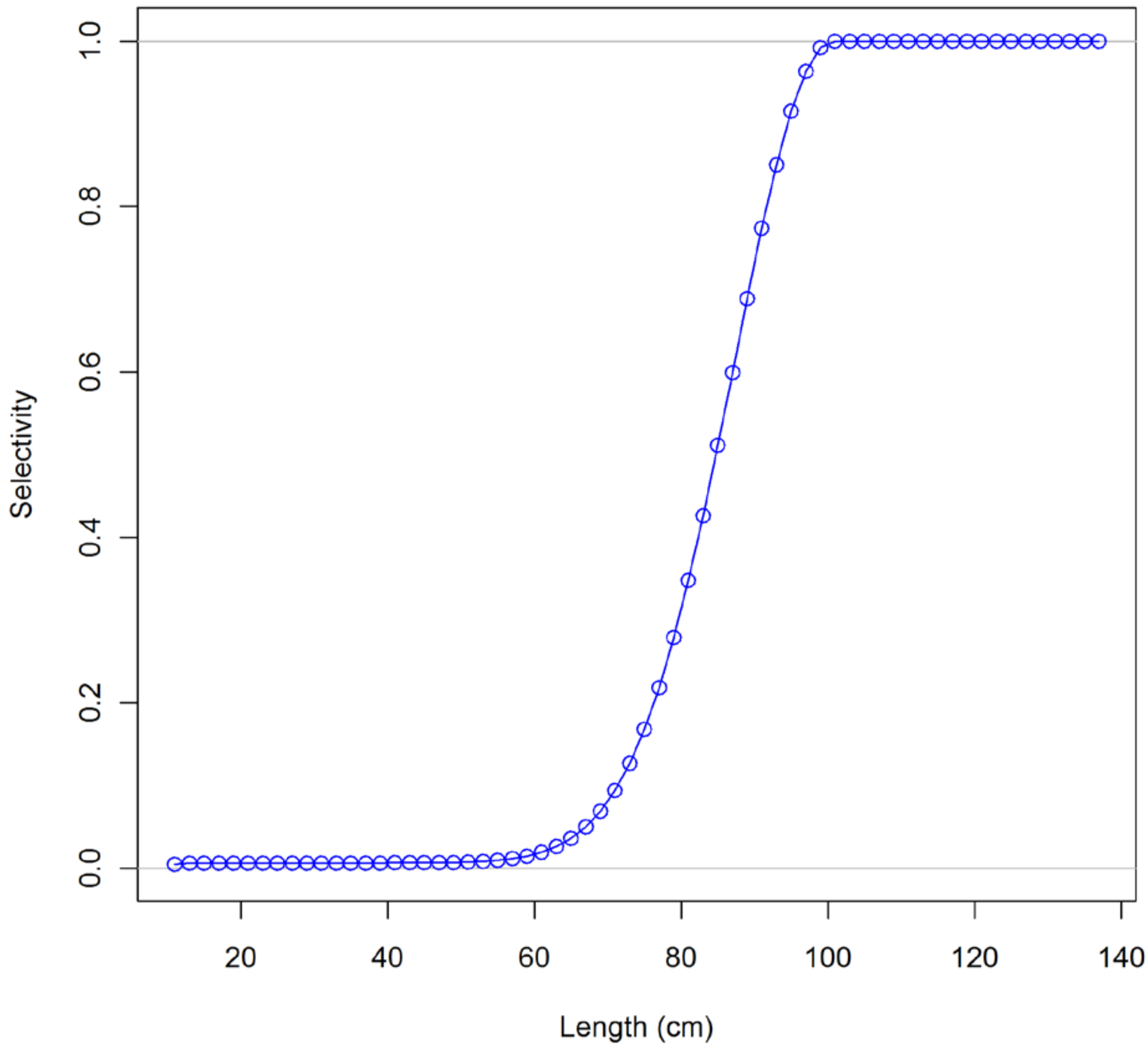

Figure 93. Length-based selectivity curve estimated for the bottom trawl discard fleet.

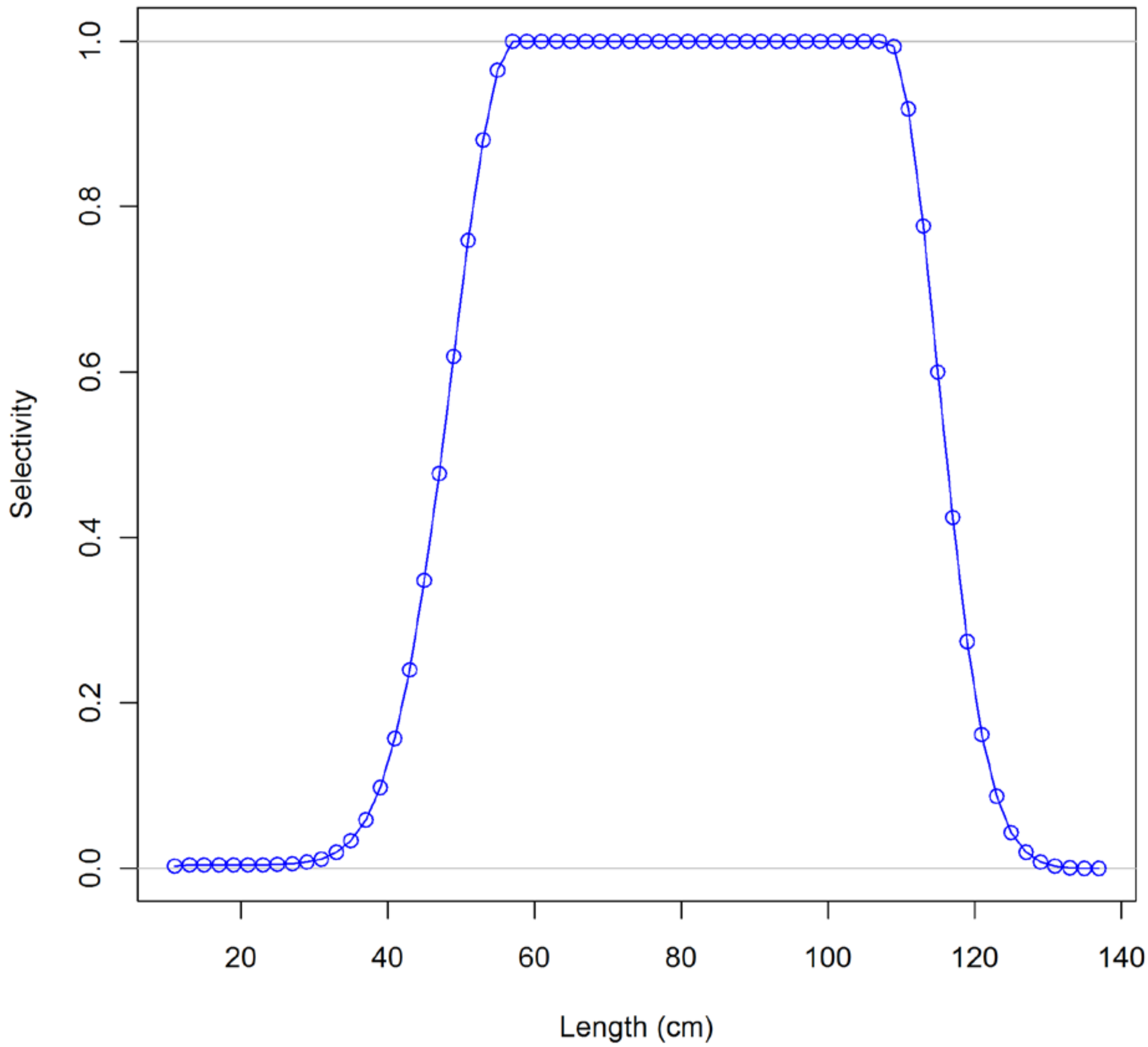

Figure 94. Length-based selectivity curve estimated for the midwater trawl fleet.

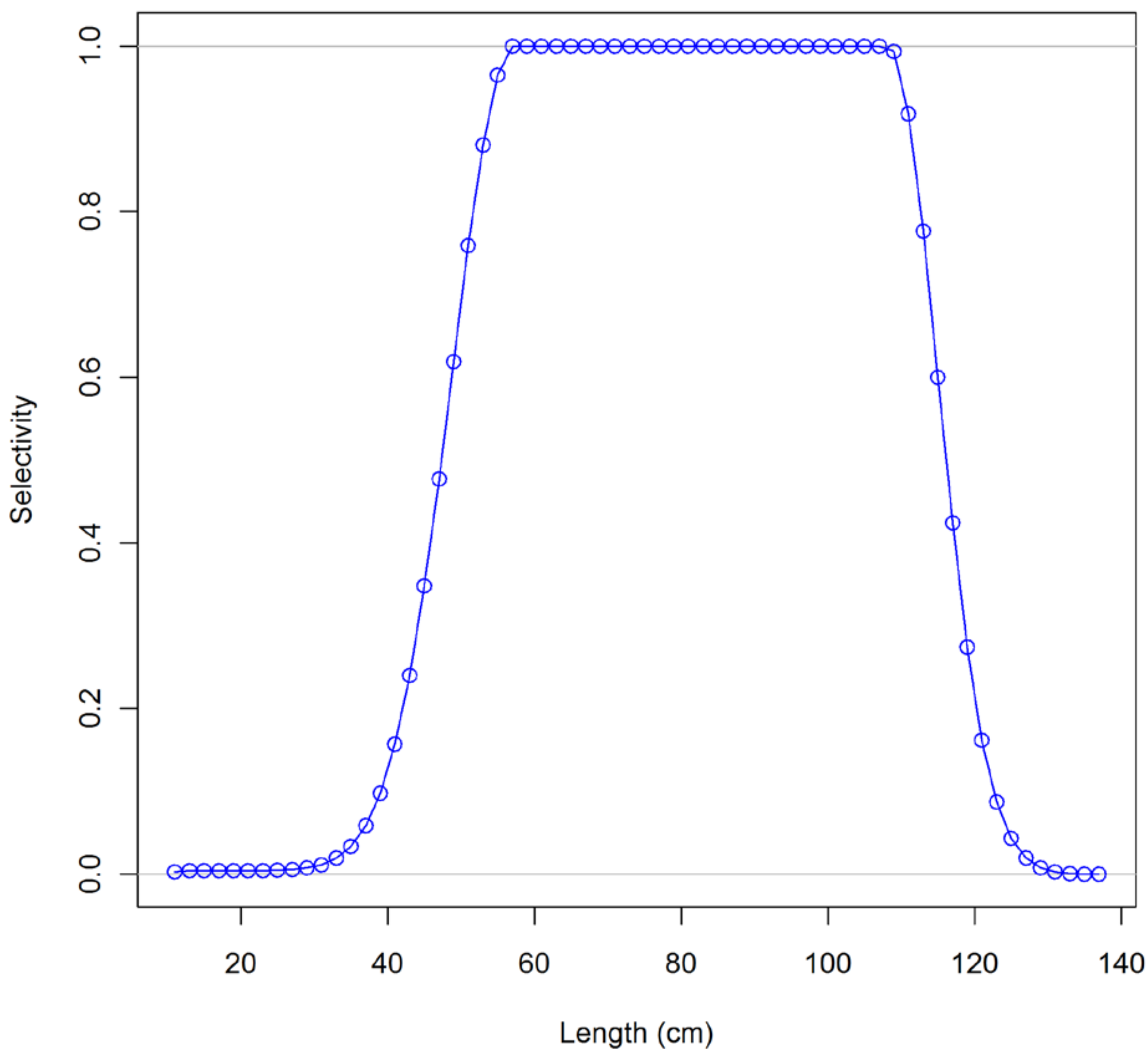

Figure 95. Length-based selectivity curve estimated for the at-sea hake bycatch fleet (mirrored to midwater trawl fleet).

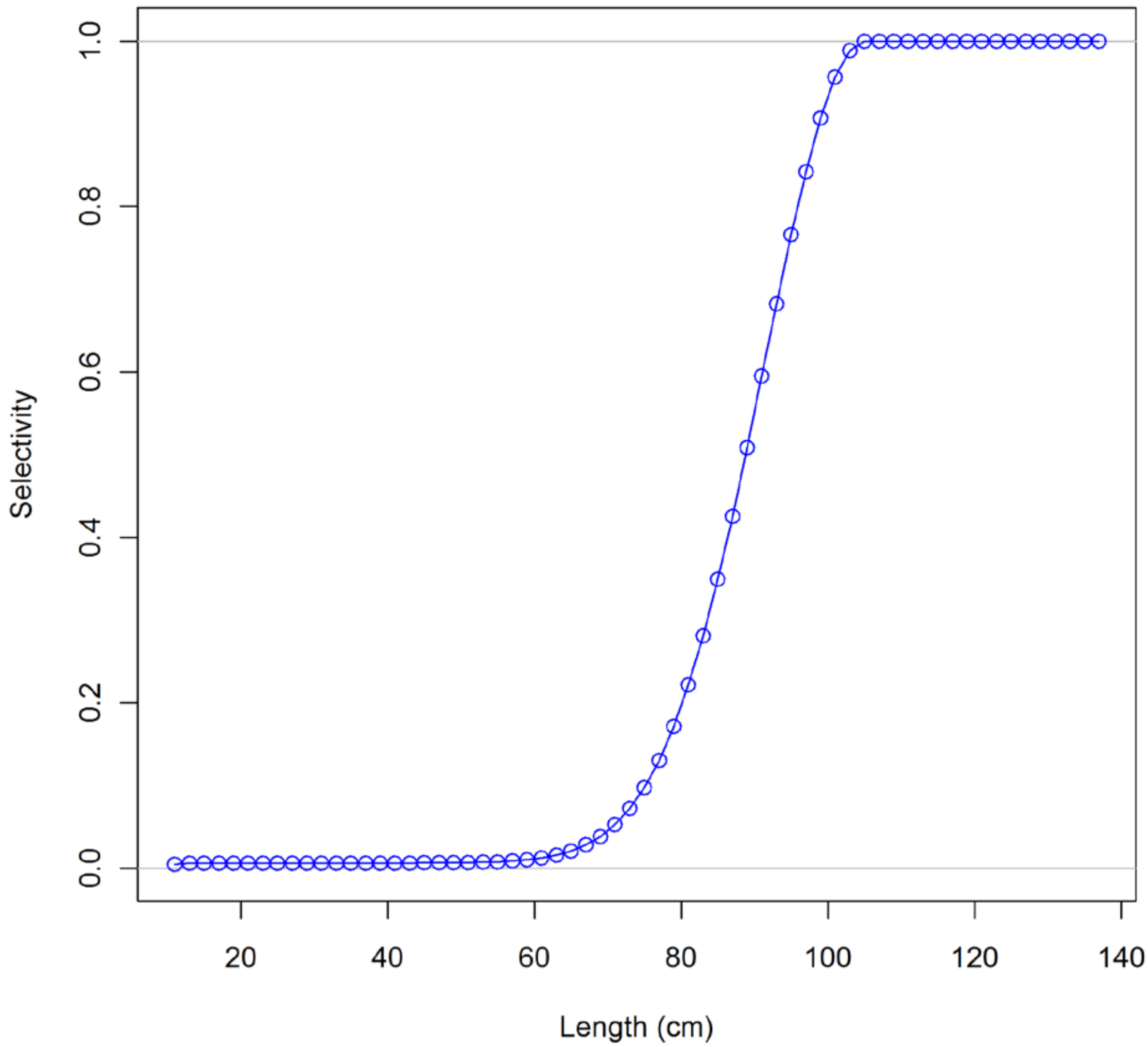

Figure 96. Length-based selectivity curve estimated for the hook-and-line fleet.

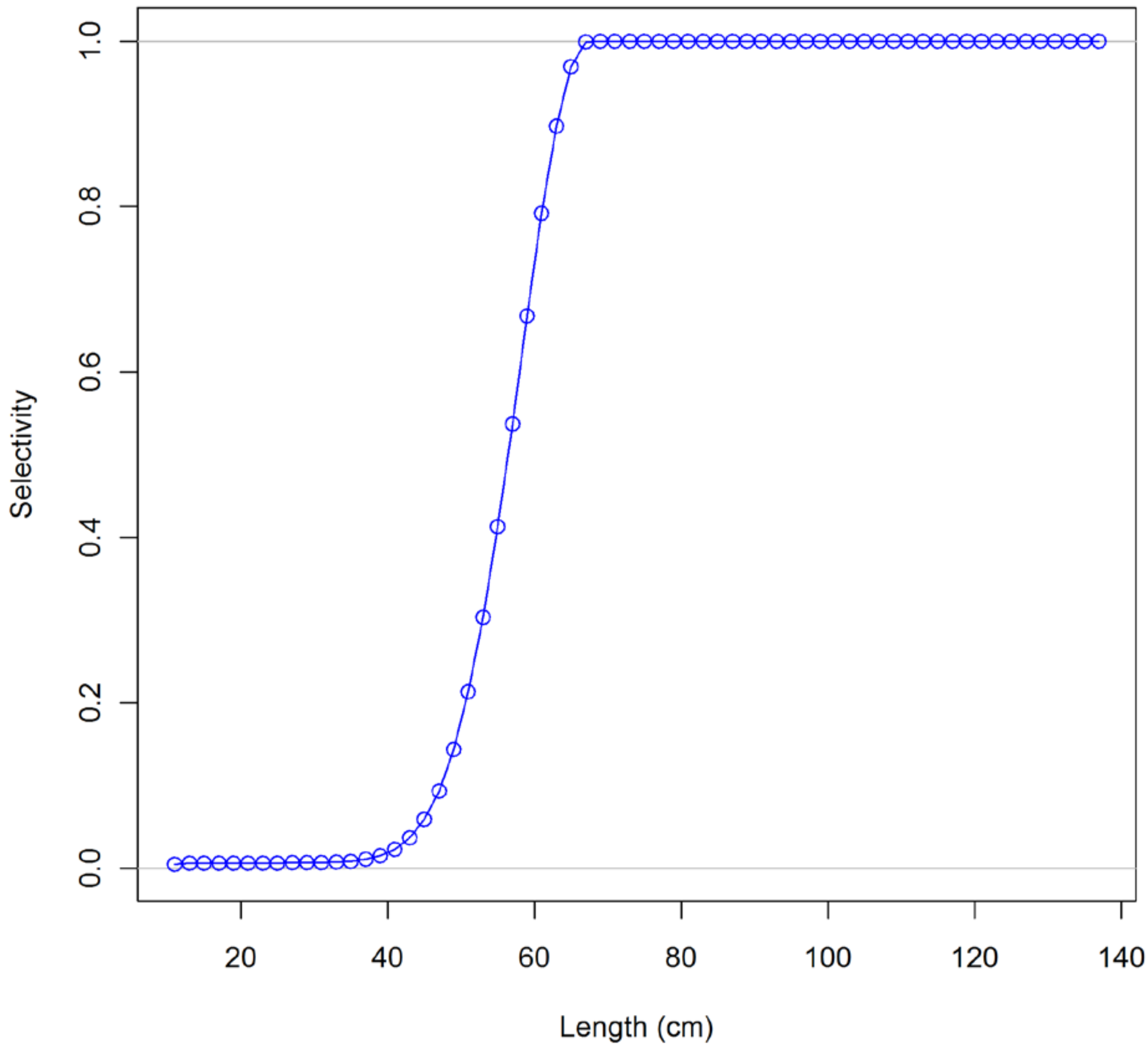

Figure 97. Length-based selectivity curve estimated for the hook-and-line discard fleet.

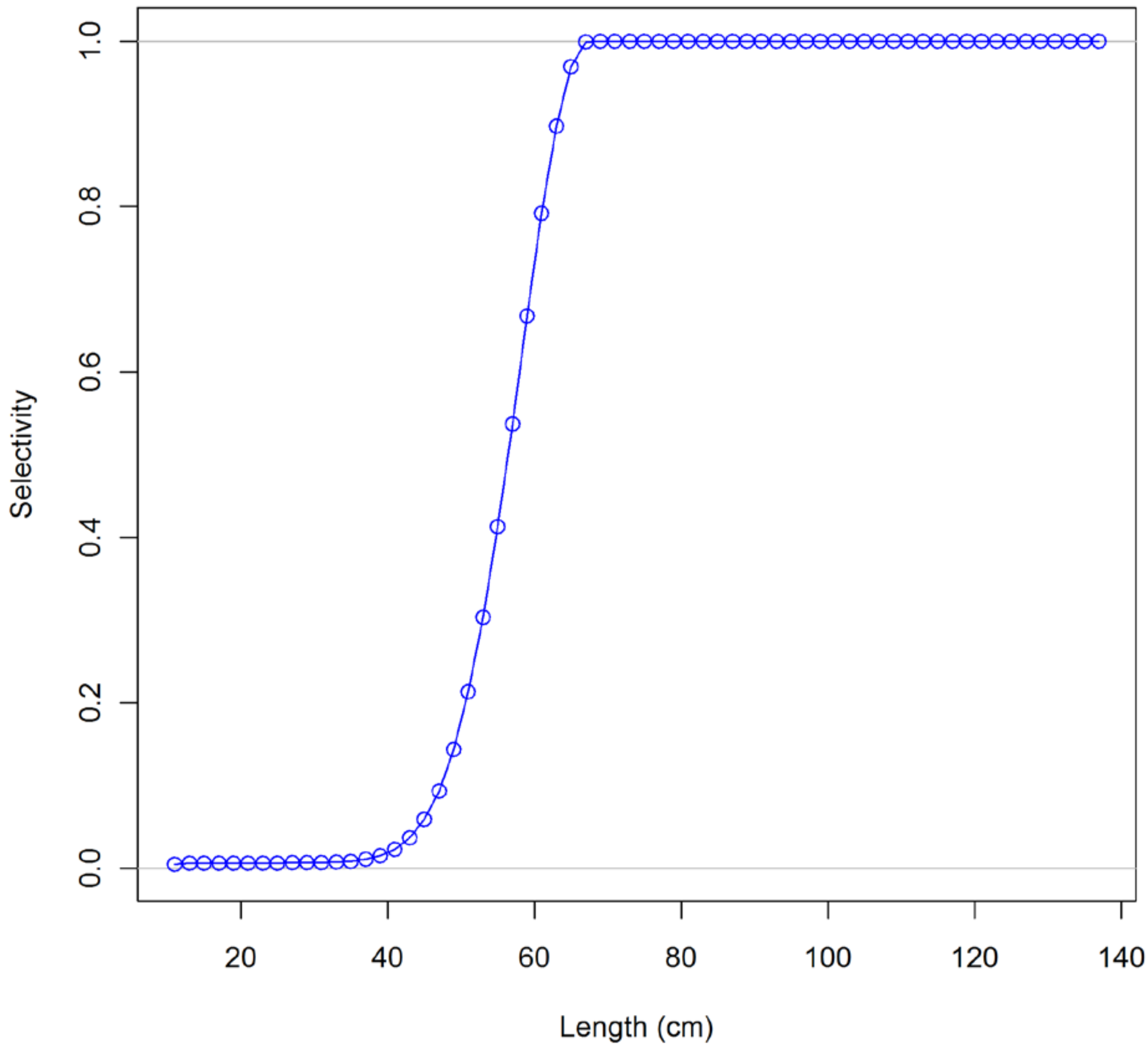

Figure 98. Length-based selectivity curve estimated for the other gears fleet (mirrored to the hook-and-line fleet).

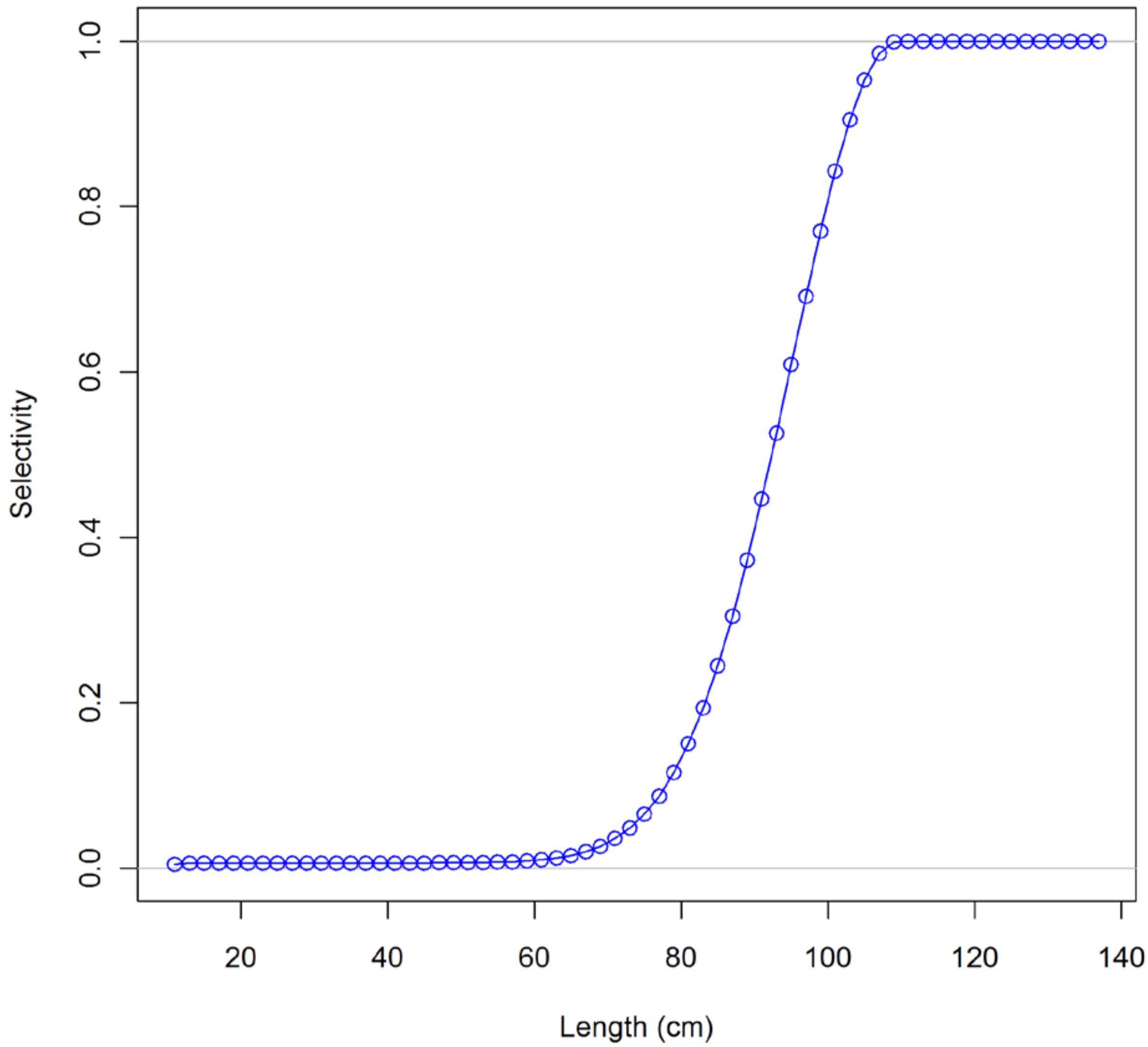

Figure 99. Length-based selectivity curve estimated for the recreational fleet.

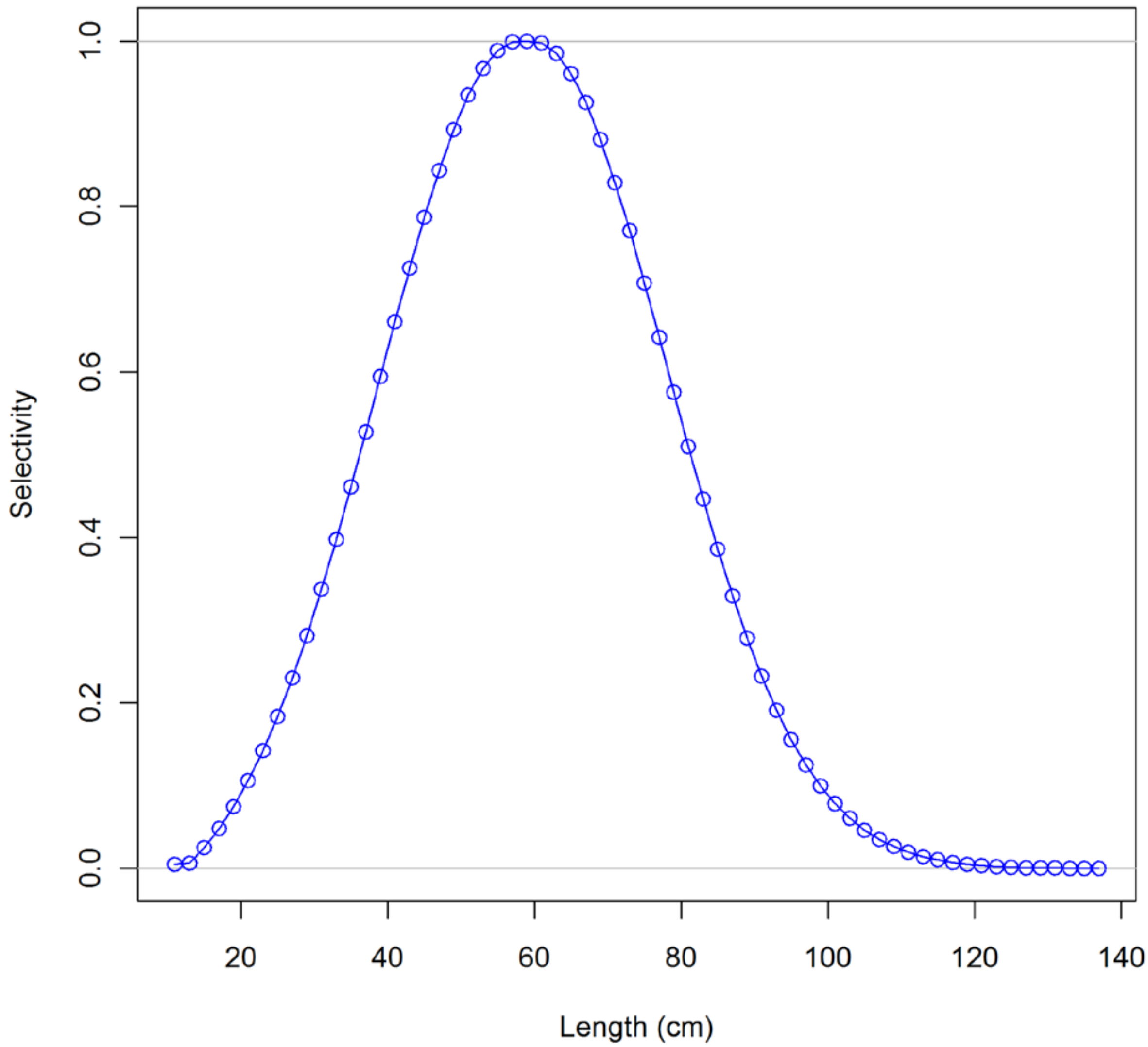

Figure 100. Length-based selectivity curve estimated for the AFSC triennial survey.

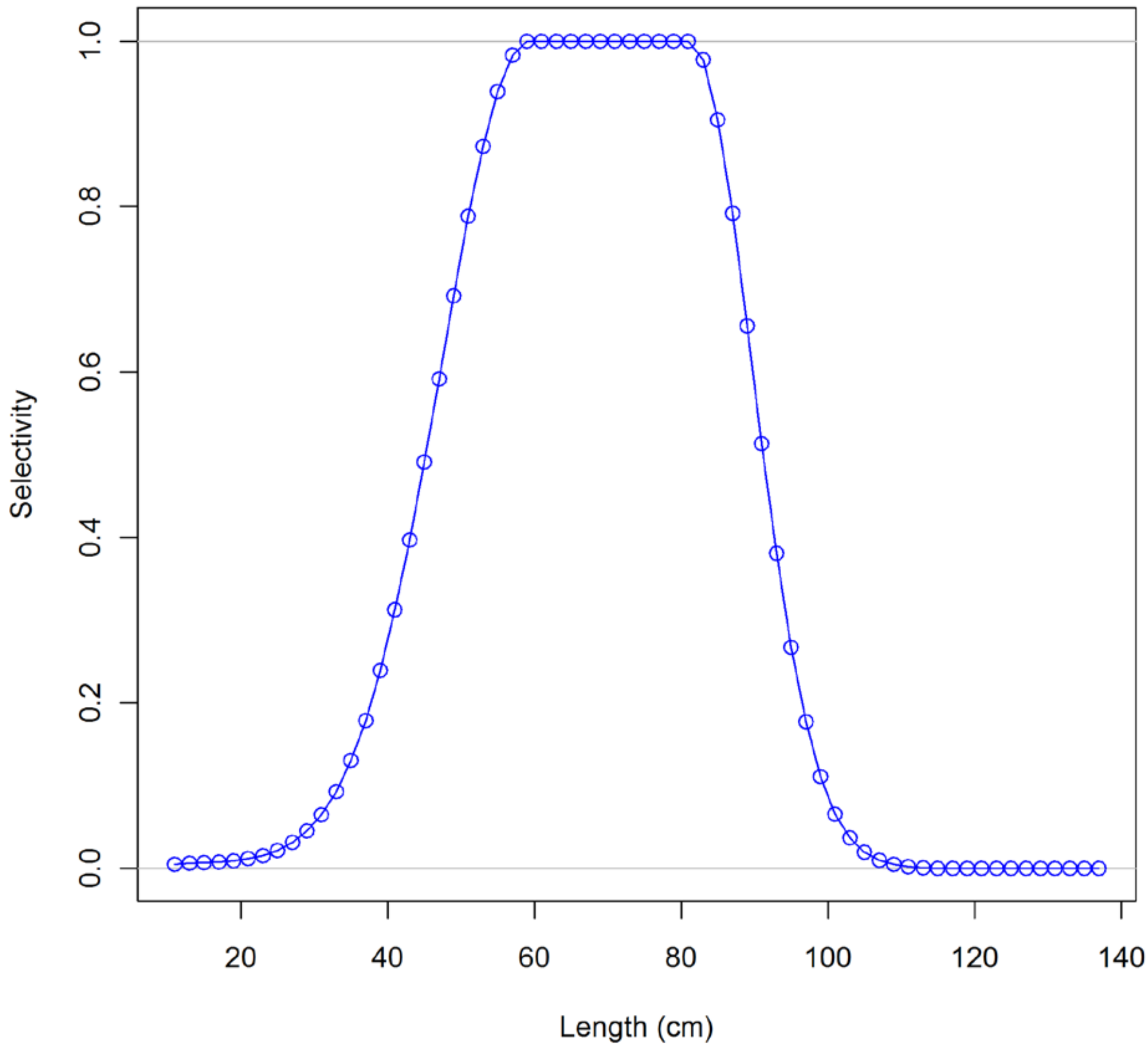

Figure 101. Length-based selectivity curve estimated for the AFSC slope survey.

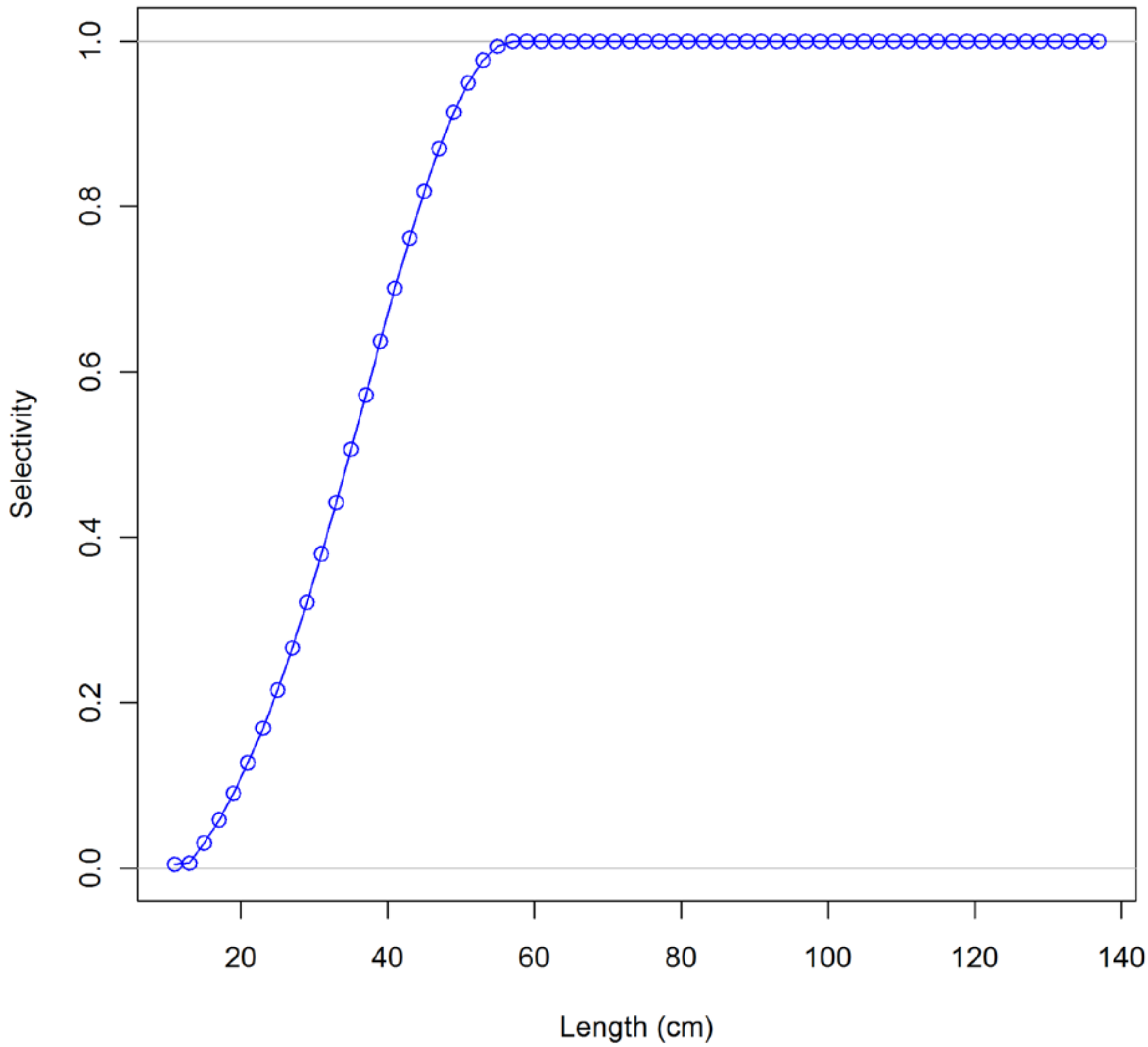

Figure 102. Length-based selectivity curve estimated for the NWFSC shelf-slope survey.

