STOCK ASSESSMENT OF GULF OF ALASKA THORNYHEADS (*SEBASTOLOBUS SP.*)

By

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Summary

This year we updated the model introduced in 1997 with available recent data, including 1998 harvest levels by gear, and biomass estimates from the 1999 NMFS triennial trawl survey. Alternate models examined assumptions regarding recruitment variability and survey catchability. Results from this year's analyses are similar to last year's, although harvest levels have increased slightly for next year under the $F_{40\%}$ fishing mortality.

The following summarizes the ABC recommendations and status of spawning biomass level for the past few years relative to the current assessment:

Assessment Year	Projection Year	Female spawning biomass	ABC Recommendation
1996	1997	20,331 t	**1,700 t**
1997	1997	22,812 t	
1997	1998	22,778 t	**2,000 t**
1998	1997	23,473 t	
1998	1998	23,483 t	
1998	1999	23,100 t	**1,990 t**
1999	1997	22,809 t	
1999	1998	22,932 t	
1999	1999	23,095 t	
1999	2000	23,084 t	**2,359 t**

Introduction

The shortspine thornyhead (*Sebastolobus alascanus*) inhabits deep waters from 92 to 1,460 m from the Bering Sea to Baja California. Thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Today thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. The population structure of shortspine thornyheads is not well defined. However, as a matter of practical convenience, thornyheads in the Gulf of Alaska have been managed as a single stock since 1980.

According to Alverson et al. (1964), groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). Two congeneric thornyhead species, the longspine thornyhead (*Sebastolobus altivelis*) and a species common off Japan, *S. macrochir*, are infrequently encountered in the Gulf of Alaska.

Catch history

As an element of the deepwater community of demersal fishes, thornyheads have been fished in the northeastern Pacific Ocean since the late l9th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-l960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea.

Thornyhead catches have been reported in a variety of ways. The earliest records available begin in 1967 as published in French et al. (1977). Active data collection began as part of the U.S. Foreign Fisheries Observer Program in l977, when the thornyhead catch in the Gulf of Alaska was estimated at 1,397 t. From l980 on, the observer program has generated annual estimates of the foreign catch of thornyheads by International North Pacific Fisheries Commission (INPFC) statistical area. Since 1983, the observer program has also estimated the catches of thornyheads in the joint venture fisheries. In l984, thornyheads were identified as a separate entity in the U.S. domestic catch statistics.

Estimated thornyhead catches thornyheads by gear type since 1967 are shown in Table 9.1. Data from 1981 to 1989 are based on reported landings extracted from the Pacific Fishery

Information Network (PacFIN) database and the NMFS Observer Program. Before this period, estimates are based on the following reports: French et al. (1977), and Wall et al. (1978-81). Catches in more recent years (1990-1998) are based on “blended” estimates provided by the NMFS Regional Office through the Observer Program. Estimates of discards for these years have been provided as well. The blended and discard estimates are based on a method that makes use of observer data as well as weekly processor reports (WPR). It is interesting to note that for years in which discard information is available, discarding appears to be much more prevalent in the longline fishery than in the trawl fishery. Discards in the domestic fishery before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. Survey research catches of thornyheads (Table 9.2) are a very small component of overall removals.

The catches of thornyheads in the Gulf of Alaska declined markedly in 1984 and 1985 due primarily to restrictions on foreign fisheries imposed by U.S. management policies. The greatest foreign-reported harvest activities for thornyheads in the Gulf of Alaska occurred during the period 1979-83. In 1985, the U.S. catch surpassed the foreign catch for the first time. U.S. catches of thornyheads continued to increase, reaching a peak in 1989 with a total removal of 3,080 t. Catches have since averaged about 1,270 t during the five-year period from 1994 to 1998.

By weight, the directed fishery for sablefish harvested the largest amount of thornyheads in 1997 and 1998, followed by rockfish and flatfish (Fig. 9.1). A similar pattern was noted for thornyheads that were not retained, however, thornyhead discard from the flatfish fishery was higher while relatively few discards were incurred from the sablefish fishery. Presumably, these differences were due to the timing of these fisheries and differences in abilities to avoid incidental harvests. The distribution of thornyhead catches range broadly throughout the Gulf of Alaska and is consistent within recent years for the different gear types (Figs. 9.2 and 9.3).

Table 9.1. Estimated retained catch and discard levels by gear type[1]. Prior to 1990 retained catch was assumed to equal retained and discard catch combined. Catches by gear type from 1981-1986 were estimated by apportioning 85% and 15% of the total all gear catch to the trawl and longline gears respectively.

	Trawl			Hook and Line			All Gears Combined		
Year	Retained	Discarded	Total	Retained	Discarded	Total	Retained	Discarded	Total
1967	7	-	7	0	-	0	7	-	7
1968	56	-	56	6	-	6	62	-	62
1969	94	-	94	3	-	3	97	-	97
1970	48	-	48	6	-	6	53	-	53
1971	230	-	230	11	-	11	241	-	241
1972	202	-	202	14	-	14	216	-	216
1973	1,550	-	1,550	15	-	15	1,565	-	1,565
1974	1,529	-	1,529	8	-	8	1,537	-	1,537
1975	1,215	-	1,215	15	-	15	1,229	-	1,229
1976	1,189	-	1,189	124	-	124	1,313	-	1,313
1977	1,163	-	1,163	234	-	234	1,397	-	1,397
1978	442	-	442	344	-	344	786	-	786
1979	645	-	645	454	-	454	1,098	-	1,098
1980	1,158	-	1,158	327	-	327	1,485	-	1,485
1981	1,139	-	1,139	201	-	201	1,340	-	1,340
1982	669	-	669	118	-	118	787	-	787
1983	620	-	620	109	-	109	729	-	729
1984	177	-	177	31	-	31	208	-	208
1985	70	-	70	12	-	12	82	-	82
1986	607	-	607	107	-	107	714	-	714
1987	1,863	-	1,863	14	-	14	1,877	-	1,877
1988	2,132	-	2,132	49	-	49	2,181	-	2,181
1989	2,547	-	2,547	69	-	69	2,616	-	2,616
1990	1,233	38	1,271	284	20	304	1,518	58	1,576
1991	1,210	72	1,282	234	497	731	1,444	569	2,013
1992	1,042	114	1,156	534	330	864	1,576	444	2,020
1993	489	173	662	401	305	706	890	478	1,368
1994	493	200	693	309	296	605	802	496	1,298
1995	635	143	778	478	107	585	1,113	250	1,363
1996	578	141	719	475	116	591	1,053	257	1,310
1997	567	224	791	397	61	458	964	285	1,249
1998	470	113	583	508	57	565	978	171	1,148
1999*			995			505			1,500

[1] ***Source***: 1967-1980 based on estimates extracted from NMFS observer reports (e.g., Wall et al. l978) 1981-1989 based on PACFIN and NMFS observer data, 1990-1998 based on blended NMFS observer data and weekly processor reports. The 1999 value was projected from October 6, 1999 NMFS reports.

Table 9.2. Research catches, 1977-1998 in tons.

Year	Domestic Longline Survey Catch	Research catch trawl	Research catch Co-op longline	Total research catch
1977		0.77		0.8
1978		1.20		1.2
1979		4.54	2.93	7.5
1980		1.42	4.98	6.4
1981		9.51	4.64	14.2
1982		5.58	4.11	9.7
1983		0.72	4.22	5.0
1984		23.89	3.10	27.0
1985		12.03	3.51	15.5
1986		1.75	3.50	5.3
1987		16.78	3.54	20.3
1988	1.95	0.04	4.73	6.7
1989	3.44	0.15	4.51	8.1
1990	3.32	3.59	3.64	10.6
1991	3.80		3.38	7.2
1992	5.40		3.72	9.1
1993	4.66	5.49	4.01	14.2
1994	4.41		4.77	9.2
1995	5.42			5.4
1996	7.05	6.05		13.1
1997	7.15			7.2
1998		9.36		9.4

Resource Surveys

Longline surveys

Longline surveys have been conducted jointly by the United States and Japan in the Gulf of Alaska each year since 1979 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m. Since 1987 a U.S. longline survey has also been conducted using similar methodology to the cooperative survey. This survey covered a complete standard area in the Gulf of Alaska beginning in 1990. For each species, the catch rate, the area, and the size composition of samples from each depth stratum were used to determine the relative population number (RPN) and weight (RPW) for each depth stratum. The RPNs and RPWs for the various depth strata (201-1,000 m for thornyheads) were summed to obtain GOA totals (Table 9.3).

Table 9.3. Relative population number (RPN) and weight (RPW) from the domestic longline survey 1990-1999 (Mike Sigler, pers. comm.). Note that the RPN data were used to tune the model.

Domestic survey

Year	RPN	RPW
1990	43,479	23,217
1991	56,615	26,618
1992	73,233	35,921
1993	66,166	32,462
1994	49,191	27,766
1995	58,553	28,797
1996	66,392	34,966
1997	62,529	32,128
1998	60,740	33,111
1999	67,901	36,228

The use of the longline survey in general may be questionable because of a possible interaction with sablefish abundance. For example, Sigler and Zenger (1994) found that thornyheads increased in areas where sablefish abundance decreased. They suggested that the increase in thornyhead catch rates between 1988 and 1989 (their data) might be partly due to the decline in sablefish abundance. They reasoned that availability of baited hooks to thornyheads may have increased. Further research is needed on the effect of hook competition between slow, low metabolism species such as shortspine thornyheads and faster, more aggressive feeding sablefish. The coefficient of variation for the domestic survey index we assumed to be 20%. We present the size compositions from this survey in the section on model fit, below.

The NMFS Auke Bay Lab staff began a feasibility study on tagging shortspine thornyheads from the longline survey in 1997 and have continued to tag shortspine thornyheads on an opportunistic basis in each year including 1999. The methods seem to be working well with minimal interference with normal survey operations. This year 628 shortspine thornyheads were tagged and released bringing the total releases of this species in the last three years up to 495 in 1997, 525 in 1998 bringing the total to 1,648 individuals. This work is part of an ongoing project to learn more about movement and growth rates of this deep-water species.

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 1999. This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provide biomass estimates using an "area-swept" methodology described in Wakabayashi et al. (1985). The 1984, 1987 and 1999 surveys extended into deeper water (>500 m) and covered the range of primary habitat for the shortspine thornyhead stock. Surveys during the 1990s did not extend to the deeper zones where concentrations of larger thornyheads are known to exist. We believe that this causes the biomass estimates to appear disjointed over time (Fig. 9.4). To account for these differences between surveys, we assume that the 1984, 1987, and 1999 surveys encountered the entire adult population while the 1990, 1993, and 1996 estimates surveyed a younger (smaller sized) portion of the stock. This was achieved by fixing the catchability coefficient equal to 1.0 for the 1980s and 1999 surveys and allowing separate, freely estimated q values for the 1990 – 1996 surveys. We feel that a significant portion of the biomass of shortspine thornyheads exists beyond depths of 500 m, as illustrated by analysis of longline survey catch-per-unit-effort data (Ianelli and Ito 1994). The ability of our assessment to reflect that actual abundance of shortspine thornyheads is hampered by the lack of reliable data in these deeper habitat areas. The spatial distribution of relative thornyhead catch rates observed in the triennial surveys from 1984-1999 suggests lower densities in 1990 and 1993 compared to other years, particularly in the western area (Fig. 9.5).

Analytic approach

In 1997 a sized based, age-structured model was developed and applied to the thornyhead resource in the Gulf of Alaska. Last year, the original model was re-written in C++ computer language in order to take advantage of analytical software designed for building large, complex models. We use essentially the same model in this assessment, with additional exploration of recruitment and catchability assumptions.

The conceptual model is similar to that commonly implemented in the stock synthesis program (Methot 1990). Catch data were from 1967 to 1998 with the last six years adjusted to include discards. Before this time we assumed harvests of the resource was negligible. Model parameters are estimated by maximizing the log likelihood (L) of the predicted observations given the data. Data are classified into different components. For example, size compositions from a survey and from a fishery represent different components. The total L is a sum of the likelihoods for each component. The total L may also include a component for a stock-recruitment relationship. The likelihood components may be weighted by an emphasis factor. For shortspine thornyheads in the GOA, the model was aggregated to have two fisheries and included the NMFS triennial trawl surveys and the NMFS domestic longline survey. Table 9.4 summarizes the data types used in this assessment. Table 9.5 presents the key equations used for the shortspine thornyheads model in the Gulf of Alaska and a description of key variables is given in Table 9.6. Statistical formulae for the likelihood components are given in Table 9.7.

Table 9.4. Data types used in the model for shortspine thornyheads in the GOA.

Data Component	**Years of data**
Trawl survey size composition and biomass estimates	1984, 1987, 1990, 1993, 1996, 1999
Longline survey relative abundance and size composition	1990-1999
Trawl fishery size composition data	1977, 1982-84,1990-96, 1998-99
Longline fishery size composition data	1977-81, 1991-95, 1998
Trawl fishery harvests	1967-1999
Longline fishery harvests	1967-1999

Table 9.5. Model equations describing population dynamics.

