

# **Status of the Shortspine Thornyhead Resource off the U.S. Pacific Coast in 1998**

## **Stock Assessment Teams (STATs) Summary Report**

August 19, 1998

This summary report has been prepared jointly by two stock assessment teams (STAT) that evaluated the status of the shortspine thornyhead population off the U.S. Pacific coast in 1998. One STAT team (STAT 3) consisted of researchers from the Fishery Resource Analysis and Monitoring Division (FRAMD) of the Northwest Fisheries Science Center (NWFS), National Marine Fisheries Service (NMFS), which included Jean Beyer Rogers, Tonya L. Builder, Paul R. Crone, Jon Brodziak, Richard D. Methot and Ramon J. Conser and Robert Lauth (NMFS AFSC). An independent group of researchers composed another STAT (STAT2), which included Ray Hilborn (University of Washington), J.-J. Maguire (Halieutikos inc.), Ana Parma (International Pacific Halibut Commission), Mark Maunder (University of Washington), and Lorraine Read (TerraStat Consulting Group). The STATs conducted independent assessments and presented results at a stock assessment review (STAR) held from July 6-10, 1998 at the Hatfield Marine Science Center located in Newport, Oregon.

The STAR panel included Michael Sigler (Chairperson, NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory), Robert Hannah (Oregon Department of Fish and Wildlife, Marine Program, Hatfield Marine Science Center), Lawrence Jacobson (Scientific and Statistical Committee representative, NMFS, Southwest Fisheries Science), Sandra Lowe (NMFS, Alaska Fisheries Science Center, Sand Point Laboratory), Robert Mohn (Canada Department of Fisheries and Oceans, Marine Fish Division), and Steven Murawski (NMFS, Northeast Fisheries Science Center, Woods Hole Laboratory). Jim Hastie (Groundfish Management Team representative) and Peter Leipzig (Groundfish Advisory Panel representative) were official observers.

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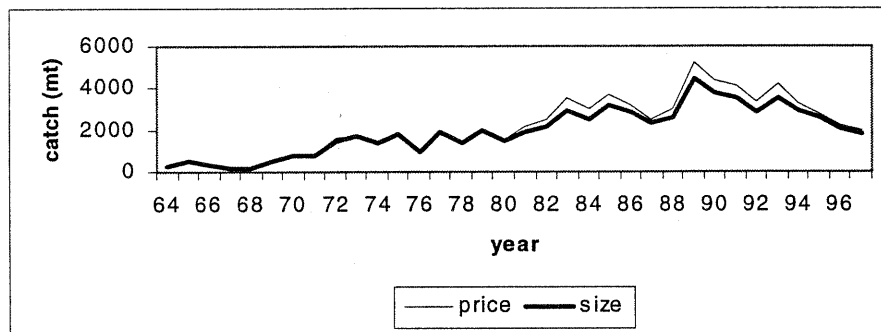
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**Stock:(Species/area)**

The assessment covered shortspine (*Sebastolobus alascanus*) thornyhead along the Pacific Coast from central California at 36°00'N to the Canadian border (48°29'N). The choices of stock area and northern and southern stock boundaries were based on the availability of survey and fishery data, as well as traditional INPFC management areas.

**Catches**

According to our estimates, shortspine thornyhead landings increased gradually to a maximum at about 1989 then decreased substantially as the first ABC and HG levels were adopted. Size-related discard appears to have changed over time, reflecting changing markets for smaller thornyheads. Management limits probably first became restrictive enough to cause discarding in 1995, when the HG levels were greatly reduced and became species-specific. Catch estimates varied depending upon the assumed proportion of discard (Figure below). Catch estimates in the STAT3 baseline model were based on discard estimates derived by fitting a retention curve (proportion-at-size of caught fish which are retained) as a function of market-acceptable minimum size. Catches for the best fitting run of the baseline model are designated “size” below. Catch estimates used by STAT2 were those derived in the 1997 assessment based on price-adjusted observer data (designated as “price” below). Both STAT teams applied estimates of an additional 30% management-induced discard for 1995-1997.