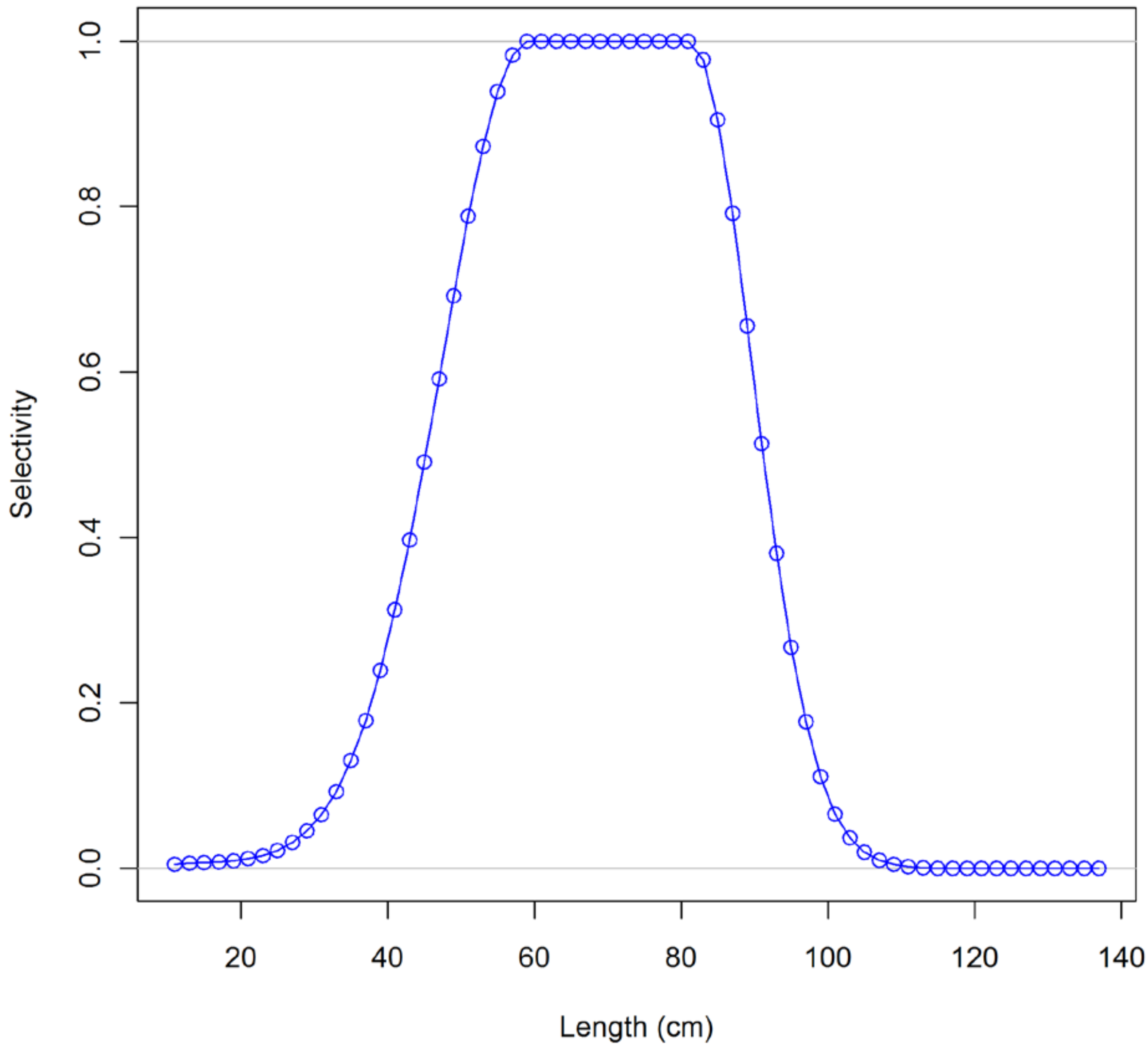

Figure 103. Length-based selectivity curve estimated for the NWFSC slope survey (mirrored to the AFSC slope survey).

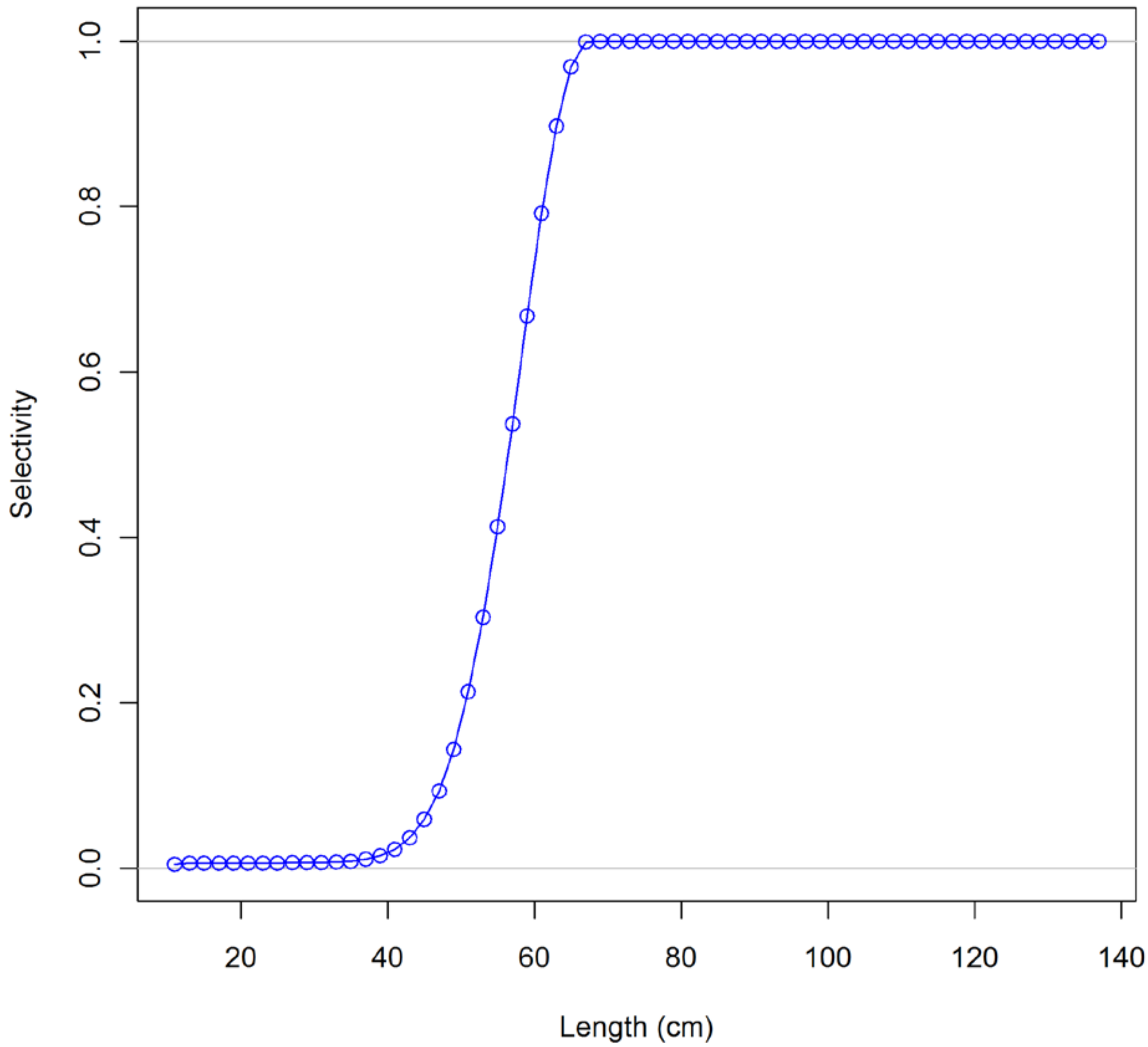

Figure 104. Length-based selectivity curve estimated for the IHPC survey (mirrored to the hook-and-line fleet).

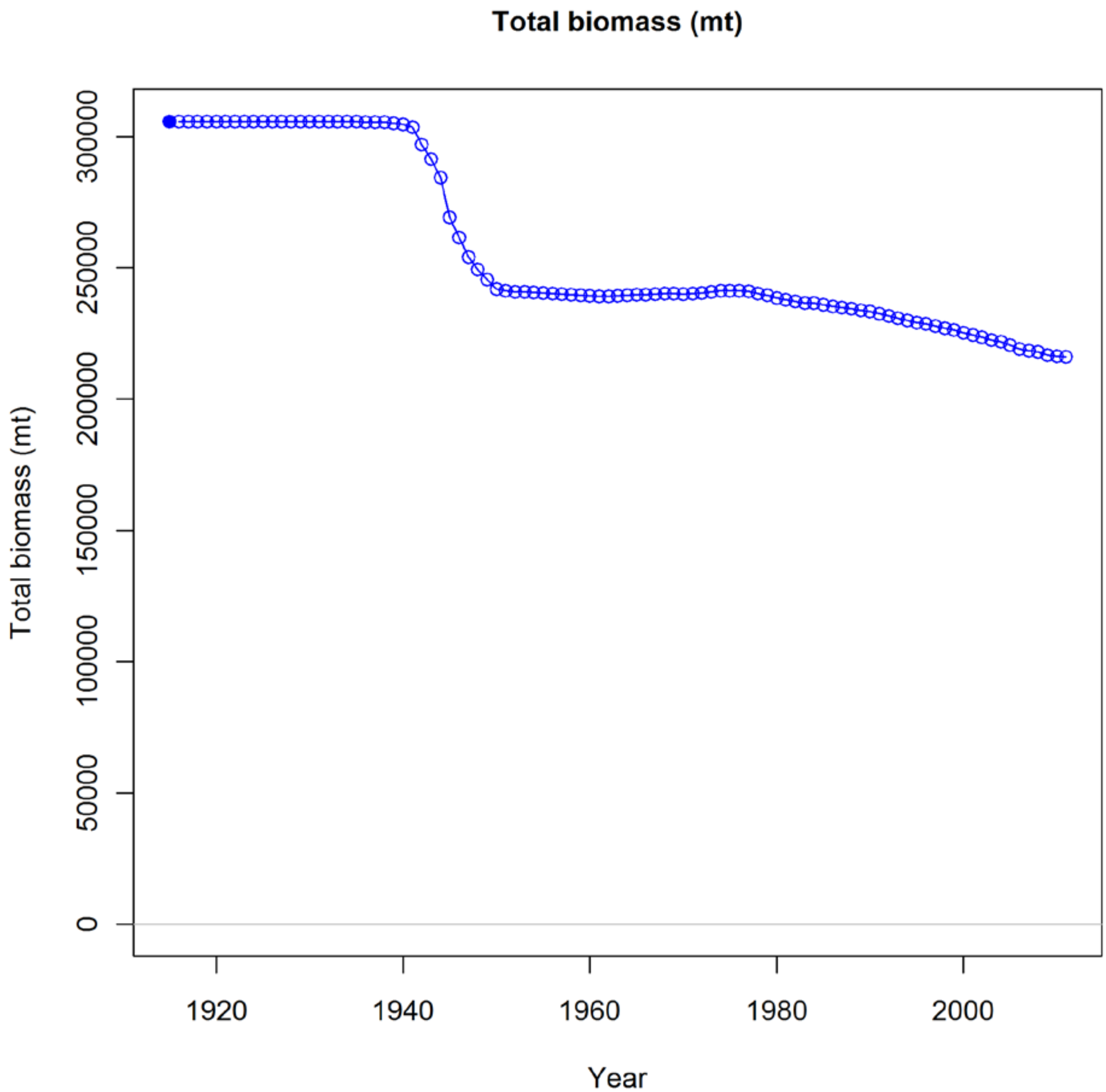

Figure 105. Time series of total biomass of spiny dogfish estimated by the base model.

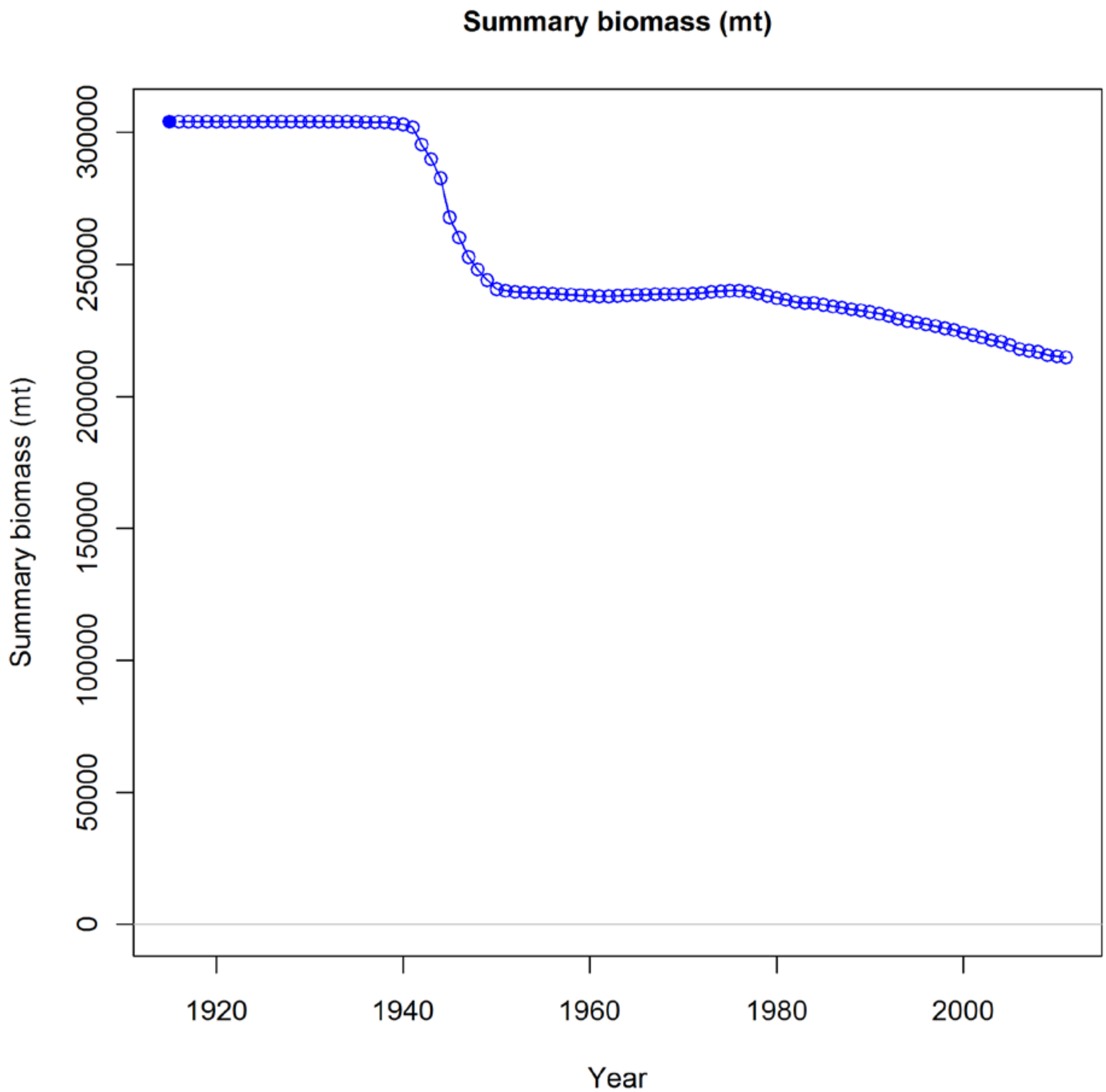

Figure 106. Time series of summary biomass of spiny dogfish estimated by the base model.

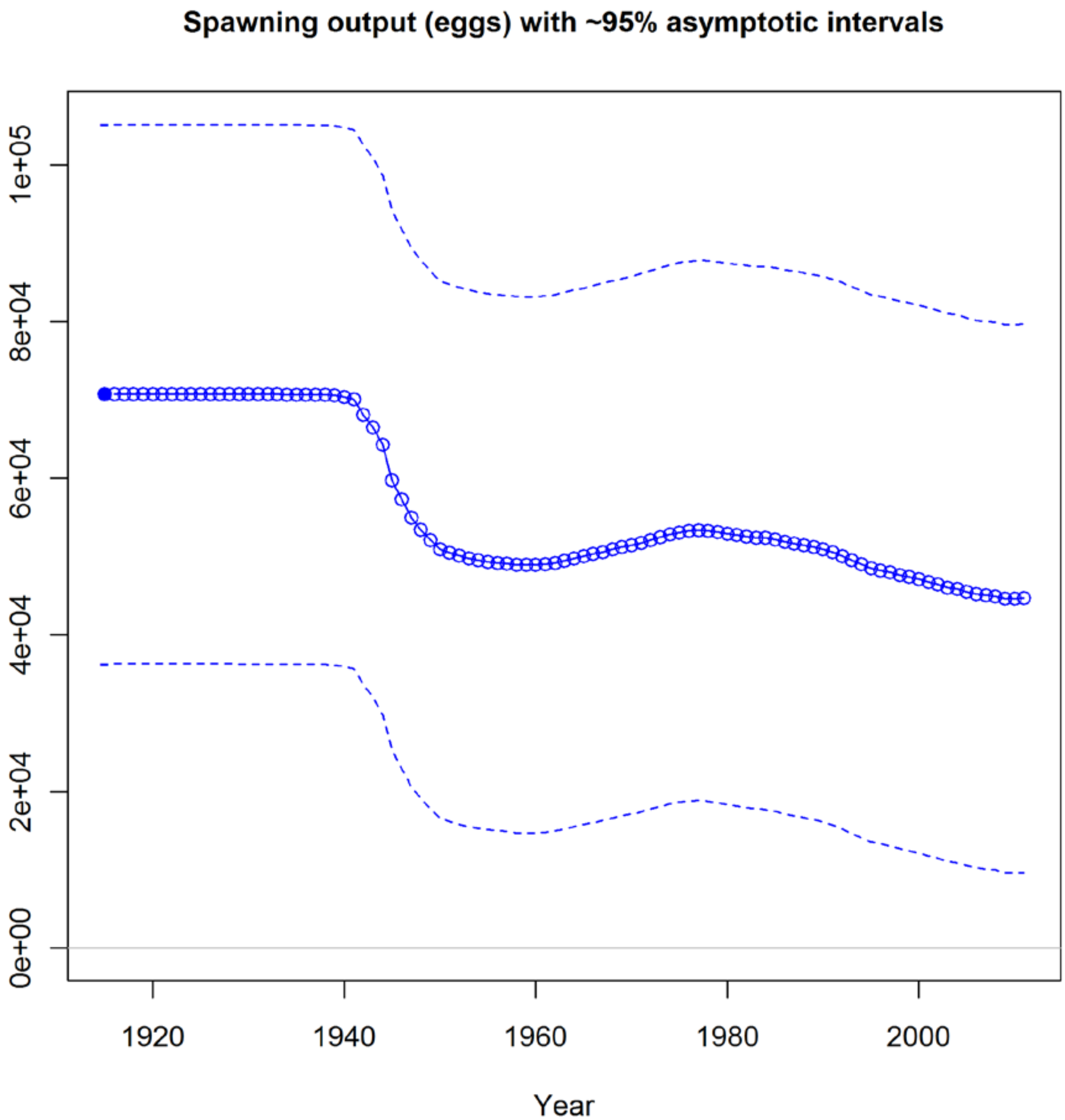

Figure 107. Time series of estimated spawning output of spiny dogfish with 95% confidence interval.

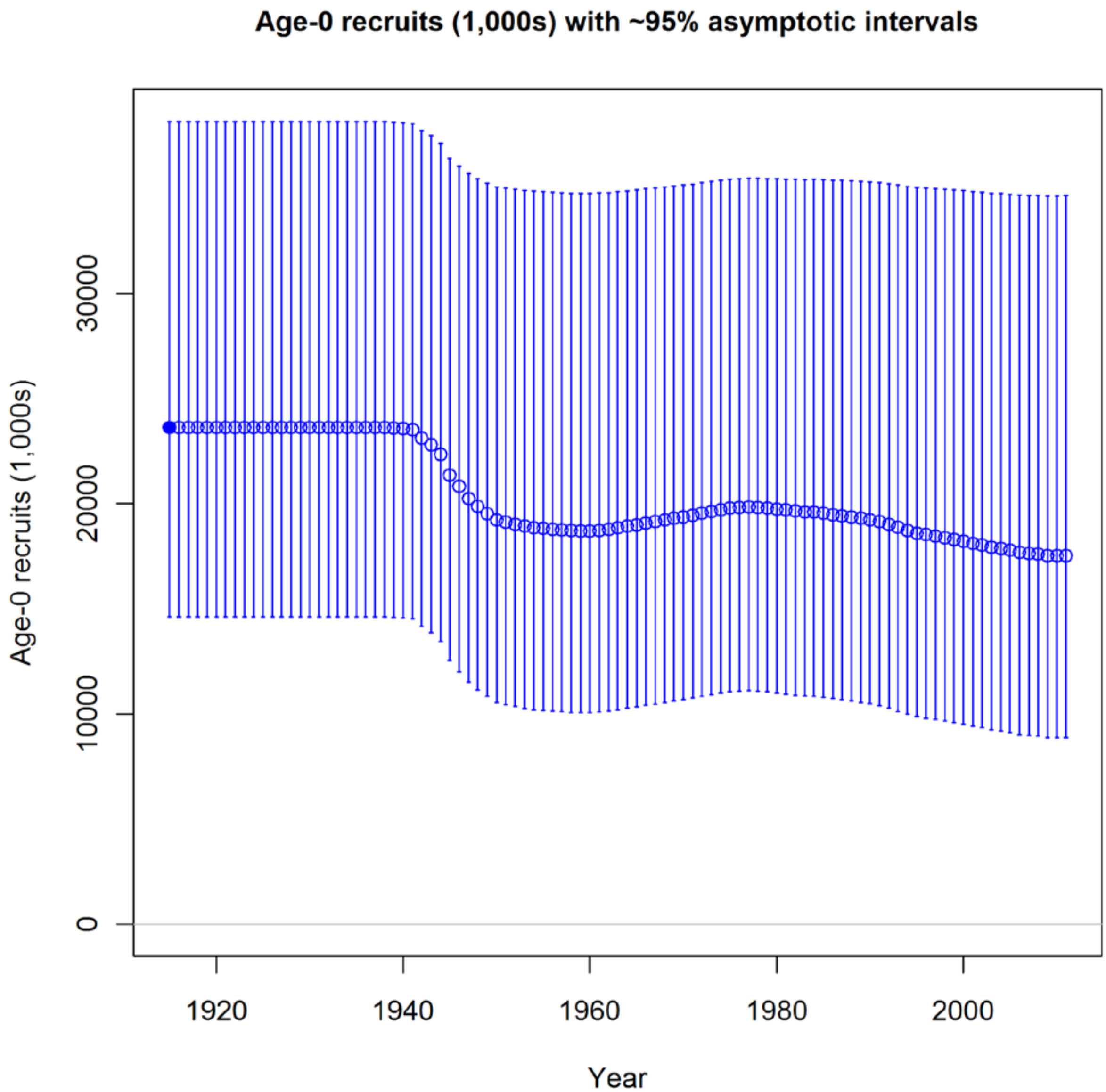

Figure 108. Time series of estimated recruitment of spiny dogfish with 95% confidence interval.

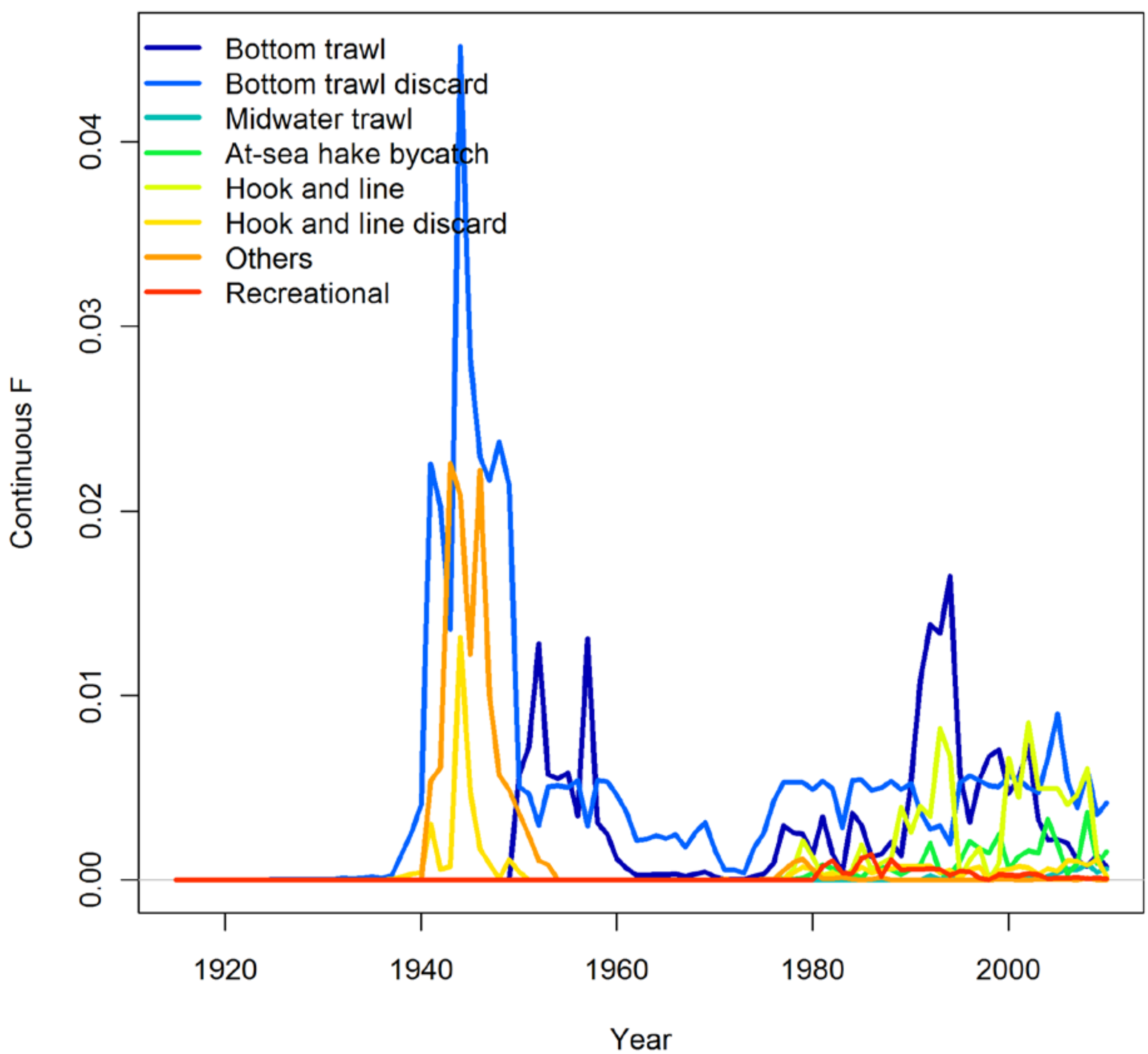

Figure 109. Time series of fishing mortality of spiny dogfish estimated by the base model.

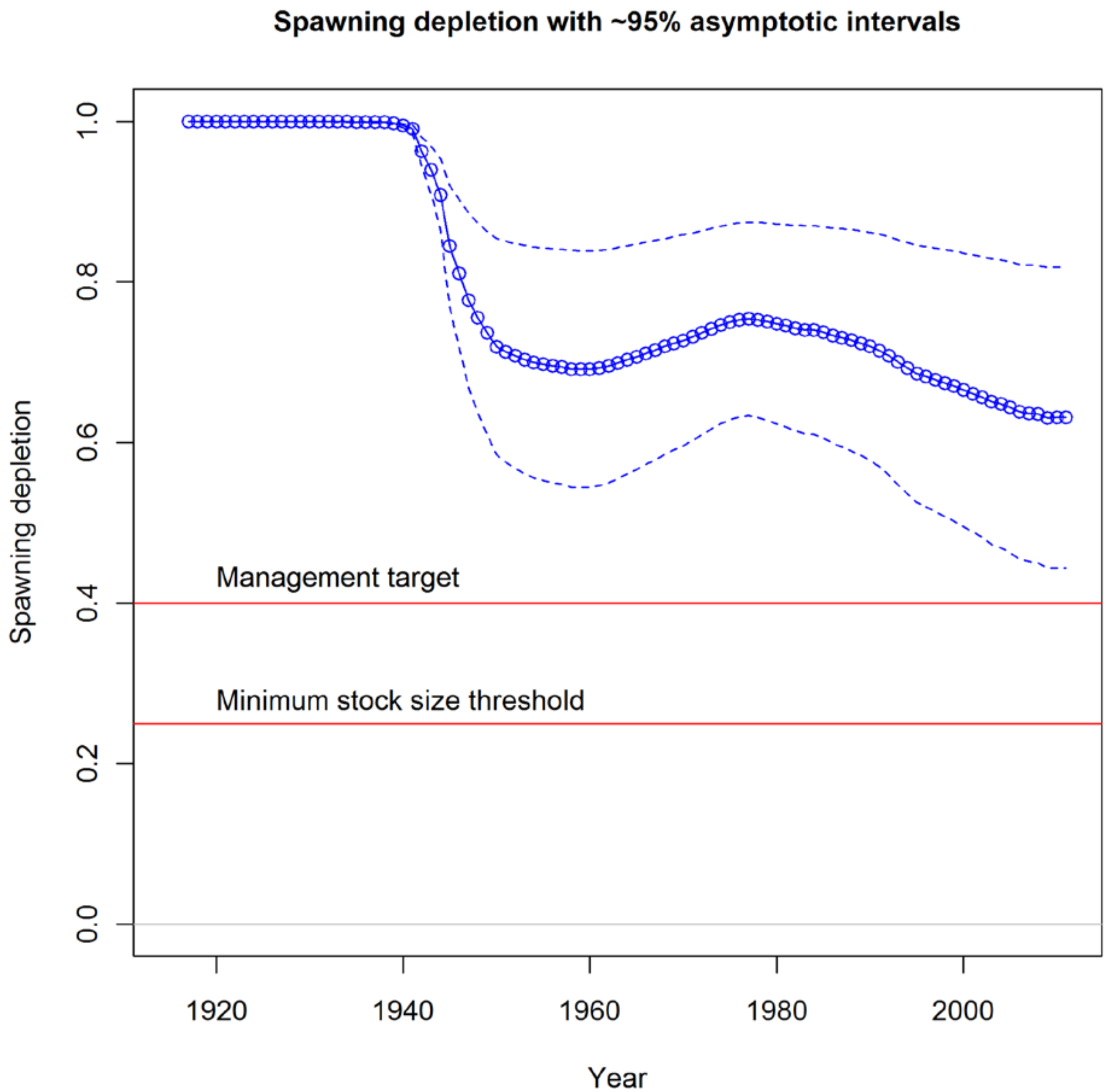

Figure 110. Time series of the estimated spawning depletion of spiny dogfish with 95% confidence interval.

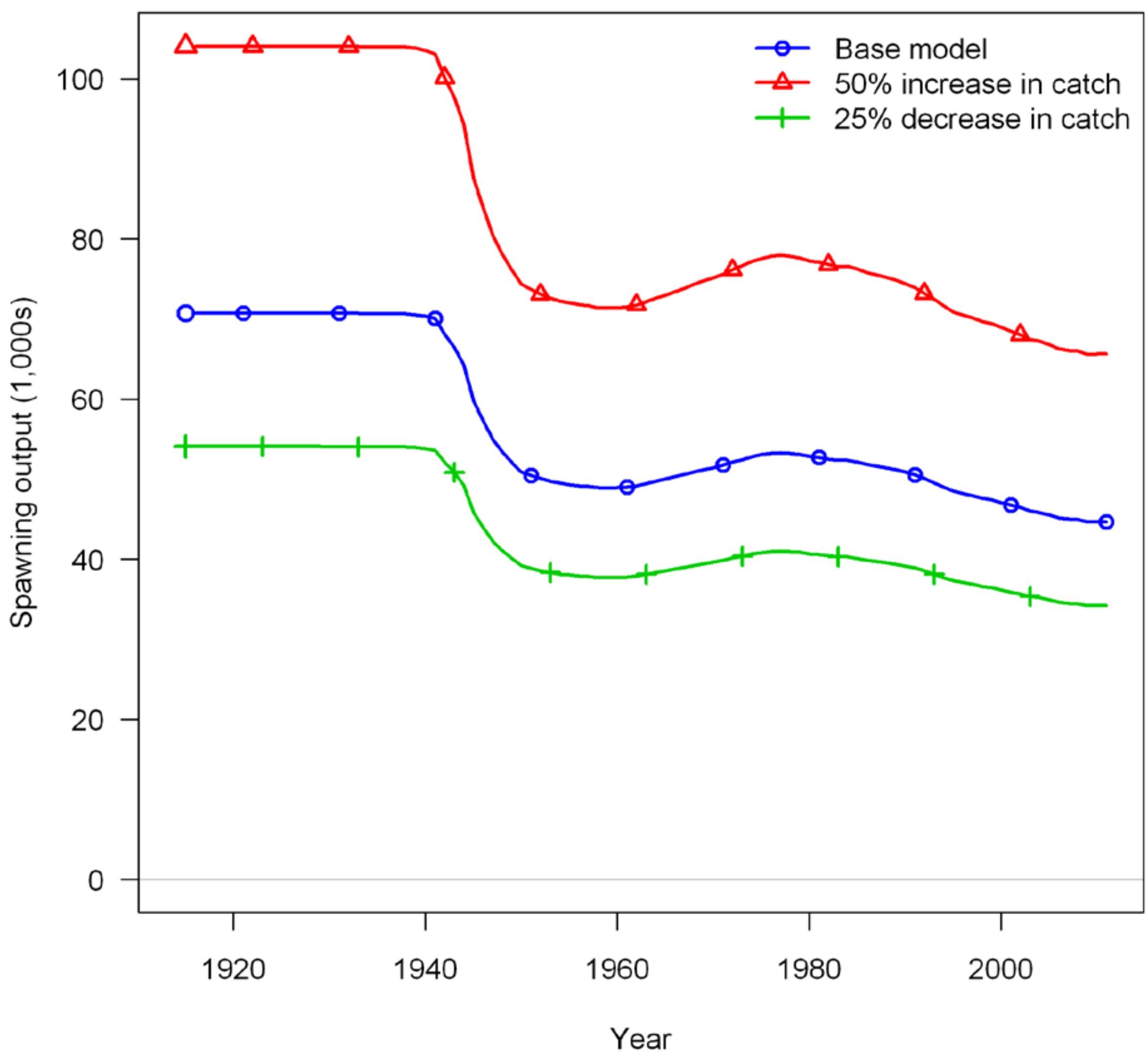

Figure 111. Sensitivity of spawning output time series to alternative assumptions regarding spiny dogfish fishery removals.

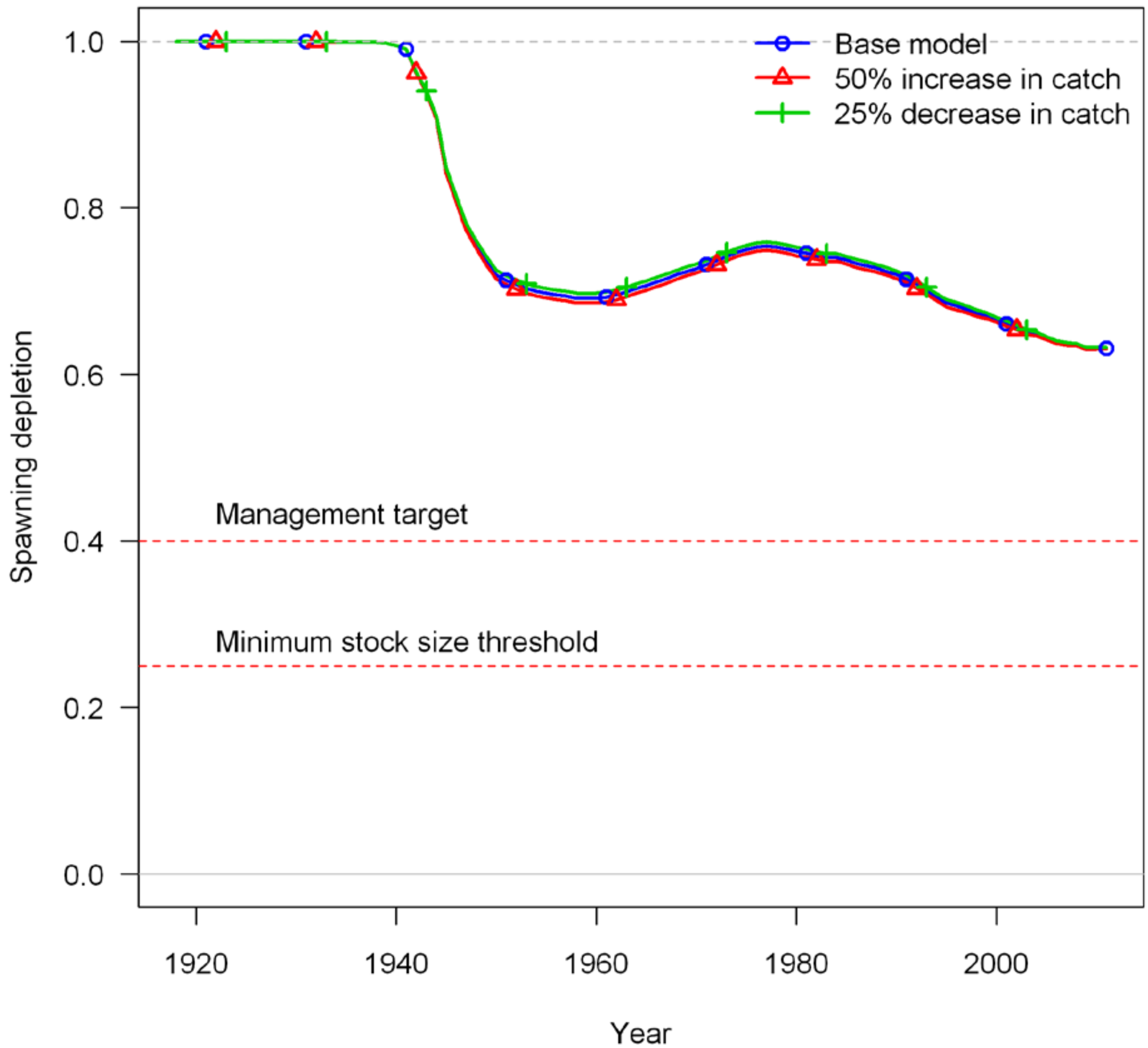

Figure 112. Sensitivity of spawning depletion time series to alternative assumptions regarding spiny dogfish fishery removals.