Equations	Description
$N_{t,1} = R_t = R_0 e^{\tau_t}\ , \quad \tau_t \sim \mathrm{N}\left(0,\sigma_R^2\right)$	Recruitment
$C_{i,t,a} = \frac{F_{i,t,a}}{Z_{t,a}}\left(1 - e^{-Z_{t,a}}\right) \ N_{t,a} \quad 1 \le t \le T \quad 1 \le a \le A$	Catch gear type i, year t, age class a
$N_{t+1,a+1} = N_{t,a} e^{-Z_{t,a}} \quad 1 < t \le T \quad 1 \le a < A$	Numbers
$S_t = \sum_{a=5}^{54+} w_{t,a}\phi_a N_{t,a}$	Spawning biomass in year t
$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}} \quad 1 \le t \le T$	Numbers in "plus" group"
$Z_{t,a} = \sum_i F_{i,t,a} + M$	Total Mortality
$F_{i,t,a} = s_{i,a}\mu_i^F \exp\left(\varepsilon_{i,t}\right) \quad \varepsilon_{i,t} \sim N\left(0,\sigma_i^2\right)$	Components of fishing mortality
$s_{i,a} = \exp\left(\eta_{i,a}\right) \quad \eta_{i,a} \sim N\left(0,\sigma_{s_{i,a}}^2\right)$	Age-effect of fishing
$C_{t\cdot}^i = \sum_{a=1}^{A} C_{t,a}^i$	Total catch for fishery i.
$p_{t,a}^i = \frac{C_{t,a}^i}{C_{t\cdot}^i}$	Proportion at age in catch
$\hat{Y}_t^i = \sum_{a=1}^{A} w_{t,a} C_{t,a}^i$	Yield in year t for fishery i.
X	Transition matrix dimensioned by 50 ages by 25 length bins (L), parameterized by growth relationship shown in Figure 6.
$\hat{g}_t^i = p_t^i \cdot X,\ \hat{g}_{t,l}^i,\ l = 1,2,3...L$	Proportion at length in vector $\hat{g}_t^i$ for fishery or survey i in year t.

Table 9.6. List of variables and their definitions used in this model.

Variable	Definition
R_t	age 1 recruitment in year t
R_0	geometric mean value of age 1 recruitment, 1967-1999
$R_0^{'}$	geometric mean value of age 1 recruitment prior to 1967 (establishes initial age composition)
τ_t	recruitment deviation in year t
T	number of years of fishing (i.e., t=1 corresponds to 1967, and $t=T$ corresponds to 1999)
A	number of age classes in the population model (A=50 ranging from a=1 that corresponds to age 5 and a=50 corresponds to fish age 54 and older,
$N_{t,a}$	number of fish age a in year t,
$C_{t,a}$	catch number of age group a in year t,
$P_{t,a}$	proportion of the total catch in year t, that is in age group a,
$C_{t\cdot}$	total catch in year t,
$W_{t,a}$	mean body weight (kg) of fish in age group a in year t,
θ_a	proportion mature at age a, $\theta_a = \frac{1}{1+e^{-(\rho a-\beta)}}$
Y_t^i, $\hat{Y}_t^i$	total yield weight in year t, fishery i, observed and estimated.
$F_{i,t,a}$	instantantaneous fishing mortality for gear type i, age group a, in year t,
M	instantantaneous natural mortality (assumed constant for all ages and years,
$Z_{t,a}$	instantantaneous total mortality for age group a, in year t,
$S_{i,a}$	age-effect of fishing for age group a in gear type i, normalized to average 1.0 over ages a=1 to A,
μ_i^F	median year-effect of fishing mortality,
$\varepsilon_{i,t}$	the residual year-effect of fishing mortality (note that effective effort fluctuates in fidelity to the total catch each year).

Table 9.7. Statistical formulae for the likelihood components.

Equations	Description
$L_1 = \sum_f \sum_t n_t^f \sum_{l=1}^{L} \ln\left(\hat{g}_{t,l}^f\right)$	Multinomial –log likelihood value for f observation types (fisheries and surveys)
$L_2 = \sum_i \sum_{t_i} \frac{\ln\left(I_{t_i}^i / \hat{I}_{t_i}^i\right)^2}{2\left(\sigma_{t_i}^i\right)^2}$	Likelihood component for indices ith abundance index (i.e., bottom trawl and longline surveys)
$L_3 = \lambda_1 \sum_{i,t} \varepsilon_{i,t}^2$	Fishing mortality term for each i fishery (provides regularity,
$L_4 = \lambda_2 \sum_{i,t} \left(Y_t^i - \hat{Y}_t^i\right)^2$	Catch biomass component
$L_5 = \lambda_3 \ln\left(\hat{M} / M_{prior}\right)^2 + \lambda_4 \ln\left(\hat{q} / q_{prior}\right)^2$	Prior components on natural mortality, and survey catchability.
$L_6 = \sum_{i,a} \frac{\left(\eta_{i,a}\right)^2}{2\sigma_{s_{i,a}}^2}$	Component constraining age-age variability in selectivity for each i gear type.
$L_{tot} = \sum_{i=1}^{6} L_i$	Total – log likelihood (or posterior pdf)

Parameters estimated independently

Miller (1985) estimated thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. The oldest thornyhead she found was 62 years old. On the U.S. continental west coast, at least one large individual was estimated to have a maximum age of about 150 years old (Jacobson 1990). However, recent radiometric analyses suggest that the maximum age is between 50-100 years (pers. comm., John Butler, SWFC, La Jolla CA). Miller (1985) estimated size-at-age for shortspine thornyheads in the GOA using conventional methods and found the maximum age to be about 60 years old. In past assessments, we attempted to estimate growth within a size-based model using some assumptions from Miller (1985). Here we extend previous assumptions by specifying that a 5-year old shortspine thornyhead has a mean size of 15 cm and a 54-year old fish has a mean length of 51 cm. The von-Bertalanfy growth parameter used to "bridge" these mean lengths, *k,* was assumed to be 0.022 based on estimates from past assessments. We selected coefficients of variation in length at age to be 9% at age 5 and 8% at age 54 (based on experience with variability in length-at-age with other rockfish; e.g., Pacific ocean perch). These values were used to create the transition matrix that the model used to convert between modeled numbers-at-age to observed proportions at size.

Miller (1985) estimated the length-weight relationship from 232 samples collected in the eastern Gulf of Alaska as follows:

$$\text{weight (kg)} = a(\text{fork-length(cm)})^b$$

$$a = 1.3627\text{x}10^{-6}, \qquad b = 3.3904$$

As in the previous assessment, we chose the size-at-maturity schedule estimated in Ianelli and Ito (1995) for shortspine thornyheads off the coast of Oregon. In this ogive, female shortspine thornyheads appear to be 50% mature at about 22 cm or about 11 years old (Fig. 6).

Results/Model evaluation

As presented in last year's assessment, we evaluate uncertainties in the estimate of natural mortality (M) by selecting a prior distribution rather than assuming a fixed value. Initial model runs using a moderately diffuse (uninformative) prior distribution about M indicated that the best fit was attained with a relatively high value of M (given constraints placed on declining selectivity with age). Therefore, we selected a relatively informative prior on M with an expected value of 0.05 and a coefficient of variation equal to 10% (Fig. 9.7). This resulted in an estimate similar to the fixed value assumed last year (0.07) but still allowed for some accounting of uncertainty in this parameter. As in the past, we selected this configuration in part with the knowledge that it would result in more conservative estimates of ABC's.

Since longline gear catches primarily large fish, the utility of longline size composition data for detecting variable cohort sizes is limited. While the trawl gear tends to catch smaller thornyheads, the sampling effort from the fishery is limited due to low observer coverage and sampling methods. The bottom trawl surveys only occur every third year and are thus also of limited use in estimating relative cohort sizes. Consequently, we configured Model 2 to have constant recruitment for comparison with the baseline model (assuming variable recruitment in each year). For the third and fourth alternative models we investigated the effect of estimating bottom trawl survey catchability for the years 1984, 1987, and 1999 (the other years are used only as a relative index) both with (Model 3) and without (Model 4) recruitment variability. The four models are compared in Tables 9.8 (goodness of fit) and 9.9 (biomass and management quantities). Descriptions of the different models are summarized here as:

Model	Recruitment	1984, 1987, & 1999 survey catchability
1	Variable	Fixed at 1.0
2	Constant	Fixed at 1.0
3	Variable	Estimated
4	Constant	Estimated

Comparing among these models, an argument could be made that the data are insufficient to estimate inter-annual recruitment variability (total –log likelihood difference of 30.8 with a change of 32 degrees of freedom. However, since its not possible to follow strict statistical likelihoods for fitting models of this sort (variance-related quantities such as sample size etc can not be accurately assessed), application of likelihood ratio tests (or their analogs) for model-selection may be inappropriate. In addition, there was very little difference in the biomass estimates (between Models 1 and 2; Table 9.10). Finally, we favor Model 1 as our reference model since allowing recruitment to vary allows projections that we feel are more realistic. Alternatively, assuming constant future recruitment would clearly underestimate uncertainty about future stock conditions. Models 3 and 4 assume that the survey estimates of absolute abundance are biased by some unknown amount (since catchability is estimated rather than assumed). The estimability of catchability requires signal from age data (here length frequencies) on changes in cohort sizes. Otherwise, the estimates will be more highly influenced by model specification errors (e.g., assumptions about natural mortality). Therefore, even though Model 3 provides the best fit to the data, we feel it is an inappropriate selection since the information on cohort strengths is relatively weak. All subsequent figures and tables reflect results from the Model 1 configuration.

The fits to the observed size composition data for these results were reasonable (Fig. 9.8), but the fit to the abundance indices was not particularly good (Fig. 9.9). The trawl survey abundance index was within the observed confidence bounds (see Fig. 9.4). However, the model did not fit the increasing trend apparent from either survey. This indicates an inconsistency between the biological aspects of the model specified and observed trends. Given the extremely slow and relatively continuous growth of thornyheads—and the low natural mortality rate that we assume—the level of increase must be attributed to somewhat stronger recruitment in recent years. The problem remains that the observations do not provide information to suggest such strong year-classes have occurred. This is due, in part, to the fact that the distribution of thornyheads is widespread and relatively homogenous (i.e., they do not form highly aggregated schools) and because the sample size on length frequency from the fisheries is low. In addition, the ability to obtain a reasonable progression of length modes may be inherently problematic given the slow and perhaps erratic growth of these fish. A sensitivity analyses on the emphasis placed on fitting the longline survey abundance index shows that the overall model fit significantly degrades with increasing longline survey index emphasis (Ianelli and Ito, 1995). Since the trend of stock increase in either the longline or the trawl surveys is over a short time period (less than 10 years) relative to the apparent longevity of this species, we feel that it is not overly conservative to fail in matching an increasing trend. Selectivity estimates for the surveys and fisheries are shown in Fig. 9.10.

Abundance and exploitation trends

Results from the modeling shows that the abundance of shortspine thornyheads has remained relatively stable since 1970 (Fig. 9.11). Fishing mortality rates peaked at about 0.04 in 1989 while for recent years, the rate has remained around 0.02 (Fig. 9.12). The estimates of biomass and recruitment over time are given in Table 9.11.

Table 9.8. Alternative model results for shortspine thornyheads in the Gulf of Alaska.

Description	Model 1	Model 2	Model 3	Model 4
Effective N				
Trawl Fishery	103	61	106	61
Longline Fishery	68	68	71	68
Trawl survey	293	213	331	212
Longline survey	322	269	306	254
Likelihoods (minus log)				
Trawl Survey	40.0	57.3	38.5	56.0
Longline Survey	7.3	6.5	6.6	6.2
Prior on q	0.0	0.0	1.1	0.2
Prior on M	23.8	24.0	24.0	23.7
Recruitment Likelihood	14.6	0.0	14.7	0.0
Trawl Fishery Size comp	73.6	91.8	72.6	91.3
Longline Fishery Size comp	54.2	54.9	53.6	54.9
Trawl Survey Size comp	17.2	21.6	17.0	21.7
Longline Survey Size comp	16.5	19.3	16.9	19.9
Trawl Fishery selectivity	1.2	0.2	1.5	0.2
Longline Fishery selectivity	1.0	2.6	1.2	2.8
Trawl Survey selectivity	3.6	4.7	3.7	4.7
Longline Survey selectivity	3.2	4.1	3.5	4.4
Catch likelihood	0.1	0.1	0.0	0.1
Total	256.3	287.1	254.8	286.1

Table 9.9. Alternative model results for shortspine thornyheads in the Gulf of Alaska.

Description	Model 1	Model 2	Model 3	Model 4
2000 Biomass	52,952	50,385	68,908	57,522
(cv)	7%	8%	6%	7%
$B_{40\%}$	35,549	27,865	42,741	30,573
(cv)	11%	7%	16%	14%
B0	89,409	69,043	107,390	75,697
(cv)	11%	7%	16%	14%
2000 Biomass / $B_{40\%}$	149%	181%	161%	188%
2000 Biomass / B0	59%	73%	64%	76%
Average age 5 recruitment (all years)	49,183	43,131	59,398	46,886
Average age 5 recruitment (since 1977 spawning)	53,625	43,131	64,768	46,886
Natural Mortality	0.081	0.082	0.082	0.081
Survey catchabililty (1984, 1987, 1999)	1.0	1.0	0.80	0.90
Yield				
2000 Yield $F_{40\%}$	2,359	2,353	3,075	2,659
2000 Yield $F_{35\%}$	2,825	2,816	3,672	3,178
Full selection F's				
Trawl $F_{40\%}$	0.036	0.030	0.037	0.028
Longline $F_{40\%}$	0.040	0.041	0.039	0.040
$F_{40\%}$ Combined	0.077	0.071	0.076	0.068
Trawl $F_{35\%}$	0.043	0.036	0.044	0.034
Longline $F_{35\%}$	0.049	0.050	0.048	0.049
$F_{35\%}$ Combined	0.092	0.085	0.091	0.082

Table 9.10. Estimates of beginning of year 5+ biomass, female spawning biomass, and recruitment for shortspine thornyheads in the Gulf of Alaska, Model 1.