<u>Year</u>	<u>Catch (mt)</u>	
	<u>Price</u>	<u>Size</u>
87	2514	2287
88	3033	2609
89	5201	4471
90	4340	3786
91	4110	3479
92	3383	2846
93	4172	3537
94	3243	2933
95	2775	2589
96	2221	2049
97	1967	1761

## Data

The resolution and availability of fishery data for thornyheads varied among states and over time. In general, fishery data were most complete for California, the state in which the fishery first developed. Length compositions for the landings were limited from Oregon and not available from Washington. Fishery data available since the last assessment included 1997 landings from all states, 1996 length compositions from California, 1997 length compositions from Oregon, as well as logbook data from Washington (1995), Oregon (1996 and 1997), and California (1993-1996).

Four potential indices were available for shortspine thornyhead (see Figure below). In 1997, a slope survey provided the first coverage of the depth and latitude range of the species in the assessed area in a single year. Brodziak (in preparation) revised the logbook index used in the 1997 assessment and provided a new index spanning 1989-1997. The triennial survey is conducted only every third year and was therefore not updated in 1997.

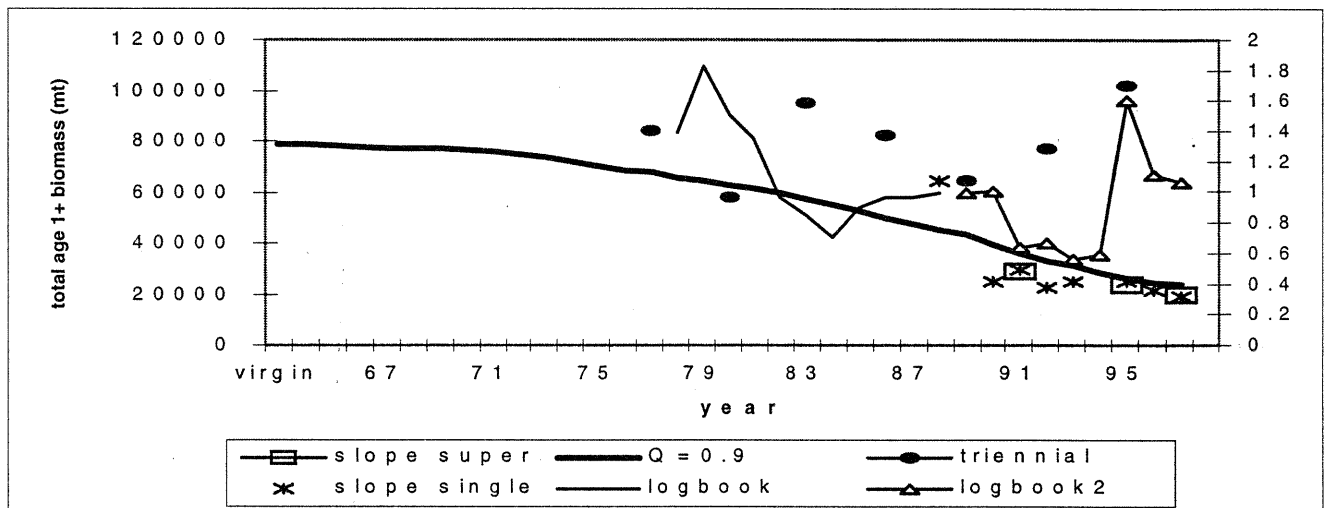


Figure above shows the indices described in the STAT3 document. The single year slope survey and logbook indices were not used in the STAT3 models. The indices are presented for the trends only - the absolute values of each point are not relevant. The line represents the estimates of total biomass from the STAT3 selected model at the slope survey catchability (q value) which best fit the data.

The two STAT teams treated the slope survey differently. The two treatments of the slope trawl survey data resulted in generally similar trends, primarily because each STAT effectively 'down-weighted' the contribution of the 1988 survey.

STAT3 combined data from individual surveys conducted in 1988, 1990-93, and 1995-97, which resulted in a reduced time series of three data points (referred to as 'super years' '1991,' '1995,' and '1997'). The index differed from the 'super years' used in the 1997 assessment in that a partial expanded CPUE method was employed to include the Monterey INPFC area. The resulting index was deemed more 'spatially' representative than either the

'super years' or 'expanded CPUE' indices compared in the last assessment. Spatial coverage was important for shortspine thornyhead because relative biomass and length compositions at depth changed from north to south. The new 'super year' index reduced the north-south noise present in the 'expanded CPUE' index (See Figure above).