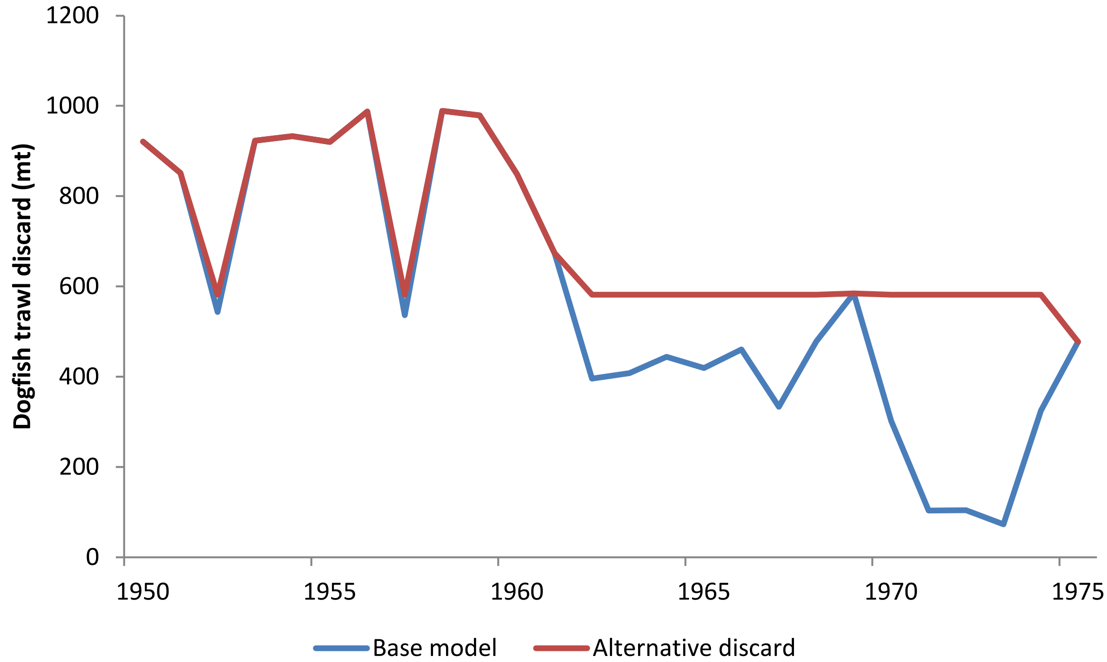

Figure 113. Historical discard estimated used in the base model and the alternative discard time series with the minimum discard amount assumed.

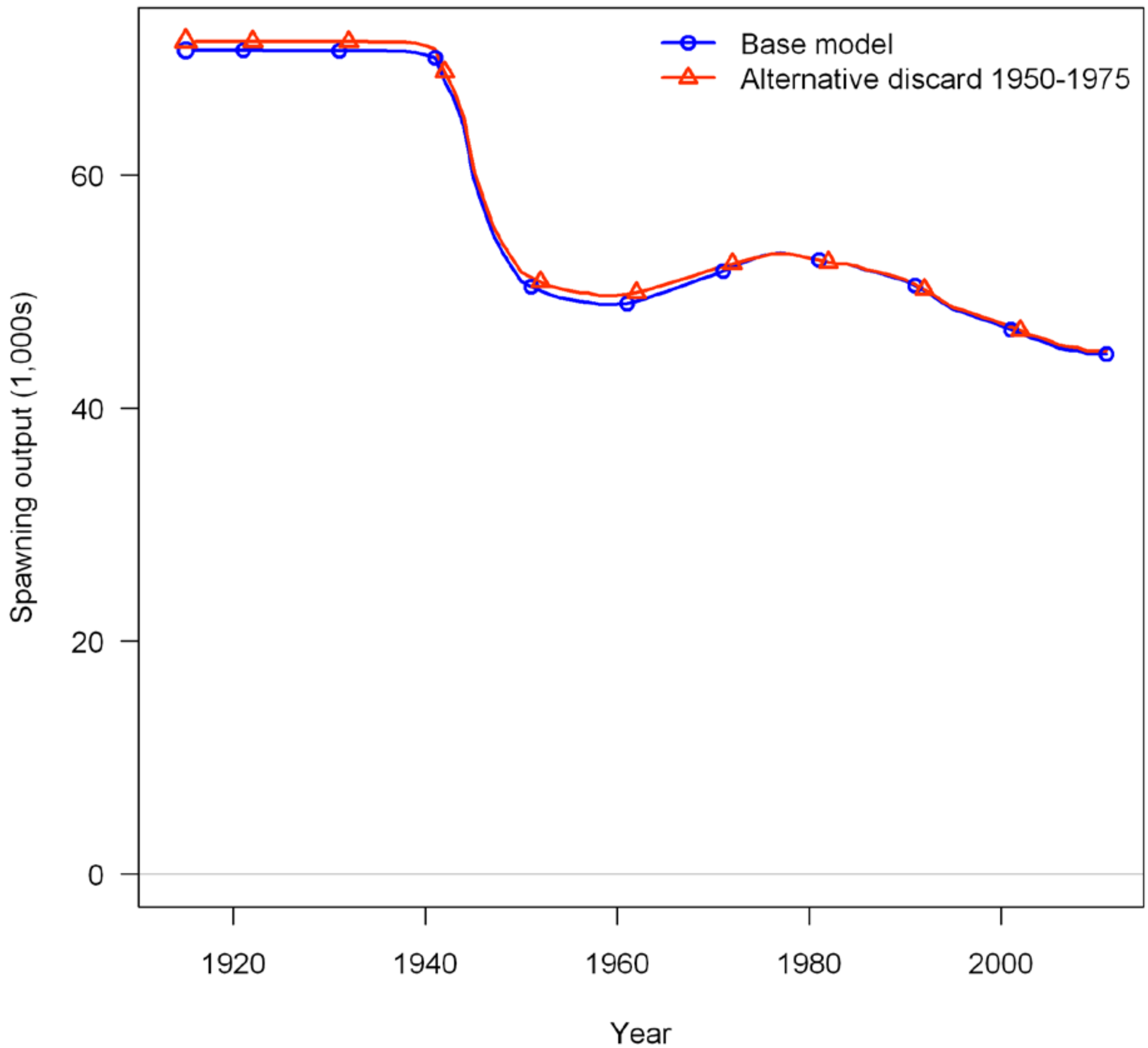

Figure 114. Sensitivity of spawning output time series to alternative assumptions regarding spiny dogfish historical discard.

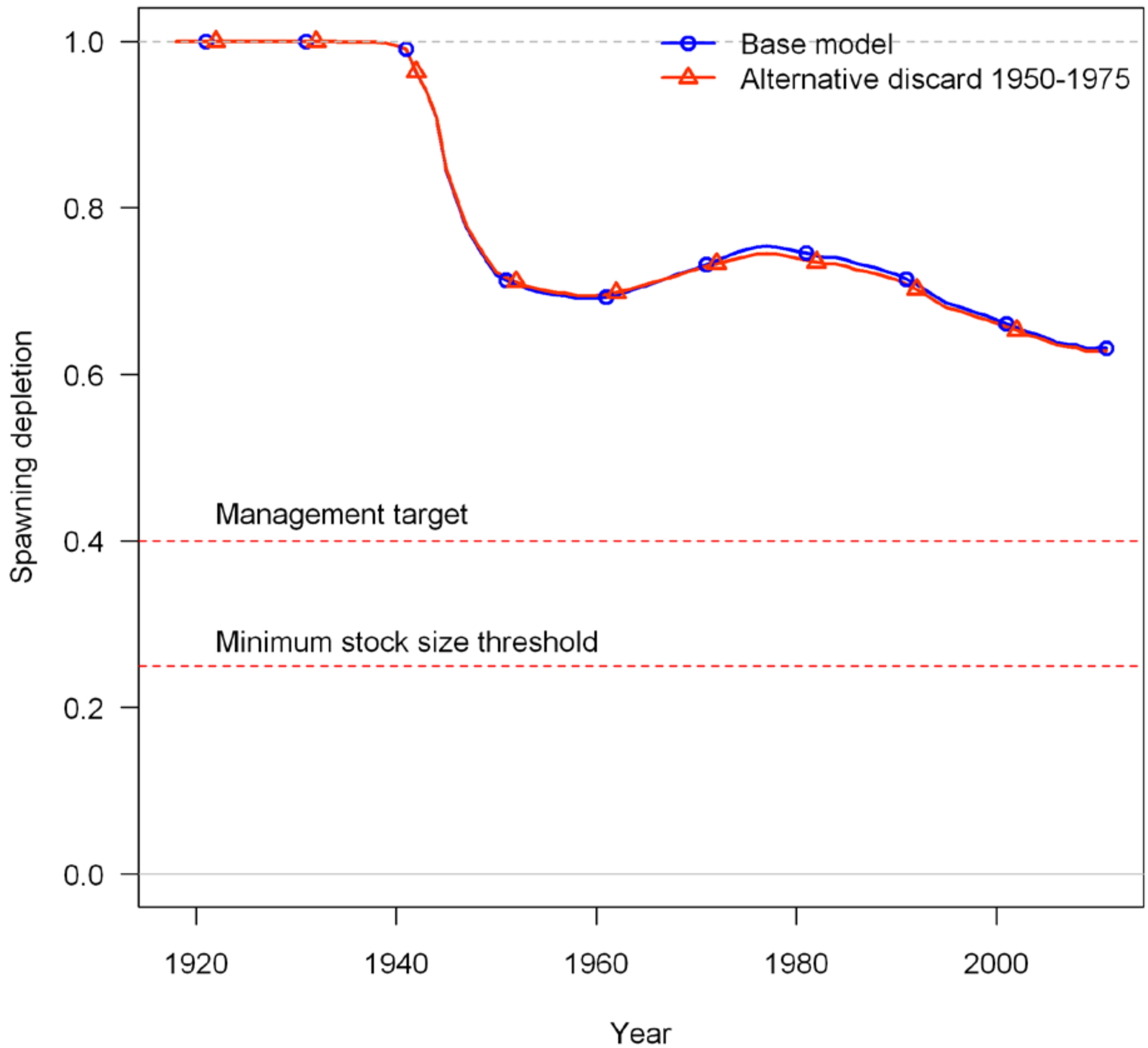

Figure 115. Sensitivity of spawning depletion time series to alternative assumptions regarding spiny dogfish historical discard.

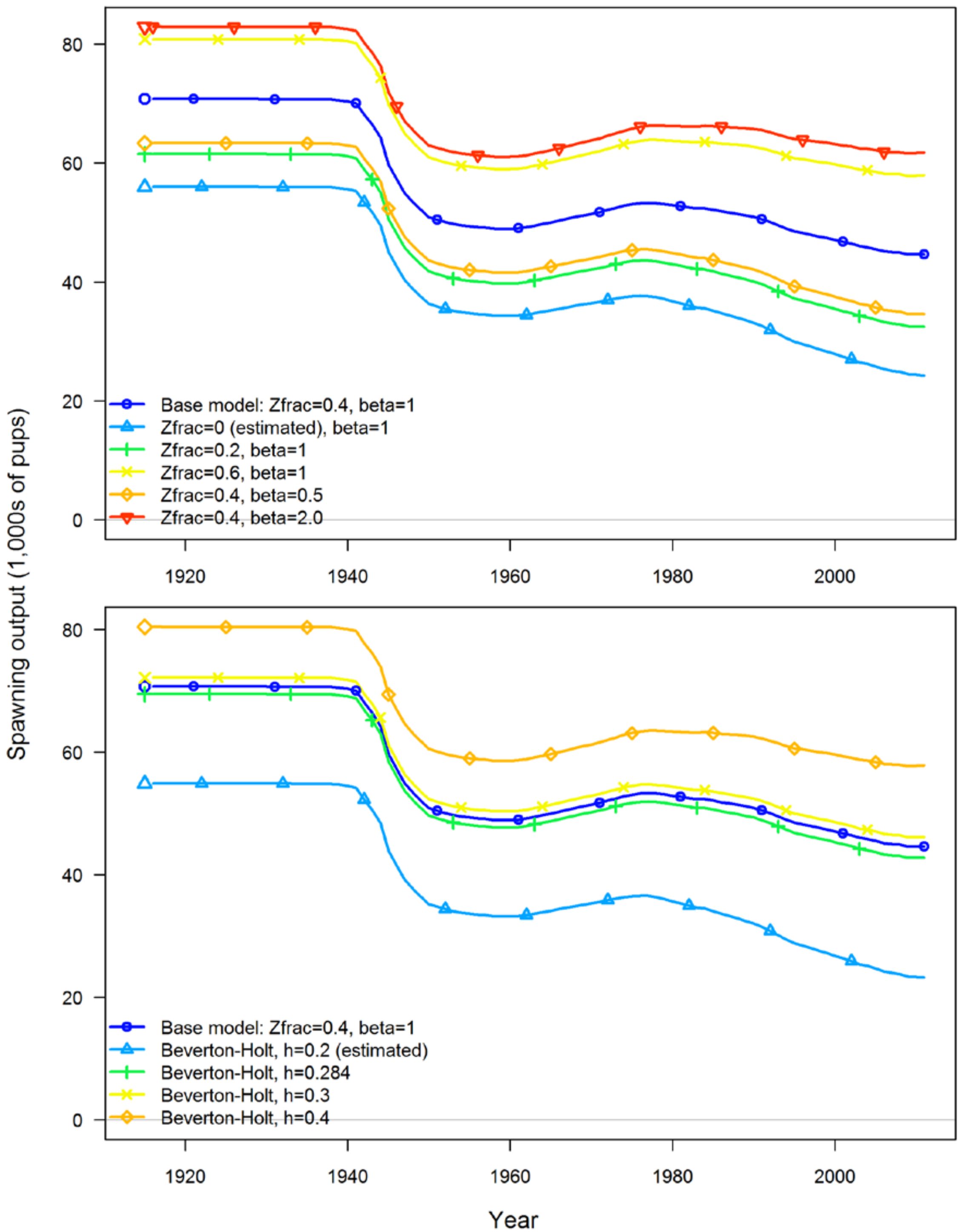

Figure 116. Spawning output for sensitivity analyses exploring alternative spawner-recruit relationships, including survival-based spawner-recruit relationships (top) and Beverton-Holt relationships (bottom).

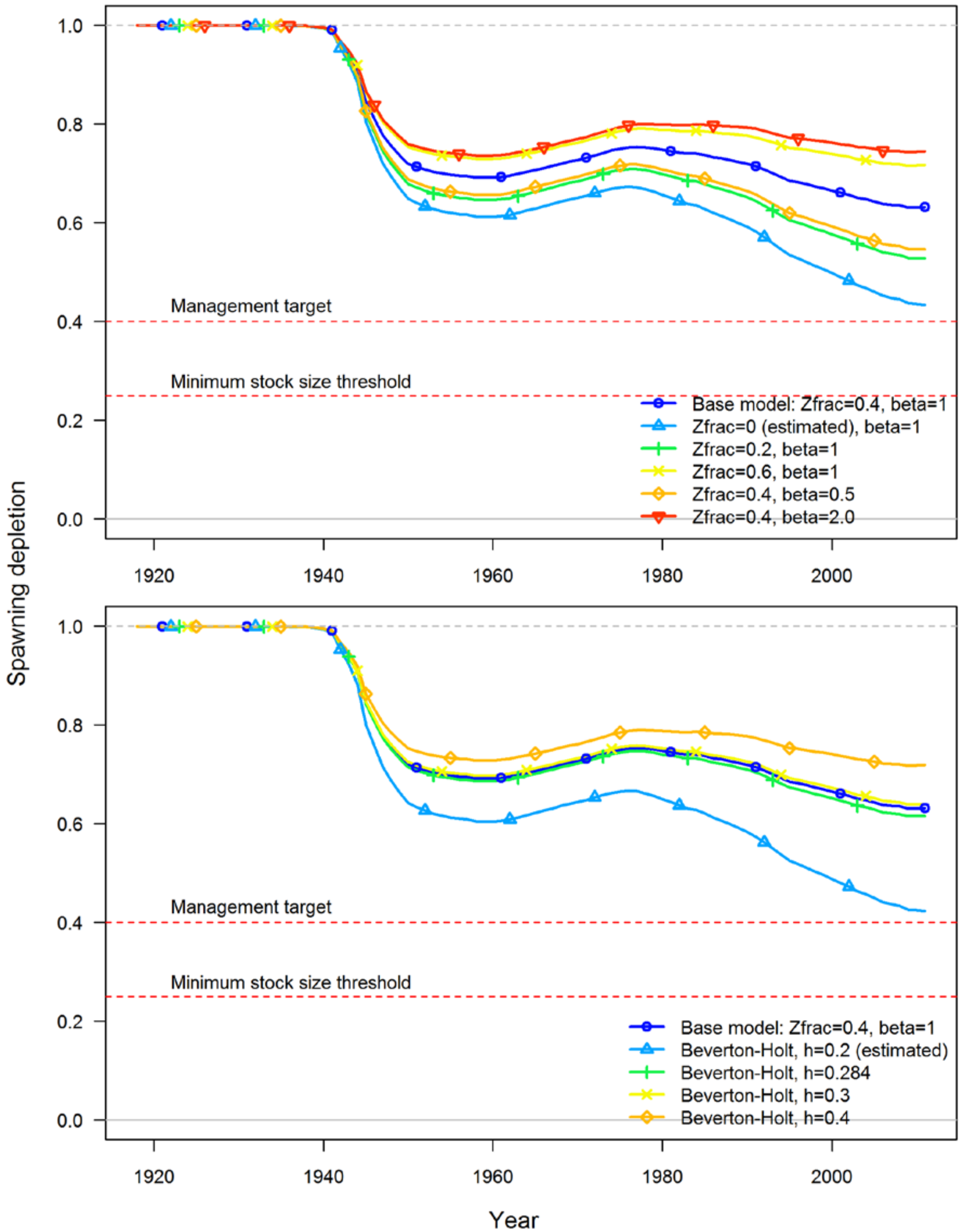

Figure 117. Spawning depletion for sensitivity analyses exploring alternative spawner-recruit relationships, including survival-based spawner-recruit relationships (top) and Beverton-Holt relationships (bottom).

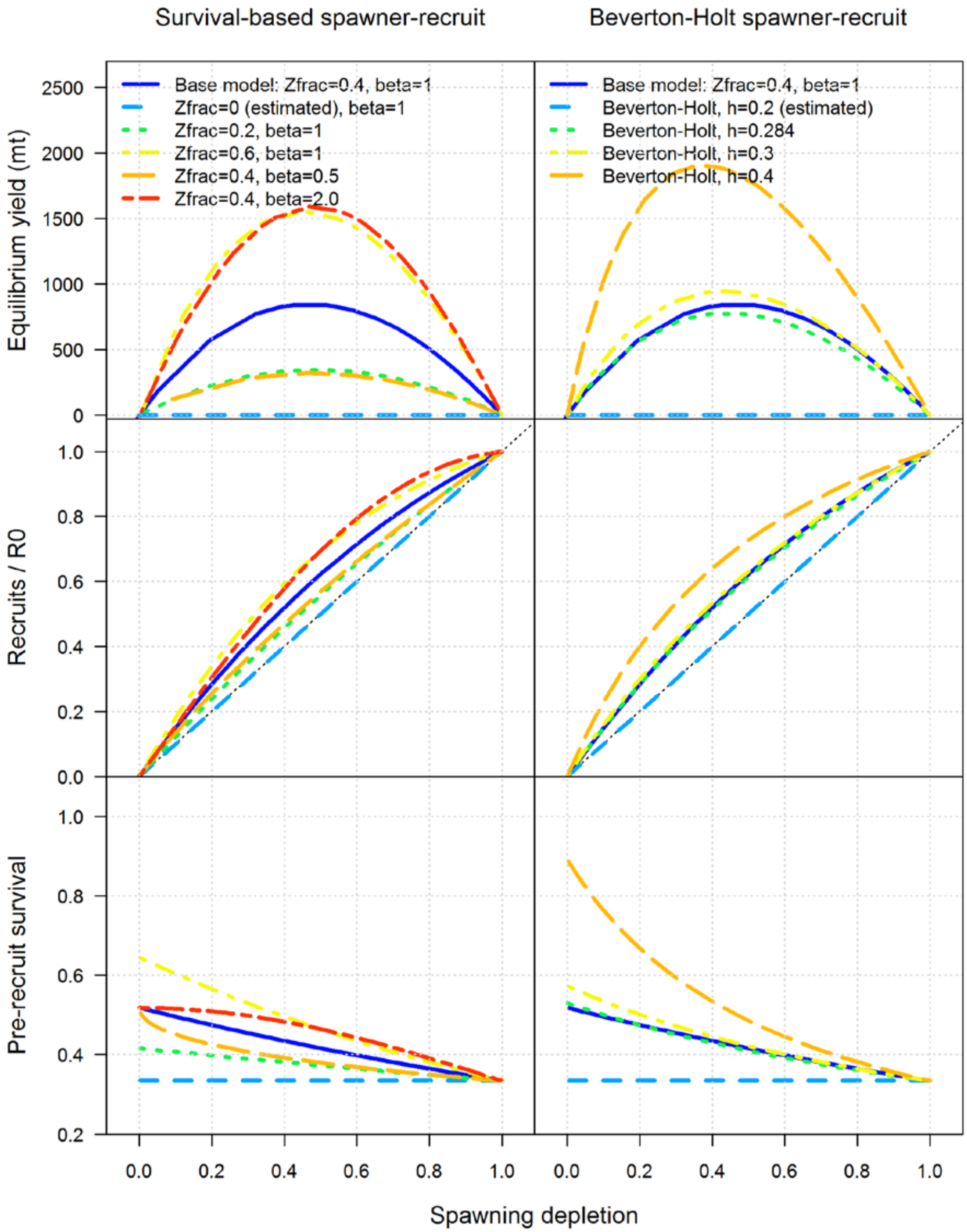

Figure 118. Equilibrium yield curves (top row), spawner-recruit curves (middle row), and pre-recruit survival (bottom row) for sensitivity analyses exploring alternative spawner-recruit relationships, including survival-based spawner-recruit relationships (left column) and Beverton-Holt relationships (right column).

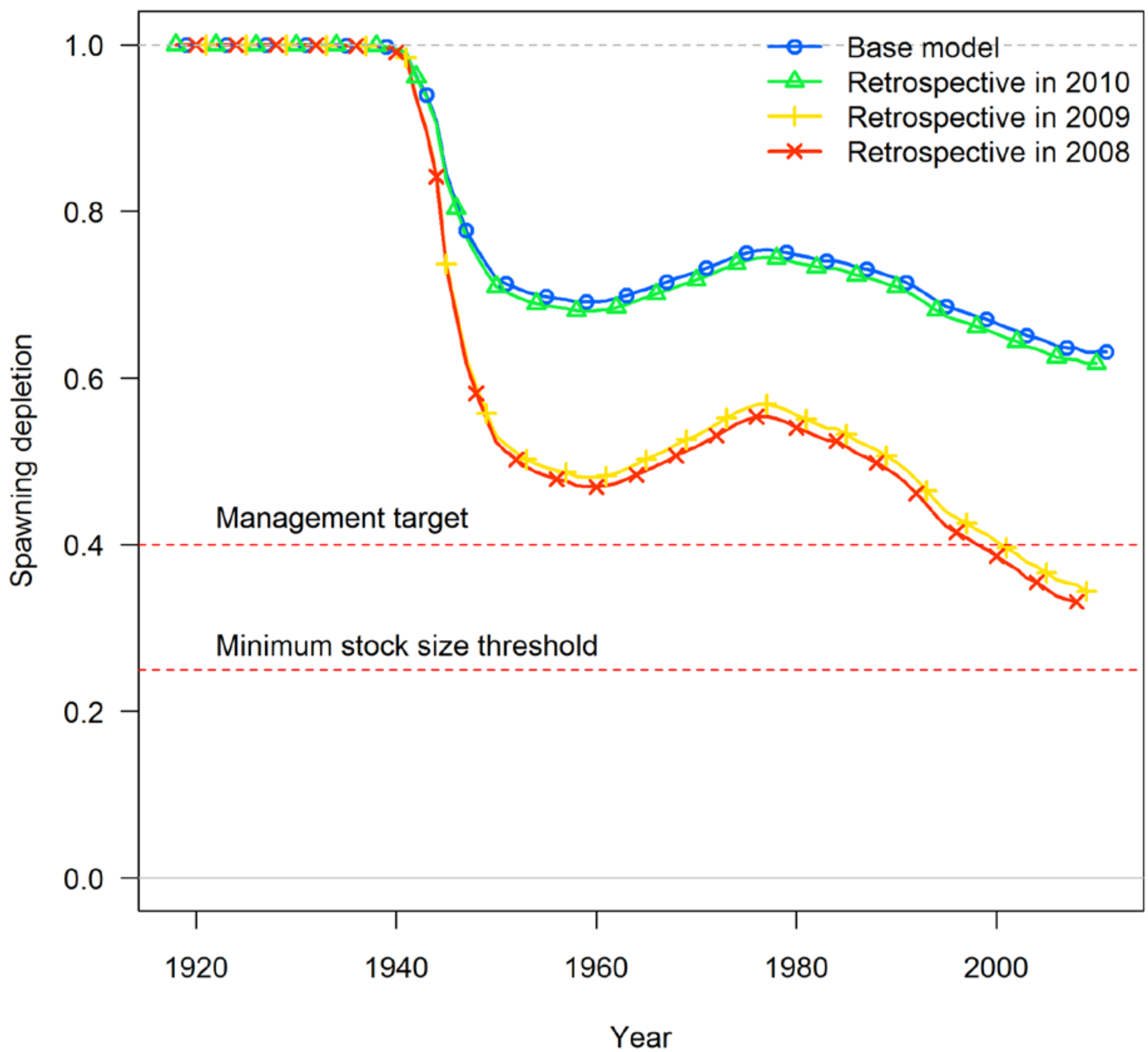

Figure 119. Spawning depletion for retrospective analysis. Each year of retrospective is performed as if the assessment were conducted in that year (i.e., retrospective in 2006 includes data through 2005).

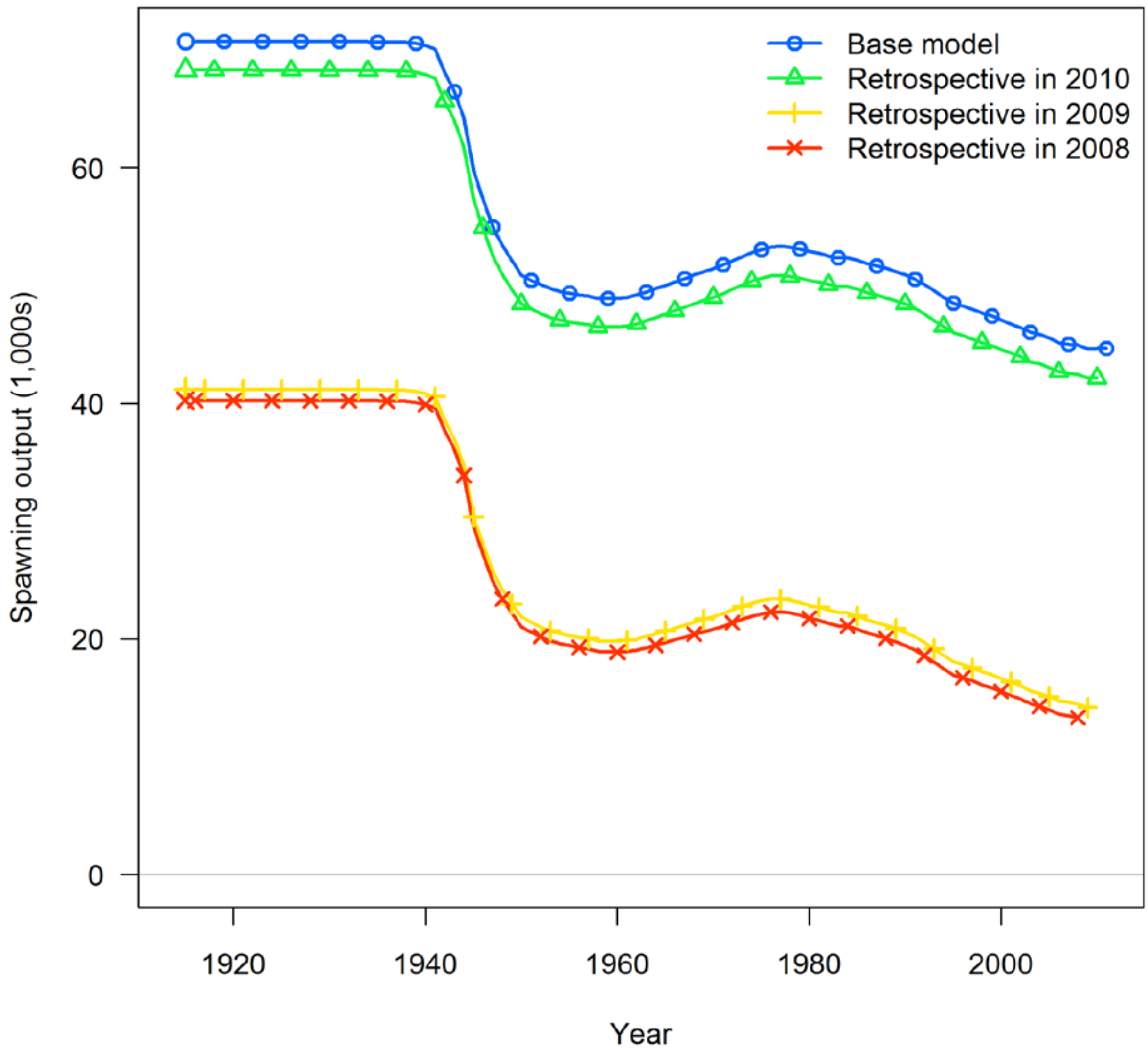

Figure 120. Spawning output for retrospective analysis. Each year of retrospective is performed as if the assessment were conducted in that year (i.e., retrospective in 2006 includes data through 2005).

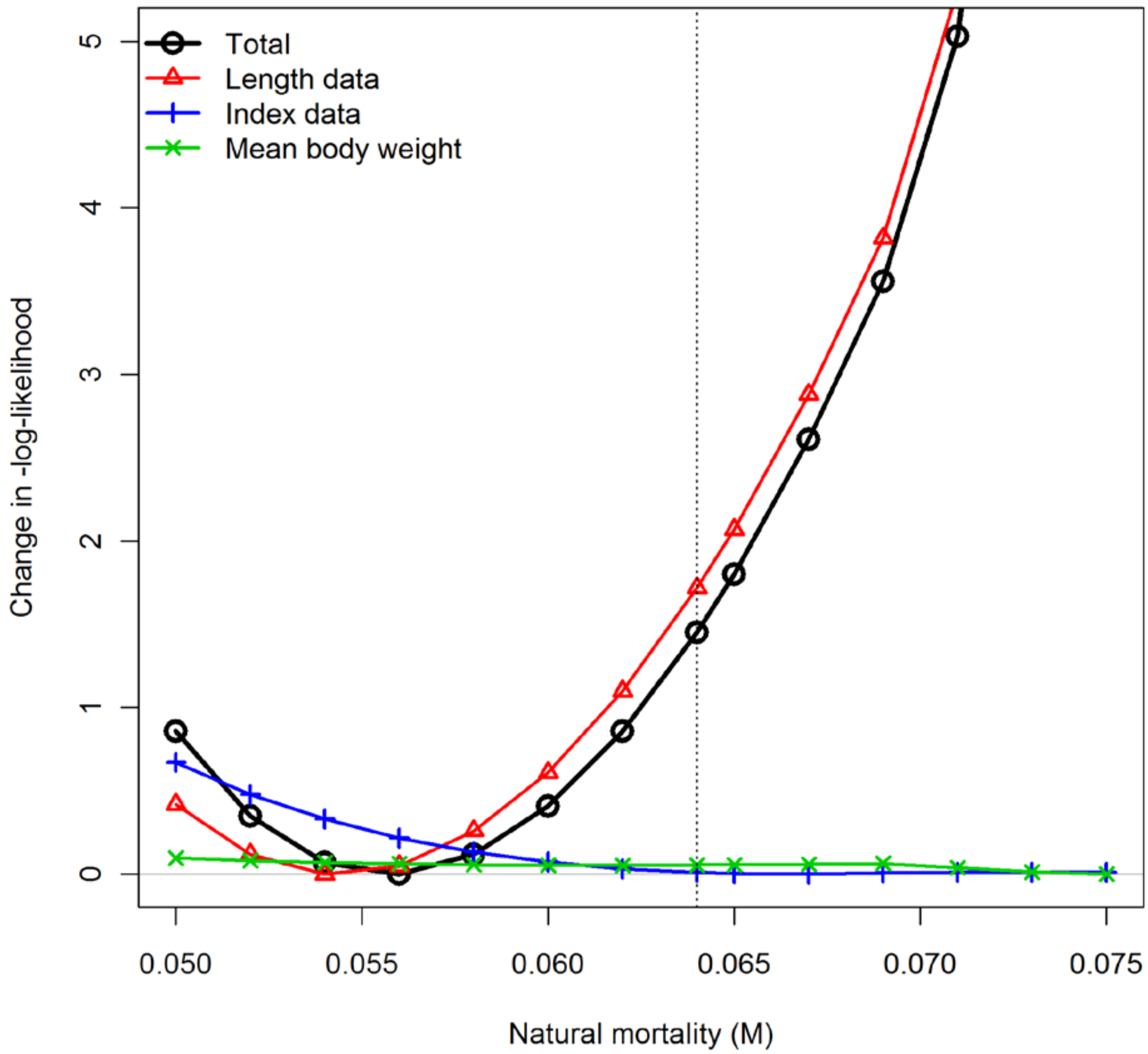

Figure 121. Likelihood profile over M showing contributions of likelihood components. All values are represented as the change relative to the lowest negative log-likelihood for that component within the range of M values shown in the figure. Dashed vertical line at M = 0.064 indicates the base model.

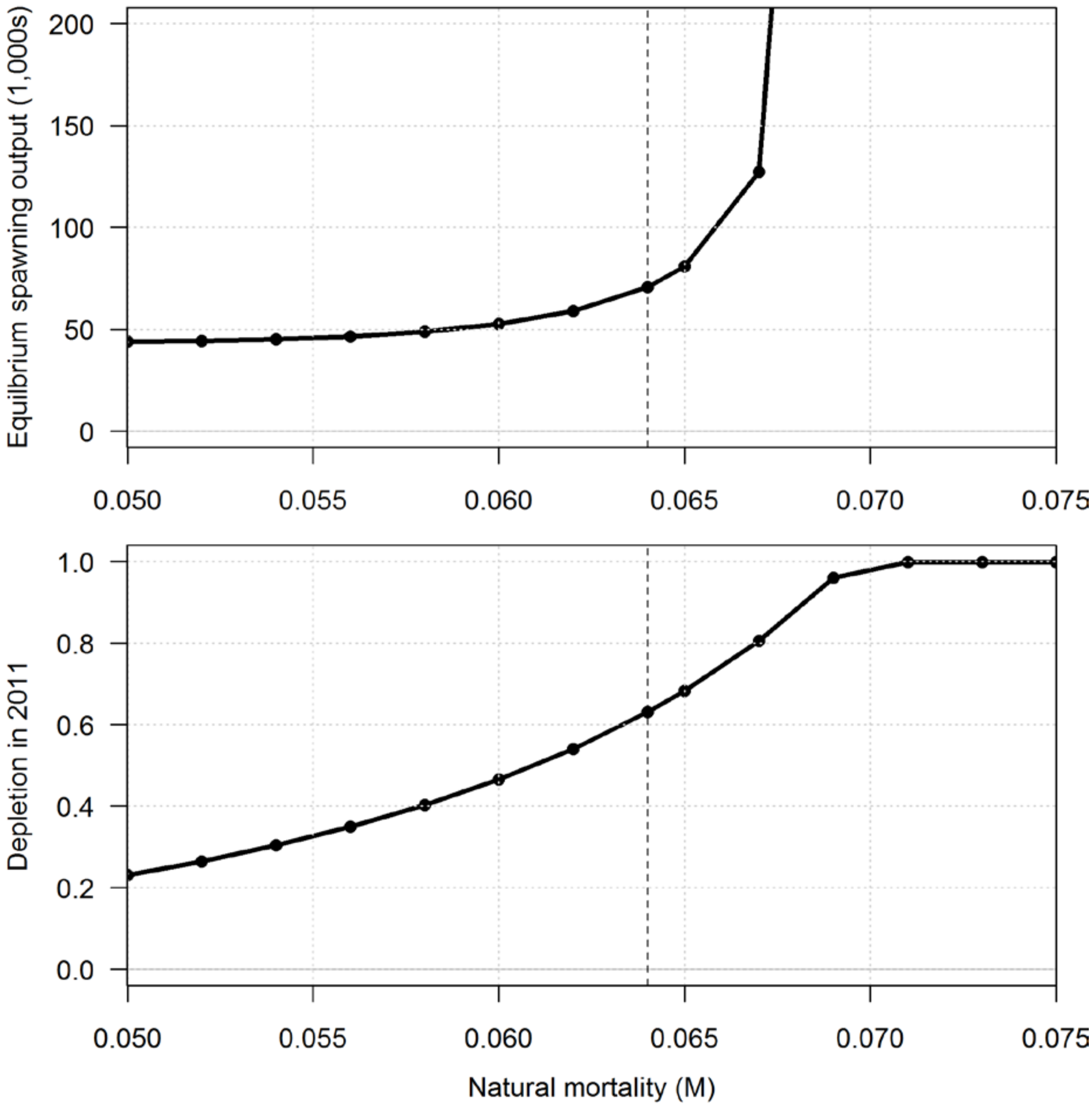

Figure 122. Values of B_0 and depletion in 2011 shown as a function of M for values used in the likelihood profile shown in Figure 121. Dashed vertical lines at M = 0.064 indicates the base model.