Year	**Total age 5+ Biomass**	**Female Spawning Biomass**	**Age 5 Recruitment**
1967	64,160	29,249	42,867
1968	64,378	29,315	43,220
1969	64,580	29,373	45,048
1970	64,808	29,432	48,136
1971	65,150	29,532	51,133
1972	65,339	29,558	51,559
1973	65,565	29,616	49,472
1974	64,404	29,025	47,884
1975	63,301	28,472	46,957
1976	62,520	28,095	44,270
1977	61,624	27,695	39,862
1978	60,630	27,268	37,572
1979	60,272	27,157	36,630
1980	59,595	26,898	36,489
1981	58,526	26,452	36,709
1982	57,619	26,074	37,271
1983	57,323	25,964	39,776
1984	57,138	25,876	43,258
1985	57,677	26,045	56,298
1986	58,404	26,280	57,489
1987	58,496	26,207	55,580
1988	57,625	25,581	70,636
1989	56,500	24,845	68,012
1990	55,149	23,947	78,189
1991	54,679	23,612	53,847
1992	53,878	23,122	57,698
1993	53,114	22,698	55,397
1994	53,005	22,653	49,883
1995	53,002	22,690	49,631
1996	52,939	22,728	47,930
1997	52,913	22,809	45,259
1998	52,960	22,932	45,936
1999	53,211	23,095	53,157

Recruitment

Results from the present study confirm Miller's (1985) suggestion that year class success is variable for shortspine thornyheads in the GOA. Several strong year-classes were apparent but the ability to resolve the precise recruitment year was poor. This is because the thornyheads appear to grow very slowly and have a variable size-at-age relationship that can mask signals of strong year-classes. A plot of the estimated stock and recruitment is very uninformative because of the lack of contrast in spawning biomass levels over the period for which estimates were available (Fig. 9.13).

Projected catch and abundance

Thornyhead exploitable biomass projected to the year 2012, assuming average recruitment of 5 year olds, shows a slow decline when fished at the $F_{40\%}$ rate (Fig. 9.14). Similarly, yields show a slow short-term decline at the $F_{40\%}$ rate (Fig. 9.15). The average recruitment was computed from the period 1967-1999. Although guidelines have indicated that recruitment from spawning that occurred from 1977 and later, we were compelled to use the entire stock assessment period for the following reasons. The model uses 50 age classes and hence responds slowly to variability in recruitment. The time scales of environmental change and harvest projection periods are relatively small. Also, since we examine constant-recruitment scenarios as plausible alternatives given available data, the impact of using the entire time series is likely to be minor.

Maximum sustainable yield (MSY) calculations require assumptions about the stock recruitment relationship, which for shortspine thornyheads may be impractical as many functional forms can fit the data equally well. As presented above, the $F_{40\%}$ harvest strategy was selected in the absence of information on the stock-recruitment productivity relationship required for calculating MSY levels.

Reference fishing mortality rates and yields

The quantities for making harvest recommendations differ considerably from those used in previous assessments of the GOA shortspine thornyhead resource. This assessment uses a time-series of data from several different sources and attempts to provide a more comprehensive view of the status of the fishery as well as its history. The values for average fishing mortality and yields are given in Table 9.12 with the historical estimates given in Table 9.13.

Since management of thornyheads is not specific to different types of fishing gear, (i.e., there are no direct allocations of the TAC) the fraction of the TAC harvest by trawl versus longline gear is unpredictable. For our recommendations, we assume that the relative proportions of the SPR (spawning-biomass per recruit) fishing mortality rate in the next year will be similar to the value estimated for 1998. Previously (Ianelli *et al.* 1997) we showed that since the SPR rates are a function of gear selectivity, and the selectivity between trawl and longline gear is quite different, not knowing the relative harvests between gears can be misleading for deriving an SPR rate. For example, longline gear tends to harvest the older segment of the stock, consequently, they are able to harvest at a higher rate and still maintain reasonable spawning stock reserves. Also, please note that we assume that spawning occurs during the month of April (Ianelli *et al.* 1994).

We attempt to present an alternative way to summarize the uncertainty in our yield recommendations. Typically, we estimate the SPR fishing mortality rate (e.g., $F_{40\%}$) by using the fixed assumed (or estimated) values of natural mortality, growth, and fishery selectivity. We then apply this rate to a single (or series of) point estimate(s) of projected stock size to compute the ABC value. This year we devised a method of doing these computations within the estimation framework, thereby enabling us to carry through measures of uncertainty in yield estimates. Without going into detail, this technique involves using the Delta method, also referred to as propogation-of-error. This method presents the uncertainty of *functions* that involve random variables. For example, how does current stock size vary if natural mortality is treated as a random variable? In addition, how do these uncertain quantities affect estimates of yield under the $F_{40\%}$ harvest rate? The result from this application is shown in Figure 9.16. The vertical axis of this figure represents the cumulative odds that the “true” yield at a given SPR rate is less than the value on the horizontal axis. For example, following the $F_{40\%}$ curve along until the horizontal axis reads xxx tons gives a vertical scale of 25%. This implies that there is (approximately) a 25% chance that the “true” yield at the $F_{40\%}$ harvest rate is *less* than 2,209 tons. Interestingly, the “point” estimate of 2,359 tons under the $F_{40\%}$ level coincides with a very minute probability (~3% chance) that the overfishing level ($F_{35\%}$) would be exceeded. This framework can also be used to reflect the uncertainty in future catch by different gear types.

Table 9.11. Reference fishing mortality rates (coefficient of variation in parenthesis), and yield for 2000 with upper and lower 25 percentiles for ABC and OFL computations. Fishing mortality rates expressed as full selection values.

	Longline	Trawl	
$F_{40\%}$	0.040	0.036	
	(13%)	(10%)	
$F_{35\%}$	0.049	0.043	
	(13%)	(10%)	
	25%	**50%**	**75%**
ABC	2209	**2359**	2519
OFL	2648	2825	3014

*Assuming relative catch in 2000 is the same between the gear types.

Table 9.12. Model 1 estimates of the trend in average (ages 5-54) and full selection fishing mortality rates by gear type and combined for shortspine thornyheads in the Gulf of Alaska.

		Average F			**Full selection F**	
Year	**Trawl**	**Longline**	**Combined**	**Trawl**	**Longline**	**Combined**
1978	0.007	0.006	0.013	0.012	0.009	0.020
1979	0.011	0.008	0.019	0.017	0.011	0.029
1980	0.019	0.006	0.025	0.031	0.008	0.039
1981	0.019	0.004	0.023	0.031	0.005	0.036
1982	0.011	0.002	0.014	0.018	0.003	0.021
1983	0.011	0.002	0.013	0.017	0.003	0.020
1984	0.003	0.001	0.004	0.005	0.001	0.006
1985	0.001	0.000	0.001	0.002	0.000	0.002
1986	0.010	0.002	0.012	0.016	0.003	0.019
1987	0.031	0.000	0.032	0.050	0.000	0.050
1988	0.037	0.001	0.038	0.059	0.001	0.060
1989	0.046	0.001	0.047	0.073	0.002	0.075
1990	0.023	0.006	0.030	0.037	0.009	0.046
1991	0.024	0.015	0.039	0.038	0.021	0.060
1992	0.022	0.018	0.041	0.035	0.026	0.062
1993	0.013	0.016	0.029	0.021	0.022	0.043
1994	0.014	0.014	0.027	0.022	0.020	0.041
1995	0.015	0.013	0.029	0.024	0.019	0.044
1996	0.014	0.014	0.028	0.023	0.020	0.042
1997	0.015	0.011	0.026	0.025	0.016	0.040
1998	0.011	0.013	0.025	0.018	0.019	0.037
1999	0.019	0.012	0.031	0.030	0.017	0.047

Acceptable biological catch

The recommended 2000 $F_{40\%}$ harvest level for shortspine thornyheads in the GOA is **2,359 t**. This is slightly increased compared to last year's $F_{40\%}$ rate of 1,990 t. The long-term expected value of female spawning biomass with fishing held at $F_{40\%}$, referred to as the $B_{40\%}$ level, is estimated at about **17,775** t. This is substantially lower than the current estimate of female spawning biomass of **23,095** t. Therefore, under the ABC and overfishing definitions (Plan Amendment 56), no adjustment to the $F_{40\%}$ harvest rate is required.

Overfishing level

The Council's overfishing definition is the fishing mortality rate which reduces the spawning biomass per recruit to 35% of its pristine level. For shortspine thornyheads in the Gulf of Alaska that value (averaged over all ages) corresponds to F=0.092 (full selection). This rate corresponds to a catch level of **2,825 t** in 2000, assuming equal catches by gear type.

Standard harvest scenarios and projections

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 1999 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2000 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 1999. In each subsequent year, the fishing mortality rate is determined based on the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2000, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

- *Scenario 1*: In all future years, *F* is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- *Scenario 2*: In all future years, *F* is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2000 recommended in the assessment to the *max* F_{ABC} for 2000. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
- *Scenario 3*: In all future years, *F* is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- *Scenario 4*: In all future years, *F* is set equal to the 1994-1998 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)
- *Scenario 5*: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Scenarios 1 through 5 were projected 5 years from 1999 (Table 9.14).

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

- *Scenario 6*: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2000 and above its MSY level in 2010 under this scenario, then the stock is not overfished.)
- *Scenario 7*: In 2000 and 2001, *F* is set equal to *max* F_{ABC}, and in all subsequent years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2012 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 6 and 7 were projected 13 years from 1999 using model 1 output (Figure 9.17). Under scenario 6, mean biomass projected for 2000 (22,014 t) is greater than ½$B_{35\%}$ (7,516 t), and mean biomass projected for 2010 (17,022 t) is greater than $B_{35\%}$ (15,032 t). Under scenario 7, mean biomass projected for 2012 (16,746 t) is also greater than $B_{35\%}$. These projections indicate that GOA thornyheads are not currently below MSST, and are not expected to approach MSST status in the next two years.

Table 9.13. Projected biomass and catch under five harvest scenarios.

Reference Points (all biomass estimates refer to female spawners)						
	B_0	42,948				
	$B_{40\%}$	17,179				
	$B_{35\%}$	15,032				
	Year	1999	2000	2001	2002	2003	2004
Scenario							
1: Max ABC							
	Mean Biomass	22,380	22,080	21,644	21,223	20,813	20,424
	Stdev Biomass	0.00	3.61	9.76	18.31	31.64	52.70
	Mean Catch	1,990	2,346	2,314	2,288	2,265	2,241
	Stdev Catch	0.00	0.57	0.94	1.34	1.86	2.55
2: 90% max ABC							
	Mean Biomass	22,380	22,109	21,783	21,464	21,148	20,846
	Stdev Biomass	0.00	3.61	9.76	18.33	31.68	52.81
	Mean Catch	1,990	2,117	2,101	2,089	2,079	2,068
	Stdev Catch	0.00	0.52	0.84	1.20	1.67	2.30
3: 50% max ABC							
	Mean Biomass	22,380	22,227	22,349	22,460	22,556	22,646
	Stdev Biomass	0.00	3.61	9.78	18.40	31.87	53.23
	Mean Catch	1,990	1,190	1,209	1,229	1,250	1,269
	Stdev Catch	0.00	0.29	0.47	0.67	0.94	1.29
4: 5 Year average F (=0.03)							
	Mean Biomass	22,380	22,204	22,238	22,262	22,274	22,282
	Stdev Biomass	0.00	3.61	9.78	18.39	31.83	53.15
	Mean Catch	1,990	1,372	1,387	1,404	1,422	1,438
	Stdev Catch	0.00	0.33	0.54	0.78	1.08	1.49
5: No catch							
	Mean Biomass	22,380	22,374	23,082	23,784	24,478	25,170
	Stdev Biomass	0.00	3.62	9.81	18.49	32.09	53.78
	Mean Catch	1,990	0	0	0	0	0
	Stdev Catch	0.00	0.00	0.00	0.00	0.00	0.00

Other considerations

Based on the most recent survey estimate that sampled in deeper strata than the other 1990s surveys, we computed the following apportionment of shortspine thornyheads ABC broken out by management areas compared to past years survey estimates as follows:

Biomass (tons)					
	Year	**Western**	**Central**	**Eastern**	**Total**
	1990	1,679	5,941	11,997	19,617
	1993	3,706	12,509	16,808	33,023
	1996	8,043	18,741	24,912	51,696
	1999	14,090	32,593	30,671	77,353
Proportion		**Western**	**Central**	**Eastern**	
	1990	9%	30%	61%	
	1993	11%	38%	51%	
	1996	16%	36%	48%	
	1999	18%	42%	40%	
		Western	**Central**	**Eastern**	**Total**
		18%	42%	40%	
	ABC	425	991	944	**2,359**

Historical removals by foreign vessels appear to have been more concentrated in the central region (Ianelli and Ito, 1995). Since this pattern may reflect current trends, we recommend that management of thornyheads be broken into these regions rather than Gulf-wide. Presently it is impossible to determine the relative magnitude of thornyhead removals in these areas since observer coverage is not evenly distributed. Further considerations on future harvest levels must also account for the impact of trawl closure areas in the eastern portion of the GOA. The impact of this closure will likely shift the relative proportion caught by gear type, but since this will increase the proportion caught by longline gear, the harvest levels recommended here are likely to be more conservative than if the pressumed shift in catch by gear type was accepted.

Summary

The management parameters of interest derived from this assessment are presented in Table 9.15. Please note, however, that management actions should be based on a more complete evaluation of the alternatives presented above rather than the single values given here.

Table 9.14. Summary management values based on this 1999 assessment for shortspine thornyheads in the Gulf of Alaska.