STAT2 developed an observation error model based on the individual surveys. This approach used each survey as representative of the entire assessment area and allowed for more realistic variances to be calculated around the biomass estimates generated from each survey year. The derived time series was based on nine data points (1988, 1990-93, and 1995-97). This treatment of the slope trawl survey data was generally similar to the 'expanded CPUE' index, which was one of three methods of analyses compared in the 1997 assessment.

### **Assessment Models**

STAT3 updated the 1997 assessment using an F=M approach (preferred by the 1997 STAR panel) and also developed a relatively simple model that incorporated discard estimates (based on the Stock Synthesis model, Methot 1998). The 1998 STAR panel selected a Stock Synthesis model configuration that:

- 1) Fitted fishery selectivity curves in which selection of the largest fish was a function of the average depth of fishing as reported in logbooks.
- 2) Fitted fishery retention curves in which the retention of the smaller fish was a function of a qualitative time series of minimum market-acceptable sizes.
- 3) Specified a single fishery harvesting the stock.
- 4) Utilized only the slope survey and triennial shelf survey as indices of abundance.
- 5) Fitted the growth parameter  $k$  in the von Bertalanffy age-length relationship.
- 6) Allowed recruitment to vary between two stanzas (before 1977 and 1977 and later).

The model was fit to the fishery length composition, the slope survey index and length compositions, the triennial shelf survey index and length compositions, as well as the average depth of fishing and minimum-acceptable sizes as described above.

STAT2 evaluated four approaches: a trend analysis of the indices of abundance; equilibrium yield calculations based on spawning biomass per recruit and sensitivity of recruitment to spawning stock size; a simple model age-structured model fit to the indices of abundance; and a full integrated age-structured model similar to the Stock Synthesis model. The following simplifications were made in the simple age-structured model:

1. The model was deterministic, and all parameters were constant in time, including the length, weight, maturity and vulnerability curves.
2. The stock was assumed to be at unfished equilibrium in 1964 when the catch history begins.

3. Slope survey selectivity was assumed to be a double-normal distribution.
4. The model was fit only to the slope survey index.

### Major sources of uncertainty

The following uncertainties were identified by the STATs:

1. The stock biomass trend as represented by the slope survey index (resulting from lack of coastwide coverage in each year and potential bias due to gear performance).
2. Age-length relationship and natural mortality.
3. Species identification in the length compositions and landings data.
4. Year class strength and stock-recruitment relationship, and
5. Discard estimates.

Some of these uncertainties are confounded which hinders resolution. For instance, increasing numbers of small fish in the landings could be due to better identification of the thornyhead species, increased retention of small fish, or strong year classes entering the fishery. Reasonable assumptions were made based on available information and sensitivity of the results to those assumptions was explored when possible.

Although STAT3 and the review panel selected a baseline model (described above) which fit best at slope survey catchability ( $q$ ) = 0.9, STAT3 sensitivity analyses for a range of assumptions regarding growth, natural mortality, discard, selectivity, and recruitments resulted in best fits over a range of  $q$  values from 0.5 – 0.98. STAT2 selected a simple age-structured model which fit best at  $q=0.5$ . They assumed that natural mortality = 0.06 and the von Bertalanffy growth curve  $k=0.037$ . Recruitment was assumed deterministic with spawner-recruit steepness = 0.889.

In recognition of the above uncertainties, the STAR panel requested that each STAT team compare their selected model results given four possible values for the slope survey catchability coefficient ( $q=0.25$ ,  $q=0.5$ ,  $q=0.75$ ,  $q=1.0$ ). Expected values were the weighted sums of estimates at those  $q$  levels. The weights were to be either: prior probabilities or posterior probabilities. The STAR panel specified that the prior probabilities be 0.10 for  $q= 0.25$  and  $q= 1.0$  and 0.40 for  $q= 0.5$  and  $q= .75$ . The chosen values imply that  $q$  for shortspine thornyhead is probably less than 1.0 and that “very low” values for  $q$  are unlikely. Given the four potential values for  $q$  considered in the weighting, the expected value of  $q$  based on the priors only was 0.63. The posterior values included a consideration of the model fit to the data and were calculated by multiplying the normalized likelihood profile by the prior probabilities. The resulting STAT3 posterior expected value of  $q$  was 0.98, slightly higher than the  $q$  of 0.9, which provided the best fit to the data. The STAT2 posterior expected value was 0.5.