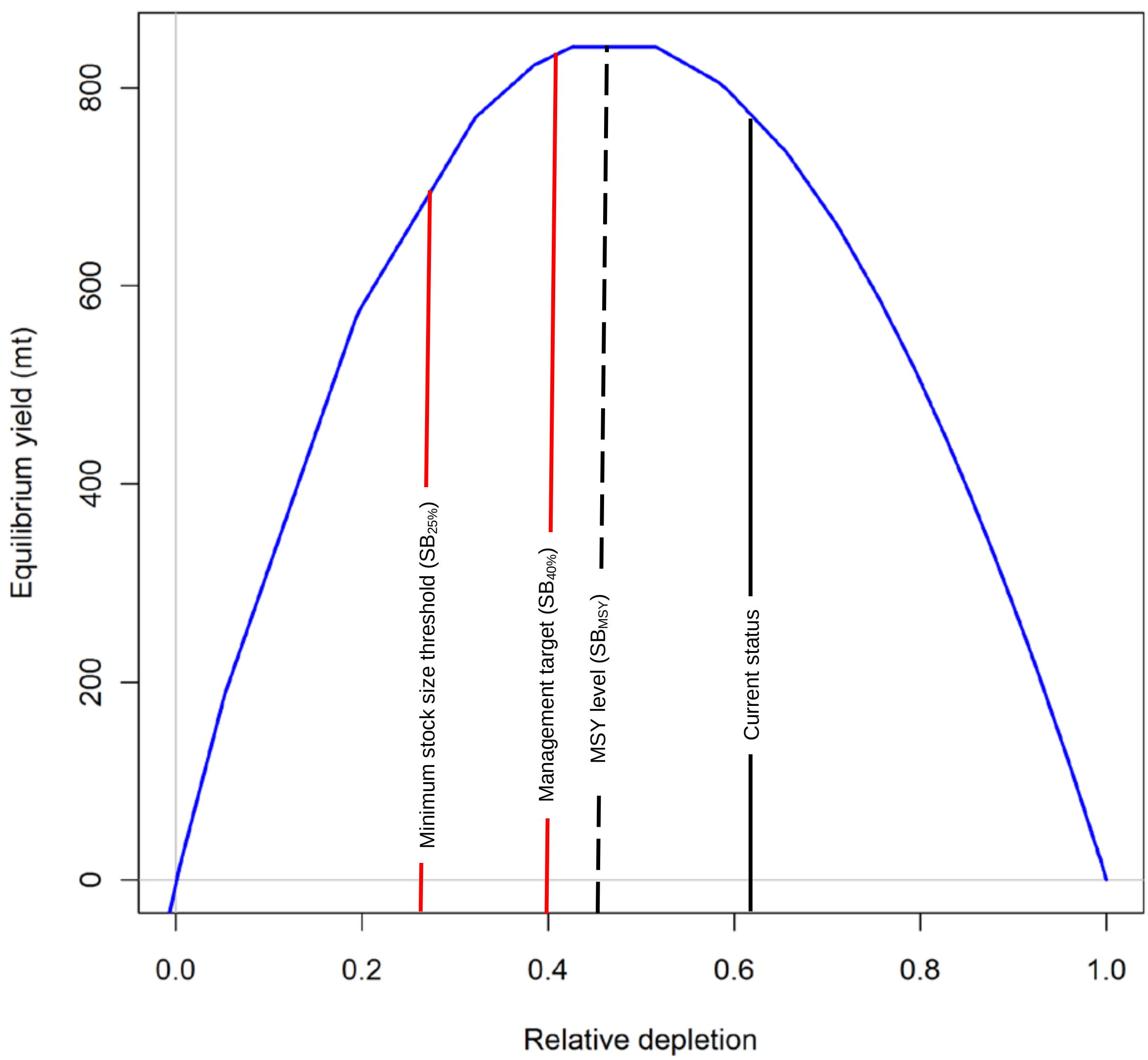

Figure 123. Equilibrium yield curve for spiny dogfish from the assessment model (based on Table 13).

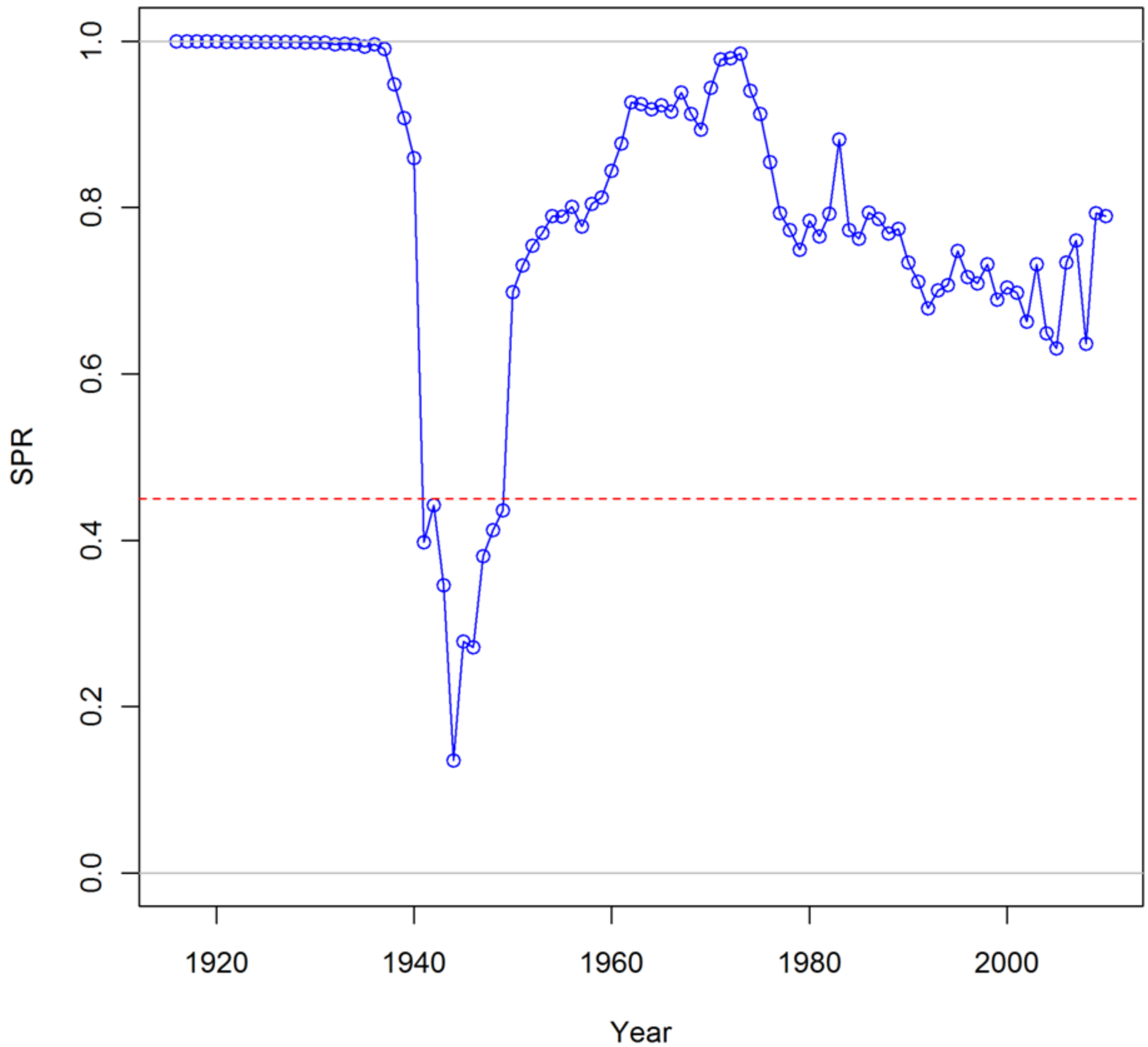

Figure 124. Time series of estimated spawning potential ratio (SPR) with SPR target of 0.45. Values below target reflect harvest that exceeded current overfishing proxy.

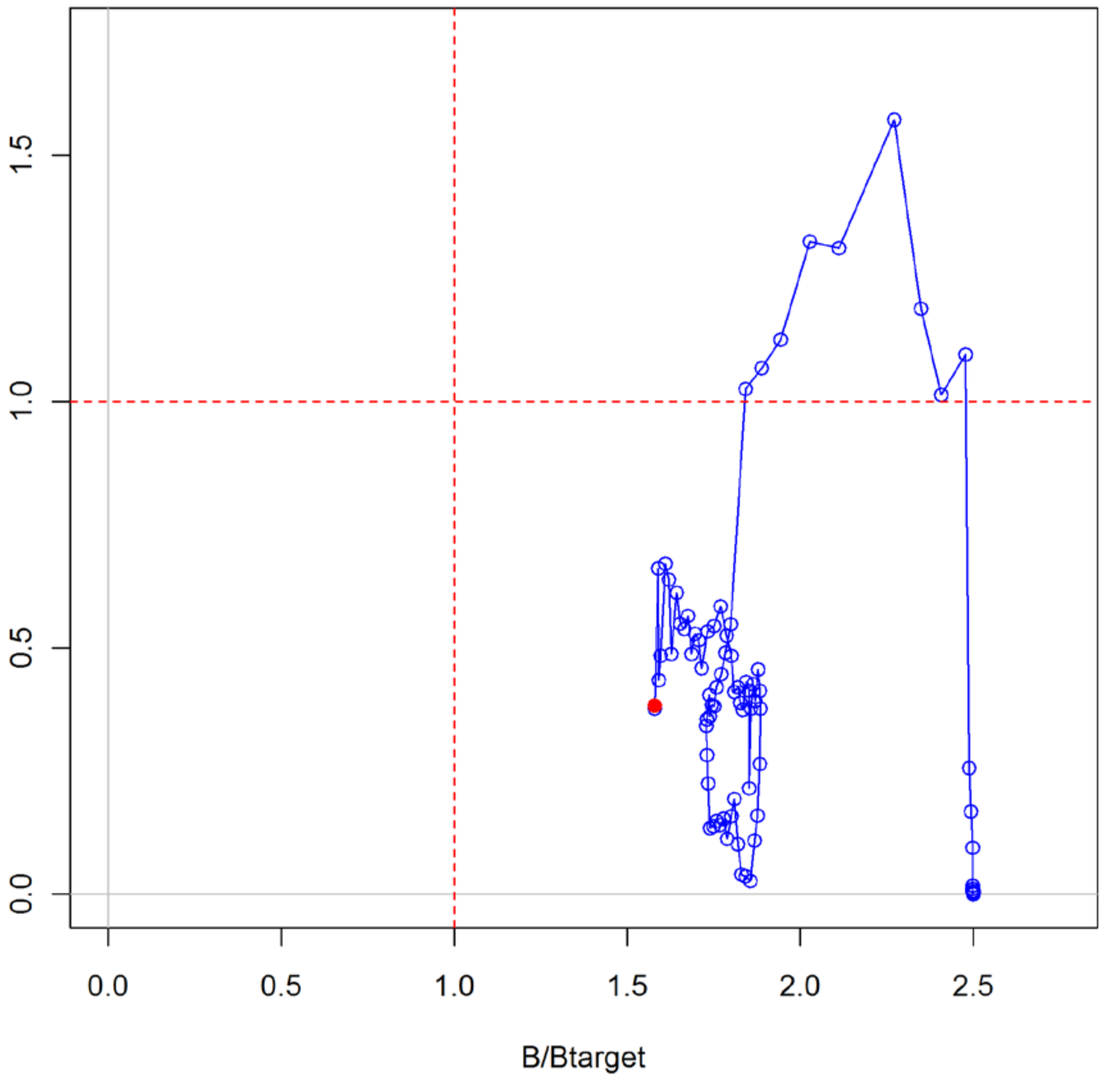

Figure 125. Estimated spawning potential ratio relative to its target of 0.45 versus estimated spawning output relative to its target of $SB_{40\%}$. Red dot indicates the point that corresponds to 2011.

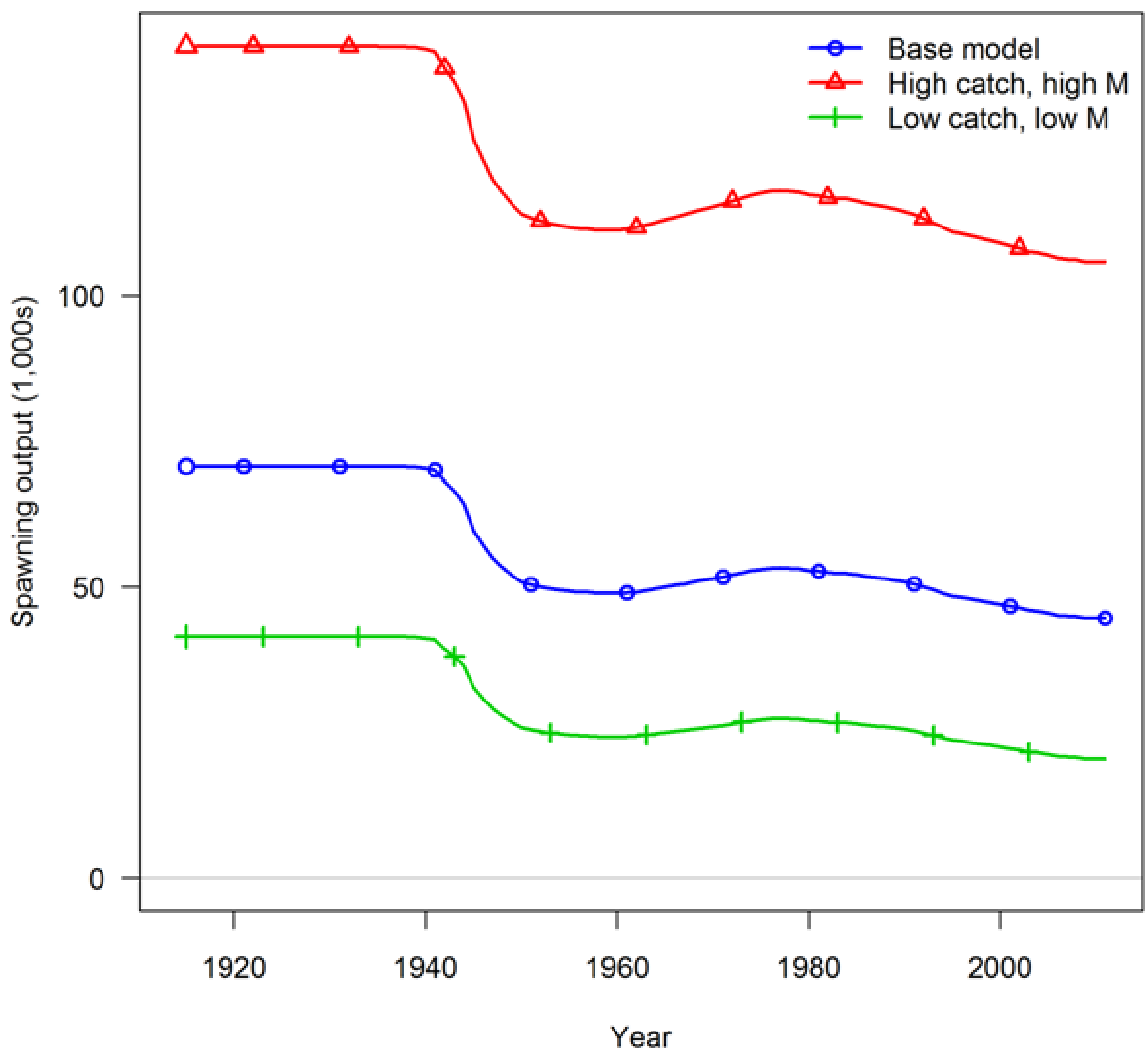

Figure 126. Time series of estimated spawning output (in 1000s of fish) for base model and alternative states of nature.

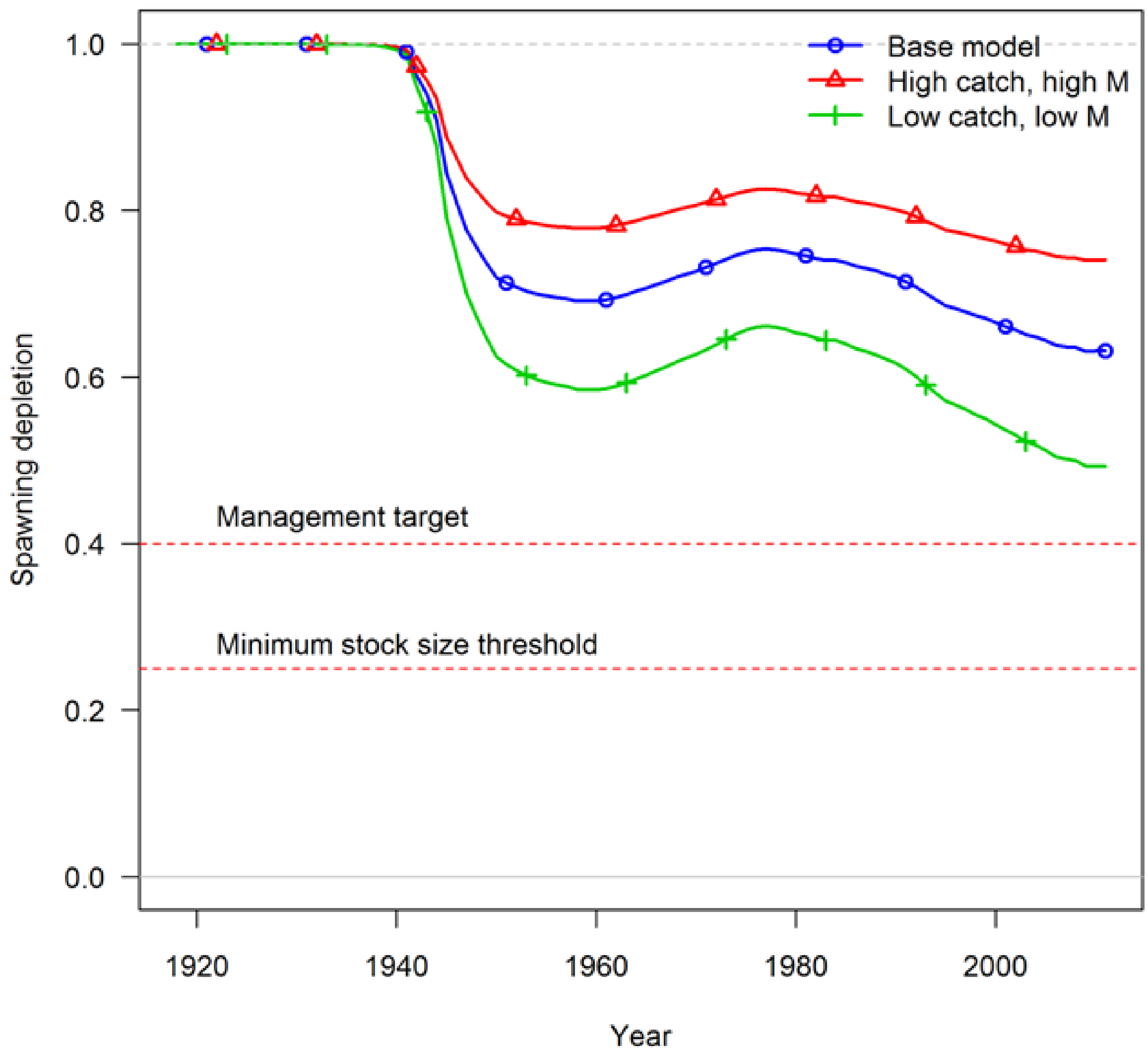

Figure 127. Time series of estimated spawning depletion (spawning output relative to unfished equilibrium) for base model and alternative states of nature.

APPENDIX A: Numbers at age estimated by the base model

A-1: Female numbers at age.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1916	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1917	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1918	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1919	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1920	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1921	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1922	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1923	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1924	11,817	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1925	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,524	4,244	3,981	3,734	3,503
1926	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,524	4,244	3,981	3,734	3,503
1927	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1928	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1929	11,816	11,083	10,396	9,752	9,147	8,580	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1930	11,815	11,083	10,396	9,752	9,147	8,580	8,048	7,550	7,082	6,643	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1931	11,815	11,083	10,396	9,752	9,147	8,580	8,048	7,549	7,082	6,643	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1932	11,815	11,083	10,396	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1933	11,814	11,083	10,396	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,980	3,734	3,502
1934	11,814	11,082	10,395	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,230	5,844	5,482	5,142	4,823	4,524	4,244	3,980	3,734	3,502
1935	11,813	11,081	10,395	9,751	9,146	8,580	8,048	7,549	7,081	6,642	6,230	5,844	5,482	5,142	4,823	4,524	4,243	3,980	3,733	3,502
1936	11,812	11,081	10,394	9,750	9,146	8,579	8,048	7,549	7,081	6,642	6,230	5,844	5,481	5,142	4,823	4,524	4,243	3,980	3,733	3,502
1937	11,812	11,080	10,394	9,750	9,146	8,579	8,047	7,549	7,081	6,642	6,230	5,844	5,481	5,141	4,823	4,524	4,243	3,980	3,733	3,502
1938	11,810	11,079	10,393	9,749	9,145	8,579	8,047	7,548	7,080	6,641	6,230	5,843	5,481	5,141	4,822	4,523	4,243	3,979	3,733	3,501
1939	11,801	11,077	10,392	9,748	9,144	8,577	8,046	7,547	7,079	6,640	6,228	5,841	5,479	5,139	4,820	4,520	4,240	3,977	3,730	3,498
1940	11,783	11,068	10,389	9,746	9,142	8,575	8,044	7,545	7,076	6,637	6,225	5,838	5,475	5,135	4,815	4,516	4,235	3,971	3,724	3,493
1941	11,756	11,050	10,379	9,743	9,139	8,572	8,040	7,541	7,073	6,633	6,220	5,833	5,469	5,128	4,808	4,509	4,227	3,964	3,716	3,485
1942	11,566	11,015	10,353	9,722	9,124	8,556	8,022	7,520	7,048	6,605	6,188	5,796	5,428	5,083	4,759	4,456	4,172	3,906	3,658	3,425
1943	11,401	10,838	10,320	9,699	9,106	8,543	8,008	7,505	7,031	6,585	6,166	5,771	5,400	5,051	4,724	4,418	4,131	3,863	3,613	3,379
1944	11,174	10,686	10,157	9,671	9,087	8,530	7,999	7,495	7,019	6,570	6,146	5,746	5,369	5,015	4,683	4,371	4,080	3,808	3,555	3,319
1945	10,685	10,456	9,997	9,499	9,040	8,488	7,960	7,456	6,974	6,517	6,085	5,676	5,289	4,925	4,582	4,262	3,963	3,685	3,427	3,188
1946	10,409	10,008	9,792	9,360	8,892	8,458	7,937	7,438	6,960	6,503	6,068	5,656	5,265	4,896	4,549	4,224	3,920	3,637	3,375	3,133
1947	10,128	9,752	9,375	9,171	8,764	8,322	7,913	7,420	6,947	6,492	6,057	5,642	5,248	4,875	4,523	4,193	3,884	3,596	3,329	3,083
1948	9,937	9,490	9,136	8,781	8,589	8,205	7,788	7,401	6,935	6,487	6,056	5,643	5,249	4,876	4,523	4,190	3,877	3,586	3,316	3,066
1949	9,769	9,310	8,890	8,557	8,223	8,040	7,678	7,284	6,916	6,476	6,052	5,644	5,253	4,880	4,527	4,193	3,879	3,585	3,312	3,058
1950	9,617	9,154	8,723	8,328	8,015	7,699	7,525	7,182	6,809	6,461	6,044	5,643	5,257	4,886	4,534	4,201	3,886	3,591	3,315	3,058
1951	9,559	9,018	8,584	8,179	7,808	7,514	7,217	7,053	6,731	6,380	6,052	5,659	5,281	4,918	4,569	4,238	3,924	3,629	3,351	3,093
1952	9,510	8,964	8,456	8,049	7,669	7,321	7,044	6,765	6,610	6,307	5,977	5,668	5,299	4,943	4,602	4,274	3,962	3,668	3,391	3,130
1953	9,465	8,919	8,406	7,930	7,547	7,191	6,864	6,604	6,342	6,196	5,911	5,601	5,311	4,964	4,630	4,309	4,001	3,709	3,432	3,172
1954	9,435	8,876	8,363	7,882	7,435	7,076	6,742	6,434	6,190	5,944	5,806	5,537	5,245	4,972	4,646	4,332	4,031	3,742	3,467	3,208
1955	9,413	8,848	8,323	7,842	7,390	6,971	6,634	6,320	6,031	5,801	5,569	5,439	5,186	4,912	4,655	4,349	4,054	3,771	3,500	3,242

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1916	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1917	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1918	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1919	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1920	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1921	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1922	3,285	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1923	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1924	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1925	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1926	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1927	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1928	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1929	3,285	3,082	2,890	2,711	2,543	2,385	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1930	3,285	3,081	2,890	2,711	2,543	2,385	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1931	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,969	1,847	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,107	1,038
1932	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,969	1,847	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,107	1,038
1933	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,968	1,846	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,106	1,038
1934	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,098	1,968	1,846	1,732	1,624	1,524	1,429	1,341	1,257	1,180	1,106	1,038
1935	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,098	1,968	1,846	1,732	1,624	1,524	1,429	1,340	1,257	1,179	1,106	1,038
1936	3,284	3,081	2,890	2,710	2,542	2,385	2,237	2,098	1,968	1,846	1,731	1,624	1,523	1,429	1,340	1,257	1,179	1,106	1,038
1937	3,284	3,081	2,890	2,710	2,542	2,385	2,237	2,098	1,968	1,846	1,731	1,624	1,523	1,429	1,340	1,257	1,179	1,106	1,037
1938	3,284	3,080	2,889	2,710	2,542	2,384	2,236	2,098	1,967	1,845	1,731	1,624	1,523	1,428	1,340	1,257	1,179	1,106	1,037
1939	3,281	3,077	2,886	2,707	2,539	2,381	2,234	2,095	1,965	1,843	1,729	1,622	1,521	1,427	1,338	1,255	1,177	1,104	1,036
1940	3,276	3,072	2,881	2,702	2,534	2,377	2,229	2,090	1,961	1,839	1,725	1,618	1,517	1,423	1,335	1,252	1,174	1,101	1,033
1941	3,267	3,064	2,873	2,694	2,526	2,369	2,221	2,083	1,954	1,832	1,718	1,612	1,512	1,418	1,330	1,247	1,170	1,097	1,029
1942	3,208	3,005	2,815	2,637	2,471	2,315	2,170	2,033	1,906	1,787	1,675	1,570	1,472	1,380	1,294	1,214	1,138	1,067	1,001
1943	3,161	2,958	2,768	2,591	2,425	2,271	2,127	1,992	1,866	1,749	1,639	1,536	1,439	1,349	1,265	1,186	1,111	1,042	977
1944	3,100	2,896	2,706	2,530	2,365	2,213	2,070	1,937	1,814	1,698	1,590	1,490	1,395	1,307	1,225	1,148	1,076	1,008	945
1945	2,968	2,764	2,575	2,401	2,240	2,090	1,952	1,824	1,705	1,594	1,491	1,395	1,305	1,222	1,144	1,071	1,003	940	881
1946	2,910	2,704	2,514	2,340	2,179	2,030	1,893	1,766	1,649	1,540	1,439	1,345	1,258	1,177	1,101	1,031	965	904	846
1947	2,857	2,649	2,458	2,282	2,121	1,973	1,837	1,711	1,595	1,488	1,389	1,297	1,212	1,133	1,059	991	927	868	812
1948	2,836	2,624	2,431	2,253	2,090	1,941	1,805	1,679	1,563	1,457	1,358	1,267	1,183	1,105	1,033	966	903	845	790
1949	2,825	2,610	2,413	2,233	2,069	1,918	1,780	1,654	1,538	1,431	1,333	1,243	1,159	1,082	1,010	944	882	825	772
1950	2,821	2,604	2,404	2,221	2,054	1,901	1,762	1,634	1,517	1,410	1,312	1,222	1,139	1,062	991	925	864	807	755
1951	2,852	2,630	2,426	2,239	2,068	1,912	1,769	1,639	1,520	1,411	1,311	1,220	1,136	1,058	986	920	859	802	750
1952	2,888	2,662	2,454	2,263	2,088	1,928	1,782	1,649	1,527	1,416	1,314	1,221	1,135	1,057	984	917	856	799	746
1953	2,927	2,700	2,489	2,294	2,114	1,950	1,800	1,663	1,538	1,424	1,320	1,225	1,138	1,058	984	916	854	796	743
1954	2,964	2,735	2,522	2,324	2,141	1,973	1,820	1,679	1,551	1,434	1,328	1,230	1,142	1,060	985	917	853	795	741
1955	2,999	2,770	2,556	2,356	2,170	2,000	1,842	1,699	1,567	1,448	1,338	1,239	1,148	1,064	988	919	854	795	741

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1916	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1917	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1918	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1919	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1920	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1921	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1922	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1923	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1924	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1925	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1926	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1927	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1928	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1929	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1930	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1931	974	913	857	804	754	707	663	622	583	547	513	482	452	424	397	373	350	328	308
1932	974	913	857	804	754	707	663	622	583	547	513	482	452	424	397	373	350	328	308
1933	974	913	857	803	754	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1934	973	913	856	803	754	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1935	973	913	856	803	754	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1936	973	913	856	803	753	707	663	622	583	547	513	481	451	423	397	373	350	328	308
1937	973	913	856	803	753	707	663	622	583	547	513	481	451	423	397	373	349	328	307
1938	973	913	856	803	753	706	663	622	583	547	513	481	451	423	397	372	349	328	307
1939	972	911	855	802	752	705	662	621	582	546	512	480	451	423	397	372	349	327	307
1940	969	909	853	800	750	704	660	619	581	545	511	479	449	422	395	371	348	326	306
1941	965	905	849	796	747	701	657	616	578	542	509	477	448	420	394	369	346	325	305
1942	938	880	825	774	726	681	639	599	562	527	494	463	435	408	382	359	336	316	296
1943	916	859	805	755	708	664	623	584	548	514	482	452	424	398	373	350	328	308	289
1944	886	831	779	730	685	642	602	564	529	496	465	437	409	384	360	338	317	297	279
1945	825	773	725	679	637	597	559	524	492	461	432	405	380	356	334	313	294	275	258
1946	793	742	696	652	611	572	537	503	471	442	414	388	364	341	320	300	281	264	247
1947	761	712	667	625	585	549	514	482	451	423	397	372	349	327	306	287	269	252	237
1948	740	693	648	607	569	533	499	468	438	411	385	361	338	317	297	279	261	245	230
1949	722	675	632	592	554	519	486	456	427	400	375	351	329	308	289	271	254	238	223
1950	706	660	618	578	541	507	475	445	416	390	366	343	321	301	282	264	248	232	218
1951	701	655	613	573	537	502	470	440	412	386	362	339	318	298	279	261	245	230	215
1952	697	651	609	569	533	498	466	437	409	383	358	336	315	295	276	259	242	227	213
1953	694	648	605	566	529	495	463	433	405	379	355	333	311	292	273	256	240	225	211
1954	692	646	603	563	526	492	460	430	403	377	353	330	309	290	271	254	238	223	209
1955	691	644	601	562	525	490	458	428	401	375	351	328	307	288	270	252	236	221	207

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1916	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1917	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1918	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1919	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1920	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1921	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1922	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1923	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1924	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1925	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1926	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1927	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1928	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1929	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1930	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1931	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1932	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1933	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1934	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1935	289	271	254	238	223	209	197	184	173	162	152	143	134	126	118	110	104	97	91
1936	288	271	254	238	223	209	196	184	173	162	152	143	134	126	118	110	104	97	91
1937	288	271	254	238	223	209	196	184	173	162	152	143	134	126	118	110	104	97	91
1938	288	270	254	238	223	209	196	184	173	162	152	143	134	125	118	110	104	97	91
1939	288	270	253	238	223	209	196	184	173	162	152	142	134	125	118	110	103	97	91
1940	287	269	253	237	222	209	196	183	172	161	151	142	133	125	117	110	103	97	91
1941	286	268	252	236	221	208	195	183	171	161	151	141	133	124	117	109	103	96	90
1942	278	260	244	229	215	202	189	177	166	156	146	137	129	121	113	106	100	93	88
1943	271	254	238	223	209	196	184	173	162	152	143	134	125	118	110	104	97	91	85
1944	261	245	230	216	202	190	178	167	156	147	138	129	121	114	107	100	94	88	82
1945	242	227	213	200	187	176	165	155	145	136	128	120	112	105	99	93	87	81	76
1946	232	218	204	191	179	168	158	148	139	130	122	115	107	101	94	89	83	78	73
1947	222	208	195	183	172	161	151	142	133	124	117	109	103	96	90	85	79	75	70
1948	215	202	189	177	166	156	146	137	129	121	113	106	100	93	88	82	77	72	68
1949	209	196	184	173	162	152	142	133	125	117	110	103	97	91	85	80	75	70	66
1950	204	191	179	168	158	148	139	130	122	114	107	101	94	88	83	78	73	68	64
1951	202	189	177	166	156	146	137	128	120	113	106	99	93	87	82	77	72	68	63
1952	200	187	175	164	154	144	135	127	119	112	105	98	92	86	81	76	71	67	63
1953	197	185	173	163	152	143	134	125	118	110	103	97	91	85	80	75	70	66	62
1954	196	183	172	161	151	142	133	124	117	109	102	96	90	84	79	74	70	65	61
1955	194	182	171	160	150	140	132	123	116	108	102	95	89	84	79	74	69	65	61

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1916	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1917	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1918	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1919	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1920	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1921	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1922	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1923	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1924	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1925	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1926	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1927	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1928	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1929	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1930	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1931	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1932	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1933	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1934	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1935	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1936	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1937	85	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1938	85	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1939	85	80	75	70	66	62	58	55	51	48	45	42	40	37	35	33	31	29	435
1940	85	80	75	70	66	62	58	54	51	48	45	42	39	37	35	33	31	29	434
1941	85	79	75	70	66	62	58	54	51	48	45	42	39	37	35	32	30	29	432
1942	82	77	72	68	64	60	56	53	49	46	43	41	38	36	34	31	30	28	419
1943	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	27	408
1944	77	73	68	64	60	56	53	49	46	43	41	38	36	34	32	30	28	26	394
1945	72	67	63	59	55	52	49	46	43	40	38	35	33	31	29	27	26	24	365
1946	69	64	60	57	53	50	47	44	41	39	36	34	32	30	28	26	25	23	349
1947	66	61	58	54	51	48	45	42	39	37	35	32	30	28	27	25	24	22	334
1948	64	60	56	52	49	46	43	41	38	36	33	31	29	28	26	24	23	21	324
1949	62	58	54	51	48	45	42	39	37	35	33	31	29	27	25	24	22	21	314
1950	60	56	53	50	47	44	41	38	36	34	32	30	28	26	25	23	22	20	306
1951	59	56	52	49	46	43	40	38	36	33	31	29	27	26	24	23	21	20	302
1952	59	55	52	48	45	43	40	37	35	33	31	29	27	25	24	22	21	20	298
1953	58	54	51	48	45	42	39	37	35	32	30	29	27	25	24	22	21	19	294
1954	57	54	50	47	44	42	39	37	34	32	30	28	27	25	23	22	21	19	291
1955	57	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	289