Management Parameter	**Value**
M (natural mortality)	0.0814 yr^{-1}
Approximate age at full recruitment	Younger for trawl, older for longline
$F_{35\%}$ (Full selection)	0.092
$F_{40\%}$ (Full selection)	0.077
Unfished female spawning biomass	44,436 t
Long-term $B_{40\%}$	
(female spawning biomass)	17,775 t
2000 female spawning biomass	23,084 t
2000 age 5+ biomass	52,952 t
F_{ABC}	0.077
ABC (Reference model)	**2,359 t**
$F_{overfishing}$	0.092
Overfishing level	**2,825 t**

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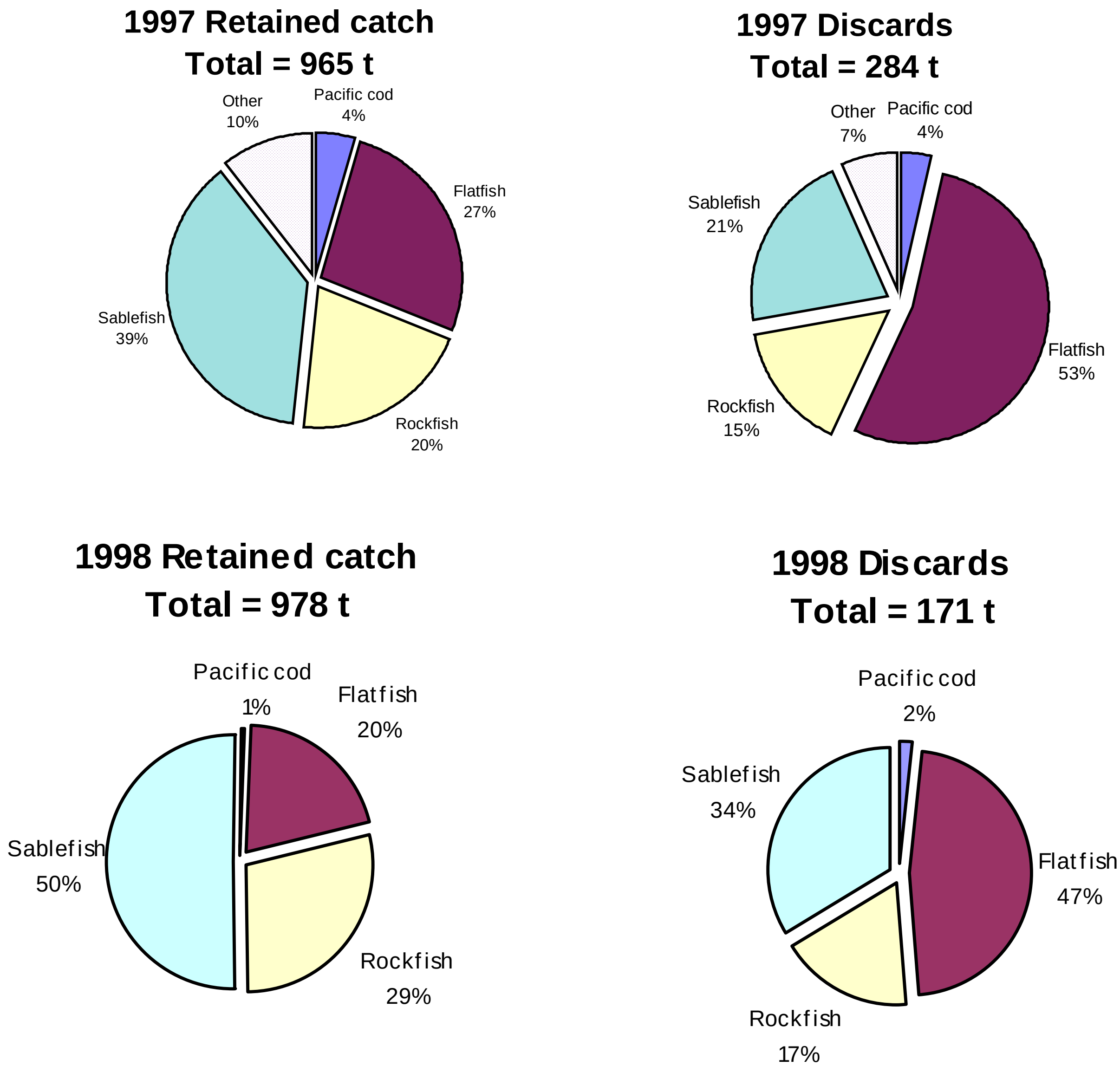

Figure 9.1. Proportion retained and discarded shortspine thornyhead by target fishery in 1998. *Source: NMFS Alaska Fisheries Science Center and Regional Office blend data.*

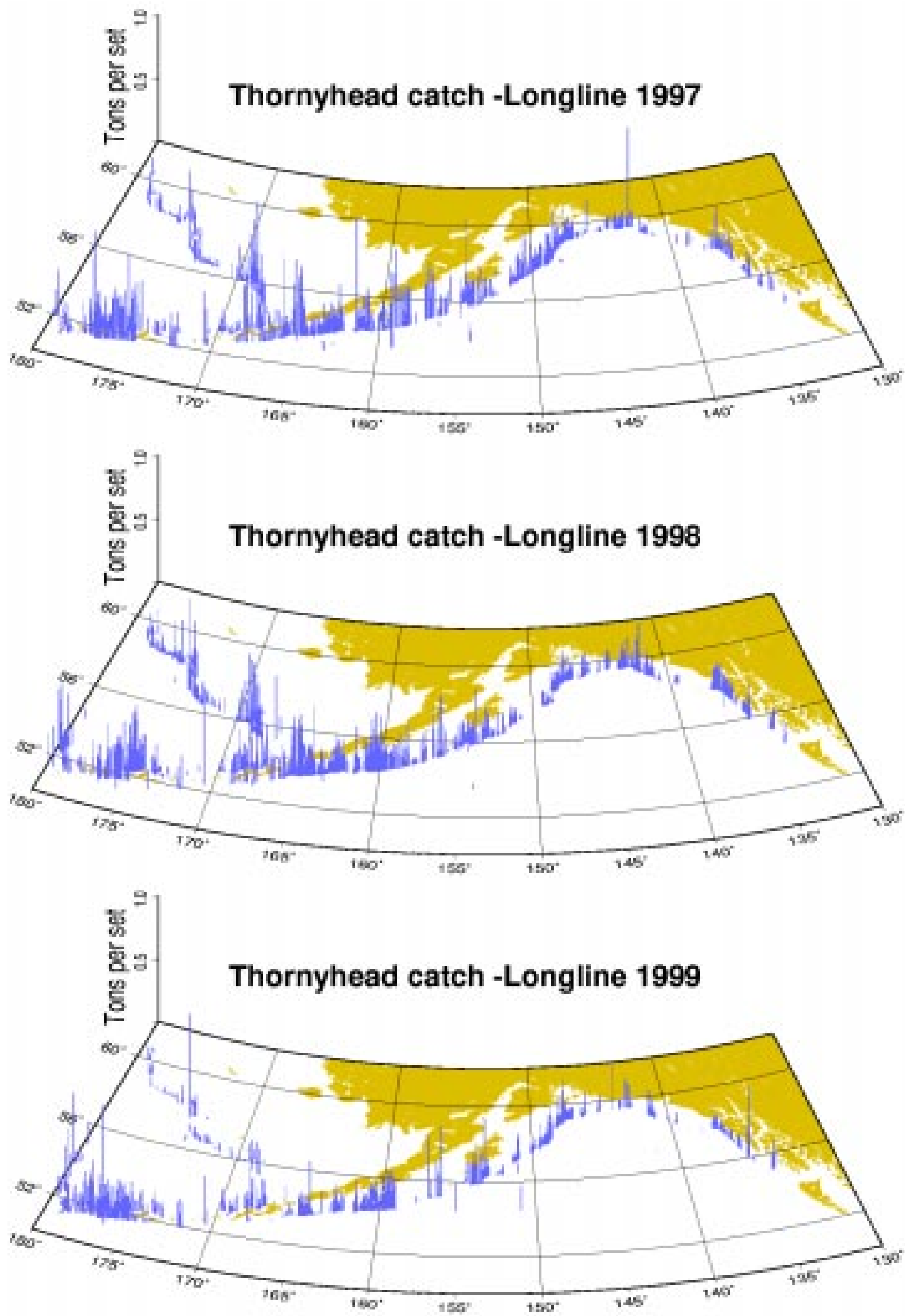

Figure 9.2. Distribution of thornyhead catches by commercial longline gear, 1997-1999.

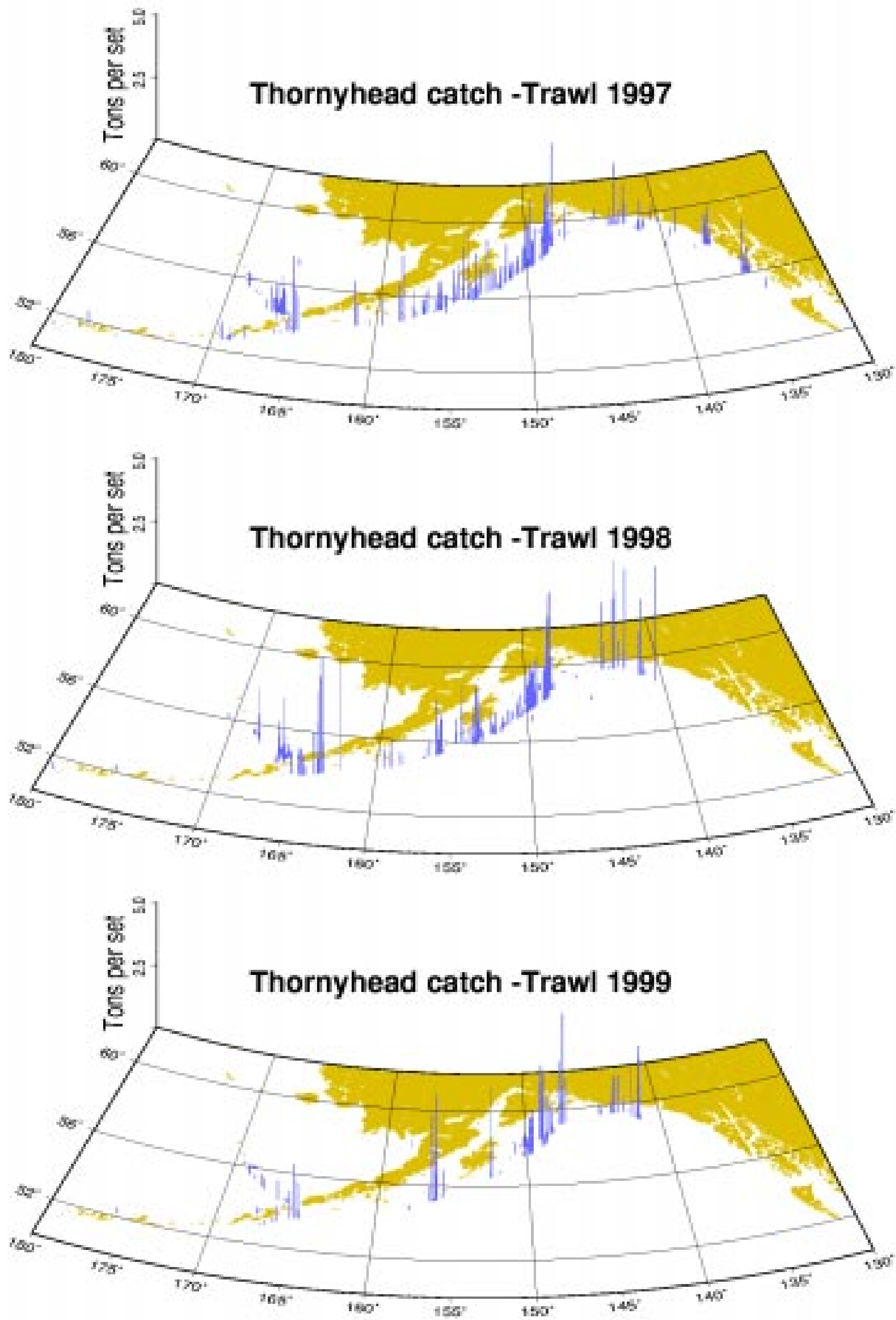

Figure 9.3. Distribution of thornyhead catches by commercial trawl gear, 1997-1999.

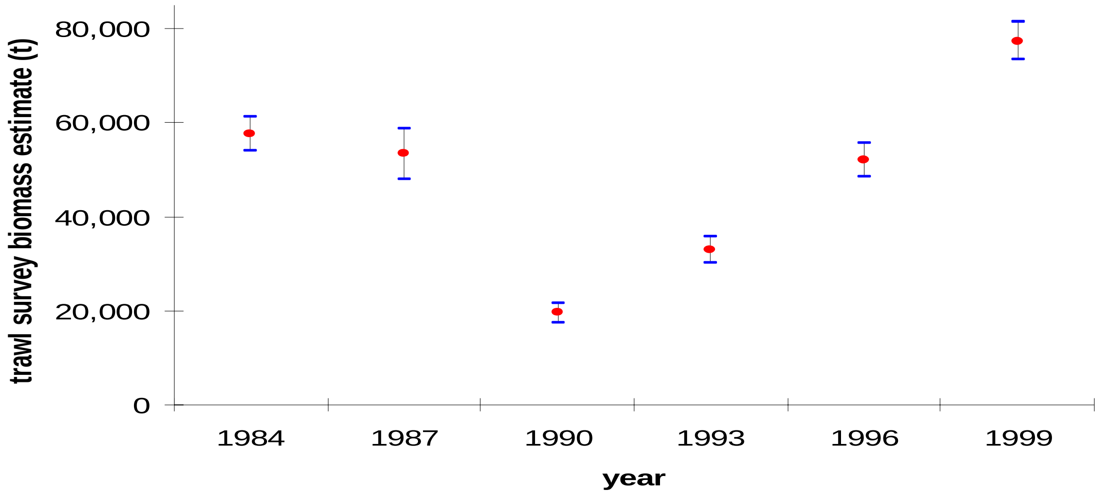

Figure 9.4. Shortspine thornyhead biomass estimates (and standard errors) from the NMFS triennial trawl survey. Note that the 1990, 1993, and 1996 surveys did not extend to deep water (>500m), consequently, a significant proportion of the stock may not have been sampled.