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1956	9,394	8,827	8,297	7,804	7,353	6,929	6,535	6,219	5,923	5,652	5,435	5,217	5,094	4,856	4,598	4,357	4,070	3,793	3,527	3,273
1957	9,383	8,809	8,277	7,779	7,318	6,894	6,496	6,126	5,829	5,551	5,295	5,092	4,886	4,770	4,546	4,304	4,077	3,807	3,547	3,298
1958	9,358	8,799	8,261	7,762	7,295	6,862	6,464	6,091	5,743	5,464	5,203	4,963	4,772	4,578	4,469	4,259	4,031	3,817	3,564	3,320
1959	9,355	8,776	8,251	7,746	7,278	6,840	6,433	6,060	5,708	5,382	5,120	4,874	4,648	4,468	4,286	4,182	3,985	3,770	3,570	3,332
1960	9,357	8,773	8,229	7,737	7,263	6,824	6,412	6,030	5,679	5,350	5,043	4,796	4,565	4,353	4,183	4,011	3,914	3,728	3,526	3,338
1961	9,370	8,775	8,227	7,717	7,255	6,810	6,398	6,011	5,652	5,323	5,013	4,725	4,493	4,276	4,076	3,916	3,755	3,662	3,488	3,299
1962	9,393	8,788	8,229	7,715	7,237	6,803	6,386	5,999	5,636	5,299	4,989	4,698	4,428	4,209	4,005	3,817	3,667	3,516	3,429	3,265
1963	9,428	8,810	8,242	7,718	7,236	6,787	6,380	5,988	5,625	5,284	4,968	4,678	4,404	4,150	3,945	3,754	3,577	3,436	3,294	3,212
1964	9,464	8,842	8,262	7,730	7,238	6,786	6,365	5,983	5,615	5,274	4,955	4,657	4,385	4,128	3,890	3,697	3,517	3,352	3,219	3,086
1965	9,501	8,876	8,293	7,749	7,249	6,788	6,364	5,968	5,610	5,265	4,945	4,645	4,366	4,110	3,869	3,645	3,464	3,295	3,140	3,016
1966	9,539	8,911	8,325	7,778	7,268	6,799	6,366	5,968	5,597	5,260	4,936	4,636	4,354	4,092	3,852	3,626	3,416	3,246	3,087	2,942
1967	9,576	8,946	8,357	7,808	7,294	6,816	6,376	5,970	5,596	5,247	4,932	4,628	4,345	4,081	3,835	3,609	3,397	3,200	3,041	2,892
1968	9,618	8,982	8,391	7,838	7,323	6,841	6,392	5,979	5,598	5,247	4,920	4,624	4,338	4,074	3,825	3,595	3,383	3,184	2,999	2,849
1969	9,655	9,021	8,424	7,870	7,351	6,867	6,416	5,994	5,606	5,249	4,919	4,612	4,334	4,066	3,818	3,584	3,368	3,169	2,982	2,809
1970	9,687	9,055	8,460	7,900	7,380	6,893	6,440	6,016	5,620	5,256	4,920	4,611	4,323	4,061	3,810	3,576	3,357	3,154	2,968	2,792
1971	9,728	9,086	8,493	7,935	7,410	6,922	6,465	6,039	5,641	5,270	4,928	4,613	4,323	4,052	3,807	3,571	3,352	3,147	2,956	2,781
1972	9,773	9,124	8,522	7,966	7,443	6,950	6,492	6,064	5,664	5,291	4,943	4,622	4,327	4,054	3,800	3,570	3,349	3,143	2,951	2,772
1973	9,817	9,167	8,558	7,994	7,472	6,981	6,519	6,089	5,687	5,313	4,962	4,635	4,335	4,058	3,802	3,564	3,348	3,140	2,948	2,767
1974	9,860	9,209	8,599	8,028	7,498	7,009	6,548	6,114	5,711	5,334	4,983	4,654	4,348	4,066	3,806	3,566	3,342	3,140	2,945	2,764
1975	9,892	9,248	8,637	8,065	7,529	7,032	6,573	6,141	5,734	5,356	5,002	4,672	4,364	4,076	3,811	3,567	3,342	3,133	2,943	2,760
1976	9,916	9,278	8,674	8,100	7,563	7,061	6,594	6,164	5,758	5,376	5,021	4,689	4,379	4,090	3,820	3,571	3,342	3,131	2,934	2,756
1977	9,925	9,299	8,701	8,134	7,596	7,092	6,620	6,182	5,778	5,397	5,038	4,705	4,393	4,102	3,830	3,576	3,343	3,128	2,930	2,745
1978	9,915	9,307	8,720	8,159	7,627	7,122	6,649	6,206	5,794	5,414	5,056	4,719	4,406	4,113	3,839	3,584	3,346	3,127	2,925	2,739
1979	9,897	9,297	8,727	8,177	7,650	7,150	6,676	6,232	5,816	5,429	5,072	4,736	4,419	4,124	3,849	3,592	3,352	3,128	2,922	2,733
1980	9,869	9,281	8,718	8,183	7,667	7,172	6,703	6,258	5,841	5,449	5,086	4,750	4,434	4,136	3,859	3,600	3,358	3,133	2,922	2,729
1981	9,851	9,255	8,703	8,175	7,673	7,188	6,724	6,283	5,865	5,473	5,105	4,764	4,448	4,150	3,870	3,610	3,366	3,140	2,928	2,731
1982	9,825	9,238	8,679	8,160	7,665	7,194	6,738	6,302	5,888	5,495	5,126	4,780	4,459	4,162	3,883	3,619	3,375	3,147	2,934	2,735
1983	9,805	9,213	8,663	8,138	7,651	7,186	6,744	6,316	5,906	5,517	5,147	4,801	4,476	4,174	3,895	3,632	3,385	3,156	2,941	2,742
1984	9,806	9,196	8,641	8,124	7,632	7,175	6,739	6,323	5,921	5,536	5,171	4,824	4,499	4,194	3,910	3,648	3,402	3,170	2,955	2,753
1985	9,775	9,195	8,623	8,102	7,617	7,155	6,726	6,316	5,926	5,548	5,186	4,843	4,517	4,211	3,924	3,658	3,412	3,181	2,963	2,761
1986	9,740	9,167	8,622	8,086	7,597	7,141	6,707	6,305	5,920	5,553	5,198	4,858	4,535	4,228	3,941	3,671	3,421	3,190	2,973	2,769
1987	9,715	9,134	8,596	8,085	7,581	7,123	6,695	6,287	5,909	5,547	5,202	4,868	4,548	4,245	3,957	3,687	3,434	3,199	2,983	2,779
1988	9,688	9,110	8,565	8,060	7,581	7,108	6,677	6,275	5,892	5,536	5,196	4,871	4,558	4,257	3,972	3,701	3,448	3,210	2,990	2,787
1989	9,654	9,085	8,543	8,031	7,557	7,107	6,663	6,258	5,881	5,520	5,186	4,866	4,561	4,266	3,983	3,715	3,461	3,223	3,000	2,794
1990	9,619	9,053	8,519	8,010	7,530	7,086	6,663	6,246	5,865	5,511	5,172	4,857	4,556	4,270	3,992	3,727	3,475	3,237	3,013	2,804
1991	9,571	9,020	8,489	7,988	7,511	7,060	6,642	6,245	5,853	5,495	5,162	4,843	4,547	4,264	3,995	3,734	3,485	3,248	3,024	2,815
1992	9,509	8,975	8,458	7,960	7,490	7,042	6,618	6,226	5,853	5,485	5,148	4,835	4,535	4,257	3,991	3,738	3,493	3,259	3,037	2,827
1993	9,438	8,918	8,416	7,931	7,463	7,022	6,601	6,203	5,834	5,483	5,137	4,820	4,525	4,243	3,982	3,732	3,494	3,264	3,044	2,836
1994	9,368	8,850	8,362	7,892	7,437	6,998	6,583	6,188	5,815	5,468	5,138	4,813	4,516	4,238	3,974	3,728	3,493	3,269	3,054	2,847

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1956	3,031	2,803	2,589	2,388	2,201	2,027	1,867	1,720	1,586	1,463	1,351	1,248	1,155	1,070	992	921	856	796	741
1957	3,059	2,833	2,619	2,418	2,230	2,055	1,893	1,743	1,606	1,480	1,365	1,260	1,165	1,078	998	926	859	798	742
1958	3,086	2,862	2,650	2,450	2,261	2,085	1,920	1,768	1,628	1,499	1,381	1,273	1,175	1,086	1,004	930	862	800	743
1959	3,104	2,884	2,675	2,476	2,288	2,112	1,946	1,793	1,650	1,519	1,399	1,289	1,188	1,096	1,013	937	867	804	746
1960	3,115	2,901	2,696	2,499	2,313	2,137	1,972	1,818	1,674	1,541	1,418	1,305	1,203	1,109	1,023	945	874	809	750
1961	3,123	2,914	2,713	2,520	2,336	2,162	1,997	1,843	1,698	1,564	1,439	1,325	1,219	1,123	1,035	955	882	816	755
1962	3,088	2,922	2,726	2,538	2,358	2,185	2,022	1,868	1,723	1,588	1,462	1,346	1,238	1,140	1,050	968	893	825	763
1963	3,058	2,892	2,737	2,553	2,377	2,208	2,046	1,893	1,749	1,614	1,487	1,369	1,260	1,159	1,067	983	906	836	772
1964	3,009	2,865	2,709	2,563	2,391	2,226	2,067	1,916	1,773	1,638	1,511	1,392	1,282	1,179	1,085	999	920	848	783
1965	2,890	2,818	2,683	2,537	2,400	2,239	2,084	1,935	1,794	1,659	1,533	1,414	1,303	1,200	1,104	1,016	935	861	794
1966	2,825	2,707	2,639	2,512	2,375	2,247	2,096	1,951	1,812	1,679	1,554	1,435	1,324	1,220	1,123	1,033	951	875	806
1967	2,755	2,645	2,535	2,471	2,352	2,224	2,104	1,962	1,826	1,696	1,572	1,454	1,343	1,239	1,142	1,051	967	890	819
1968	2,710	2,581	2,478	2,375	2,315	2,204	2,083	1,971	1,838	1,711	1,589	1,472	1,362	1,258	1,160	1,069	984	906	833
1969	2,668	2,537	2,417	2,321	2,224	2,167	2,063	1,950	1,845	1,720	1,601	1,487	1,378	1,274	1,177	1,086	1,000	921	847
1970	2,629	2,498	2,375	2,262	2,172	2,081	2,028	1,930	1,824	1,726	1,609	1,498	1,391	1,289	1,192	1,101	1,016	936	861
1971	2,617	2,464	2,340	2,225	2,119	2,035	1,949	1,900	1,808	1,709	1,617	1,507	1,403	1,303	1,207	1,116	1,031	951	876
1972	2,608	2,453	2,310	2,194	2,086	1,987	1,907	1,827	1,781	1,695	1,602	1,516	1,413	1,315	1,221	1,132	1,047	967	892
1973	2,599	2,445	2,300	2,166	2,058	1,956	1,863	1,788	1,713	1,670	1,589	1,502	1,421	1,325	1,233	1,145	1,061	981	906
1974	2,595	2,437	2,293	2,157	2,031	1,929	1,834	1,747	1,677	1,607	1,566	1,490	1,408	1,332	1,242	1,156	1,074	995	920
1975	2,590	2,431	2,284	2,148	2,021	1,903	1,807	1,718	1,636	1,571	1,505	1,467	1,396	1,319	1,248	1,164	1,083	1,005	932
1976	2,584	2,425	2,276	2,138	2,011	1,892	1,781	1,692	1,608	1,532	1,470	1,408	1,373	1,306	1,234	1,168	1,089	1,013	941
1977	2,578	2,417	2,268	2,129	1,999	1,880	1,769	1,665	1,581	1,503	1,431	1,374	1,316	1,282	1,220	1,153	1,091	1,017	946
1978	2,566	2,409	2,258	2,118	1,988	1,866	1,755	1,651	1,554	1,475	1,402	1,335	1,281	1,227	1,196	1,138	1,075	1,017	948
1979	2,558	2,396	2,249	2,108	1,977	1,854	1,741	1,637	1,539	1,448	1,375	1,307	1,244	1,194	1,143	1,114	1,060	1,001	947
1980	2,552	2,388	2,236	2,098	1,966	1,844	1,729	1,623	1,525	1,434	1,349	1,281	1,217	1,158	1,111	1,064	1,037	986	932
1981	2,550	2,383	2,230	2,087	1,958	1,835	1,720	1,613	1,514	1,423	1,337	1,258	1,194	1,134	1,080	1,036	992	966	919
1982	2,550	2,381	2,225	2,081	1,948	1,827	1,711	1,604	1,504	1,411	1,326	1,246	1,172	1,113	1,057	1,006	965	924	899
1983	2,556	2,382	2,224	2,077	1,943	1,818	1,705	1,597	1,497	1,403	1,316	1,237	1,162	1,093	1,037	985	938	899	861
1984	2,566	2,392	2,229	2,081	1,944	1,818	1,701	1,595	1,494	1,400	1,312	1,231	1,157	1,087	1,022	970	921	877	841
1985	2,572	2,397	2,234	2,081	1,942	1,814	1,696	1,587	1,488	1,393	1,305	1,223	1,147	1,078	1,013	952	904	858	816
1986	2,579	2,403	2,238	2,085	1,943	1,812	1,692	1,582	1,480	1,387	1,298	1,216	1,140	1,069	1,004	943	887	841	799
1987	2,587	2,410	2,244	2,090	1,947	1,814	1,692	1,579	1,476	1,381	1,294	1,211	1,135	1,063	997	936	879	827	784
1988	2,596	2,416	2,250	2,095	1,951	1,817	1,692	1,578	1,473	1,377	1,287	1,207	1,129	1,058	991	929	873	820	770
1989	2,603	2,424	2,256	2,100	1,955	1,820	1,695	1,578	1,472	1,374	1,284	1,200	1,125	1,052	986	923	865	813	763
1990	2,611	2,432	2,264	2,107	1,961	1,825	1,699	1,581	1,472	1,373	1,281	1,197	1,119	1,048	981	918	860	806	757
1991	2,619	2,437	2,270	2,113	1,965	1,829	1,702	1,584	1,474	1,372	1,279	1,193	1,114	1,041	975	912	854	800	750
1992	2,630	2,446	2,276	2,119	1,971	1,833	1,705	1,586	1,476	1,373	1,277	1,190	1,110	1,036	968	907	848	794	743
1993	2,639	2,454	2,282	2,122	1,975	1,837	1,708	1,588	1,477	1,373	1,277	1,188	1,106	1,031	962	899	841	787	736
1994	2,652	2,467	2,294	2,132	1,982	1,844	1,714	1,593	1,480	1,376	1,279	1,189	1,105	1,029	959	894	835	781	730

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1956	690	644	600	560	523	488	456	427	399	373	349	327	306	286	268	251	235	220	206
1957	691	644	600	559	522	487	455	425	397	372	347	325	304	285	266	249	234	219	205
1958	691	643	599	558	520	485	453	423	395	369	345	323	302	282	264	247	231	217	203
1959	693	644	599	558	520	485	452	422	394	368	344	322	301	281	263	246	230	216	202
1960	696	646	601	559	520	485	452	422	393	367	343	321	300	280	262	245	229	215	201
1961	700	650	603	561	522	486	453	422	394	367	343	320	299	280	262	245	229	214	200
1962	706	654	607	564	524	488	454	423	394	368	343	320	299	280	261	244	229	214	200
1963	714	661	613	568	528	491	456	425	396	369	344	321	300	280	262	245	229	214	200
1964	723	668	619	573	532	494	459	427	398	371	345	322	301	281	262	245	229	214	200
1965	732	676	625	579	537	498	462	430	400	372	347	323	301	281	263	245	229	214	200
1966	743	685	633	585	542	502	466	433	402	374	348	324	302	282	263	246	230	215	201
1967	754	695	641	592	548	507	470	436	405	376	350	326	304	283	264	246	230	215	201
1968	767	706	651	601	555	513	475	440	408	379	352	328	305	284	265	247	231	215	201
1969	780	718	661	609	562	519	480	444	412	382	355	330	307	285	266	248	231	216	201
1970	792	729	671	618	570	526	485	449	415	385	357	332	308	287	267	249	232	216	202
1971	807	742	683	629	579	533	492	455	420	389	360	334	311	289	268	250	233	217	202
1972	821	756	696	640	589	543	500	461	426	394	365	338	313	291	271	252	234	218	203
1973	836	770	709	652	600	552	509	469	433	399	369	342	317	294	273	254	236	220	205
1974	850	784	722	665	612	563	518	477	440	406	375	346	321	297	276	256	238	221	206
1975	862	796	734	676	622	573	527	485	447	412	380	351	324	300	278	258	240	223	207
1976	872	806	745	687	633	582	536	493	454	418	385	355	328	303	281	260	241	224	208
1977	879	814	753	695	641	591	544	500	460	424	390	360	332	306	283	262	243	225	209
1978	882	819	759	702	648	597	550	507	466	429	395	363	335	309	285	264	244	226	210
1979	883	821	762	706	653	603	556	512	471	434	399	367	338	312	287	265	245	227	210
1980	881	821	764	709	657	607	561	517	476	438	403	371	341	314	290	267	247	228	211
1981	868	821	765	711	660	612	566	522	481	443	408	375	345	318	293	270	249	230	212
1982	855	808	764	712	662	615	569	526	486	448	413	380	349	321	295	272	251	231	213
1983	838	797	753	712	663	617	573	530	490	453	417	384	354	325	299	275	253	233	215
1984	805	784	745	704	665	620	577	535	496	458	423	390	359	330	304	280	257	237	218
1985	783	749	730	694	655	619	577	537	498	461	426	394	363	334	307	283	260	239	220
1986	760	729	697	679	645	610	576	537	499	463	429	396	366	337	311	286	263	242	222
1987	745	708	679	650	633	601	568	537	500	465	431	399	369	341	314	289	266	245	225
1988	731	694	660	633	605	589	560	529	500	466	433	402	372	344	317	292	269	248	228
1989	717	680	646	614	589	563	548	521	492	465	433	403	374	346	320	295	272	250	230
1990	711	668	633	601	572	548	524	510	485	458	433	403	375	348	322	297	274	253	233
1991	704	661	621	589	559	531	509	487	474	450	425	402	374	348	323	299	276	255	235
1992	696	653	613	576	546	518	492	472	451	439	417	394	372	346	322	298	276	255	235
1993	689	645	605	568	533	505	479	455	436	417	406	385	364	343	320	297	276	255	236
1994	683	638	598	561	526	494	468	443	421	403	386	375	356	336	317	295	274	254	235

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1956	193	181	169	159	149	139	131	122	115	108	101	94	89	83	78	73	68	64	60
1957	192	180	168	158	148	138	130	122	114	107	100	94	88	82	77	72	68	64	60
1958	190	178	167	156	146	137	128	120	113	106	99	93	87	82	76	72	67	63	59
1959	189	177	166	155	145	136	128	120	112	105	98	92	86	81	76	71	67	63	59
1960	188	176	165	154	145	135	127	119	111	104	98	92	86	81	75	71	66	62	58
1961	187	176	164	154	144	135	126	118	111	104	97	91	86	80	75	70	66	62	58
1962	187	175	164	154	144	135	126	118	111	104	97	91	85	80	75	70	66	62	58
1963	187	175	164	153	144	135	126	118	111	104	97	91	85	80	75	70	66	62	58
1964	187	175	164	153	144	134	126	118	110	103	97	91	85	80	75	70	66	61	58
1965	187	175	164	153	144	134	126	118	110	103	97	91	85	80	75	70	65	61	58
1966	187	175	164	153	144	134	126	118	110	103	97	91	85	79	74	70	65	61	57
1967	188	175	164	153	144	134	126	118	110	103	97	90	85	79	74	70	65	61	57
1968	188	176	164	154	144	134	126	118	110	103	97	90	85	79	74	70	65	61	57
1969	188	176	164	154	144	134	126	118	110	103	97	90	85	79	74	70	65	61	57
1970	188	176	164	154	144	134	126	118	110	103	96	90	84	79	74	69	65	61	57
1971	189	176	165	154	144	134	126	118	110	103	96	90	84	79	74	69	65	61	57
1972	190	177	165	154	144	135	126	118	110	103	97	90	85	79	74	69	65	61	57
1973	191	178	166	155	145	135	126	118	111	103	97	91	85	79	74	70	65	61	57
1974	192	179	167	156	145	136	127	119	111	104	97	91	85	79	74	70	65	61	57
1975	193	180	167	156	146	136	127	119	111	104	97	91	85	79	74	70	65	61	57
1976	194	180	168	157	146	136	127	119	111	104	97	91	85	79	74	70	65	61	57
1977	195	181	168	157	146	136	127	119	111	104	97	91	85	79	74	69	65	61	57
1978	195	181	168	157	146	136	127	118	111	103	97	90	84	79	74	69	65	60	57
1979	195	181	168	157	146	136	127	118	110	103	96	90	84	78	73	69	64	60	56
1980	195	181	168	156	146	135	126	118	110	102	96	89	83	78	73	68	64	60	56
1981	196	182	169	157	146	135	126	117	109	102	95	89	83	78	73	68	63	59	55
1982	197	183	169	157	146	135	126	117	109	102	95	89	83	77	72	67	63	59	55
1983	199	184	170	158	146	136	126	117	109	102	95	88	82	77	72	67	63	59	55
1984	201	186	172	159	147	137	127	118	110	102	95	89	83	77	72	67	63	59	55
1985	203	187	173	160	148	137	127	118	110	102	95	88	82	77	72	67	62	58	54
1986	205	189	174	160	148	137	127	118	109	102	95	88	82	76	71	66	62	58	54
1987	207	191	176	162	149	138	128	118	110	102	95	88	82	76	71	66	62	58	54
1988	209	193	177	163	151	139	129	119	110	102	95	88	82	76	71	66	62	58	54
1989	212	195	179	165	152	140	129	120	111	102	95	88	82	76	71	66	62	57	54
1990	214	197	181	167	153	141	130	120	111	103	95	88	82	76	71	66	61	57	53
1991	216	199	183	168	154	142	131	121	111	103	95	88	82	76	71	66	61	57	53
1992	217	200	184	169	155	143	131	121	112	103	95	88	82	76	70	65	61	56	53
1993	217	200	184	169	156	143	132	121	112	103	95	88	81	75	70	65	60	56	52
1994	217	200	185	170	156	144	132	121	112	103	95	87	81	75	69	64	60	55	51

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1956	56	53	50	46	44	41	38	36	34	32	30	28	26	24	23	22	20	19	286
1957	56	52	49	46	43	41	38	36	33	31	29	28	26	24	23	21	20	19	284
1958	55	52	49	46	43	40	38	35	33	31	29	27	26	24	22	21	20	19	280
1959	55	52	48	45	42	40	37	35	33	31	29	27	25	24	22	21	20	18	278
1960	55	51	48	45	42	40	37	35	33	31	29	27	25	24	22	21	19	18	276
1961	54	51	48	45	42	39	37	35	32	30	29	27	25	24	22	21	19	18	275
1962	54	51	48	45	42	39	37	34	32	30	28	27	25	23	22	21	19	18	274
1963	54	51	48	45	42	39	37	34	32	30	28	27	25	23	22	21	19	18	273
1964	54	51	47	44	42	39	37	34	32	30	28	27	25	23	22	21	19	18	272
1965	54	51	47	44	42	39	37	34	32	30	28	26	25	23	22	20	19	18	272
1966	54	50	47	44	42	39	37	34	32	30	28	26	25	23	22	20	19	18	271
1967	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	271
1968	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	270
1969	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	269
1970	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	268
1971	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	268
1972	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	268
1973	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	268
1974	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	268
1975	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	267
1976	53	50	47	44	41	39	36	34	32	30	28	26	24	23	22	20	19	18	267
1977	53	50	47	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	266
1978	53	50	46	43	41	38	36	33	31	29	28	26	24	23	21	20	19	18	263
1979	53	49	46	43	40	38	35	33	31	29	27	26	24	22	21	20	19	17	261
1980	52	49	46	43	40	38	35	33	31	29	27	25	24	22	21	20	18	17	259
1981	52	49	45	43	40	37	35	33	31	29	27	25	24	22	21	19	18	17	257
1982	52	48	45	42	40	37	35	32	30	28	27	25	23	22	21	19	18	17	254
1983	51	48	45	42	39	37	34	32	30	28	27	25	23	22	20	19	18	17	253
1984	51	48	45	42	39	37	34	32	30	28	26	25	23	22	20	19	18	17	252
1985	51	48	45	42	39	36	34	32	30	28	26	25	23	22	20	19	18	17	249
1986	51	47	44	41	39	36	34	32	30	28	26	24	23	21	20	19	18	16	247
1987	50	47	44	41	38	36	34	32	30	28	26	24	23	21	20	19	17	16	245
1988	50	47	44	41	38	36	34	31	29	27	26	24	23	21	20	19	17	16	243
1989	50	47	44	41	38	36	33	31	29	27	26	24	22	21	20	18	17	16	241
1990	50	46	43	41	38	35	33	31	29	27	25	24	22	21	19	18	17	16	239
1991	49	46	43	40	38	35	33	31	29	27	25	23	22	21	19	18	17	16	236
1992	49	46	43	40	37	35	32	30	28	26	25	23	22	20	19	18	17	16	233
1993	48	45	42	39	37	34	32	30	28	26	24	23	21	20	19	17	16	15	229
1994	48	45	41	39	36	34	31	29	27	26	24	22	21	20	18	17	16	15	224

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1995	9,300	8,785	8,299	7,841	7,400	6,973	6,561	6,172	5,801	5,451	5,125	4,815	4,510	4,231	3,970	3,721	3,491	3,270	3,060	2,857
1996	9,266	8,721	8,237	7,782	7,352	6,938	6,537	6,149	5,784	5,435	5,105	4,799	4,507	4,220	3,958	3,713	3,479	3,263	3,055	2,858
1997	9,229	8,689	8,177	7,724	7,296	6,892	6,503	6,125	5,761	5,416	5,088	4,777	4,489	4,214	3,944	3,697	3,467	3,248	3,045	2,850
1998	9,187	8,654	8,147	7,667	7,241	6,839	6,460	6,094	5,738	5,395	5,071	4,762	4,469	4,198	3,940	3,686	3,454	3,238	3,032	2,841
1999	9,153	8,615	8,115	7,639	7,189	6,789	6,411	6,054	5,709	5,375	5,052	4,747	4,456	4,181	3,926	3,683	3,445	3,227	3,024	2,831
2000	9,108	8,583	8,078	7,608	7,162	6,739	6,362	6,007	5,671	5,346	5,031	4,727	4,440	4,166	3,907	3,667	3,439	3,215	3,011	2,821
2001	9,064	8,540	8,047	7,574	7,133	6,714	6,316	5,963	5,629	5,312	5,007	4,711	4,425	4,154	3,897	3,653	3,428	3,214	3,003	2,811
2002	9,022	8,499	8,008	7,545	7,101	6,687	6,293	5,919	5,587	5,272	4,974	4,687	4,408	4,139	3,884	3,642	3,413	3,202	3,000	2,803
2003	8,965	8,459	7,969	7,508	7,074	6,656	6,267	5,897	5,545	5,232	4,936	4,656	4,385	4,123	3,869	3,630	3,403	3,188	2,989	2,800
2004	8,938	8,407	7,932	7,472	7,040	6,632	6,239	5,874	5,526	5,195	4,900	4,621	4,357	4,103	3,856	3,618	3,393	3,179	2,978	2,791
2005	8,893	8,381	7,882	7,437	7,005	6,598	6,214	5,845	5,500	5,172	4,860	4,582	4,319	4,070	3,830	3,597	3,374	3,163	2,962	2,773
2006	8,842	8,338	7,857	7,389	6,970	6,564	6,182	5,820	5,472	5,147	4,838	4,543	4,281	4,033	3,799	3,573	3,354	3,144	2,946	2,758
2007	8,822	8,292	7,818	7,367	6,928	6,535	6,153	5,794	5,454	5,126	4,821	4,529	4,252	4,005	3,772	3,551	3,339	3,134	2,936	2,751
2008	8,810	8,273	7,776	7,331	6,908	6,495	6,126	5,767	5,429	5,110	4,802	4,514	4,240	3,979	3,747	3,528	3,320	3,121	2,928	2,743
2009	8,767	8,261	7,757	7,290	6,872	6,474	6,086	5,738	5,400	5,081	4,779	4,488	4,217	3,958	3,713	3,494	3,288	3,093	2,906	2,725
2010	8,768	8,222	7,747	7,274	6,836	6,444	6,070	5,705	5,378	5,059	4,759	4,475	4,202	3,947	3,704	3,473	3,267	3,074	2,891	2,715
2011	8,771	8,223	7,711	7,265	6,821	6,409	6,040	5,689	5,346	5,038	4,738	4,456	4,188	3,931	3,691	3,463	3,246	3,053	2,872	2,700

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1995	2,663	2,480	2,306	2,143	1,991	1,851	1,721	1,599	1,485	1,380	1,282	1,191	1,106	1,028	956	891	831	775	725
1996	2,668	2,486	2,315	2,152	2,000	1,857	1,726	1,604	1,491	1,384	1,286	1,194	1,109	1,030	957	890	829	773	721
1997	2,666	2,488	2,318	2,157	2,005	1,862	1,730	1,607	1,493	1,387	1,288	1,196	1,111	1,032	958	890	828	771	718
1998	2,659	2,486	2,319	2,160	2,010	1,868	1,735	1,611	1,496	1,390	1,291	1,198	1,112	1,033	959	890	827	769	716
1999	2,652	2,482	2,319	2,163	2,014	1,874	1,741	1,616	1,500	1,393	1,294	1,202	1,115	1,035	961	892	828	769	715
2000	2,640	2,472	2,312	2,161	2,015	1,876	1,744	1,620	1,504	1,395	1,295	1,203	1,117	1,036	962	892	828	769	714
2001	2,633	2,463	2,306	2,157	2,014	1,878	1,748	1,625	1,508	1,400	1,299	1,205	1,119	1,039	963	894	829	769	714
2002	2,623	2,456	2,297	2,150	2,010	1,877	1,749	1,627	1,512	1,404	1,302	1,208	1,121	1,040	965	895	830	770	714
2003	2,615	2,446	2,289	2,141	2,003	1,871	1,747	1,627	1,513	1,406	1,305	1,210	1,122	1,040	965	895	830	770	714
2004	2,614	2,441	2,283	2,136	1,997	1,867	1,745	1,628	1,516	1,410	1,310	1,215	1,126	1,044	968	898	833	772	716
2005	2,598	2,433	2,271	2,123	1,986	1,856	1,735	1,621	1,512	1,408	1,309	1,215	1,127	1,045	968	898	833	772	715
2006	2,581	2,417	2,262	2,111	1,973	1,844	1,723	1,611	1,504	1,403	1,306	1,214	1,127	1,045	968	897	831	771	715
2007	2,574	2,408	2,255	2,110	1,968	1,839	1,719	1,606	1,501	1,401	1,306	1,216	1,130	1,049	972	901	835	773	717
2008	2,569	2,404	2,248	2,104	1,969	1,836	1,715	1,603	1,497	1,399	1,306	1,217	1,133	1,052	977	905	839	777	720
2009	2,552	2,389	2,235	2,089	1,955	1,829	1,705	1,592	1,488	1,389	1,298	1,211	1,129	1,050	976	905	839	777	720
2010	2,546	2,384	2,231	2,086	1,950	1,825	1,707	1,591	1,486	1,388	1,296	1,210	1,129	1,053	979	910	844	782	724
2011	2,536	2,377	2,225	2,082	1,947	1,820	1,703	1,592	1,484	1,386	1,295	1,208	1,129	1,053	982	913	848	787	729

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1995	677	633	592	554	519	487	457	433	410	389	373	356	346	329	310	293	272	253	235
1996	674	630	589	550	515	483	452	425	402	381	362	346	331	322	306	288	272	253	235
1997	670	627	585	547	511	478	448	420	394	373	354	336	322	307	299	284	267	252	235
1998	667	622	582	543	508	474	444	416	390	366	346	328	312	298	285	277	263	248	234
1999	666	620	578	541	505	472	441	412	386	362	340	322	305	289	277	265	257	244	230
2000	664	618	576	537	502	468	437	409	382	358	336	315	298	282	268	257	245	238	226
2001	663	616	573	534	498	465	434	405	379	354	332	311	292	276	261	248	238	227	220
2002	663	615	572	532	495	462	431	402	376	351	328	307	288	270	256	242	230	220	210
2003	662	614	570	529	492	458	427	399	372	347	324	303	284	266	249	236	224	212	203
2004	664	615	571	529	492	457	426	397	370	345	322	301	281	264	247	231	219	207	197
2005	663	615	570	528	490	455	423	394	367	343	320	298	279	260	244	228	214	203	192
2006	662	614	569	527	489	453	421	391	364	339	317	295	276	258	241	225	211	198	187
2007	665	616	571	529	490	454	421	391	364	338	315	294	274	256	239	223	209	196	184
2008	668	619	573	531	492	456	423	392	364	338	315	293	274	255	238	222	208	194	182
2009	667	618	573	530	491	455	422	391	363	337	313	291	271	253	236	220	206	192	180
2010	671	621	576	534	494	458	424	393	364	338	314	291	271	253	236	220	205	191	179
2011	675	625	579	537	497	461	427	395	366	340	315	292	272	253	235	220	205	191	178

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**
1995	217	200	185	170	157	144	132	122	112	103	95	87	81	74	69	64	59	55	51
1996	218	202	186	172	158	145	134	123	113	104	95	88	81	75	69	64	59	55	51
1997	218	202	187	173	159	147	135	124	114	105	96	89	82	75	69	64	59	55	51
1998	218	202	187	173	160	148	136	125	115	106	97	89	82	76	70	64	59	55	51
1999	217	202	188	174	161	149	137	126	116	107	98	90	83	76	70	65	60	55	51
2000	213	201	187	174	161	149	138	127	117	107	99	91	83	77	70	65	60	55	51
2001	209	197	186	173	161	149	138	127	117	108	99	91	84	77	71	65	60	55	51
2002	204	194	183	172	160	149	138	128	118	109	100	92	84	78	71	66	60	55	51
2003	194	188	179	168	159	148	137	127	118	109	100	92	85	78	72	66	60	56	51
2004	188	180	175	166	156	147	137	127	118	109	101	93	85	79	72	66	61	56	51
2005	182	174	166	162	153	144	136	127	118	109	101	93	86	79	73	67	61	56	52
2006	177	168	161	154	149	142	133	126	117	109	101	93	86	79	73	67	62	57	52
2007	174	164	156	149	143	138	131	124	117	109	101	93	86	80	73	68	62	57	52
2008	171	161	153	145	139	132	129	122	115	108	101	94	87	80	74	68	63	58	53
2009	168	158	149	141	134	128	122	119	113	106	100	93	87	80	74	68	63	58	53
2010	167	157	147	139	132	125	119	114	111	105	99	93	87	81	75	69	64	59	54
2011	167	156	146	137	130	123	116	111	106	103	98	92	87	81	75	70	64	59	55

A-1 (continued): Female numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1995	47	44	41	38	36	33	31	29	27	25	24	22	21	19	18	17	16	15	220
1996	47	44	41	38	35	33	31	29	27	25	23	22	20	19	18	17	16	15	218
1997	47	44	41	38	35	33	31	29	27	25	23	22	20	19	18	17	16	15	216
1998	47	44	41	38	35	33	30	28	26	25	23	22	20	19	18	16	15	14	213
1999	47	44	41	38	35	33	30	28	26	25	23	21	20	19	17	16	15	14	211
2000	47	44	40	38	35	32	30	28	26	24	23	21	20	18	17	16	15	14	209
2001	47	44	40	37	35	32	30	28	26	24	23	21	20	18	17	16	15	14	206
2002	47	44	40	37	35	32	30	28	26	24	22	21	19	18	17	16	15	14	203
2003	47	43	40	37	34	32	30	27	25	24	22	21	19	18	17	16	15	14	200
2004	47	44	40	37	34	32	30	27	25	24	22	20	19	18	17	15	14	13	198
2005	48	44	40	37	34	32	29	27	25	23	22	20	19	18	16	15	14	13	195
2006	48	44	40	37	34	32	29	27	25	23	22	20	19	17	16	15	14	13	192
2007	48	44	41	38	35	32	29	27	25	23	22	20	19	17	16	15	14	13	191
2008	49	45	41	38	35	32	30	27	25	23	22	20	19	17	16	15	14	13	189
2009	49	45	41	38	35	32	30	27	25	23	22	20	19	17	16	15	14	13	187
2010	50	46	42	39	35	33	30	28	25	24	22	20	19	17	16	15	14	13	186
2011	50	46	43	39	36	33	30	28	26	24	22	20	19	17	16	15	14	13	186