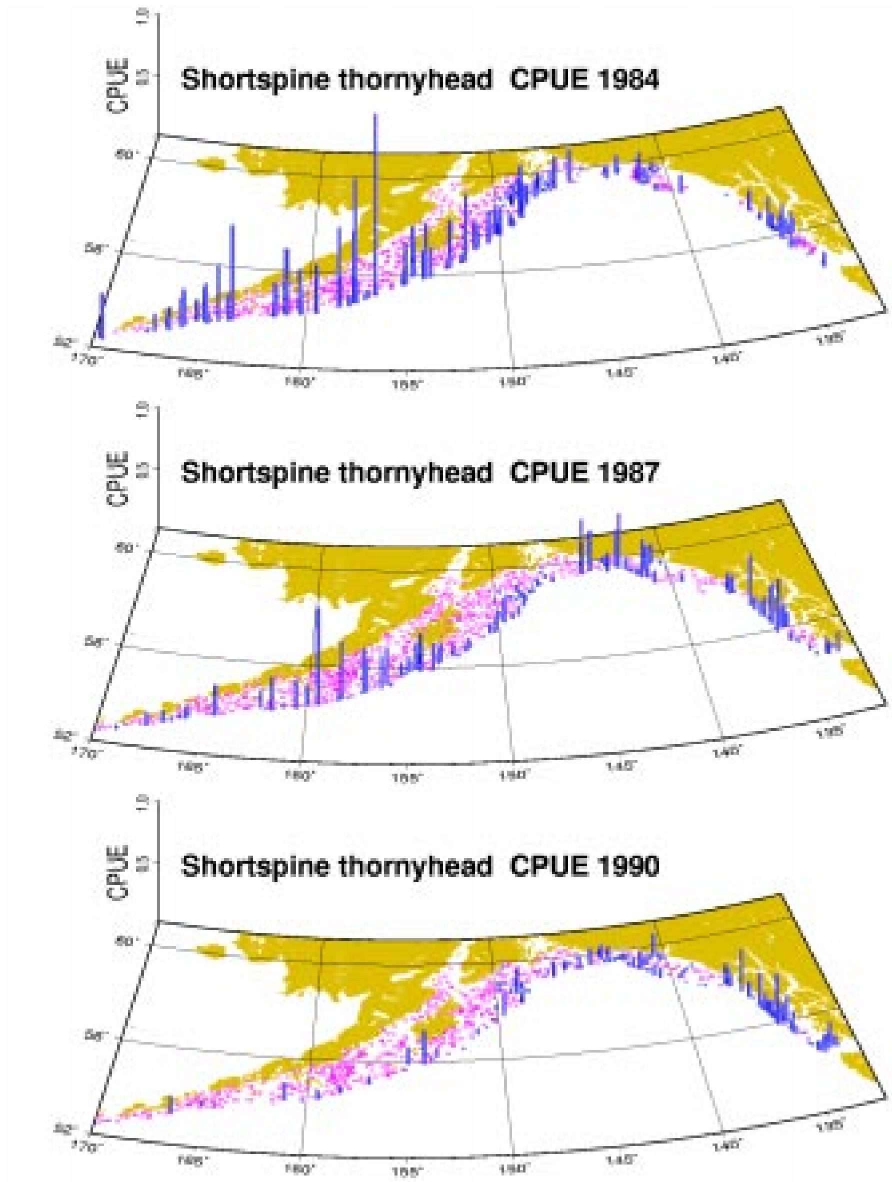

Figure 9.5. Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured.

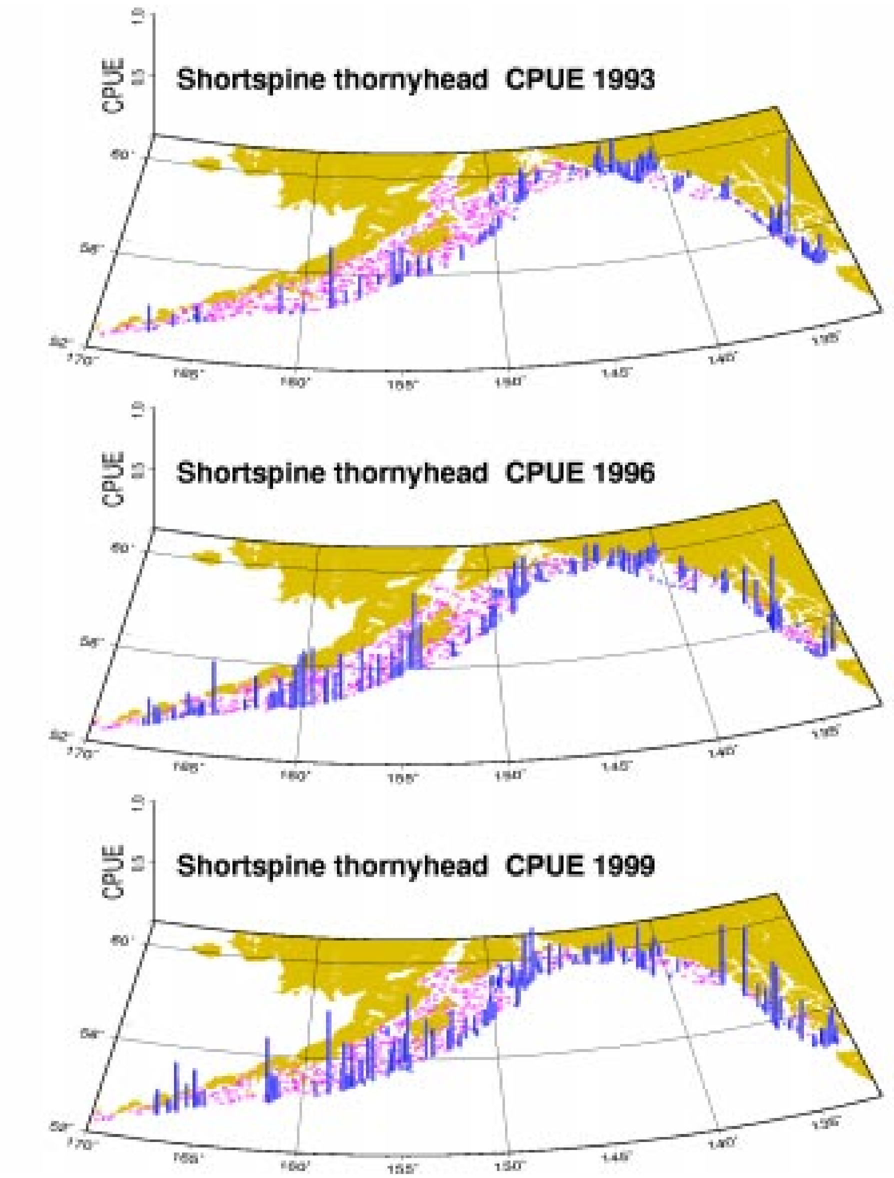

Figure 9.5 (cont'd). Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured.

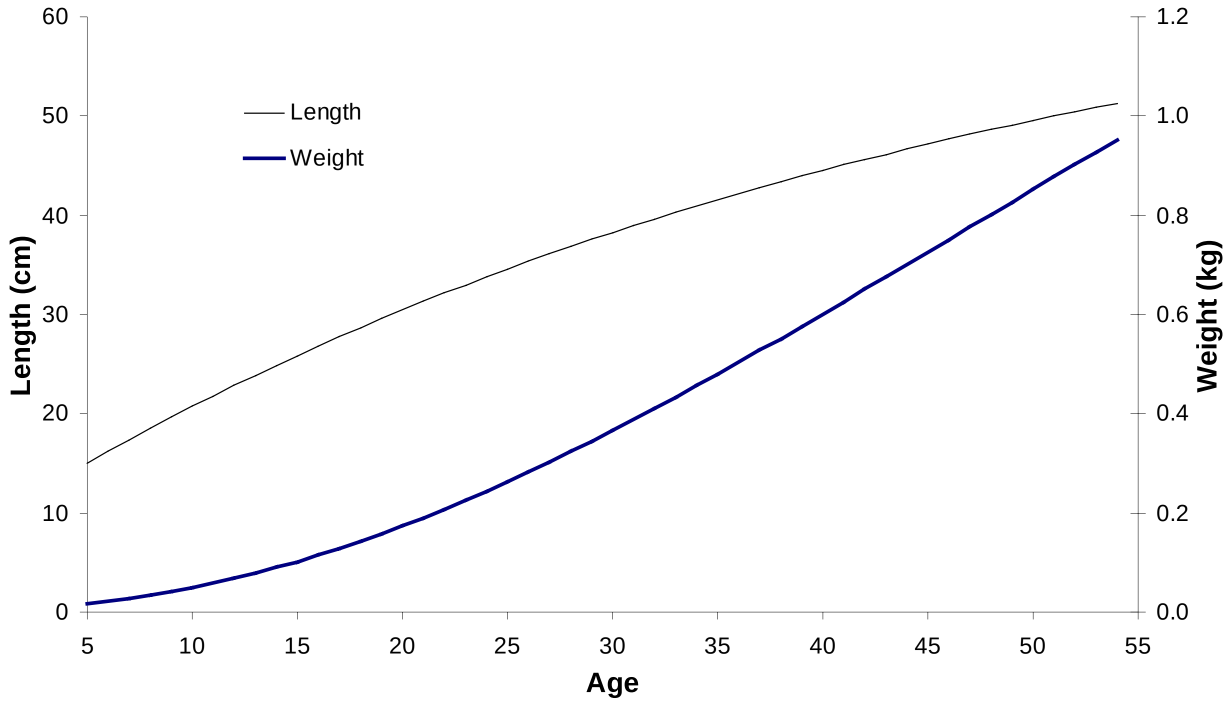

Figure 9.6. Assumed average length and weight at age for Gulf of Alaska shortspine thornyheads.

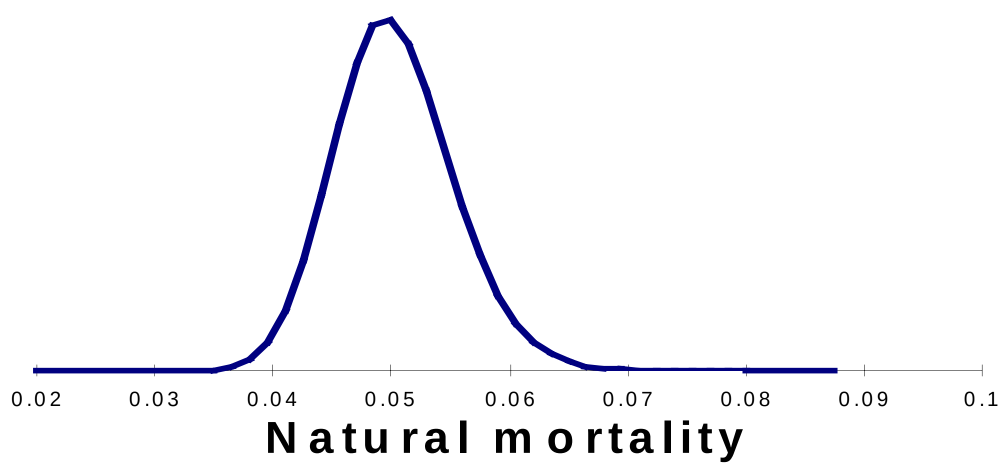

Figure 9.7. Prior distribution assumed for natural mortality of thornyheads.