A-2: Male numbers at age.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1916	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1917	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1918	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1919	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1920	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1921	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1922	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,525	4,244	3,981	3,734	3,503
1923	11,817	11,084	10,397	9,753	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,524	4,244	3,981	3,734	3,503
1924	11,817	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,824	4,524	4,244	3,981	3,734	3,503
1925	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1926	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,845	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1927	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1928	11,816	11,084	10,397	9,752	9,148	8,581	8,049	7,550	7,082	6,643	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1929	11,816	11,083	10,396	9,752	9,147	8,580	8,049	7,550	7,082	6,643	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1930	11,815	11,083	10,396	9,752	9,147	8,580	8,048	7,550	7,082	6,642	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,981	3,734	3,502
1931	11,815	11,083	10,396	9,752	9,147	8,580	8,048	7,549	7,081	6,642	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,980	3,734	3,502
1932	11,815	11,083	10,396	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,231	5,844	5,482	5,142	4,823	4,524	4,244	3,980	3,734	3,502
1933	11,814	11,082	10,396	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,230	5,844	5,482	5,142	4,823	4,524	4,243	3,980	3,733	3,502
1934	11,814	11,082	10,395	9,751	9,147	8,580	8,048	7,549	7,081	6,642	6,230	5,844	5,482	5,142	4,823	4,524	4,243	3,980	3,733	3,502
1935	11,813	11,081	10,395	9,751	9,146	8,580	8,048	7,549	7,081	6,642	6,230	5,844	5,481	5,142	4,823	4,524	4,243	3,980	3,733	3,502
1936	11,812	11,081	10,394	9,750	9,146	8,579	8,047	7,549	7,081	6,642	6,230	5,843	5,481	5,141	4,822	4,523	4,243	3,980	3,733	3,501
1937	11,812	11,080	10,394	9,750	9,146	8,579	8,047	7,548	7,080	6,641	6,230	5,843	5,481	5,141	4,822	4,523	4,243	3,979	3,733	3,501
1938	11,810	11,079	10,393	9,749	9,145	8,579	8,047	7,548	7,080	6,641	6,229	5,843	5,480	5,141	4,822	4,523	4,242	3,979	3,732	3,500
1939	11,801	11,077	10,392	9,747	9,144	8,577	8,045	7,546	7,078	6,638	6,226	5,840	5,477	5,137	4,818	4,519	4,238	3,975	3,728	3,497
1940	11,783	11,068	10,389	9,745	9,141	8,574	8,042	7,542	7,074	6,634	6,221	5,834	5,471	5,131	4,811	4,512	4,231	3,968	3,721	3,489
1941	11,756	11,050	10,379	9,742	9,138	8,570	8,037	7,537	7,068	6,627	6,214	5,826	5,462	5,121	4,801	4,501	4,220	3,957	3,710	3,479
1942	11,566	11,014	10,350	9,718	9,117	8,546	8,008	7,502	7,026	6,579	6,160	5,766	5,396	5,051	4,727	4,425	4,142	3,878	3,631	3,400
1943	11,401	10,837	10,318	9,693	9,097	8,529	7,989	7,479	6,999	6,547	6,122	5,723	5,349	4,999	4,672	4,367	4,082	3,816	3,569	3,338
1944	11,174	10,685	10,155	9,666	9,077	8,513	7,974	7,460	6,974	6,514	6,081	5,674	5,293	4,935	4,602	4,291	4,003	3,734	3,485	3,254
1945	10,685	10,455	9,992	9,490	9,022	8,459	7,917	7,396	6,897	6,423	5,975	5,553	5,158	4,788	4,445	4,126	3,832	3,560	3,310	3,079
1946	10,409	10,007	9,788	9,351	8,875	8,430	7,894	7,376	6,879	6,401	5,947	5,518	5,115	4,738	4,388	4,062	3,762	3,486	3,233	3,000
1947	10,128	9,751	9,372	9,163	8,749	8,296	7,870	7,358	6,863	6,385	5,927	5,492	5,082	4,698	4,339	4,007	3,701	3,420	3,162	2,926
1948	9,937	9,489	9,134	8,775	8,576	8,182	7,751	7,346	6,859	6,387	5,933	5,497	5,084	4,696	4,333	3,995	3,683	3,397	3,134	2,894
1949	9,769	9,310	8,887	8,552	8,212	8,020	7,645	7,235	6,848	6,386	5,938	5,507	5,094	4,704	4,338	3,996	3,680	3,388	3,120	2,876
1950	9,617	9,153	8,721	8,323	8,005	7,682	7,496	7,139	6,749	6,379	5,940	5,516	5,108	4,718	4,350	4,005	3,685	3,389	3,117	2,867
1951	9,559	9,018	8,583	8,176	7,802	7,503	7,198	7,022	6,685	6,317	5,968	5,555	5,155	4,771	4,404	4,058	3,735	3,435	3,157	2,903
1952	9,510	8,963	8,456	8,047	7,665	7,313	7,031	6,744	6,578	6,260	5,913	5,584	5,195	4,819	4,458	4,114	3,789	3,486	3,205	2,945
1953	9,465	8,919	8,405	7,929	7,545	7,187	6,856	6,590	6,321	6,163	5,864	5,537	5,229	4,863	4,510	4,171	3,848	3,543	3,259	2,995
1954	9,435	8,875	8,363	7,881	7,433	7,073	6,735	6,424	6,174	5,919	5,770	5,488	5,181	4,890	4,547	4,215	3,897	3,594	3,309	3,043
1955	9,413	8,847	8,322	7,841	7,389	6,968	6,629	6,312	6,019	5,783	5,543	5,402	5,137	4,848	4,575	4,252	3,941	3,643	3,359	3,092

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1916	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1917	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1918	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1919	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1920	3,286	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1921	3,285	3,082	2,891	2,712	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1922	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1923	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1924	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1925	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1926	3,285	3,082	2,891	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1927	3,285	3,082	2,890	2,711	2,543	2,386	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1928	3,285	3,081	2,890	2,711	2,543	2,385	2,238	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1929	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,969	1,847	1,732	1,625	1,524	1,430	1,341	1,258	1,180	1,107	1,038
1930	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,969	1,847	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,107	1,038
1931	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,969	1,846	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,107	1,038
1932	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,099	1,968	1,846	1,732	1,625	1,524	1,429	1,341	1,258	1,180	1,107	1,038
1933	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,098	1,968	1,846	1,732	1,624	1,524	1,429	1,341	1,258	1,180	1,106	1,038
1934	3,285	3,081	2,890	2,711	2,543	2,385	2,237	2,098	1,968	1,846	1,732	1,624	1,524	1,429	1,341	1,257	1,179	1,106	1,038
1935	3,284	3,081	2,890	2,710	2,542	2,385	2,237	2,098	1,968	1,846	1,732	1,624	1,523	1,429	1,340	1,257	1,179	1,106	1,038
1936	3,284	3,080	2,889	2,710	2,542	2,384	2,236	2,098	1,968	1,846	1,731	1,624	1,523	1,429	1,340	1,257	1,179	1,106	1,037
1937	3,284	3,080	2,889	2,710	2,542	2,384	2,236	2,098	1,968	1,846	1,731	1,624	1,523	1,429	1,340	1,257	1,179	1,106	1,037
1938	3,283	3,080	2,889	2,709	2,541	2,384	2,236	2,097	1,967	1,845	1,731	1,623	1,523	1,428	1,340	1,257	1,179	1,106	1,037
1939	3,279	3,076	2,885	2,706	2,538	2,380	2,233	2,094	1,964	1,842	1,728	1,621	1,520	1,426	1,338	1,255	1,177	1,104	1,035
1940	3,273	3,069	2,878	2,699	2,532	2,374	2,227	2,089	1,959	1,838	1,723	1,617	1,516	1,422	1,334	1,251	1,174	1,101	1,033
1941	3,262	3,059	2,868	2,689	2,522	2,365	2,218	2,080	1,951	1,830	1,716	1,610	1,510	1,416	1,328	1,246	1,168	1,096	1,028
1942	3,185	2,983	2,795	2,619	2,454	2,301	2,156	2,022	1,895	1,777	1,666	1,562	1,465	1,374	1,289	1,209	1,133	1,063	997
1943	3,123	2,923	2,736	2,562	2,399	2,247	2,105	1,973	1,849	1,733	1,624	1,523	1,428	1,339	1,255	1,177	1,104	1,035	971
1944	3,040	2,841	2,656	2,484	2,324	2,175	2,036	1,907	1,786	1,674	1,568	1,470	1,378	1,292	1,211	1,135	1,065	998	936
1945	2,867	2,671	2,491	2,324	2,170	2,028	1,896	1,773	1,659	1,553	1,454	1,362	1,276	1,196	1,121	1,050	985	923	866
1946	2,787	2,591	2,411	2,246	2,094	1,954	1,824	1,704	1,593	1,490	1,395	1,305	1,222	1,145	1,073	1,005	942	883	828
1947	2,711	2,515	2,335	2,170	2,020	1,882	1,754	1,637	1,529	1,429	1,336	1,250	1,170	1,095	1,026	961	900	844	791
1948	2,675	2,476	2,294	2,129	1,978	1,839	1,713	1,596	1,489	1,390	1,299	1,214	1,136	1,063	995	932	873	818	766
1949	2,653	2,450	2,266	2,098	1,946	1,806	1,679	1,563	1,456	1,358	1,268	1,184	1,107	1,035	969	907	849	795	745
1950	2,640	2,434	2,246	2,076	1,921	1,780	1,652	1,536	1,429	1,331	1,241	1,158	1,082	1,011	945	884	828	775	726
1951	2,669	2,457	2,264	2,089	1,930	1,786	1,655	1,536	1,427	1,327	1,236	1,153	1,075	1,004	939	878	821	768	719
1952	2,706	2,488	2,290	2,109	1,946	1,797	1,663	1,541	1,429	1,328	1,235	1,150	1,072	1,000	934	873	816	763	714
1953	2,752	2,528	2,324	2,138	1,969	1,816	1,677	1,551	1,437	1,333	1,238	1,151	1,072	999	932	870	813	760	711
1954	2,796	2,568	2,359	2,168	1,994	1,836	1,693	1,564	1,446	1,339	1,242	1,154	1,073	999	931	868	810	757	708
1955	2,842	2,611	2,398	2,202	2,023	1,861	1,713	1,580	1,459	1,349	1,249	1,158	1,076	1,000	931	868	809	755	705

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1916	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1917	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1918	974	914	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1919	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1920	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1921	974	913	857	804	754	707	663	622	584	547	514	482	452	424	398	373	350	328	308
1922	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1923	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1924	974	913	857	804	754	707	663	622	584	547	513	482	452	424	398	373	350	328	308
1925	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1926	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1927	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1928	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1929	974	913	857	804	754	707	663	622	584	547	513	482	452	424	397	373	350	328	308
1930	974	913	857	804	754	707	663	622	583	547	513	482	452	424	397	373	350	328	308
1931	974	913	857	804	754	707	663	622	583	547	513	482	452	424	397	373	350	328	308
1932	974	913	857	803	754	707	663	622	583	547	513	482	452	424	397	373	350	328	308
1933	973	913	857	803	754	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1934	973	913	856	803	754	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1935	973	913	856	803	753	707	663	622	583	547	513	481	452	424	397	373	350	328	308
1936	973	913	856	803	753	707	663	622	583	547	513	481	451	423	397	373	349	328	308
1937	973	913	856	803	753	707	663	622	583	547	513	481	451	423	397	373	349	328	307
1938	973	912	856	803	753	706	663	622	583	547	513	481	451	423	397	372	349	328	307
1939	971	911	855	802	752	705	662	621	582	546	512	480	451	423	396	372	349	327	307
1940	969	908	852	799	750	703	660	619	580	544	511	479	449	421	395	371	348	326	306
1941	964	904	848	796	746	700	657	616	578	542	508	477	447	420	394	369	346	325	305
1942	935	877	823	772	724	679	637	597	560	526	493	462	434	407	382	358	336	315	295
1943	911	854	801	751	705	661	620	582	545	512	480	450	422	396	371	348	327	307	288
1944	878	823	772	724	679	637	598	561	526	493	463	434	407	382	358	336	315	295	277
1945	812	761	714	669	628	589	552	518	486	456	427	401	376	353	331	310	291	273	256
1946	776	728	682	640	600	563	528	495	464	435	408	383	359	337	316	297	278	261	245
1947	741	695	652	611	573	537	504	473	443	416	390	366	343	322	302	283	265	249	234
1948	718	673	631	592	555	520	488	457	429	402	377	354	332	311	292	274	257	241	226
1949	698	654	613	575	539	505	474	444	417	391	366	344	322	302	284	266	249	234	219
1950	680	637	597	560	525	492	461	432	406	380	357	334	314	294	276	259	243	228	214
1951	674	631	591	554	519	487	456	428	401	376	353	331	310	291	273	256	240	225	211
1952	669	626	586	549	515	483	452	424	397	373	349	328	307	288	270	253	238	223	209
1953	665	622	583	546	511	479	449	421	394	370	346	325	305	286	268	251	235	221	207
1954	662	619	579	542	508	476	446	418	391	367	344	322	302	283	266	249	234	219	205
1955	659	617	577	540	505	473	443	415	389	365	342	320	300	281	264	247	232	217	204

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1916	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1917	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1918	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1919	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1920	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1921	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1922	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1923	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1924	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1925	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1926	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1927	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1928	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1929	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1930	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	111	104	97	91
1931	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1932	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1933	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1934	289	271	254	238	223	210	197	184	173	162	152	143	134	126	118	110	104	97	91
1935	288	271	254	238	223	209	197	184	173	162	152	143	134	126	118	110	104	97	91
1936	288	271	254	238	223	209	196	184	173	162	152	143	134	126	118	110	104	97	91
1937	288	271	254	238	223	209	196	184	173	162	152	143	134	126	118	110	104	97	91
1938	288	270	254	238	223	209	196	184	173	162	152	143	134	125	118	110	104	97	91
1939	288	270	253	238	223	209	196	184	173	162	152	142	134	125	118	110	103	97	91
1940	287	269	253	237	222	208	196	183	172	161	151	142	133	125	117	110	103	97	91
1941	286	268	251	236	221	208	195	183	171	161	151	141	133	124	117	109	103	96	90
1942	277	260	244	229	214	201	189	177	166	156	146	137	129	121	113	106	100	93	88
1943	270	253	237	223	209	196	184	172	162	152	142	133	125	117	110	103	97	91	85
1944	260	244	229	215	201	189	177	166	156	146	137	129	121	113	106	100	93	88	82
1945	240	225	211	198	186	174	164	153	144	135	127	119	111	105	98	92	86	81	76
1946	230	215	202	189	178	167	156	147	138	129	121	114	106	100	94	88	82	77	73
1947	219	205	193	181	170	159	149	140	131	123	115	108	102	95	89	84	79	74	69
1948	212	199	187	175	164	154	144	135	127	119	112	105	98	92	87	81	76	71	67
1949	206	193	181	170	159	149	140	132	123	116	109	102	95	90	84	79	74	69	65
1950	200	188	176	165	155	145	136	128	120	113	106	99	93	87	82	77	72	67	63
1951	198	186	174	163	153	144	135	126	119	111	104	98	92	86	81	76	71	67	63
1952	196	184	172	162	152	142	133	125	117	110	103	97	91	85	80	75	70	66	62
1953	194	182	171	160	150	141	132	124	116	109	102	96	90	84	79	74	70	65	61
1954	193	181	169	159	149	140	131	123	115	108	101	95	89	84	78	74	69	65	61
1955	191	179	168	158	148	139	130	122	114	107	101	94	88	83	78	73	68	64	60

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1916	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1917	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1918	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1919	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1920	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1921	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1922	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1923	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1924	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1925	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1926	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1927	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1928	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1929	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1930	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1931	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1932	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1933	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1934	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1935	86	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1936	85	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1937	85	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1938	85	80	75	71	66	62	58	55	51	48	45	42	40	37	35	33	31	29	436
1939	85	80	75	70	66	62	58	55	51	48	45	42	40	37	35	33	31	29	435
1940	85	80	75	70	66	62	58	54	51	48	45	42	39	37	35	33	31	29	434
1941	85	79	75	70	66	62	58	54	51	48	45	42	39	37	35	32	30	29	432
1942	82	77	72	68	64	60	56	52	49	46	43	41	38	36	34	31	29	28	419
1943	80	75	70	66	62	58	54	51	48	45	42	40	37	35	33	31	29	27	408
1944	77	72	68	64	60	56	52	49	46	43	41	38	36	34	31	30	28	26	393
1945	71	67	63	59	55	52	48	45	43	40	38	35	33	31	29	27	26	24	363
1946	68	64	60	56	53	49	46	43	41	38	36	34	32	30	28	26	24	23	347
1947	65	61	57	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	331
1948	63	59	55	52	49	46	43	40	38	35	33	31	29	27	26	24	23	21	320
1949	61	57	54	50	47	44	42	39	37	34	32	30	28	27	25	23	22	21	311
1950	59	56	52	49	46	43	40	38	36	33	31	29	28	26	24	23	21	20	303
1951	59	55	52	48	45	43	40	37	35	33	31	29	27	26	24	22	21	20	299
1952	58	54	51	48	45	42	40	37	35	33	31	29	27	25	24	22	21	20	296
1953	57	54	51	47	44	42	39	37	34	32	30	28	27	25	23	22	21	19	292
1954	57	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	290
1955	56	53	50	47	44	41	38	36	34	32	30	28	26	25	23	22	20	19	287

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1956	9,394	8,827	8,296	7,803	7,351	6,926	6,531	6,212	5,913	5,637	5,415	5,189	5,056	4,806	4,535	4,278	3,975	3,684	3,404	3,138
1957	9,383	8,809	8,277	7,778	7,316	6,891	6,491	6,120	5,820	5,538	5,279	5,069	4,856	4,730	4,495	4,240	3,999	3,715	3,442	3,180
1958	9,358	8,799	8,261	7,761	7,294	6,859	6,460	6,085	5,736	5,454	5,190	4,945	4,748	4,548	4,429	4,208	3,969	3,742	3,476	3,220
1959	9,355	8,775	8,251	7,745	7,276	6,837	6,428	6,054	5,701	5,372	5,107	4,858	4,628	4,442	4,254	4,141	3,934	3,709	3,497	3,247
1960	9,357	8,773	8,229	7,736	7,261	6,821	6,408	6,024	5,671	5,339	5,030	4,780	4,546	4,330	4,155	3,978	3,872	3,677	3,466	3,267
1961	9,370	8,775	8,226	7,716	7,253	6,807	6,394	6,005	5,644	5,313	5,001	4,710	4,475	4,255	4,052	3,887	3,720	3,620	3,438	3,240
1962	9,393	8,787	8,229	7,714	7,235	6,801	6,382	5,993	5,628	5,289	4,978	4,684	4,412	4,191	3,984	3,792	3,638	3,481	3,387	3,216
1963	9,428	8,809	8,242	7,717	7,234	6,785	6,377	5,984	5,619	5,276	4,958	4,665	4,390	4,134	3,926	3,732	3,553	3,407	3,261	3,172
1964	9,464	8,842	8,262	7,729	7,238	6,784	6,362	5,979	5,610	5,267	4,946	4,647	4,372	4,113	3,873	3,678	3,496	3,327	3,191	3,053
1965	9,501	8,876	8,293	7,749	7,249	6,787	6,361	5,965	5,605	5,259	4,937	4,635	4,354	4,096	3,854	3,628	3,445	3,274	3,116	2,988
1966	9,539	8,911	8,325	7,777	7,267	6,797	6,364	5,964	5,592	5,255	4,929	4,627	4,343	4,080	3,838	3,610	3,398	3,227	3,066	2,918
1967	9,576	8,946	8,357	7,807	7,294	6,814	6,374	5,967	5,591	5,242	4,925	4,619	4,336	4,069	3,822	3,595	3,381	3,182	3,021	2,871
1968	9,618	8,982	8,391	7,838	7,322	6,840	6,390	5,976	5,594	5,242	4,914	4,617	4,330	4,063	3,813	3,581	3,368	3,168	2,981	2,830
1969	9,655	9,021	8,424	7,869	7,350	6,866	6,413	5,991	5,603	5,244	4,913	4,605	4,326	4,056	3,806	3,572	3,354	3,154	2,966	2,791
1970	9,687	9,055	8,460	7,900	7,379	6,892	6,437	6,012	5,616	5,251	4,914	4,603	4,314	4,051	3,798	3,564	3,344	3,139	2,952	2,776
1971	9,728	9,086	8,493	7,935	7,409	6,920	6,463	6,036	5,637	5,265	4,923	4,606	4,315	4,043	3,797	3,560	3,340	3,133	2,941	2,766
1972	9,773	9,124	8,522	7,966	7,442	6,949	6,491	6,062	5,661	5,287	4,938	4,616	4,320	4,046	3,791	3,560	3,338	3,131	2,938	2,758
1973	9,817	9,167	8,558	7,993	7,472	6,980	6,518	6,088	5,685	5,310	4,958	4,631	4,329	4,051	3,794	3,555	3,338	3,130	2,936	2,754
1974	9,860	9,209	8,599	8,028	7,498	7,008	6,547	6,113	5,710	5,332	4,980	4,650	4,343	4,060	3,799	3,558	3,334	3,131	2,935	2,753
1975	9,892	9,248	8,637	8,065	7,529	7,031	6,572	6,139	5,732	5,353	4,999	4,668	4,359	4,070	3,805	3,560	3,334	3,124	2,933	2,749
1976	9,916	9,278	8,673	8,100	7,563	7,060	6,593	6,162	5,755	5,373	5,017	4,684	4,374	4,084	3,813	3,564	3,334	3,122	2,925	2,746
1977	9,925	9,299	8,700	8,133	7,595	7,090	6,618	6,179	5,774	5,392	5,033	4,699	4,386	4,094	3,822	3,567	3,334	3,118	2,919	2,734
1978	9,915	9,307	8,720	8,157	7,625	7,119	6,645	6,201	5,788	5,407	5,048	4,710	4,396	4,102	3,828	3,572	3,334	3,114	2,912	2,726
1979	9,897	9,297	8,727	8,176	7,648	7,147	6,672	6,226	5,808	5,420	5,062	4,724	4,406	4,111	3,834	3,577	3,337	3,113	2,907	2,718
1980	9,869	9,280	8,718	8,182	7,664	7,168	6,698	6,250	5,831	5,438	5,073	4,735	4,418	4,118	3,841	3,581	3,340	3,114	2,904	2,712
1981	9,851	9,255	8,702	8,174	7,671	7,184	6,718	6,275	5,855	5,460	5,090	4,747	4,429	4,131	3,850	3,589	3,345	3,119	2,907	2,711
1982	9,825	9,237	8,678	8,159	7,662	7,189	6,732	6,293	5,877	5,481	5,110	4,762	4,439	4,141	3,860	3,596	3,352	3,123	2,911	2,713
1983	9,805	9,213	8,662	8,136	7,649	7,182	6,737	6,307	5,894	5,503	5,130	4,781	4,454	4,151	3,871	3,607	3,360	3,131	2,917	2,718
1984	9,806	9,196	8,641	8,123	7,630	7,172	6,733	6,316	5,911	5,523	5,155	4,806	4,478	4,171	3,886	3,623	3,376	3,144	2,929	2,729
1985	9,775	9,195	8,623	8,101	7,615	7,151	6,721	6,309	5,915	5,535	5,170	4,824	4,495	4,187	3,899	3,632	3,385	3,153	2,936	2,734
1986	9,740	9,166	8,622	8,084	7,595	7,138	6,702	6,297	5,909	5,539	5,181	4,838	4,513	4,204	3,915	3,644	3,393	3,161	2,944	2,740
1987	9,715	9,134	8,595	8,084	7,579	7,119	6,689	6,279	5,898	5,533	5,185	4,849	4,526	4,220	3,930	3,659	3,405	3,169	2,952	2,749
1988	9,688	9,110	8,564	8,059	7,578	7,104	6,671	6,267	5,881	5,522	5,179	4,851	4,535	4,232	3,945	3,672	3,417	3,179	2,959	2,756
1989	9,654	9,084	8,542	8,030	7,555	7,103	6,657	6,250	5,869	5,506	5,168	4,845	4,537	4,240	3,955	3,685	3,430	3,191	2,968	2,761
1990	9,619	9,053	8,518	8,009	7,528	7,082	6,657	6,237	5,854	5,496	5,155	4,837	4,533	4,243	3,964	3,697	3,444	3,204	2,980	2,771
1991	9,571	9,020	8,488	7,986	7,508	7,056	6,636	6,236	5,841	5,481	5,144	4,822	4,523	4,238	3,966	3,703	3,452	3,215	2,990	2,780
1992	9,509	8,975	8,458	7,959	7,487	7,038	6,612	6,218	5,841	5,470	5,131	4,814	4,511	4,231	3,962	3,706	3,460	3,225	3,002	2,792
1993	9,438	8,917	8,416	7,930	7,461	7,017	6,594	6,194	5,822	5,468	5,118	4,799	4,501	4,216	3,952	3,700	3,461	3,230	3,009	2,801
1994	9,368	8,850	8,362	7,891	7,435	6,994	6,578	6,180	5,804	5,454	5,121	4,793	4,492	4,212	3,945	3,697	3,461	3,236	3,019	2,812

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1956	2,888	2,655	2,438	2,238	2,055	1,888	1,736	1,599	1,474	1,360	1,258	1,165	1,080	1,003	932	868	809	754	704
1957	2,931	2,697	2,478	2,276	2,089	1,918	1,762	1,620	1,491	1,375	1,269	1,173	1,086	1,007	935	869	809	754	703
1958	2,974	2,740	2,521	2,316	2,127	1,952	1,792	1,646	1,513	1,392	1,283	1,184	1,094	1,013	939	872	810	754	703
1959	3,007	2,777	2,559	2,353	2,162	1,985	1,821	1,672	1,535	1,411	1,299	1,197	1,104	1,021	945	876	813	756	703
1960	3,033	2,808	2,593	2,389	2,197	2,018	1,852	1,699	1,560	1,432	1,316	1,211	1,116	1,030	952	881	817	758	705
1961	3,053	2,834	2,624	2,423	2,231	2,052	1,885	1,730	1,587	1,456	1,337	1,229	1,131	1,042	962	889	822	762	708
1962	3,030	2,855	2,650	2,453	2,265	2,086	1,918	1,762	1,617	1,483	1,361	1,250	1,149	1,057	974	899	830	769	712
1963	3,011	2,838	2,674	2,482	2,297	2,120	1,953	1,796	1,649	1,513	1,389	1,274	1,170	1,075	989	911	841	777	719
1964	2,970	2,820	2,657	2,503	2,323	2,150	1,985	1,828	1,681	1,544	1,417	1,300	1,193	1,095	1,006	926	853	787	727
1965	2,859	2,781	2,640	2,487	2,343	2,174	2,012	1,858	1,711	1,573	1,445	1,326	1,216	1,116	1,025	942	866	798	737
1966	2,798	2,677	2,603	2,471	2,328	2,193	2,035	1,884	1,739	1,601	1,472	1,352	1,241	1,138	1,044	959	881	811	747
1967	2,732	2,619	2,506	2,437	2,313	2,179	2,053	1,905	1,763	1,627	1,498	1,378	1,265	1,161	1,065	977	897	825	759
1968	2,689	2,559	2,453	2,347	2,282	2,166	2,040	1,922	1,784	1,651	1,524	1,403	1,290	1,185	1,087	997	915	840	772
1969	2,650	2,517	2,395	2,296	2,196	2,136	2,027	1,909	1,799	1,669	1,545	1,426	1,313	1,207	1,108	1,017	933	856	786
1970	2,612	2,479	2,355	2,240	2,148	2,054	1,998	1,896	1,786	1,682	1,561	1,444	1,333	1,227	1,128	1,036	951	872	800
1971	2,600	2,447	2,322	2,206	2,098	2,012	1,924	1,871	1,775	1,672	1,575	1,462	1,353	1,248	1,150	1,057	970	890	817
1972	2,593	2,438	2,294	2,177	2,068	1,967	1,886	1,804	1,754	1,664	1,568	1,477	1,370	1,268	1,170	1,078	991	910	835
1973	2,586	2,431	2,286	2,150	2,041	1,939	1,844	1,768	1,691	1,644	1,560	1,470	1,384	1,285	1,189	1,097	1,010	929	853
1974	2,583	2,425	2,280	2,143	2,016	1,914	1,818	1,729	1,658	1,585	1,542	1,463	1,378	1,298	1,204	1,115	1,029	947	871
1975	2,579	2,419	2,271	2,135	2,007	1,888	1,792	1,702	1,619	1,552	1,485	1,444	1,370	1,290	1,215	1,128	1,044	963	887
1976	2,574	2,414	2,264	2,125	1,998	1,878	1,767	1,677	1,593	1,515	1,452	1,389	1,351	1,282	1,207	1,137	1,055	976	901
1977	2,567	2,406	2,256	2,116	1,986	1,867	1,755	1,651	1,567	1,488	1,415	1,357	1,297	1,261	1,197	1,127	1,062	985	912
1978	2,553	2,396	2,245	2,105	1,974	1,853	1,741	1,636	1,539	1,461	1,387	1,319	1,265	1,209	1,176	1,116	1,051	990	918
1979	2,543	2,381	2,234	2,093	1,962	1,840	1,726	1,622	1,525	1,434	1,361	1,292	1,229	1,178	1,126	1,095	1,039	978	921
1980	2,534	2,371	2,219	2,082	1,950	1,828	1,714	1,608	1,511	1,420	1,335	1,267	1,203	1,144	1,096	1,048	1,019	966	910
1981	2,530	2,364	2,212	2,070	1,941	1,818	1,704	1,597	1,498	1,408	1,323	1,244	1,180	1,120	1,065	1,021	976	949	900
1982	2,529	2,360	2,205	2,062	1,930	1,810	1,695	1,588	1,488	1,396	1,312	1,232	1,159	1,099	1,043	992	951	909	883
1983	2,533	2,360	2,202	2,057	1,924	1,800	1,688	1,580	1,481	1,388	1,302	1,223	1,149	1,080	1,024	973	925	886	847
1984	2,542	2,369	2,207	2,060	1,924	1,799	1,683	1,578	1,477	1,384	1,297	1,217	1,143	1,074	1,010	958	909	864	828
1985	2,547	2,372	2,210	2,059	1,921	1,794	1,677	1,569	1,471	1,377	1,290	1,209	1,134	1,065	1,000	940	892	847	805
1986	2,552	2,376	2,213	2,061	1,920	1,791	1,672	1,563	1,462	1,370	1,283	1,202	1,126	1,056	992	931	876	830	788
1987	2,558	2,382	2,217	2,065	1,923	1,791	1,670	1,559	1,458	1,363	1,278	1,196	1,120	1,050	984	924	868	816	774
1988	2,565	2,387	2,222	2,068	1,925	1,793	1,670	1,557	1,454	1,359	1,270	1,191	1,115	1,044	978	917	861	809	760
1989	2,571	2,393	2,226	2,072	1,928	1,795	1,671	1,556	1,451	1,354	1,266	1,184	1,109	1,038	972	911	854	802	753
1990	2,578	2,400	2,233	2,077	1,932	1,798	1,674	1,558	1,451	1,353	1,262	1,180	1,103	1,034	967	906	849	796	747
1991	2,585	2,404	2,237	2,081	1,935	1,801	1,675	1,559	1,451	1,351	1,259	1,175	1,098	1,026	962	900	843	789	740
1992	2,595	2,412	2,242	2,087	1,941	1,804	1,678	1,561	1,452	1,351	1,258	1,172	1,094	1,022	955	895	837	784	734
1993	2,604	2,420	2,248	2,090	1,944	1,808	1,680	1,562	1,453	1,351	1,257	1,170	1,090	1,017	950	887	831	777	728
1994	2,617	2,432	2,259	2,099	1,950	1,814	1,686	1,567	1,456	1,354	1,259	1,171	1,089	1,015	946	884	826	773	723

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1956	657	614	574	537	503	471	441	413	387	362	339	318	298	279	262	246	230	216	202
1957	656	613	573	535	501	469	439	411	385	360	338	316	296	278	260	244	229	214	201
1958	655	611	571	533	499	466	436	408	382	358	335	314	294	276	258	242	227	213	199
1959	655	611	570	532	497	465	435	407	381	356	334	312	293	274	257	241	226	211	198
1960	656	611	569	531	496	463	433	405	379	355	332	311	291	273	256	239	224	210	197
1961	658	612	570	531	496	463	433	404	378	354	331	310	290	272	255	239	223	209	196
1962	661	615	572	533	497	463	433	404	378	353	331	309	290	271	254	238	223	209	196
1963	667	619	575	535	498	465	434	405	378	354	331	309	290	271	254	238	223	209	195
1964	673	624	579	538	501	466	435	406	379	354	331	309	289	271	254	237	222	208	195
1965	681	630	584	542	504	469	436	407	380	355	331	310	290	271	253	237	222	208	195
1966	689	637	590	546	507	471	439	408	381	355	332	310	290	271	253	237	222	208	195
1967	699	645	596	552	511	475	441	410	382	356	332	310	290	271	253	237	222	208	195
1968	710	654	604	558	516	479	444	413	384	358	334	311	291	271	254	237	222	208	195
1969	722	665	612	565	522	483	448	416	386	359	335	312	291	272	254	237	222	208	194
1970	735	675	621	572	528	488	452	419	389	361	336	313	292	272	254	237	222	208	194
1971	750	688	632	582	536	495	457	423	392	364	338	315	293	273	255	238	222	208	194
1972	766	703	645	593	545	502	464	428	397	368	341	317	295	275	256	239	223	208	195
1973	783	718	659	605	556	511	471	435	402	372	345	320	297	276	258	240	224	209	195
1974	800	734	673	618	567	521	479	442	408	377	349	323	300	279	259	241	225	210	196
1975	815	749	687	630	578	531	488	449	414	382	353	326	302	281	261	243	226	211	197
1976	830	763	700	643	590	541	497	456	420	387	357	330	305	283	263	244	227	211	197
1977	841	775	712	654	600	550	505	464	426	392	361	333	308	285	264	245	228	212	197
1978	849	784	722	664	609	559	513	471	432	397	365	336	310	287	265	246	228	212	197
1979	855	791	730	672	618	567	520	477	438	402	369	340	313	289	267	247	229	212	197
1980	857	795	736	679	625	574	527	484	444	407	374	343	316	291	269	248	230	213	198
1981	848	798	741	685	632	582	535	491	451	413	379	348	320	294	271	250	231	214	198
1982	838	789	743	689	638	588	542	498	457	419	385	353	324	298	274	252	233	215	199
1983	823	781	735	692	642	594	548	505	464	426	391	358	329	302	277	255	235	217	200
1984	792	770	730	687	647	600	555	512	472	434	398	365	335	307	282	259	238	220	203
1985	771	737	717	680	640	603	559	517	477	439	404	370	340	312	286	262	241	222	204
1986	749	718	686	667	633	596	561	520	481	444	409	375	345	316	290	266	244	224	206
1987	735	698	669	639	621	589	555	522	485	448	414	381	350	321	295	270	248	227	209
1988	721	684	651	623	596	579	549	517	487	451	417	385	354	326	299	274	252	231	212
1989	708	671	637	606	580	554	539	511	481	453	420	389	358	330	303	278	255	234	215
1990	702	659	625	593	564	540	516	502	476	448	422	391	362	334	307	282	259	238	218
1991	695	652	613	581	552	524	502	480	466	442	416	392	363	336	310	285	262	241	221
1992	688	646	606	570	540	512	487	466	446	433	410	386	364	337	312	288	265	243	223
1993	681	639	599	563	529	501	475	451	432	413	401	380	358	337	312	289	266	245	225
1994	677	633	593	557	522	491	465	441	419	401	383	372	353	332	312	289	268	247	227

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1956	190	178	167	156	147	138	129	121	113	106	100	94	88	82	77	72	68	64	60
1957	189	177	166	155	146	137	128	120	113	106	99	93	87	82	77	72	67	63	59
1958	187	175	164	154	144	135	127	119	112	105	98	92	86	81	76	71	67	63	59
1959	186	174	163	153	144	135	126	118	111	104	98	91	86	80	75	71	66	62	58
1960	185	173	162	152	143	134	125	118	110	103	97	91	85	80	75	70	66	62	58
1961	184	172	162	151	142	133	125	117	110	103	96	90	85	80	75	70	66	62	58
1962	183	172	161	151	142	133	124	117	109	103	96	90	85	79	74	70	65	61	57
1963	183	172	161	151	141	132	124	116	109	102	96	90	84	79	74	70	65	61	57
1964	183	171	161	151	141	132	124	116	109	102	96	90	84	79	74	69	65	61	57
1965	183	171	160	150	141	132	124	116	109	102	96	90	84	79	74	69	65	61	57
1966	182	171	160	150	141	132	124	116	109	102	95	89	84	79	74	69	65	61	57
1967	182	171	160	150	140	132	123	116	108	102	95	89	84	78	74	69	65	61	57
1968	182	171	160	150	140	131	123	115	108	101	95	89	84	78	73	69	65	61	57
1969	182	170	160	149	140	131	123	115	108	101	95	89	83	78	73	69	64	60	57
1970	182	170	159	149	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1971	182	170	159	149	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1972	182	170	160	149	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1973	183	171	160	150	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1974	183	171	160	150	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1975	184	172	160	150	140	131	123	115	108	101	95	89	83	78	73	68	64	60	56
1976	184	172	160	150	140	131	123	115	108	101	94	88	83	78	73	68	64	60	56
1977	184	172	160	150	140	131	122	115	107	100	94	88	83	77	73	68	64	60	56
1978	184	171	160	149	139	130	122	114	107	100	94	88	82	77	72	68	63	59	56
1979	184	171	159	149	139	130	121	113	106	99	93	87	82	76	72	67	63	59	55
1980	184	171	159	148	138	129	121	113	105	99	92	86	81	76	71	66	62	58	55
1981	184	171	159	148	138	129	120	112	105	98	92	86	80	75	71	66	62	58	54
1982	184	171	159	148	138	128	120	112	104	98	91	85	80	75	70	66	61	58	54
1983	185	172	159	148	138	128	120	112	104	97	91	85	80	74	70	65	61	57	54
1984	187	173	160	149	138	129	120	112	104	97	91	85	79	74	70	65	61	57	53
1985	188	174	161	149	139	129	120	112	104	97	91	85	79	74	69	65	61	57	53
1986	190	175	162	150	139	129	120	111	104	97	90	84	79	74	69	64	60	56	53
1987	192	177	163	151	140	129	120	112	104	97	90	84	78	73	68	64	60	56	52
1988	195	179	165	152	140	130	120	112	104	97	90	84	78	73	68	64	60	56	52
1989	197	181	166	153	141	131	121	112	104	97	90	84	78	73	68	63	59	55	52
1990	200	183	168	155	143	132	122	113	104	97	90	84	78	73	68	63	59	55	52
1991	202	186	170	156	144	133	122	113	104	97	90	83	78	72	67	63	59	55	51
1992	205	188	172	158	145	133	123	113	105	97	90	83	77	72	67	62	58	54	51
1993	207	189	174	159	146	134	123	114	105	97	90	83	77	72	67	62	58	54	50
1994	209	191	175	161	147	135	124	114	105	97	90	83	77	71	66	62	57	53	50

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1956	56	53	49	46	43	41	38	36	34	31	30	28	26	24	23	21	20	19	285
1957	56	52	49	46	43	40	38	36	33	31	29	27	26	24	23	21	20	19	283
1958	55	52	48	45	43	40	37	35	33	31	29	27	26	24	22	21	20	19	280
1959	55	51	48	45	42	40	37	35	33	31	29	27	25	24	22	21	20	18	278
1960	54	51	48	45	42	39	37	35	33	31	29	27	25	24	22	21	19	18	276
1961	54	51	48	45	42	39	37	35	32	30	28	27	25	23	22	21	19	18	275
1962	54	51	47	44	42	39	37	34	32	30	28	27	25	23	22	21	19	18	274
1963	54	50	47	44	42	39	37	34	32	30	28	27	25	23	22	21	19	18	273
1964	54	50	47	44	42	39	37	34	32	30	28	26	25	23	22	20	19	18	273
1965	54	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	272
1966	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	271
1967	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	271
1968	53	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	270
1969	53	50	47	44	41	38	36	34	32	30	28	26	25	23	22	20	19	18	269
1970	53	50	47	44	41	38	36	34	32	30	28	26	24	23	22	20	19	18	268
1971	53	50	46	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	268
1972	53	50	46	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	268
1973	53	50	46	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	268
1974	53	50	46	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	268
1975	53	49	46	43	41	38	36	34	32	30	28	26	24	23	21	20	19	18	267
1976	53	49	46	43	41	38	36	34	31	29	28	26	24	23	21	20	19	18	266
1977	52	49	46	43	41	38	36	33	31	29	28	26	24	23	21	20	19	18	265
1978	52	49	46	43	40	38	35	33	31	29	27	26	24	23	21	20	19	17	263
1979	52	48	45	43	40	37	35	33	31	29	27	25	24	22	21	20	18	17	261
1980	51	48	45	42	40	37	35	33	31	29	27	25	24	22	21	19	18	17	259
1981	51	48	45	42	39	37	35	32	30	28	27	25	23	22	21	19	18	17	257
1982	51	47	44	42	39	37	34	32	30	28	26	25	23	22	20	19	18	17	255
1983	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	17	253
1984	50	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	17	252
1985	50	47	44	41	38	36	34	32	30	28	26	24	23	21	20	19	18	17	250
1986	49	46	43	41	38	36	33	31	29	27	26	24	23	21	20	19	18	16	248
1987	49	46	43	40	38	35	33	31	29	27	26	24	23	21	20	19	17	16	246
1988	49	46	43	40	38	35	33	31	29	27	25	24	22	21	20	18	17	16	244
1989	49	45	43	40	37	35	33	31	29	27	25	24	22	21	19	18	17	16	242
1990	48	45	42	40	37	35	33	30	29	27	25	23	22	21	19	18	17	16	240
1991	48	45	42	39	37	34	32	30	28	26	25	23	22	20	19	18	17	16	238
1992	47	44	41	39	36	34	32	30	28	26	25	23	22	20	19	18	17	16	235
1993	47	44	41	38	36	34	31	29	28	26	24	23	21	20	19	17	16	15	231

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1994	9,368	8,850	8,362	7,891	7,435	6,994	6,578	6,180	5,804	5,454	5,121	4,793	4,492	4,212	3,945	3,697	3,461	3,236	3,019	2,812
1995	9,300	8,785	8,299	7,841	7,399	6,971	6,557	6,166	5,792	5,438	5,110	4,797	4,488	4,206	3,943	3,692	3,460	3,237	3,026	2,823
1996	9,266	8,721	8,237	7,781	7,350	6,934	6,531	6,142	5,774	5,422	5,089	4,780	4,485	4,195	3,930	3,683	3,448	3,230	3,021	2,824
1997	9,229	8,689	8,176	7,722	7,293	6,887	6,496	6,115	5,748	5,401	5,069	4,756	4,465	4,188	3,915	3,666	3,435	3,214	3,010	2,815
1998	9,187	8,654	8,147	7,665	7,238	6,834	6,452	6,083	5,724	5,378	5,051	4,739	4,443	4,170	3,909	3,654	3,420	3,203	2,996	2,805
1999	9,153	8,614	8,114	7,638	7,185	6,783	6,403	6,043	5,695	5,357	5,031	4,723	4,429	4,152	3,894	3,650	3,410	3,191	2,988	2,794
2000	9,108	8,582	8,077	7,607	7,159	6,733	6,353	5,994	5,655	5,326	5,008	4,701	4,411	4,134	3,874	3,632	3,403	3,178	2,973	2,783
2001	9,064	8,540	8,047	7,572	7,130	6,709	6,308	5,951	5,613	5,293	4,983	4,684	4,395	4,122	3,862	3,617	3,391	3,176	2,965	2,773
2002	9,022	8,499	8,007	7,544	7,097	6,682	6,285	5,908	5,571	5,252	4,951	4,659	4,377	4,105	3,849	3,605	3,375	3,162	2,961	2,764
2003	8,965	8,459	7,968	7,507	7,071	6,651	6,259	5,886	5,530	5,213	4,912	4,628	4,354	4,088	3,833	3,592	3,363	3,147	2,948	2,759
2004	8,938	8,406	7,932	7,471	7,037	6,627	6,232	5,863	5,511	5,176	4,877	4,594	4,327	4,069	3,819	3,579	3,353	3,139	2,937	2,750
2005	8,893	8,380	7,881	7,435	7,001	6,591	6,204	5,831	5,483	5,150	4,834	4,552	4,285	4,033	3,790	3,556	3,331	3,120	2,919	2,730
2006	8,842	8,337	7,856	7,386	6,966	6,557	6,171	5,805	5,453	5,123	4,809	4,511	4,245	3,994	3,756	3,529	3,309	3,098	2,900	2,712
2007	8,822	8,292	7,817	7,365	6,924	6,528	6,143	5,780	5,436	5,103	4,793	4,498	4,217	3,966	3,730	3,507	3,293	3,087	2,890	2,704
2008	8,810	8,273	7,775	7,330	6,905	6,490	6,118	5,755	5,413	5,089	4,776	4,484	4,206	3,942	3,706	3,485	3,275	3,075	2,882	2,696
2009	8,767	8,261	7,756	7,288	6,868	6,467	6,075	5,723	5,380	5,056	4,750	4,455	4,180	3,918	3,670	3,449	3,241	3,045	2,857	2,677
2010	8,768	8,222	7,746	7,273	6,833	6,438	6,061	5,692	5,360	5,037	4,732	4,444	4,166	3,908	3,662	3,429	3,222	3,026	2,843	2,667
2011	8,771	8,222	7,710	7,263	6,818	6,404	6,032	5,677	5,329	5,017	4,713	4,426	4,154	3,893	3,651	3,420	3,201	3,007	2,824	2,653

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1994	2,617	2,432	2,259	2,099	1,950	1,814	1,686	1,567	1,456	1,354	1,259	1,171	1,089	1,015	946	884	826	773	723
1995	2,628	2,445	2,272	2,110	1,960	1,821	1,693	1,573	1,461	1,358	1,262	1,173	1,091	1,015	945	881	822	768	719
1996	2,633	2,451	2,280	2,118	1,967	1,826	1,696	1,577	1,465	1,361	1,265	1,175	1,093	1,016	945	880	820	765	715
1997	2,630	2,452	2,282	2,122	1,971	1,830	1,699	1,578	1,467	1,363	1,266	1,176	1,093	1,016	944	878	817	762	711
1998	2,622	2,449	2,283	2,125	1,975	1,834	1,703	1,581	1,468	1,364	1,267	1,177	1,093	1,016	944	877	816	760	708
1999	2,615	2,445	2,283	2,128	1,979	1,840	1,708	1,586	1,472	1,366	1,270	1,179	1,095	1,017	945	878	816	759	706
2000	2,602	2,435	2,275	2,124	1,979	1,841	1,711	1,588	1,474	1,368	1,270	1,180	1,096	1,017	945	878	815	758	704
2001	2,594	2,425	2,269	2,120	1,978	1,843	1,714	1,593	1,478	1,372	1,273	1,181	1,097	1,019	946	878	816	758	704
2002	2,584	2,417	2,259	2,112	1,973	1,841	1,715	1,595	1,482	1,375	1,276	1,183	1,098	1,020	947	879	816	758	704
2003	2,575	2,407	2,251	2,103	1,966	1,836	1,713	1,595	1,483	1,377	1,278	1,185	1,099	1,020	947	879	816	757	703
2004	2,573	2,401	2,244	2,098	1,959	1,832	1,710	1,595	1,485	1,381	1,282	1,190	1,103	1,023	949	881	818	759	705
2005	2,556	2,391	2,230	2,083	1,947	1,819	1,700	1,587	1,480	1,378	1,281	1,189	1,103	1,023	948	880	817	758	703
2006	2,536	2,373	2,219	2,069	1,933	1,806	1,686	1,576	1,471	1,372	1,277	1,187	1,102	1,022	947	878	815	756	702
2007	2,528	2,363	2,211	2,067	1,927	1,800	1,682	1,570	1,467	1,369	1,277	1,188	1,104	1,025	950	881	817	758	703
2008	2,523	2,358	2,204	2,062	1,928	1,797	1,678	1,567	1,463	1,367	1,276	1,189	1,107	1,028	955	885	821	761	705
2009	2,504	2,342	2,189	2,045	1,913	1,788	1,666	1,556	1,453	1,356	1,267	1,182	1,102	1,026	953	884	820	760	705
2010	2,498	2,337	2,185	2,042	1,908	1,784	1,668	1,554	1,451	1,355	1,265	1,181	1,102	1,027	956	888	824	764	709
2011	2,488	2,330	2,179	2,038	1,904	1,779	1,663	1,554	1,448	1,352	1,263	1,179	1,101	1,027	957	891	828	768	712

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1994	677	633	593	557	522	491	465	441	419	401	383	372	353	332	312	289	268	247	227
1995	672	629	589	551	517	485	456	432	409	389	372	355	345	327	308	289	268	248	229
1996	669	625	585	547	513	481	451	424	401	381	361	346	330	321	304	286	269	249	230
1997	664	622	581	544	509	476	447	419	394	373	353	336	321	307	298	282	266	250	232
1998	661	617	577	540	505	472	442	415	389	365	346	328	312	298	285	276	262	246	232
1999	658	614	574	537	502	469	439	411	386	362	340	322	305	290	277	265	257	243	229
2000	656	611	570	532	498	465	435	407	381	358	335	315	298	283	268	257	245	238	226
2001	655	609	568	530	494	463	432	404	378	354	332	311	292	277	262	249	238	228	221
2002	654	608	566	527	492	459	429	401	375	351	328	308	289	271	257	243	231	221	211
2003	653	607	564	525	489	456	425	398	372	348	325	304	285	267	251	238	225	214	205
2004	654	607	564	524	488	454	424	395	370	345	323	302	283	265	249	233	221	209	199
2005	653	606	563	523	486	452	421	392	366	343	320	299	280	262	245	230	216	204	194
2006	651	604	561	521	484	449	418	389	363	339	317	296	277	259	242	227	213	200	189
2007	653	605	562	522	484	450	418	389	362	337	315	294	275	257	240	225	211	198	186
2008	655	608	564	523	485	451	419	389	362	337	314	293	274	256	239	224	209	196	184
2009	653	607	563	522	484	450	417	387	360	335	312	291	271	254	237	221	207	194	182
2010	657	609	565	524	486	451	419	389	361	335	312	290	271	253	236	221	206	193	180
2011	660	612	567	527	489	453	420	390	362	336	312	291	271	252	235	220	206	192	180

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1994	209	191	175	161	147	135	124	114	105	97	90	83	77	71	66	62	57	53	50
1995	210	193	177	162	149	137	125	115	106	97	90	83	77	71	66	61	57	53	49
1996	212	195	180	165	151	138	127	116	107	98	90	83	77	71	66	61	57	53	49
1997	214	197	181	167	153	140	128	118	108	99	91	84	77	72	66	61	57	53	49
1998	215	199	183	168	155	142	130	119	109	100	92	85	78	72	66	61	57	53	49
1999	215	200	184	170	156	144	132	121	111	101	93	85	79	72	67	62	57	53	49
2000	212	200	185	171	158	145	133	122	112	103	94	86	79	73	67	62	57	53	49
2001	209	197	185	172	159	146	134	123	113	104	95	87	80	73	67	62	57	53	49
2002	205	194	182	172	159	147	135	125	114	105	96	88	81	74	68	63	58	53	49
2003	195	190	180	169	159	147	136	125	115	106	97	89	82	75	69	63	58	53	49
2004	190	181	176	167	157	147	137	126	116	107	98	90	83	76	69	64	58	54	49
2005	184	176	168	163	154	145	137	126	117	108	99	91	83	76	70	64	59	54	50
2006	179	170	163	155	151	143	134	126	117	108	100	92	84	77	71	65	59	54	50
2007	176	166	158	151	144	140	133	125	117	109	100	92	85	78	72	66	60	55	51
2008	173	163	155	147	141	134	130	123	116	109	101	93	86	79	73	67	61	56	51
2009	170	160	151	143	136	130	124	120	114	107	101	93	86	80	73	67	62	56	52
2010	169	159	149	141	133	127	121	116	112	106	100	94	87	80	74	68	63	57	53
2011	168	158	148	139	131	124	118	113	108	105	99	93	88	81	75	69	63	58	53

A-2 (continued): Male numbers at age of spiny dogfish estimated by the base model.

Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1994	46	43	41	38	35	33	31	29	27	26	24	22	21	20	18	17	16	15	228
1995	46	43	40	38	35	33	31	29	27	25	24	22	21	19	18	17	16	15	225
1996	46	43	40	37	35	33	30	29	27	25	23	22	21	19	18	17	16	15	223
1997	46	43	40	37	35	32	30	28	26	25	23	22	20	19	18	17	16	15	220
1998	46	42	40	37	34	32	30	28	26	25	23	22	20	19	18	17	15	15	218
1999	45	42	39	37	34	32	30	28	26	24	23	21	20	19	17	16	15	14	216
2000	45	42	39	36	34	32	30	28	26	24	23	21	20	18	17	16	15	14	213
2001	45	42	39	36	34	31	29	27	26	24	22	21	20	18	17	16	15	14	211
2002	45	42	39	36	34	31	29	27	25	24	22	21	19	18	17	16	15	14	208
2003	45	42	39	36	33	31	29	27	25	23	22	20	19	18	17	16	15	14	205
2004	46	42	39	36	33	31	29	27	25	23	22	20	19	18	17	16	15	14	203
2005	46	42	39	36	33	31	29	27	25	23	22	20	19	18	16	15	14	13	201
2006	46	42	39	36	33	31	29	27	25	23	21	20	19	17	16	15	14	13	198
2007	46	43	39	36	33	31	29	27	25	23	21	20	19	17	16	15	14	13	196
2008	47	43	40	37	34	31	29	27	25	23	21	20	18	17	16	15	14	13	195
2009	47	43	40	37	34	31	29	27	25	23	21	20	18	17	16	15	14	13	192
2010	48	44	40	37	34	31	29	27	25	23	21	20	18	17	16	15	14	13	191
2011	49	45	41	38	35	32	29	27	25	23	21	20	18	17	16	15	14	13	190

APPENDIX B: Spiny dogfish assessment model files

B-1: Stock Synthesis starter file

```
#V3.21f
# Starter File for Spiny Dogfish Assessment 2011
Spiny_Dogfish.DAT
Spiny_Dogfish.CTL
0 # 0=use init values in control file; 1=use ss3.par
1 # run display detail (0,1,2)
1 # detailed age-structured reports in REPORT.SSO (0,1)
0 # write detailed checkup.sso file (0,1)
0 # write parm values to ParmTrace.sso
1 # report level in CUMREPORT.SSO (0,1,2)
1 # Include prior_like for non-estimated parameters (0,1)
1 # Use Soft Boundaries to aid convergence
3 # Number of bootstrap datafiles to produce
10 # Turn off estimation for parameters entering after this phase
10 # MCMC burn interval
2 # MCMC thin interval
0 # jitter initial parm value by this fraction
-1 # min yr for sdreport outputs (-1 for styr)
-2 # max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs
0 # N individual STD years
0.0001 # final convergence criteria
0 # retrospective year relative to end year
1 # min age for calc of summary biomass
1 # Depletion basis:  denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
1.0 # Fraction (X) for Depletion denominator
4 # (1-SPR)_reporting:  0=skip; 1=rel(1-SPR); 2=rel(1-SPR_MSY); 3=rel(1-SPR_Btarget);
4=notrel
1 # F_std reporting: 0=skip; 1=exploit(Bio); 2=exploit(Num); 3=sum(frates)
0 # F_report_basis: 0=raw; 1=rel Fspr; 2=rel Fmsy ; 3=rel Fbtgt
999
```

B-2: Stock Synthesis forecast file

```
#V3.21f
# Forecast File for Spiny Dogfish Assessment 2011
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0
for endyr, neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy
1 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)
0.45 # SPR target (e.g. 0.40)
0.4 # Biomass target (e.g. 0.40)
#_Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter
actual year, or values of 0 or -integer to be rel. endyr)
0 0 0 0 0 0
1 #Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
2 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F; 5=input annual F
12 # N forecast years
0.2 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF  (enter actual year, or
values of 0 or -integer to be rel. endyr)
0 0 -10 0
1 # Control rule method (1=catch=f(SSB) west coast; 2=F=f(SSB) )
0.4 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40)
0.1 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
1 # Control rule target as fraction of Flimit (e.g. 0.75)
3 #_N forecast loops (1-3) (fixed at 3 for now)
3 #_First forecast loop with stochastic recruitment
0 #_Forecast loop control #3 (reserved for future bells&whistles)
0 #_Forecast loop control #4 (reserved for future bells&whistles)
0 #_Forecast loop control #5 (reserved for future bells&whistles)
2011  #FirstYear for caps and allocations (should be after years with fixed inputs)
0 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause
active impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
1999 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to
1999)
2002 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas(row) x fleet(col)
below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
2 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio;
3=retainbio; 5=deadnum; 6=retainnum)
# max totalcatch by fleet (-1 to have no max)
-1 -1 -1 -1 -1 -1 -1 -1
# max totalcatch by area (-1 to have no max)
 -1
# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not
included in an alloc group)
0 0 0 0 0 0 0 0
#_Conditional on >1 allocation group
# allocation fraction for each of: 0 allocation groups
# no allocation groups
0 # Number of forecast catch levels to input (else calc catch from forecast F)
2 # basis for input Fcast catch:  2=dead catch; 3=retained catch; 99=input Hrate(F)
999 # verify end of input
```

B-3: Stock Synthesis data file

```
#V3.21f
# Data File for Spiny Dogfish Assessment 2011
1916 # Start Year
2010 # End Year
1    # Number Seasons/Year
12   # Months per Season
1    # Spawning Season
8    # Number of Fleets
5    # Number of Surveys
1    # Number of Areas
# Fleet & Survey Names
TRAWL%Trawl_Discard%MIDWATER%A-
SHOP%HKL%Hkl_Discard%OTHERS%RECREATIONAL%AFSC_triennial%AFSC_slope%NWFSC_shelf_slope%N
WFSC_slope%IPHC
0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5   0.5  # Fleet &
Survey CPUE
1     1     1     1     1     1     1     1     1     1     1     1     1    # Area
Assignment
1     1     1     1     1     1     1     1       # Catch Units:  1=bio; 2=num
0.05  0.05  0.05  0.05  0.05  0.05  0.05  0.05    # Catch Log(SE)
2 # Number of Sexes
95 # Last Age in Plus Group
0   0  0  0  0  0  0  0 # Initial Equilibrium Catch
95 # Number of Catch Observations
#catch biomass(mtons):
# note: for years prior to 1950, all trawl and hook&line catch is put in the discard
column
#       in order to meet the assumptions about selectivity that were chosen in the
STAR panel
#       this is directed catch, but assumed to have the selectivity equal to the
recent discard fleets
#
#Trawl,         Trawl_Discard,          Mdt,            A-SHOP,         Hkl,
Hkl_Discard,    Others,         Recreational,   Year,           Season
0               0                       0               0               0
0               0               0               1916            1
0               0.596304383             0               0               0
0.072169812     0               0               1917            1
0               1.192608766             0               0               0
0.144339625     0               0               1918            1
0               1.788913149             0               0               0
0.216509437     0               0               1919            1
0               2.385217532             0               0               0
0.28867925      0               0               1920            1
0               2.981521915             0               0               0
0.360849062     0               0               1921            1
0               3.577826298             0               0               0
0.433018874     0               0               1922            1
0               4.174130681             0               0               0
0.505188687     0               0               1923            1
0               4.770435064             0               0               0
0.577358499     0               0               1924            1
0               5.366739447             0               0               0
0.649528312     0               0               1925            1
0               5.96304383              0               0               0
0.721698124     0               0               1926            1
0               6.559348213             0               0               0
0.793867936     0               0               1927            1
```

0	7.155652596		0		0		0
0.866037749	0	0		1928		1	
0	7.751956979		0		0		0
0.938207561	0	0		1929		1	
0	8.348261362		0		0		0
1.010377374	0	0		1930		1	
0	8.944565745		0		0		0
1.082547186	0	0		1931		1	
0	20.43055995		0		0		0
2.472679592	0	0		1932		1	
0	18.923749		0		0		0
2.290312555	0	0		1933		1	
0	20.43946162		0		0		0
2.473756948	0	0		1934		1	
0	38.98003394		0		0		0
4.717694212	0	0		1935		1	
0	20.86795593		0		0		0
2.525616962	0	0		1936		1	
0	57.00309519		0		0		0
6.8989979	0	0		1937		1	
0	333.5105921		0		0		0
40.36427964	0	0		1938		1	
0	610.0079735		0		0		0
73.82833711	0	0		1939		1	
0	975.4849		0		0		0
96.0835	0	0		1940		1	
0	5287.2201		0		0		0
709.6981	1255.2287	0		1941		1	
0	4635.2701		0		0		0
131.4911	1393.4676	0		1942		1	
0	3035.8817		0		0		0
160.5703	5024.8393	0		1943		1	
0	9643.7868		0		0		0
2797.1053	4434.9781	0		1944		1	
0	5766.4744		0		0		0
968.8869	2476.9022	0		1945		1	
0	4503.255		0		0		0
328.4953	4338.1391	0		1946		1	
0	4144.5862		0		0		0
170.2249	1919.8137	0		1947		1	
0	4452.2802		0		0		0
10.1446	1056.3244	0		1948		1	
0	3946.457		0		0		0
204.5898	895.8662	0		1949		1	
366.0055	920.9162321		0		0		0
81.6238	659.2438	0		1950		1	
462.4746	851.6267363		0		0		0
0	436.112	0		1951		1	
818.1237	543.4039674		0		0		0
0	188.1868	0		1952		1	
362.8121	922.9874637		0		0		0
0	152.1163	0		1953		1	
347.5241	932.6472171		0		0		0
0	0	0		1954		1	
367.2795	920.0850331		0		0		0
0	0	0		1955		1	
219.455	987.5453922		0		0		0
0	0	0		1956		1	
825.4756	536.6213804		0		0		0
0	0	0		1957		1	

195.4037	988.9861212	0		0	0
0	0	0	1958	1	
155.699	979.2218719	0		0	0
0	0	0	1959	1	
73.1958	848.2355696	0		0	0
0	0	0	1960	1	
40.284	673.9864808	0		0	0
0	0	0	1961	1	
16.3487	396.038109	0		0	0
0	0	0	1962	1	
17.0856	408.3536595	0		0	0
0	0	0	1963	1	
19.3455	444.1095114	0		0	0
0	0	0	1964	1	
17.7798	419.6522685	0		0	0
0	0	0	1965	1	
20.4738	460.904419	0		0	0
0	0	0	1966	1	
12.8835	333.2747185	0		0	0
0	0	0	1967	1	
21.7144	478.6159352	0		0	0
0	0	0	1968	1	
30.473	584.7567931	0		0	0.0417
0.134674418	0.5021	0	1969	1	
11.3442	302.5440091	0		0	0
0	0.665	0	1970	1	
3.2561	103.5747721	0		0	1.3032
4.141169362	7.775	0	1971	1	
3.2812	104.3112206	0		0	0.5139
1.649619559	0.6908	0	1972	1	
2.2536	73.42903534	0		0	0.8233
2.632311639	0.4994	0	1973	1	
12.4729	325.2612897	0		0	0
0	0.4894	0	1974	1	
21.6483	477.6917746	0		0	0.01
0.032309256	6.6029	0	1975	1	
61.992	803.8859626	0		0	0.0454
0.146616937	7.3822	0	1976	1	
200.3865	989.058777	0		12.4325	1.8234
5.755936913	94.4343	0	1977	1	
173.7376	985.933113	0		7.91407	32.8928
73.25836581	177.681	0	1978	1	
167.4599	984.0851095	0		19.75448	117.3201
130.5780351	211.9014	0.696794286	1979	1	
93.3401	904.5433869	0		76.41622	66.4493
108.9591493	100.6806	0.111372857	1980	1	
227.9273	986.0720633	0		166.91934	12.7663
35.29607248	14.8833	32.80966143	1981	1	
94.8756	907.900765	0		129.82523	23.6499
57.94911972	11.0344	46.23674571	1982	1	
24.864	520.3417678	0		64.49924	5.792
17.4000305	24.4672	17.30393	1983	1	
240.1648	983.1974474	0		64.98355368	31.2195
70.71339739	7.6113	16.10179571	1984	1	
196.0251	989.0068165	0		23.16035022	101.2614
126.4665335	0.998	51.87868143	1985	1	
82.67	877.8384293	0		123.2568952	28.6974
66.69629337	4.635	62.17879571	1986	1	
90.7159	898.5401757	0		138.3310032	48.9093
93.47640793	23.0947	8.458904286	1987	1	

```
133.7367	964.1243391	0	107.7968396	62.2165
105.7367262	1.8072	48.45677571	1988	1
83.7912	880.9468012	0	54.57644214	207.1846
129.3161537	0.9235	24.15494	1989	1
341.2976	936.4521908	0	112.2883744	134.7367
133.0700248	2.5954	25.33195386	1990	1
693.5718	656.5770202	0	159.4495774	207.7048
129.2319268	0.8922	25.11564409	1991	1
879.8594	486.1664371	42.7706	384.7866094	176.6036
133.0584523	0.8822	25.30739754	1992	1
842.5961	520.7899102	8.2613	74.11029513	415.886
66.4500359	2.775	24.8376809	1993	1
1029.6417	345.1400793	25.1155	53.26381344	337.1246
94.94520656	0.0685	11.16399809	1994	1
357.9134	926.1297804	0.1288	198.3762707	7.3414
21.64236008	0.8396	19.6175701	1995	1
193.3781	988.8949422	3.8335	400.9655243	53.7291
98.32345067	0.2935	18.40475993	1996	1
336.1383	939.5443164	3.3363	327.7501725	85.4165
120.222759	0.226	4.569268571	1997	1
409.5933	891.0525784	49.7823	275.2463122	0.8437
2.696830255	1.9754	0.840440088	1998	1
430.2773	875.9916554	32.3109	470.1202253	43.6029
87.53142062	4.3473	11.16452777	1999	1
285.3583	966.4832706	35.5658	117.2884269	320.6128
100.3886637	5.094	10.03601385	2000	1
332.8282	941.4980552	12.6666	236.7773329	216.3483
127.7448328	2.2318	9.316	2001	1
436.8959	855.9127283	29.4944	299.3509609	409.0656
113.6479403	0.4132	14.54424867	2002	1
193.9074	806.6882175	7.9375	270.7074948	236.9134
56.65332154	8.7648	11.432	2003	1
129.2035	1114.186482	38.1816	612.9370771	235.1929
100.4075502	5.0159	2.53849929	2004	1
129.2396	1517.406426	71.1694	355.3752279	233.187
77.9092215	7.305	4.322033521	2005	1
117.4251	906.3998715	106.21	58.54476411	191.0573
177.5600694	6.1212	3.502790168	2006	1
62.8044	658.0122781	98.4422	155.0136718	217.3404
166.8892357	0.0408	5.553408202	2007	1
42.6347	993.7352345	157.6481	672.6961484	281.0582
134.6786785	14.8801	2.759732699	2008	1
78.4532	587.0116879	75.8513	163.8148972	54.5927
181.4842761	1.2818	4.170583234	2009	1
42.4513	690.5303626	111.1701	277.7304911	9.9342
28.39123871	0.166	2.134951406	2010	1
#
37 # Number of Survey Observations
#_Units:  0=numbers; 1=biomass; 2=F
#_Errtype:  -1=normal; 0=lognormal; >0=T
#_Fleet Units Errtype
1	1	0 # TRAWL
2	1	0 # Trawl_Discard
3	1	0 # MIDWATER
4	1	0 # ASHOP
5	1	0 # HKL
6	1	0 # Hkl_Discard
7	1	0 # OTHERS
8	1	0 # RECREATIONAL
9	1	0 # AFSC_triennial
10	1	0 # AFSC_slope
```

```
11      1       0 # NWFSC_shelf_slope
12      1       0 # NWFSC_slope
13      0       0 # IPHC
#
#Year     Seas     Flt/Svy   Value            se(log)
#AK triennial early
1980      1        9          18273.54929      0.151893682
1983      1        9          47555.38734      0.118063544
1986      1        9          19401.1589       0.079169309
1989      1        9          47852.12199      0.092937629
1992      1        9          43344.25016      0.122436401
#AK triennial late
1995      1        9          17029.6425       0.113045158
1998      1        9          36857.00747      0.088431907
2001      1        9          19207.08261      0.130304265
2004      1        9          19591.52487      0.130245646
#AK slope survey
1997      1       10        170735.4357       0.208844092
1999      1       10         95279.04731      0.225988167
2000      1       10        151995.9085       0.305576749
2001      1       10         25888.8171       0.274455916
#NWFSC shelf-slope survey
2003      1       11        381759.1918       0.160463469
2004      1       11        159888.5846       0.108160502
2005      1       11         69961.21087      0.085743992
2006      1       11         52320.96023      0.098684747
2007      1       11         45088.54529      0.10646107
2008      1       11         38536.16147      0.089546878
2009      1       11         12661.33472      0.096037614
2010      1       11         36687.68982      0.097444537
#NWFSC slope survey
1998      1       12         18303.95129      0.294833338
1999      1       12         30482.30829      0.37382539
2000      1       12          4836.27698      0.263906345
2001      1       12          1338.66508      0.289792009
2002      1       12          3104.27484      0.224642233
#IPHC survey index
1999      1        13         0.04660894      0.04042673
2001      1        13         0.03154061      0.060150
2002      1        13         0.03046442      0.06380108
2003      1        13         0.03382919      0.0585752
2004      1        13         0.02191657      0.06942163
2005      1        13         0.04115358      0.04518476
2006      1        13         0.02760627      0.06088055
2007      1        13         0.05916682      0.04517815
2008      1        13         0.04034273      0.05284818
2009      1        13         0.03501256      0.04846891
2010      1        13         0.03108719      0.04795516
#
0 #_N_fleets_with_discard
0 #_N_discard_obs
#
8 # Number of Mean Body Weight Observations
#_Year  Seas  Flt/Svy    Part(0=whole catch, 1=discarded, 2=retained)  Value(kg)    CV
30 # degrees of freedom for bodywt T-distribution
#Fishery Trawl_Discard
2002    1      2      0     1.17        0.5
2003    1      2      0     1.19        0.5
2004    1      2      0     1.11        0.5
2005    1      2      0     1.17        0.5
#Fishery Hkl Discard
```

```
2002    1      6      0     1.36        0.5
2003    1      6      0     1.14        0.5
2004    1      6      0     1.55        0.5
2005    1      6      0     2.06        0.5
#
# Population Length Structure
2 # Population Length Bin Option (1=use databins; 2=generate from binwidth,min,max
below; 3=read vector)
2
10
136
-1 # Compress Tails
1e-005 # value added to comps
0 # Combine Males int Females Below Bin
31 # Number of Observed Length Bins
12  16  20  24  28  32  36  40  44  48  52  56  60  64  68  72  76  80  84  88  92  96
100  104  108  112  116  120  124  128  132
63 # Number of Length Observations
#_Year seas Flt/Svy Gender Part Nsamp datavector(female-male)
#Fishery Trawl Langings
#                             F12 F16 F20 F24 F28 F32 F36 F40 F44 F48   F52 F56   F60
F64   F68   F72   F76   F80   F84   F88   F92   F96   F100  F104  F108  F112  F116
F120  F124  F128  F132  M12  M16  M20  M24  M28 M32 M36 M40 M44   M48   M52   M56
M60  M64   M68   M72   M76   M80   M84   M88  M92 M96 M100  M104  M108  M112  M116
M120  M124  M128  M132
2003  1   1   3   2   4       0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 9 6 2 5 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2006  1   1   3   2   38      0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 2 3 0 5 2 2 4 10  4 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 3 12  75  64  46  13  0 0 0 0 0 0 0 0 0 0 0
2007  1   1   3   2   63      0 0 0 0 0 0 0 0 0 1 1 0 0 0 3 3 5 2 16  17  24  48  42
33  28  10  2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 11  21  54  47  41  12  0 0 0 0 0 0
0 0 0 0 0
2009  1   1   3   2   28      0 0 0 0 0 0 0 0 0 1 1 3 7 6 6 7 4 2 0 1 1 0 1 2 4 5 6 1
0 1 1 0 0 0 0 0 0 0 0 0 1 2 5 9 12  8 9 3 12  11  10  3 2 2 0 0 1 1 0 0 0 0
#Fishery Trawl Discard
#                             F12  F16  F20  F24  F28  F32  F36  F40  F44  F48  F52
F56  F60  F64  F68  F72  F76  F80  F84  F88  F92  F96  F100  F104  F108  F112  F116
F120  F124  F128  F132  M12  M16  M20  M24  M28  M32  M36  M40  M44  M48  M52  M56
M60  M64  M68  M72  M76  M80  M84  M88  M92  M96  M100  M104  M108  M112  M116  M120
M124  M128  M132
#WDFW at sea sampling (EFP)
2004  1   2   3   0   40      0 0 0 0 0 0 0 1 1 4 2 13  8 16  11  9 12  3 6 5 3 2 3 1
2 2 1 0 0 1 0 0 0 0 0 0 0 0 1 1 6 8 8 9 21  13  20  9 5 0 1 0 0 0 0 0 0 0 0 0 0 0
#WCGOP
2006  1   2   3   0   909     0 2 3 13  22  13  28  37  60  82  86  78  75  75  55  45
21  21  24  15  12  8 10  7 1 1 0 0 0 1 0 0 0 3 3 14  10  18  26  46  40  46  68  67
85  97  99  80  53  38  22  4 4 1 0 0 0 0 0 0 0 0
2007  1   2   3   0   678     3 3 2 8 5 5 10  22  31  48  56  58  54  56  25  27  14
13  13  8 7 10  10  6 6 1 1 1 0 0 0 2 4 5 4 4 4 8 17  25  40  58  56  73  80  88  80
66  45  26  10  3 1 0 0 0 0 0 0 0 0 0
2008  1   2   3   0   314     0 0 0 2 6 1 4 9 5 12  16  23  31  37  25  2 6 8 5 14  13
13  5 11  5 4 0 0 0 0 0 0 0 0 2 4 5 6 1 6 7 12  19  33  37  45  34  42  29  16  12  0
2 1 0 0 0 1 0 0 0 0
2009  1   2   3   0   1282    0 0 0 7 12  12  14  35  38  62  77  103 94  100 92  45
30  27  26  40  28  48  62  39  30  8 1 1 0 0 0 0 0 0 5 4 2 12  20  16  46  80  91
102 115 125 164 160 177 89  40  8 6 2 2 0 0 0 0 0 0 0
#Mdt
#                             F12  F16  F20  F24  F28  F32  F36  F40  F44  F48  F52
F56  F60  F64  F68  F72  F76  F80  F84  F88  F92  F96  F100  F104  F108  F112  F116
F120  F124  F128  F132  M12  M16  M20  M24  M28  M32  M36  M40  M44  M48  M52  M56
```