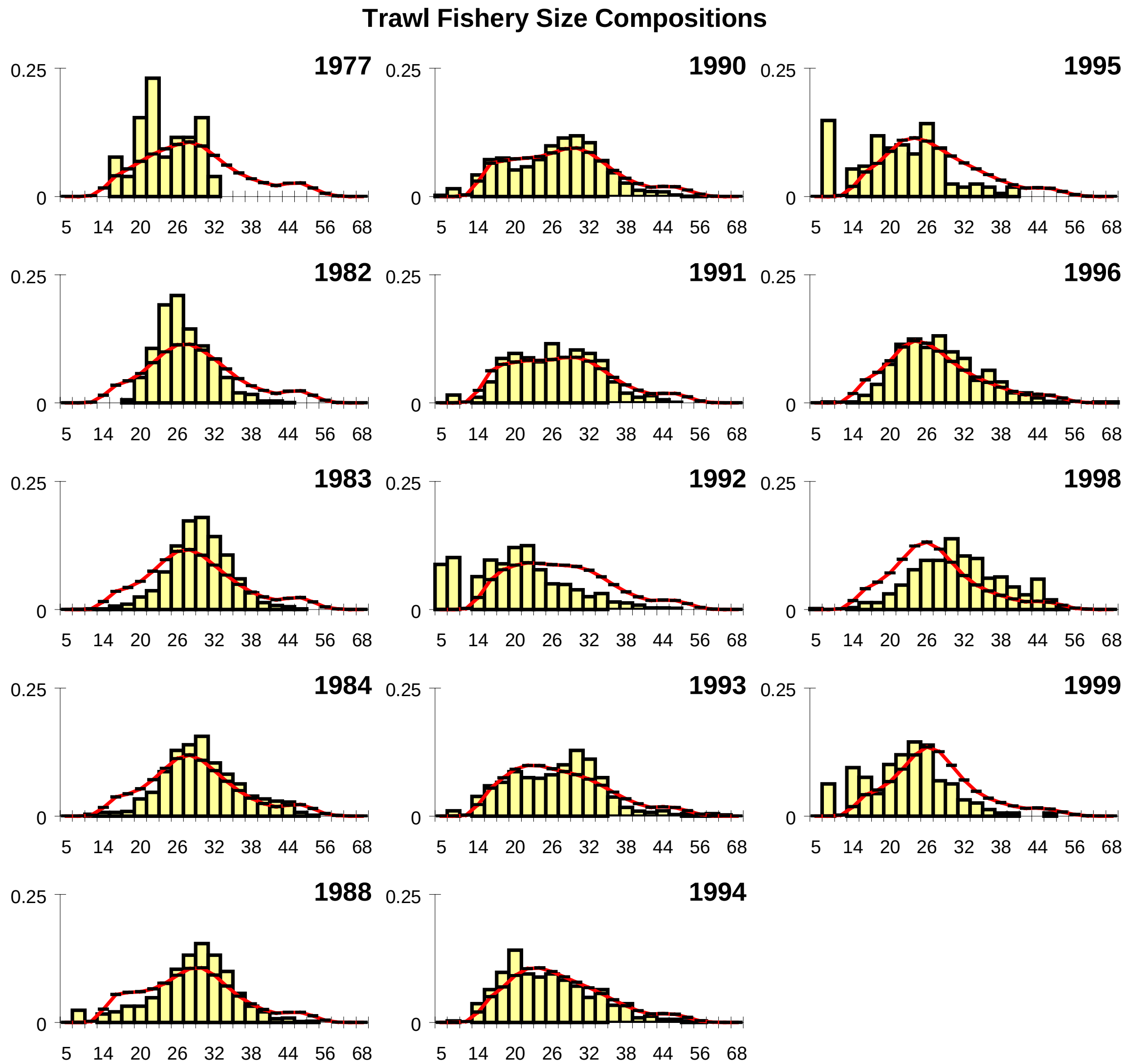

Figure 9.8. Model fits to the trawl shortspine thornyheads fishery size composition data.

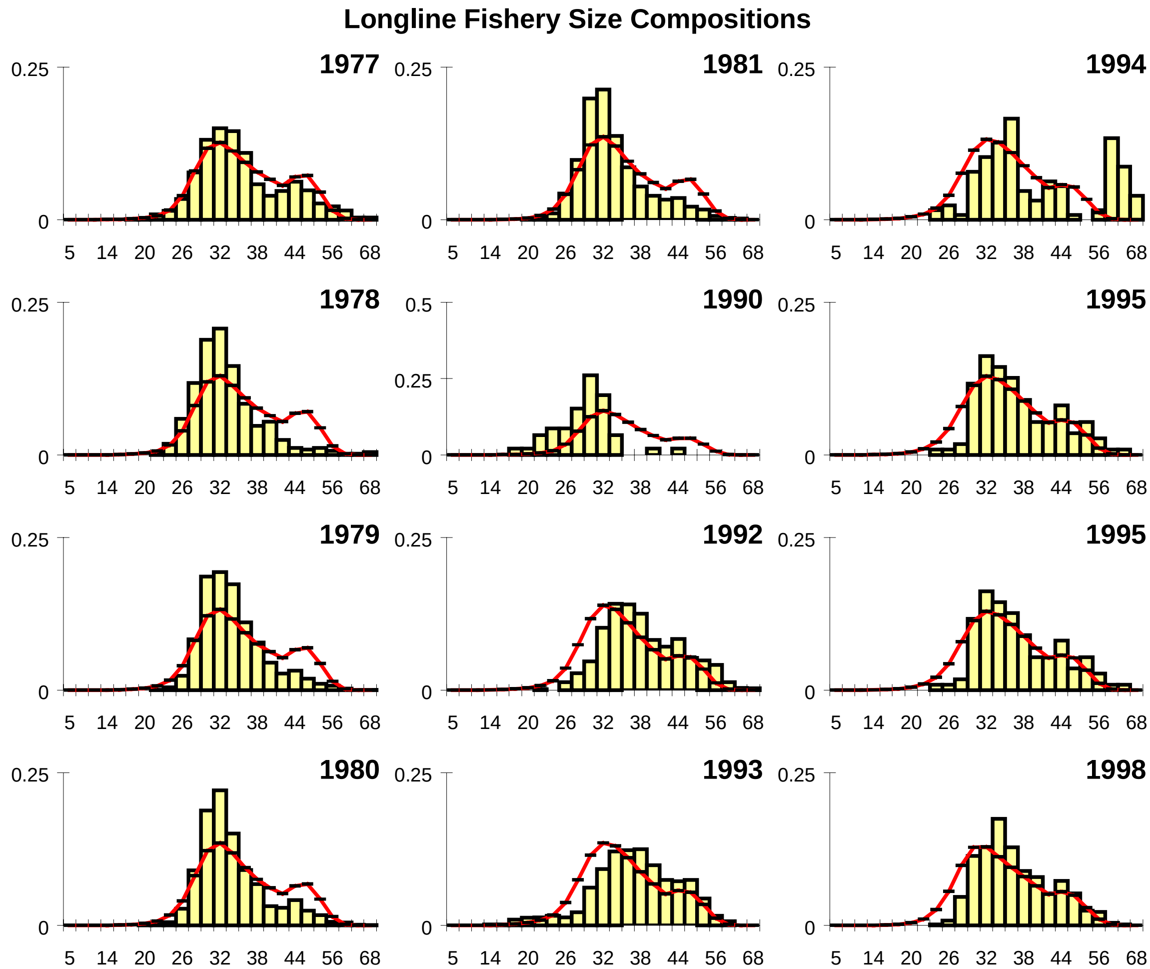

Figure 9.8. (Cont'd) Model fits to the longline shortspine thornyheads fishery size composition data.

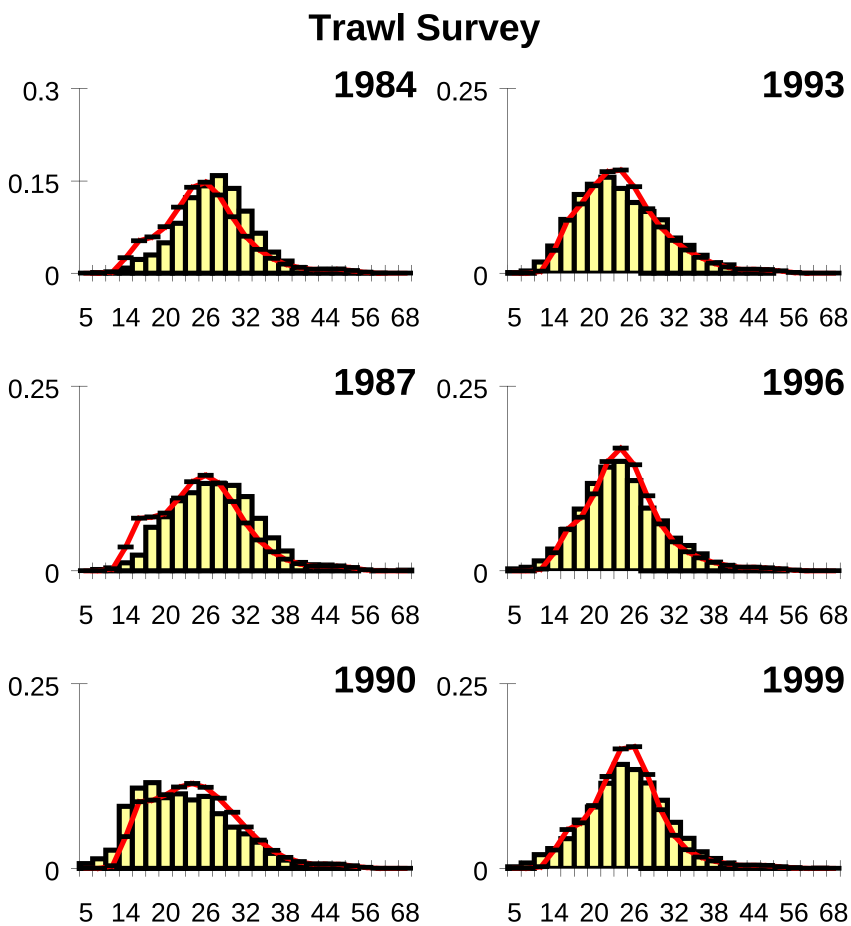

Figure 9.8. (Cont'd) Model fits to the trawl survey size composition data.

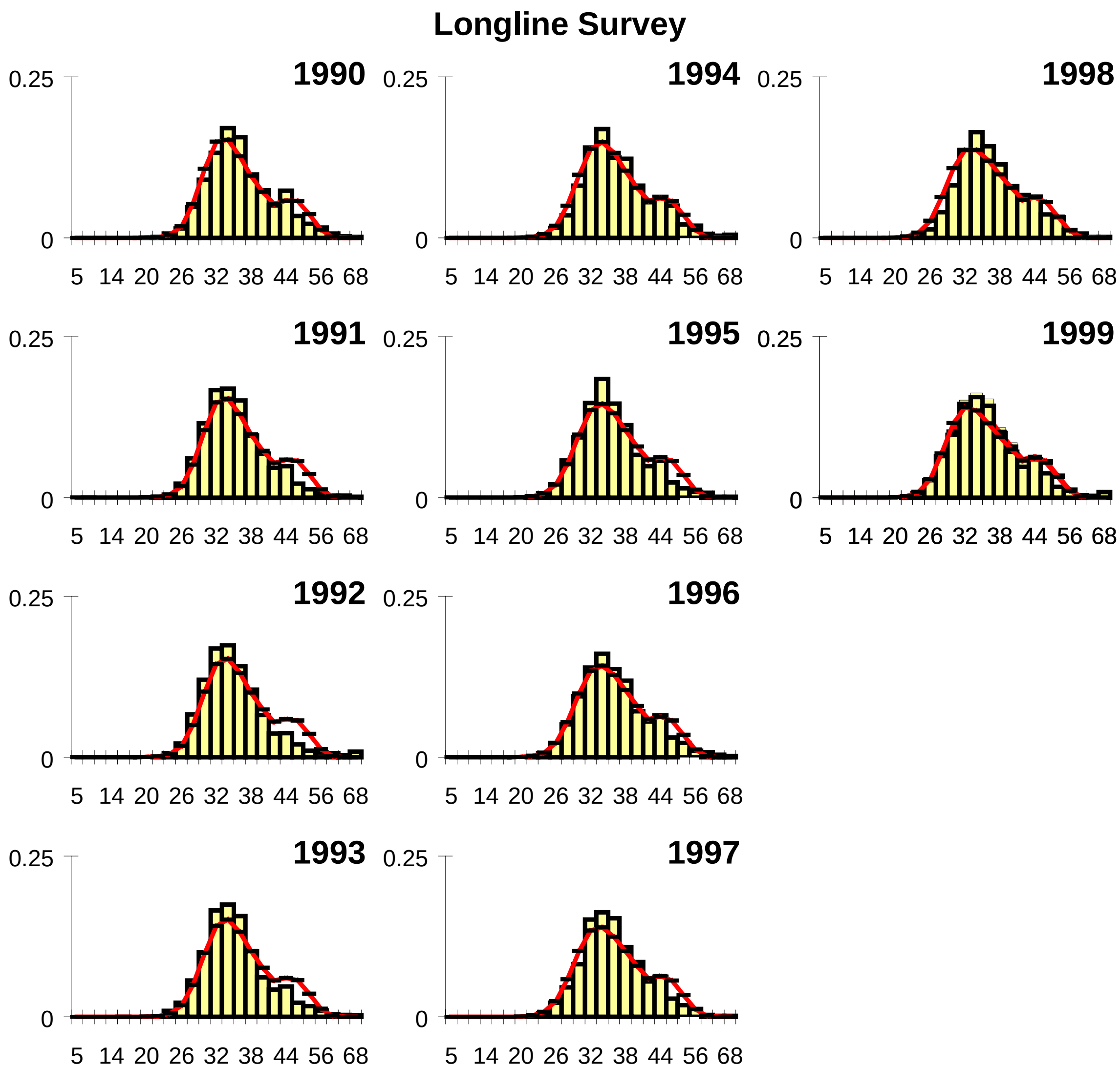

Figure 9.8. (Cont'd) Model fits to the longline survey shortspine thornyheads size composition data.