M60 M64 M68 M72 M76 M80 M84 M88 M92 M96 M100 M104 M108 M112 M116 M120
M124 M128 M132
2005 1   3   3   2   21   0 0 0 0 0 0 0 8 16 16 8 19 11 10 3 2 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 3 17 12 8 17 21 10 11 4 1 1 0 1 0 0 0 0 0 0 0 0 0
0 0
2006 1   3   3   2   56   0 0 0 0 8 13 50 52 41 19 10 2 4 5 8 2 1 3 0 0 0 1
0 0 0 0 0 0 0 0 0 0 0 0 0 0 6 17 40 43 55 22 7 9 14 8 16 7 14 9 6 0 0 0 0 0 0 0
0 0 0 0 0
2007 1   3   3   2   106   0 0 0 0 0 0 5 18 41 51 31 52 44 75 53 17 13 1
1 2 0 2 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 2 9 26 45 52 48 56 84 64 38 75 34 32
2 0 0 0 0 0 0 0 0 0 0 0
2008 1   3   3   2   21   0 0 0 0 0 0 0 0 1 0 1 2 8 16 15 5 4 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 1 3 4 8 9 21 17 10 14 8 2 0 0 0 0 0 0 0 0 0 0 0 0
2009 1   3   3   2   28   0 0 0 0 0 1 7 12 9 3 3 14 11 5 2 0 1 0 1 1 8 7 12 6
1 0 1 0 0 0 0 0 1 0 0 1 1 4 9 10 6 5 8 9 10 6 4 1 1 0 0 0 0 0 0 0 0 0 0 0 0
2010 1   3   3   2   78   0 0 0 0 0 0 0 1 6 25 39 58 38 40 12 6 0 0 0 1 3 2
3 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 17 34 62 40 42 31 21 32 19 17 23 7 2 0
0 0 0 0 0 0 0 0
#A-SHOP
F12 F16 F20 F24 F28 F32 F36 F40 F44 F48 F52 F56 F60 F64
F68 F72 F76 F80 F84 F88 F92 F96 F100 F104 F108 F112 F116 F120 F124 F128 F132
M12 M16 M20 M24 M28 M32 M36 M40 M44 M48 M52 M56 M60 M64 M68 M72 M76 M80 M84 M88 M92
M96 M100 M104 M108 M112 M116 M120 M124 M128 M132
2007 1   4   3   0   2883   0 0 0 0 0 4 16 41 134 206 148 221 172 160 94 26 20
16 16 17 30 43 66 39 34 13 8 3 3 1 1 0 2 0 2 3 5 21 52 124 145 227 228 174
227 151 96 101 65 45 29 18 9 4 2 1 1 0 1 0 0 0
2008 1   4   3   0   15657   0 0 1 3 11 14 20 56 562 1350 959 1149 1102 1221
573 248 177 97 94 128 118 142 163 108 90 23 8 1 1 0 0 3 4 3 3 10 19 14 56 506
970 1350 1264 1203 1523 1280 944 1237 698 389 81 7 5 3 1 2 1 0 0 0 0 0
2009 1   4   3   0   4236   0 0 0 0 0 2 6 23 124 216 113 119 114 176 173 111 109 47
42 45 35 63 42 25 18 4 1 0 0 0 0 0 1 1 0 0 1 3 23 106 161 232 126 120 237 419
486 706 407 218 40 3 1 0 0 1 0 0 0 0 0 0
2010 1   4   3   0   8384   0 3 0 1 1 10 30 99 336 533 555 765 484 376 198 71 44
15 18 24 34 58 64 32 26 9 4 1 0 0 0 1 0 0 0 3 12 43 88 331 402 736 816 581
633 501 470 756 437 240 49 6 2 1 0 0 0 0 0 0 0 0
#Hkl Landings
F12 F16 F20 F24 F28 F32 F36 F40 F44 F48 F52 F56 F60 F64
F68 F72 F76 F80 F84 F88 F92 F96 F100 F104 F108 F112 F116 F120 F124 F128 F132
M12 M16 M20 M24 M28 M32 M36 M40 M44 M48 M52 M56 M60 M64 M68 M72 M76 M80 M84 M88 M92
M96 M100 M104 M108 M112 M116 M120 M124 M128 M132
2003 1   5   3   2   18   0 0 0 0 0 0 0 0 0 0 0 0 0 2 1 1 1 1 3 5 4 13 11 11 2 9
2 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 6 2 7 8 4 1 0 2 0 0 0 0 0 0 0 0 0
2004 1   5   3   2   14   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 1 0 3 8 7 13 20 16 9
1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 4 1 4 1 0 0 0 0 0 0 0 0 0 0 0
2006 1   5   3   2   71   0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 6 35 34 58 58 50 111
95 64 44 13 5 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 15 43 45 31 8 1 0 0 0 0 0
0 0 0 0 0
2007 1   5   3   2   56   0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 3 10 11 27 64 56 122
133 70 48 16 6 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 11 31 24 14 8 0 0 0 0 0 0
0 0 0 0 0
2008 1   5   3   2   106   0 0 0 0 0 0 0 0 0 1 0 3 5 19 21 12 22 7 27 38 42
75 63 46 29 6 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 2 7 28 44 56 105 65 38 19 1 0
0 0 0 0 0 0 0 0 0
2009 1   5   3   2   35   0 0 0 0 0 0 0 0 0 1 0 3 6 8 7 8 8 4 11 12 11 1 4 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 6 26 13 32 35 27 21 5 0 0 0 0 0 0 0 0 0 0 0
#Fishery Hkl Discard
F12 F16 F20 F24 F28 F32 F36 F40 F44 F48 F52
F56 F60 F64 F68 F72 F76 F80 F84 F88 F92 F96 F100 F104 F108 F112 F116
F120 F124 F128 F132 M12 M16 M20 M24 M28 M32 M36 M40 M44 M48 M52 M56
M60 M64 M68 M72 M76 M80 M84 M88 M92 M96 M100 M104 M108 M112 M116 M120
M124 M128 M132

```
#WDFW at sea sampling (EFP)
2003  1   6   0   0   35      0 0 0 6 5 68  368 290 855 514 314 517 205 212 73  116
143 7 20  3 15  4 15  7 7 9 1 1 0 0 0 0 0 0 6 5 68  368 290 855 514 314 517 205 212 73
116 143 7 20  3 15  4 15  7 7 9 1 1 0 0 0
2004  1   6   0   0   21      0 0 0 0 0 1 11  31  134 194 61  245 84  195 63  86  95
15  58  17  13  1 4 1 0 3 1 0 0 0 0 0 0 0 0 0 1 11  31  134 194 61  245 84  195 63  86
95  15  58  17  13  1 4 1 0 3 1 0 0 0 0
#WCGOP
2006  1   6   3   0   572     0 0 0 0 0 0 1 1 8 19  27  43  67  61  57  41  36  16  24
11  15  11  6 3 2 1 0 0 0 0 0 0 0 0 0 0 1 0 1 5 21  25  37  42  75  80  74  52  49  33
7 3 0 1 0 0 0 0 0 0 0 0
2007  1   6   3   0   629     0 0 0 0 0 0 0 6 4 16  27  75  74  50  37  34  33  38  19
27  27  12  14  6 4 3 0 0 0 0 0 0 0 0 0 0 0 0 2 4 15  33  71  89  115 102 108 68  48
16  5 2 1 0 0 0 0 0 0 0 0 0
2008  1   6   3   0   29      0 0 0 0 0 0 0 0 0 1 0 5 4 2 4 2 1 0 2 2 0 4 2 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 6 7 3 2 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
2009  1   6   3   0   44      0 0 0 0 0 0 0 0 0 1 0 4 3 5 1 1 2 0 0 0 4 3 1 3 3 4 5 3
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 4 2 4 4 12  3 3 0 1 0 0 0 0 0 0 0 0 0 0
#
#Fishery Recreational
#                             U12  U16  U20  U24  U28  U32  U36  U40  U44  U48  U52
U56  U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112  U116
U120  U124  U128  U132  U12  U16  U20  U24  U28  U32  U36  U40  U44  U48  U52  U56
U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112  U116  U120
U124  U128  U132
1993  1   8   0   0   15      0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 3 2 2 1 1 2 0 2 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 3 2 2 1 1 2 0 2 0 0 0 0 0 0 0
1994  1   8   0   0   14      0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 2 5 2 0 2 2 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 2 5 2 0 2 2 0 0 0 0 0 0 0 0 0
1995  1   8   0   0   16      0 0 0 0 0 0 0 0 0 0 0 0 0 1 2 2 2 1 2 5 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 2 2 2 1 2 5 1 0 0 0 0 0 0 0 0 0 0
1996  1   8   0   0   18      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 3 1 2 3 3 1 1 2 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 3 1 2 3 3 1 1 2 0 0 0 0 0 0
1997  1   8   0   0   6       0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 2 1 1 0 0 0 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 2 1 1 0 0 0 1 0 0 0 0 0 0
1999  1   8   0   0   27      0 0 0 0 0 0 0 0 0 0 0 1 4 2 1 0 3 4 3 3 0 2 0 1 2 0 0 0
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 4 2 1 0 3 4 3 3 0 2 0 1 2 0 0 0 1 0 0
2000  1   8   0   0   12      0 0 0 0 0 0 0 0 0 0 0 0 3 1 1 2 1 0 0 0 2 1 1 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 1 1 2 1 0 0 0 2 1 1 0 0 0 0 0 0 0 0
2001  1   8   0   0   6       0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 2 1 0 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 2 1 0 1 0 0 0 0 0 0
2002  1   8   0   0   9       0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 2 2 1 1 1 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 2 2 1 1 1 1 0 0 0 0 0 0
2003  1   8   0   0   13      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 4 0 3 2 2 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 4 0 3 2 2 0 0 0 0 0 0
2004  1   8   0   0   17      0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 3 2 2 1 0 0 2 1 2 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 3 2 2 1 0 0 2 1 2 1 1 0 0 0 0 0 0
2005  1   8   0   0   27      0 0 0 0 0 0 0 0 0 1 1 1 1 0 4 0 2 3 2 2 3 1 2 2 0 1 1
0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 4 0 2 3 2 2 3 1 2 2 0 1 1 0 0 0
2006  1   8   0   0   66      0 0 0 0 0 0 0 0 1 2 3 4 3 2 3 3 7 9 4 5 1 4 6 3 2 3 0 0
0 0 0 0 0 0 0 0 0 0 0 1 2 3 4 3 2 3 3 7 9 4 5 1 4 6 3 2 3 0 0 0 0 0 0
2007  1   8   0   0   46      0 0 0 0 0 0 1 0 1 1 1 1 0 2 2 1 1 1 2 5 2 11  6 3 2 2 0
0 1 0 0 0 0 0 0 0 0 1 0 1 1 1 1 0 2 2 1 1 1 2 5 2 11  6 3 2 2 0 0 1 0 0
2008  1   8   0   0   31      0 0 0 1 0 0 1 0 0 0 1 1 1 0 1 0 2 4 3 0 3 2 5 4 1 0 0 0
1 0 0 0 0 0 0 1 0 1 0 0 0 1 1 1 0 1 0 2 4 3 0 3 2 5 4 1 0 0 0 1 0 0
2009  1   8   0   0   32      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 3 2 1 2 10  7 4 0 0
2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 3 2 1 2 10  7 4 0 0 2 0 0 0
2010  1   8   0   0   13      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 1 2 0 3 3 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 0 0 1 2 0 3 3 0 0 0 0 0 0
#AFSC triennial survey
#year season  fleet gender  partition Nsamp
```

```
#                                 U12  U16  U20  U24  U28  U32  U36  U40  U44  U48
U52  U56  U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112
U116  U120  U124  U128  U132  U12  U16  U20  U24  U28  U32  U36  U40  U44  U48  U52
U56  U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112  U116
U120  U124  U128  U132
1998    1    9    0     0     88  0 0 1 16  93  78  52  78  136 179 191 110 29  17  3
1 4 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 16  93  78  52  78  136 179 191 110 29  17  3 1
4 1 0 0 1 0 0 0 0 0 0 0 0 0 0
#                                 F12  F16  F20  F24  F28  F32  F36  F40  F44  F48
F52  F56  F60  F64  F68  F72  F76  F80  F84  F88  F92  F96  F100  F104  F108  F112
F116  F120  F124  F128  F132  M12  M16  M20  M24  M28  M32  M36  M40  M44  M48  M52
M56  M60  M64  M68  M72  M76  M80  M84  M88  M92  M96  M100  M104  M108  M112  M116
M120  M124  M128  M132
2001    1    9    3    0     261  0 0 3 22  75  74  46  37  48  76  108 140 75  32  23
10  4 2 1 3 2 1 5 4 3 1 0 0 0 0 0 0 0 0 2 14  53  67  38  26  37  64  88  101 109 53  34
44  43  30  21  4 3 0 0 0 0 0 0 0 0 0 0
2004    1    9    3    0     296  0 0 2 12  54  45  67  103 70  104 96  116 170 129 45
16  3 0 0 0 1 1 1 0 2 0 0 0 0 0 0 0 0 0 1 15  52  64  70  115 75  113 95  115 164 166
103 69  67  50  26  11  2 0 0 0 0 0 0 0 0 0 0
#AFSC slope survey
#                                 U12  U16  U20  U24  U28  U32  U36  U40  U44  U48
U52  U56  U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112
U116  U120  U124  U128  U132  U12  U16  U20  U24  U28  U32  U36  U40  U44  U48  U52
U56  U60  U64  U68  U72  U76  U80  U84  U88  U92  U96  U100  U104  U108  U112  U116
U120  U124  U128  U132
1997  1    10    0    0      275   0  0 5 9 67  115 31  67  239 320 351 353 309 151
100 164 253 277 142 35  6 7 5 2 0 1 0 0 0 0 0 0 0 5 9 67  115 31  67  239 320 351 353
309 151 100 164 253 277 142 35  6 7 5 2 0 1 0 0 0 0 0
#         10                        F12  F16  F20  F24  F28  F32  F36  F40  F44  F48
F52  F56  F60  F64  F68  F72  F76  F80  F84  F88  F92  F96  F100  F104  F108  F112
F116  F120  F124  F128  F132  M12  M16  M20  M24  M28  M32  M36  M40  M44  M48  M52
M56  M60  M64  M68  M72  M76  M80  M84  M88  M92  M96  M100  M104  M108  M112  M116
M120  M124  M128  M132
1999  1    10    3    0      219   0  0 0 1 1 3 18  45  83  125 170 168 118 47  19  5
3 1 3 1 2 1 0 0 1 0 1 0 0 0 0 0 0 0 0 0 5 4 12  38  59  115 161 171 106 66  54  78  64
63  44  15  1 0 0 0 0 0 0 0 0 0 0
2000  1    10    3    0      139   0  0 0 1 37  45  8 24  50  63  95  123 92  49  18
16  3 3 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 22  42  6 24  63  74  116 160 99  73  28  29
34  27  20  6 1 0 0 0 0 0 0 0 0 0 0
2001  1    10    3    0      84    0  0 2 2 2 8 5 13  19  15  37  67  63  32  20  5 0
0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 5 4 6 7 15  23  51  47  48  41  43  41  25  14
5 1 0 0 0 0 0 0 0 0 0 0
#NWFSC shelf-slope survey
#                                 F12  F16  F20    F24      F28      F32      F36
F40      F44        F48        F52        F56        F60        F64        F68
F72      F76      F80      F84      F88      F92      F96      F100    F104    F108
F112    F116  F120  F124  F128  F132  M12  M16    M20      M24      M28      M32
M36      M40      M44        M48        M52        M56        M60        M64
M68        M72        M76      M80      M84      M88      M92      M96      M100  M104
M108  M112  M116  M120  M124  M128  M132
2003  1    11   3    0      444   0 0 2 5 23  71  75  88  108 122 155 231 300 239 94
40  35  10  6 6 0 4 2 1 2 0 0 0 0 0 0 0 0 0 3 19  62  74  68  83  115 144 239 310 279
156 161 187 151 77  32  5 1 0 0 0 0 0 0 0 0 0
2004  1    11   3    0      334   0 0 1 8 66  52  80  98  89  101 87  133 178 103 39
19  12  3 5 7 12  6 4 5 4 3 2 0 0 0 0 0 0 0 7 52  42  64  102 75  86  76  149 186 186
119 61  50  42  43  18  5 0 0 0 0 0 0 0 0 0 0
2005  1    11   3    0      500   0 0 0 25  77  63  59  111 175 265 243 228 197 122 46
33  17  16  2 7 3 4 5 1 0 0 1 0 0 0 0 0 0 0 1 26  55  79  63  100 154 214 221 199 209
174 134 104 72  30  17  4 3 0 0 0 0 0 0 0 0 0
```

```
2006  1    11   3    0      497   0 0 0 33  75  44  70  99  249 397 358 240 168 76  26
10  6 3 3 5 2 4 8 2 1 1 0 0 0 0 0 0 0 0 0 28  89  47  50  98  177 335 375 249 162 138 72
70  61  30  14  6 0 0 0 0 0 0 0 0 0 0 0
2007  1    11   3    0      398   0 0 2 81  104 69  86  73  111 163 139 111 78  52  23
13  3 5 1 4 4 8 10  5 5 1 0 0 0 0 0 0 0 0 2 68  101 85  77  61  108 140 132 126 92  87
65  70  43  34  13  5 0 1 0 0 0 0 0 0 0 0 0
2008  1    11   3    0      447   0 0 0 10  70  62  56  81  138 186 236 194 132 81  33
12  5 6 2 5 2 3 5 3 5 2 1 0 0 0 0 0 0 0 0 19  88  61  47  74  95  171 219 200 154 128 77
57  55  36  13  0 0 0 0 1 0 0 0 0 0 0 0 0
2009  1    11   3    0      320   0 0 0 53  123 116 74  49  41  64  61  56  39  19  16
7 3 3 4 3 6 11  7 11  2 1 0 1 0 0 0 0 0 0 1 55  126 115 81  45  43  56  73  63  44  34
25  28  41  38  8 4 2 0 0 0 0 0 0 0 0 0 0
2010  1    11   3    0      347   0 0 1 13  87  74  65  60  49  78  87  78  53  30  13
7 5 9 10  13  24  27  22  32  7 4 0 0 0 0 0 0 0 0 10  67  69  60  53  62  73  104 109
61  35  41  52  39  20  13  5 1 0 1 0 0 0 0 0 0 0 0
#
91 # Number of Age Bins
0 1 2 3 4 5 6 7 8 9 10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26
27  28  29  30  31  32  33  34  35  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
71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90
1 # Number of Ageing Error Sets
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  16.5  17.5
18.5  19.5  20.5  21.5  22.5  23.5  24.5  25.5  26.5  27.5  28.5  29.5  30.5  31.5
32.5  33.5  34.5  35.5  36.5  37.5  38.5  39.5  40.5  41.5  42.5  43.5  44.5  45.5
46.5  47.5  48.5  49.5  50.5  51.5  52.5  53.5  54.5  55.5  56.5  57.5  58.5  59.5
60.5  61.5  62.5  63.5  64.5  65.5  66.5  67.5  68.5  69.5  70.5  71.5  72.5  73.5
74.5  75.5  76.5  77.5  78.5  79.5  80.5  81.5  82.5  83.5  84.5  85.5  86.5  87.5
88.5  89.5  90.5  91.5  92.5  93.5  94.5  95.5
0.0986548 0.0986548 0.197731  0.297273  0.397333  0.497964  0.599228  0.70119 0.803922
0.907503  1.01202 1.11757 1.22425 1.33217 1.44147 1.55226 1.66471 1.77897 1.89521
2.01363 2.13443 2.25783 2.3841  2.51348 2.64629 2.78282 2.92344 3.06851 3.21845 3.3737
3.53476 3.70214 3.87642 4.05823 4.24823 4.44718 4.65587 4.87516 5.10601 5.34944
5.60656 5.87858 6.16681 6.47267 6.79772 7.14362 7.51219 7.90541 8.32542 8.77452
9.25525 9.77031 10.3227 10.9155 11.5524 12.237  12.9734 13.766  14.6196 15.5394 16.531
17.6005 18.7545 20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20
20  20  20  20  20  20  20  20  20  20  20  20  20  20  20
0 # Number Age Observations
3 # Age-Length Bin Option (1=poplenbins; 2=datalenbins; 3=lengths)
0 # Combine Males & Females Below this Bin
#
0 # Number of Mean Size at Age Observations
0 # Number of Environmental Variables
0 # Number of Environmental Observations
0 # Number of Weight Frequency Observations
0 # Number of Tagging Data Observations
0 # Number of Morph Composition Observations
999  # End of Data
```

B-4: Stock Synthesis control file

```
#V3.21f
# Control File for Spiny Dogfish Assessment 2011
1       #_N_Growth_Patterns
1       #_N_Morphs_Within_GrowthPattern
0       #_Nblock_Patterns
0.5     #_fracfemale
0       #_natM_type:_0=1Parm;
1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
1       # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=notimplemented;
4=notimplemented
0       #_Growth_Age_for_L1
999     #_Growth_Age_for_L2 (999 to use as Linf)
0       #_SD_add_to_LAA (setto  0.1 SS2 V1.x compatibility)
0       #_CV_Growth_Pattern: 0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A)
1       #_maturity_option:      1=length logistic; 2=age logistic; 3=read age-maturity
matrix by growth_pattern; 4=read  age-fecundity;  5=read  fec And wt from wtatage.ss
1       #_First_Mature_Age
4       #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b;
(4)eggs=a+b*L; (5)eggs=a+b*W
0       #_hermaphroditism       option: 0=none; 1=age-specific  fxn
2       #_parameter_offset_approach     (1=none,        2=      M,      G,      CV_G
as      offset  from    female-GP1,     3=like  SS2     V1.x)
1       #_env/block/dev_adjust_method   (1=standard;    2=logistic      transform
keeps   in      base    parm    bounds; 3=standard      w/      no      bound   check)
#
#_growth_parms
#_LO    HI      INIT        PRIOR     PR_type SD   PHASE   env-var use_dev devmnyr
devmxyr devstd  Block   Block_Fxn
# female growth
0.01    0.12    0.064       0.064      -1    99   -2      0       0       0       0
0       0       0   # NatM_p_1_Fem_GP_1
10      50      25.2456     25.2456    -1    99   -2      0       0       0       0
0       0       0   # L_at_Amin_Fem_GP_1
80      200     109.1       109.1      -1    99   -3      0       0       0       0
0       0       0   # L_at_Amax_Fem_GP_1
0.005   0.1     0.0262574   0.0262574  -1    99   -2      0       0       0       0
0       0       0   # VonBert_K_Fem_GP_1
0.05    0.3     0.123153    0.123153   -1    99   -3      0       0       0       0
0       0       0   # CV_young_Fem_GP_1
0.05    0.3     0.240138    0.240138   -1    99   -3      0       0       0       0
0       0       0   # CV_old_Fem_GP_1
# male growth as offsets (parameter offset approach = 2)
-3      3       0           0          -1    99   -3      0       0       0       0
0       0       0   # NatM_p_1_Mal_GP_1
-3      3       0           0          -1    99   -3      0       0       0       0
0       0       0   # L_at_Amin_Mal_GP_1
-3      3       -0.236493  -0.236493   -1    99   -2      0       0       0       0
0       0       0   # L_at_Amax_Mal_GP_1
-3      3       0.685115    0.685115   -1    99   -2      0       0       0       0
0       0       0   # VonBert_K_Mal_GP_1
-3      3       0.444534    0.444534   -1    99   -3      0       0       0       0
0       0       0   # CV_young_Mal_GP_1
-3      3      -1.43528    -1.43528    -1    99   -3      0       0       0       0
0       0       0   # CV_old_Mal_GP_1
## female weight and maturity
0       1       2.3065E-6   2.3065E-6  -1    99   -5      0       0       0       0
0       0       0   # Wtlen_1_Fem
2       4       3.1526      3.1526     -1    99   -5      0       0       0       0
0       0       0   # Wtlen_2_Fem
```

```
50      100     88.2        88.2       -1    99   -5      0       0       0       0
0       0       0   # Mat50%_Fem
-2      0      -0.27       -0.27       -1    99   -5      0       0       0       0
0       0       0   # Mat_slope_Fem
-20     20     -14.7        1          -1    99   -5      0       0       0       0
0       0       0   # Intercept of fecundity at length
0       1       0.214       0          -1    99   -5      0       0       0       0
0       0       0   # Slope of fecundity at length
# male weight as direct assignment
0       1       3.4911E-6   3.4911E-6  -1    99   -5      0       0       0       0
0       0       0   # Wtlen_1_Mal
2       4       3.0349      3.0349     -1    99   -5      0       0       0       0
0       0       0   # Wtlen_2_Mal
# stuff that we don't need for this model
0       2       1           1          -1    99   -5      0       0       0       0
0       0       0   # RecrDist_GP_1
0       2       1           1          -1    99   -5      0       0       0       0
0       0       0   # RecrDist_Area_1
0       2       1           1          -1    99   -5      0       0       0       0
0       0       0   # RecrDist_Seas_1
0       2       1           1          -1    99   -5      0       0       0       0
0       0       0   # CohortGrowDev
#_seasonal_effects_on_biology_parms
#_femwtlen1, femwtlen2, mat1, mat2, fec1, fec2, Malewtlen1, malewtlen2, L1, K
0       0       0       0       0       0     0     0       0       0
#
#_Spawner-Recruitment
7       #_SR_function:  1=B-H_flattop; 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey;
6=Shepard_3Parm;  7=Survivorship function (3 parameters)
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
8       18      10.5    10.5    -1      99       1   # SR_log(R0)
0       1       0.4     0.4     -1      99      -5   # Zfrac
0.2     5       1.0     1       -1      99      -5   # Beta
#
0.01    1       0.2     1.1     -1      99      -6   # SR_sigmaR
-5      5       0       0       -1      99      -5   # SR_envlink
-5      5       0       0       -1      99      -5   # SR_R1_offset
0       2       0       1       -1      99      -5   # SR_autocorr
0       #_SR_env_link
0       #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1       #do_recdev:     0=none; 1=devvector; 2=simple deviations
1916    # first year of main recr_devs; early devs can preceed this era
2010    # last year of main recr_devs; forecast devs start in following year
-1      #_recdev phase
1       # (0/1) to read 13 advanced options
0       #_recdev_early_start (0=none; neg value makes relative to recdev_start)
-3      #_recdev_early_phase
-5      #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
1       #_lambda for Fcast_recr_like occurring before endyr+1
1950    #_last_early_yr_nobias_adj_in_MPD
1960    #_first_yr_fullbias_adj_in_MPD
2008    #_last_yr_fullbias_adj_in_MPD
2009    #_first_recent_yr_nobias_adj_in_MPD
0.9     #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all
estimated recdevs)
0       #_period of cycles in recruitment (N parms read below)
-3      #min rec_dev
3       #max rec_dev
0       #_read_recdevs
#_end of advanced SR options
#
```

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#Fishing Mortality info
0.3     # F ballpark for tuning early phases
-2001   # F ballpark year (neg value to disable)
3       # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4       # max F or harvest rate, depends on F_Method
4       # N iterations for tuning F in hybrid method (recommend 3 to 7)
#
#_initial_F_parms
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
0       1       0       0.01    0       99      -1      # InitF_1TRAWL
0       1       0       0.01    0       99      -1      # InitF_2Trawl_Discard
0       1       0       0.01    0       99      -1      # InitF_3MIDWATER
0       1       0       0.01    0       99      -1      # InitF_4ASHOP
0       1       0       0.01    0       99      -1      # InitF_5HKL
0       1       0       0.01    0       99      -1      # InitF_6Hkl_Discard
0       1       0       0.01    0       99      -1      # InitF_7OTHERS
0       1       0       0.01    0       99      -1      # InitF_8RECREATIONAL
#
#_Q_setup
# Q_type options:  <0=mirror, 0=median_float, 1=mean_float, 2=parameter,
3=parm_w_random_dev, 4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm
#_Den-dep env-var extra_se    Q_type
0         0       0           0       # 1  TRAWL
0         0       0           0       # 2  Trawl_Discard
0         0       0           0       # 3  MIDWATER
0         0       0           0       # 4  ASHOP
0         0       0           0       # 5  HKL
0         0       0           0       # 6  Hkl_Discard
0         0       0           0       # 7  OTHERS
0         0       0           0       # 8  RECREATIONAL
0         0       1           4       # 9  AFSC_triennial
0         0       1           0       # 10 AFSC_slope
0         0       1           0       # 11 NWFSC_shelf_slope
0         0       1           0       # 12 NWFSC_slope
0         0       1           0       # 13 IPHC
#
1 #_0=read one parm for each fleet with random q; 1=read a parm for each year of index
#_Q_parms(if_any)
# Lo  Hi  Init    Prior   Prior_type Prior_sd   Phase
0     1   0.4     0.1     -1         99          3 # Q_extraSD_9_AFSC_triennial
0     1   0.4     0.1     -1         99          3 # Q_extraSD_10_AFSC_slope
0     1   0.4     0.1     -1         99          3 # Q_extraSD_11_NWFSC_shelf_slope
0     1   0.4     0.1     -1         99          3 # Q_extraSD_12_NWFSC_slope
0     1   0.1     0.1     -1         99         -3 # Q_extraSD_13_IPHC
# Early period
-10   2  -0.0003  0       -1         99          1 # Triennial (log) base parameter
(1980)
-4    4   0       0       -1         99         -5 # Triennial 1983 deviation
-4    4   0       0       -1         99         -5 # Triennial 1986 deviation
-4    4   0       0       -1         99         -5 # Triennial 1989 deviation
-4    4   0       0       -1         99         -5 # Triennial 1992 deviation
# Late period
-4    4   0       0       -1         99          1 # Triennial 1995 deviation
-4    4   0       0       -1         99         -5 # Triennial 1998 deviation
-4    4   0       0       -1         99         -5 # Triennial 2001 deviation
-4    4   0       0       -1         99         -5 # Triennial 2004 deviation
#
#_size_selex_types
#_Pattn Discard Male    Special
24      0       0       0       # 1  TRAWL
24      0       0       0       # 2  Trawl_Discard
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24      0       0       0       # 3  MIDWATER
5       0       0       3       # 4  ASHOP
24      0       0       0       # 5  HKL
24      0       0       0       # 6  Hkl_Discard
5       0       0       6       # 7  OTHERS
24      0       0       0       # 8  RECREATIONAL
24      0       0       0       # 9  AFSC_triennial
24      0       0       0       # 10 AFSC_slope
24      0       0       0       # 11 NWFSC_shelf_slope
5       0       0       10      # 12 NWFSC_slope
5       0       0       6       # 13 IPHC
#
#_age_selex_types
#_Pattn Retent. Male    Special
11      0       0       0       # 1  TRAWL
11      0       0       0       # 2  Trawl_Discard
11      0       0       0       # 3  MIDWATER
11      0       0       0       # 4  ASHOP
11      0       0       0       # 5  HKL
11      0       0       0       # 6  Hkl_Discard
11      0       0       0       # 7  OTHERS
11      0       0       0       # 8  RECREATIONAL
11      0       0       0       # 9  AFSC_triennial
11      0       0       0       # 10 AFSC_slope
11      0       0       0       # 11 NWFSC_shelf_slope
11      0       0       0       # 12 NWFSC_slope
11      0       0       0       # 13 IPHC
#size   selex
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_min
dev_max dev_std Block   Block_Fxn
#_size_sel: Fishery_Trawl
20      120     100     100     0       99       1      0       0       0       0
0.5     0       0  # PEAK
-6      4       -1      -1      0       99      -3      0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
-1      9        6       6      0       99       3      0       0       0       0
0.5     0       0  # Asc_width
-1      9        5       5      0       99      -3      0       0       0       0
0.5     0       0  # Desc_width
-5      9       -5      -5      0       99      -3      0       0       0       0
0.5     0       0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99      -3      0       0       0       0
0.5     0       0  # FINAL:_selectivity_at_last_bin
#_size_sel: Fishery_Trawl_Discard
20      120      75      75     0       99       1      0       0       0       0
0.5     0       0  # PEAK
-6      4       -1      -1      0       99      -3      0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
-1      9        6       6      0       99       3      0       0       0       0
0.5     0       0  # Asc_width
-1      9        5       5      0       99      -3      0       0       0       0
0.5     0       0  # Desc_width
-5      9       -5      -5      0       99       3      0       0       0       0
0.5     0       0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99      -3      0       0       0       0
0.5     0       0  # FINAL:_selectivity_at_last_bin
#_size_sel: Fishery_Mdt and ASHOP
20      120      55      55     0       99       1      0       0       0       0
0.5     0       0  # PEAK
-6      4        0       0      0       99       3      0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
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-1      9        5       5      0       99      3       0       0       0       0
0.5     0        0  # Asc_width
-1      9        5       5      0       99      3       0       0       0       0
0.5     0        0  # Desc_width
-9      9       -7      -7      0       99      3       0       0       0       0
0.5     0        0  # INIT:_selectivity_at_fist_bin
-999   -999    -999      0      0       99     -3       0       0       0       0
0.5     0        0  # FINAL:_selectivity_at_last_bin
#_size_sel: ASHOP mirrored To Fishery_Mdt
0       0        0       0      0       99     -3       0       0       0       0
0.5     0        0  # Min_Bin_Number
0       0        0       0      0       99     -3       0       0       0       0
0.5     0        0  # Max_Bin_Number
#_size_sel: Fishery_Hkl
20      120    110     110      0       99      1       0       0       0       0
0.5     0        0  # PEAK
-6      4       -1      -1      0       99     -3       0       0       0       0
0.5     0        0  # TOP:_width_of_plateau
-1      9        6       6      0       99      3       0       0       0       0
0.5     0        0  # Asc_width
-1      9        5       5      0       99     -3       0       0       0       0
0.5     0        0  # Desc_width
-5      9       -5      -5      0       99     -3       0       0       0       0
0.5     0        0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99     -3       0       0       0       0
0.5     0        0  # FINAL:_selectivity_at_last_bin
#_size_sel: Fishery_Hkl_discard
20      120      70      70     0       99      1       0       0       0       0
0.5     0        0  # PEAK
-6      4       -1      -1      0       99     -3       0       0       0       0
0.5     0        0  # TOP:_width_of_plateau
-1      9        5       5      0       99      3       0       0       0       0
0.5     0        0  # Asc_width
-1      9        5       5      0       99     -3       0       0       0       0
0.5     0        0  # Desc_width
-5      9       -3      -3      0       99      3       0       0       0       0
0.5     0        0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99     -3       0       0       0       0
0.5     0        0  # FINAL:_selectivity_at_last_bin
#_size_sel: Fishery_Others mirrored To Hkl
0       0        0       0      0       99     -3       0       0       0       0
0.5     0        0  # Min_Bin_Number
0       0        0       0      0       99     -3       0       0       0       0
0.5     0        0  # Max_Bin_Number
#_size_sel: Fishery_Recreational
20      120    110     110      0       99      1       0       0       0       0
0.5     0        0  # PEAK
-6      4       -1      -1      0       99     -3       0       0       0       0
0.5     0        0  # TOP:_width_of_plateau
-1      9        6       6      0       99      3       0       0       0       0
0.5     0        0  # Asc_width
-1      9        5       5      0       99     -3       0       0       0       0
0.5     0        0  # Desc_width
-5      9       -5      -5      0       99     -3       0       0       0       0
0.5     0        0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99     -3       0       0       0       0
0.5     0        0  # FINAL:_selectivity_at_last_bin
#_size_sel: AFSC_triennial
25      100      60      60     0       99      1       0       0       0       0
0.5     0        0  # PEAK
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-9      3       -8      -8      0       99      3       0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
-4      12       6       6      0       99      3       0       0       0       0
0.5     0       0  # Asc_width
-2      15       6       6      0       99      3       0       0       0       0
0.5     0       0  # Desc_width
-5      9       -5      -5      0       99     -3       0       0       0       0
0.5     0       0  # INIT:_selectivity_at_fist_bin
-999   -999     -999     0      0       99     -3       0       0       0       0
0.5     0       0  # FINAL:_selectivity_at_last_bin
#_size_sel: AFSC_slope
25      100      60      60     0       99      1       0       0       0       0
0.5     0       0  # PEAK
-9      3       -1      -1      0       99      3       0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
-4      12       5       5      0       99      3       0       0       0       0
0.5     0       0  # Asc_width
-2      15       5       5      0       99      3       0       0       0       0
0.5     0       0  # Desc_width
-5      9       -5      -5      0       99     -3       0       0       0       0
0.5     0       0  # INIT:_selectivity_at_fist_bin
-999  -999     -999      0      0       99     -3       0       0       0       0
0.5     0       0  # FINAL:_selectivity_at_last_bin
#_size_sel: NWFSC_shelf_slope
20      120     60      60      0       99      1       0       0       0       0
0.5     0       0  # PEAK
-6      4       -1      -1      0       99     -3       0       0       0       0
0.5     0       0  # TOP:_width_of_plateau
-1      9        6       6      0       99      3       0       0       0       0
0.5     0       0  # Asc_width
-1      9        5       5      0       99     -3       0       0       0       0
0.5     0       0  # Desc_width
-5      9       -5      -5      0       99     -3       0       0       0       0
0.5     0       0  # INIT:_selectivity_at_fist_bin
-5      9        9      -5      0       99     -3       0       0       0       0
0.5     0       0  # FINAL:_selectivity_at_last_bin
#_size_sel: NWFSC_slope (mirrored to AFSC_slope)
0       0       0       0       0       99     -3       0       0       0       0
0.5     0       0  # Min_Bin_Number
0       0       0       0       0       99     -3       0       0       0       0
0.5     0       0  # Max_Bin_Number
#_size_sel: IPHC mirrored To Hkl
0       0       0       0       0       99     -3       0       0       0       0
0.5     0       0  # Min_Bin_Number
0       0       0       0       0       99     -3       0       0       0       0
0.5     0       0  # Max_Bin_Number
# age sel: select all ages following user manual instructions:
# "If it is desired that age 0 fish be selected, then use pattern #11 and set the
minimum age to 0.1"
# all ages selected for fleets 1 & 2
0       1       0.1     0.1     0       99     -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99     -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99     -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99     -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99     -3       0       0       0       0
0.5     0       0  # Min age selected
```

```
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
0       1       0.1     0.1     0       99      -3       0       0       0       0
0.5     0       0  # Min age selected
0       100     100     100     0       99      -3       0       0       0       0
0.5     0       0  # Max age selected
#
# Tag loss and Tag reporting parameters go next
0  # TG_custom:  0=no read; 1=read if tags exist
#
1  #_Variance_adjustments_to_input_values
#_fleet:
#1    2     3     4     5     6     7     8     9     10    11    12    13
0     0     0     0     0     0     0     0     0     0     0     0     0
#_add_to_survey_CV
0     0     0     0     0     0     0     0     0     0     0     0     0
#_add_to_discard_stddev
0     0     0     0     0     0     0     0     0     0     0     0     0
#_add_to_bodywt_CV
# tuning
0.673 0.441 1     0.028 0.700 0.655 1     0.790 0.571 0.511 0.299 1     1
#_mult_by_lencomp_N
0.768 1     0.776 0.899 0.712 1     1     1     1     1     0.897 1     1
#_mult_by_agecomp_N
```

```
1     1     1     1     1     1     1     1     1     1     1     1     1
#_mult_by_size-at-age_N
#
4       #_maxlambdaphase
1       #_sd_offset
#
0 # number of changes to make to default Lambdas (default value is 1.0)
0 # (0/1) read specs for more stddev reporting
999 # code for end of file
```