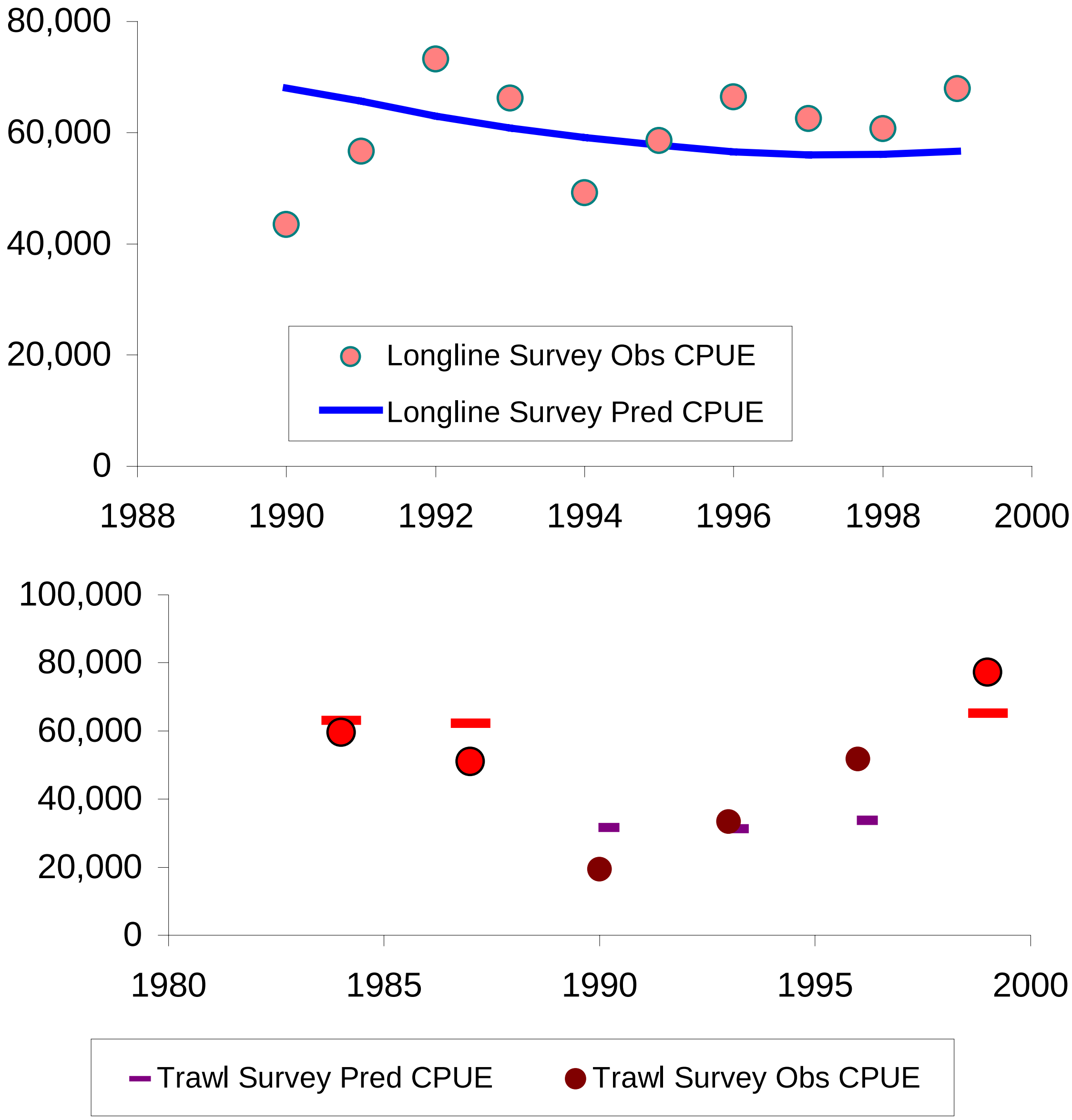

Figure 9.9. Model fits to the relative abundance index from the longline surveys (RPN, top panel) and the triennial trawl surveys (bottom panel) for shortspine thornyheads. Note that the triennial survey was modeled with two catchability terms to reflect the change in distribution covered by the survey after 1989.

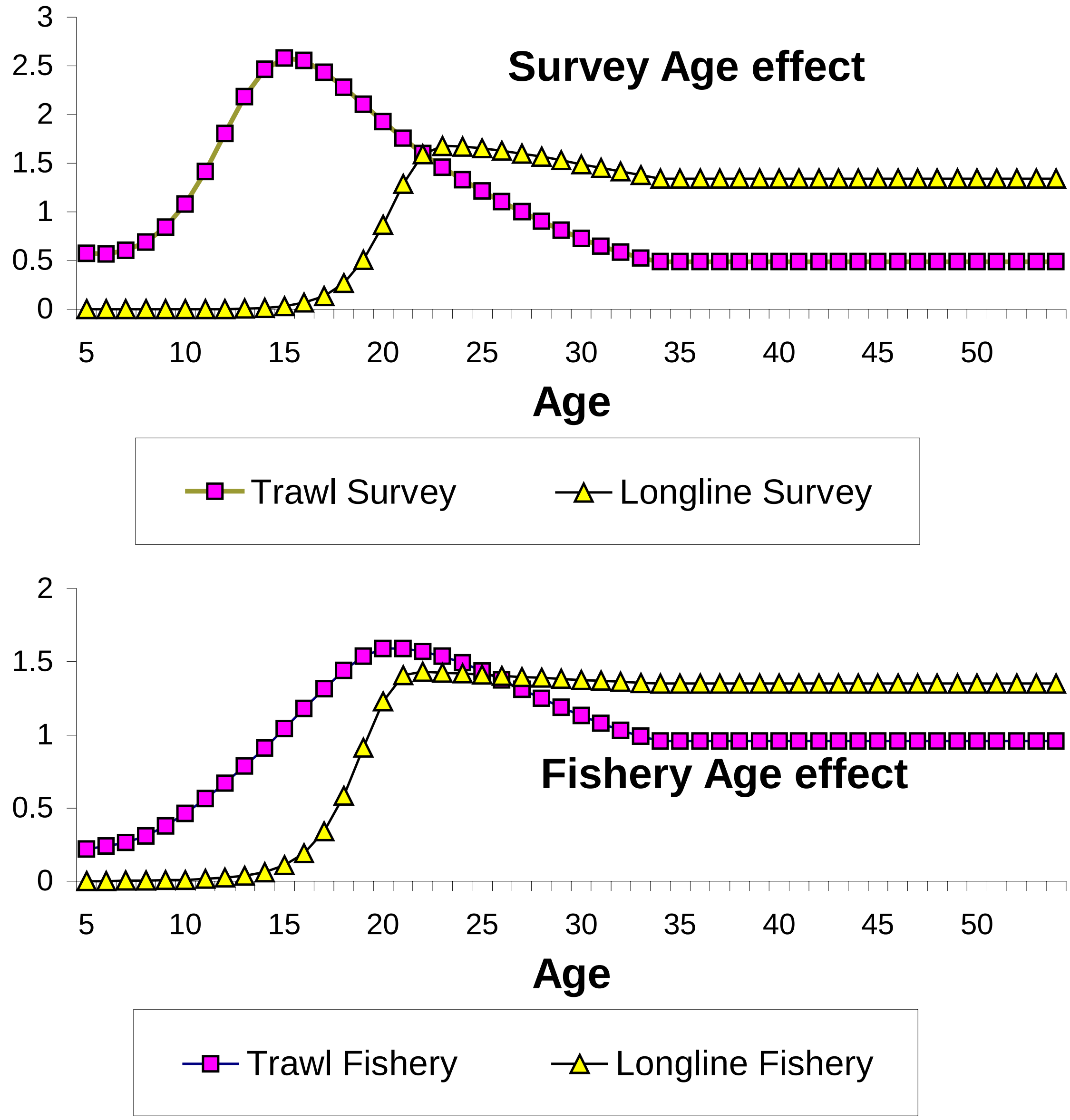

Figure 9.10. Selectivity of GOA shortspine thornyheads estimated for the surveys (upper panel) and fisheries.

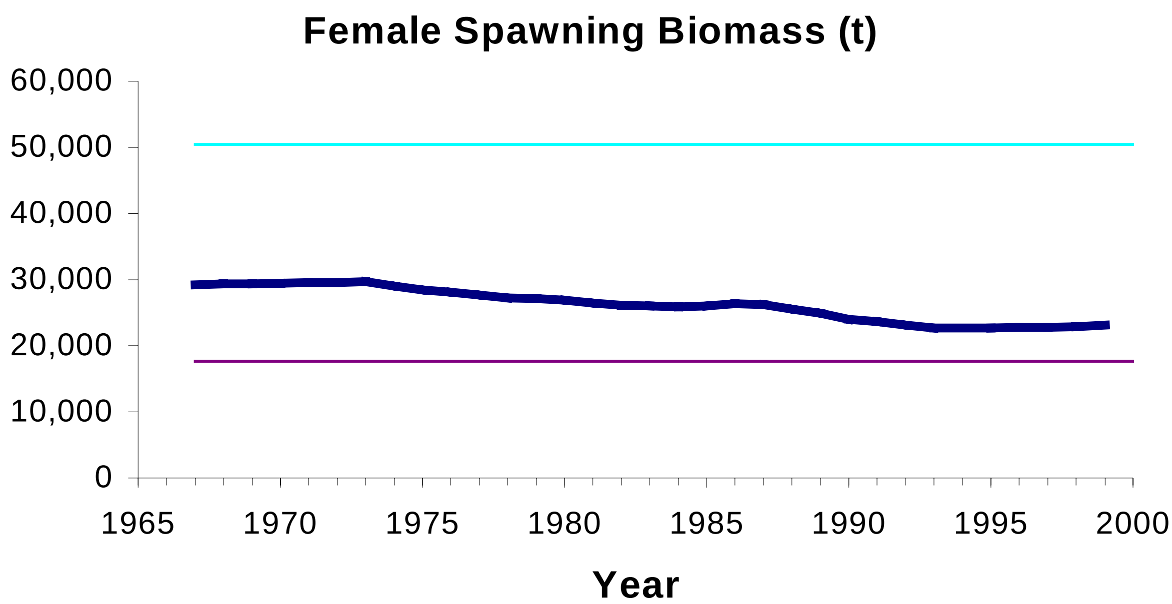

Figure 9.11. Estimated female spawner biomass trajectory (heavy line) for shortspine thornyheads in the Gulf of Alaska. Upper straight line is unfished biomass, lower straight line is $B_{35\%}$ (as defined from average year-class estimates since 1977).

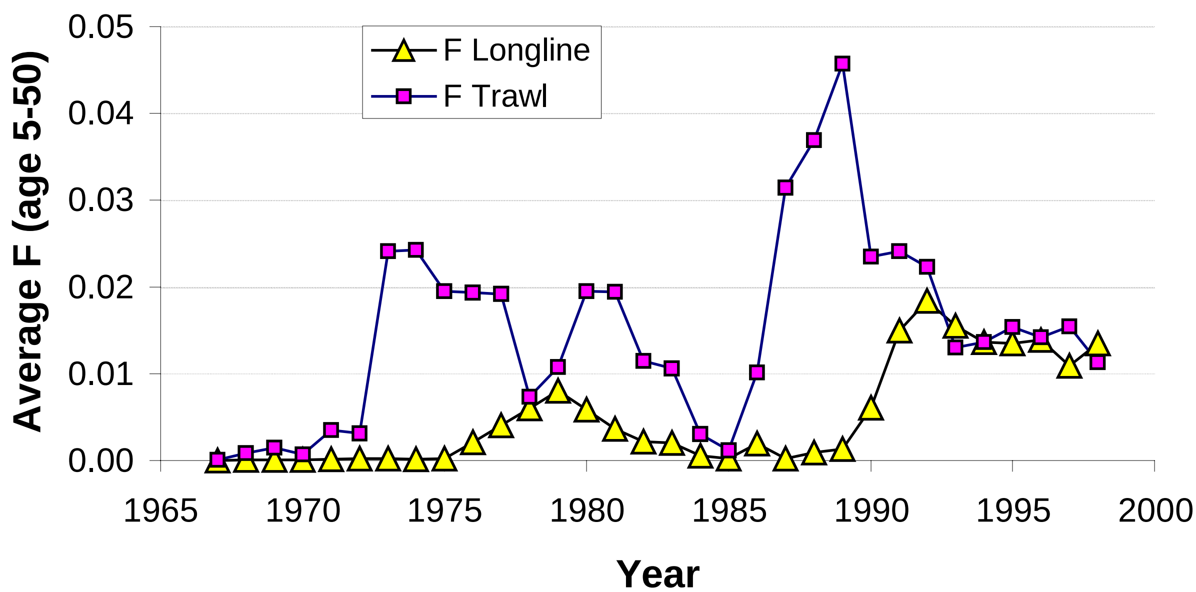

Figure 9.12. Average (over ages 5-54) fishing mortality rate by gear type on shortspine thornyheads in the Gulf of Alaska, 1967-1997.

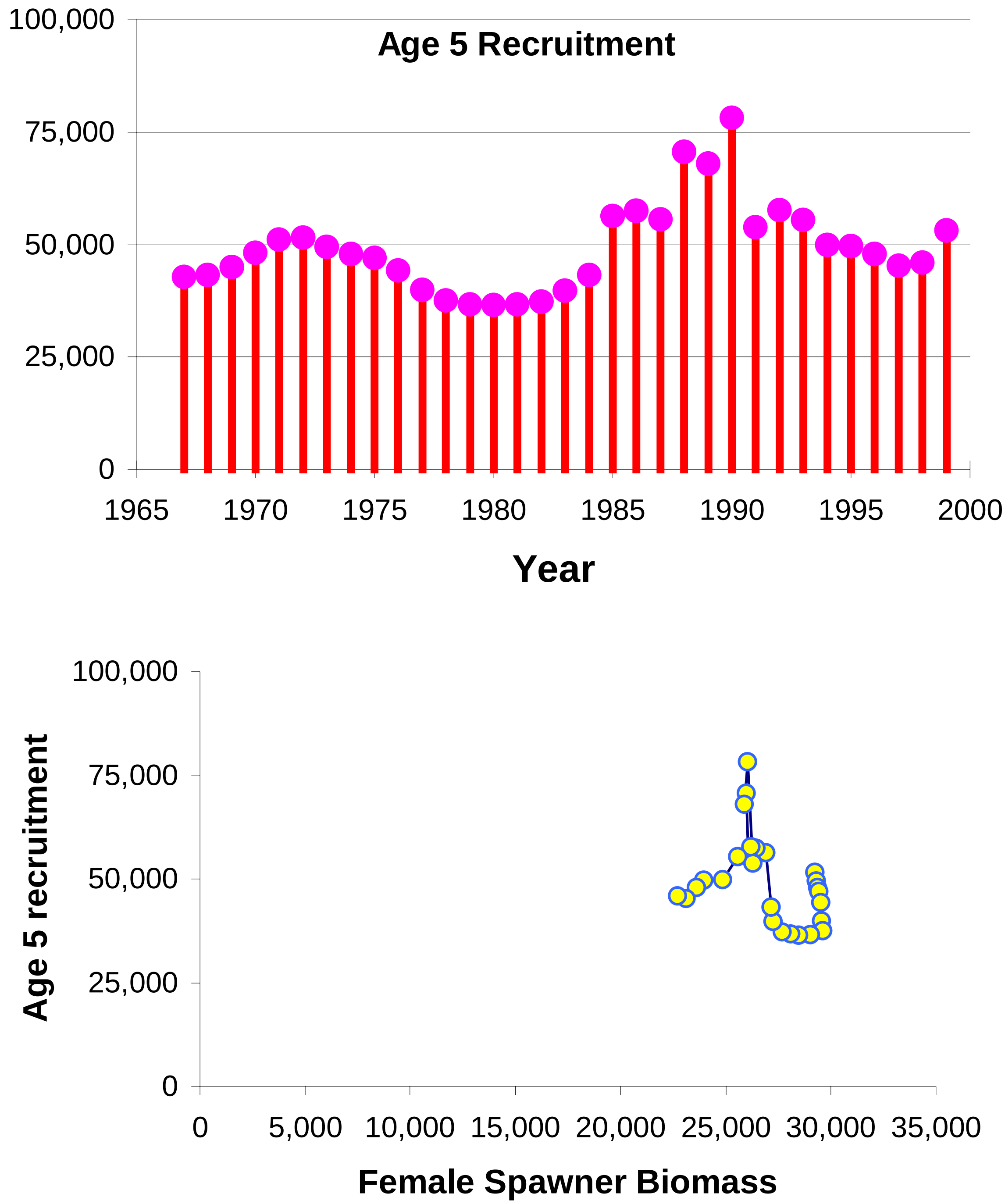

Figure 9.13. Time series of recruitment strengths (upper panel) and the stock-recruitment plot (lower panel) for shortspine thornyheads in the Gulf of Alaska.

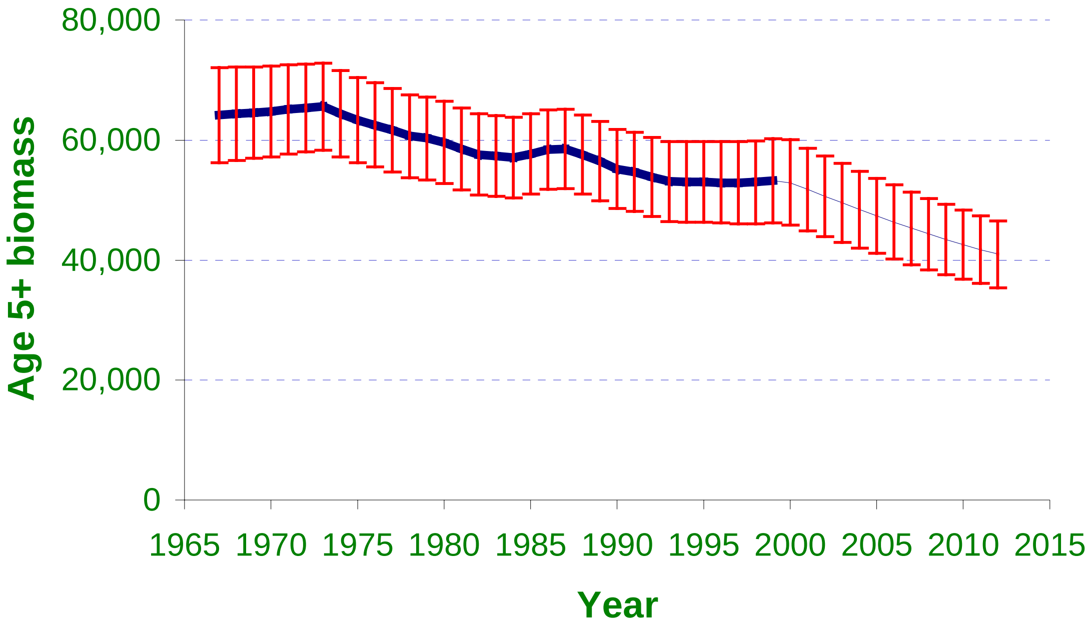

Figure 9.14. Historical and projected shortspine thornyhead age 5+ biomass with 2 standard deviations. Note that future projections are based on an assumed $F_{40\%}$ fishing mortality rate.

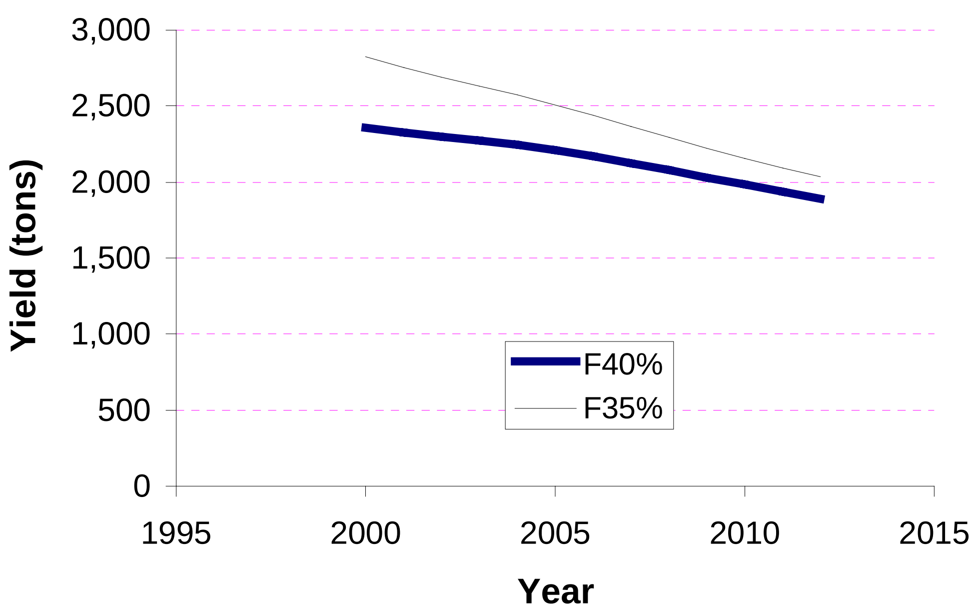

Figure 9.15. Projected future yield of shortspine thornyheads under alternative SPR fishing mortality rates.

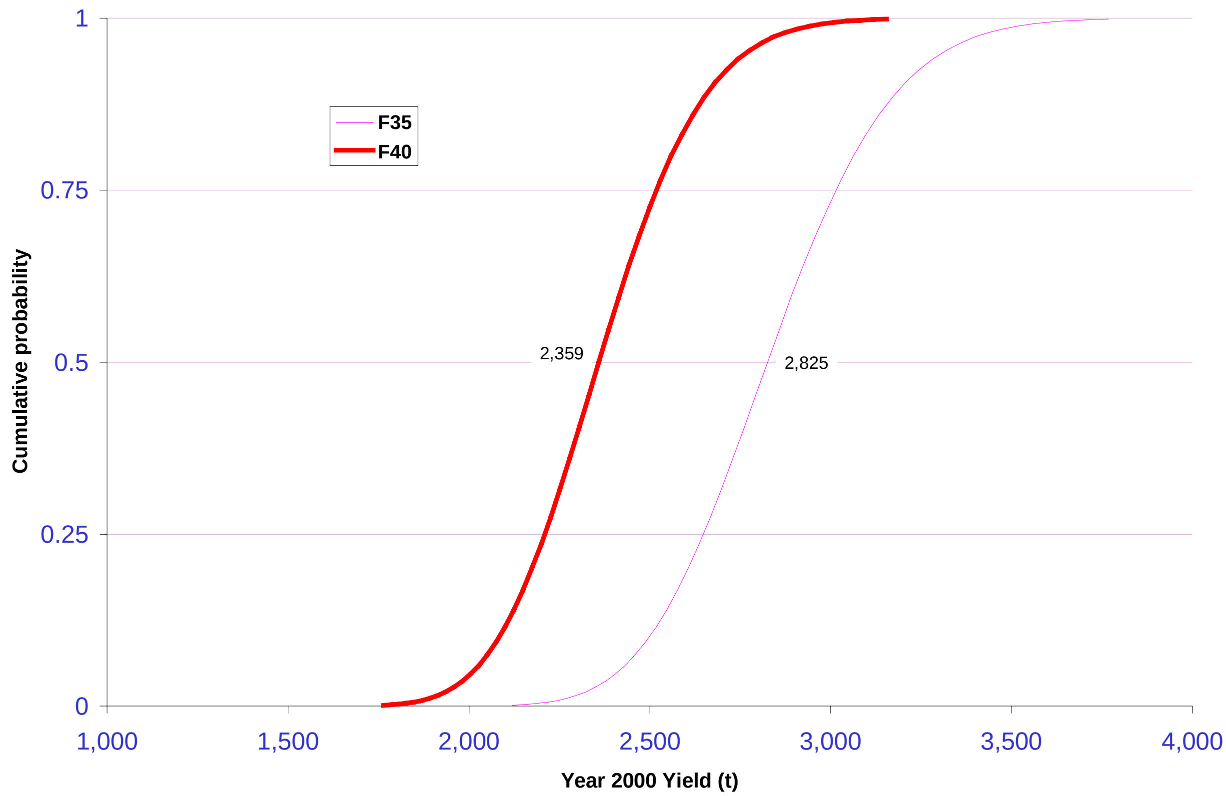

Figure 9.16. Projected 1999 shortspine thornyhead yield under alternative SPR harvest rates. The cumulative probability reflects uncertainty in the current stock size in addition to uncertainty in estimating the SPR rates themselves.

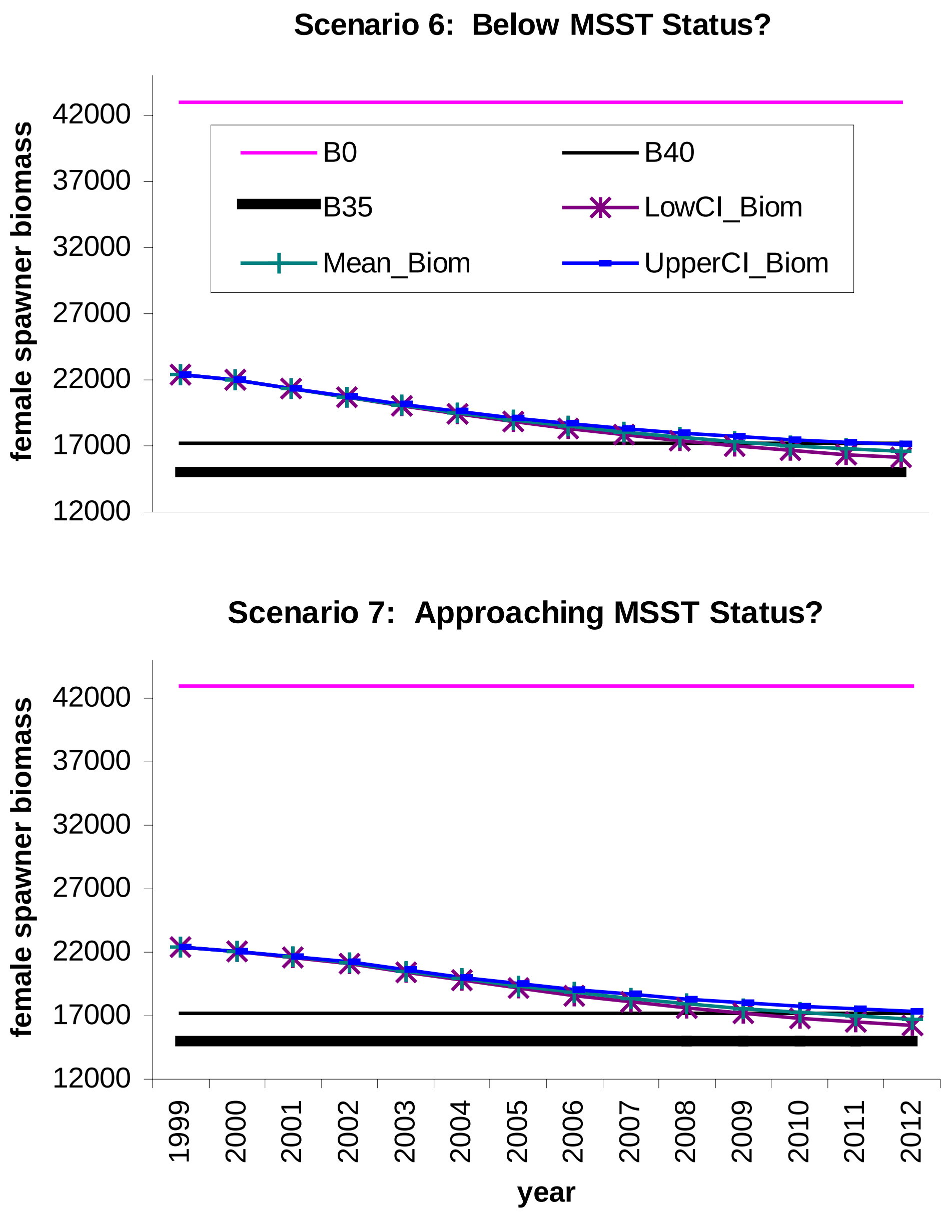

Figure 9.17. Projected shortspine thornyhead female spawning biomass under two scenarios. Top panel (scenario 6 in text): In all future years, F is set equal to F_{OFL}. Bottom pane (scenario 7 in text): In 2000 and 2001, F is set equal to $max\ F_{ABC}$, and in all subsequent years, F is set equal to F_{OFL}.