## Reference Points

1998 Exploitation rates (1998 catch/available biomass) corresponding to F35% were:

Slope survey q	STAT3	STAT2
.25	.043	.04
.50	.047	.042
.75	.052	.042
1.0	.055	.042

## Stock Biomass

The selected models estimated various rates of decline of the shortspine thornyhead spawning biomass depending on the assumed q as shown in the figure 1 and table below (1998 spawning biomass/ virgin spawning biomass):

Slope survey q	STAT3	STAT2
.25	.74	.61
.50	.48	.41
.75	.28	.29
1.0	.21	.22

## Recruitment

Fitting individual recruitments based on the data may be uninformative because species identification in the fisheries length compositions may be uncertain, there is a lack of strong year-class signals in the length compositions, and recruitment estimates are confounded with changes in selection and retention of small fish over time. There is some indication, however, that recruitment has not been constant (the trawl logbook CPUE and the shelf survey biomass index (see figure above), and, to a lesser degree, the shelf survey length frequency). The STAR panel recommended that the STAT3 synthesis model be set to internally estimate a step function for recruitment, with the discontinuity taking place around 1977. This recommendation was based on a STAT3 model run with yearly recruitment estimated (annual variation dampened) (Figure 1) and recent literature on recruitment variability in the northeast Pacific Ocean which suggests that decadal scale variation in recruitment is common for many stocks. The resulting STAT3 model indicated increasing recruitments after 1977, but the amount of the increase was dependent upon the value of q selected (Figure 1). The overall fit to the data did not improve; allowing the recruitments to increase provided a better fit the triennial index but degraded the fit to the slope survey index. STAT3 Recruitments in 1998 and in the projected years were assumed to be average. The STAT2 model estimated that recruitments declined as the stock declined over time.

## Exploitation Status

Similarly, the exploitation rates for shortspine thornyhead are dependent on the assumed value of the catchability in the slope survey. The STAT3 model estimated that exploitation rates increased from the beginning of the fishery with a substantial increase between 1988 and 1989 and a decline after 1993 (Table 1, Figure 1). The STAT2 simple age-structured model suggested that the exploitation rate increased more or less steadily from the beginning of the fishery to the

late 1980s, and that it has generally declined since then, with the exception of 1993 when all curves exhibit a peak.

## **Management Performance**

In 1991, landings in the Eureka INPFC area substantially exceeded the Allowable Biological Catch (ABC), but there was no Harvest Guideline (HG) (Table 2). Total catch (landings plus discard) exceeded the HG in 1992 and 1993 for the thornyhead species group. In 1995 and 1996, total catches of shortspine thornyhead (8% discard assumed) exceeded the HG; overfishing of shortspine thornyhead occurred in 1995 (total catch exceeded the F20% yield of 1,757 mt). In 1997, the total catch harvest guideline (30% discard assumed) was set at 50 mt under the overfishing level estimated in the 1994 assessment.

## **Decision Table**

The decision tables for shortspine thornyhead are given in Tables 3-4. The STAR panel asked that the expected values of projected biomass, fishing exploitation rates, etc. be estimated for a range of potential catch levels over 3 and 10 year time spans.

STAT3 expected values for ABC yields at the target harvest rate of F35% averaged over the next three years were 800 mt using the posteriors and 1550 mt using only the prior values (Table 3). Baseline model projections indicated that if a 700 mt ABC is adopted and the true state of nature is based on the expected value derived using posterior weights, then spawning biomass will begin to increase and will reach 25% of the virgin level by 2001. If, however, the fit of the baseline model to the data is not considered and only the prior values are used, then spawning biomass is expected to increase if a 900 mt ABC is adopted, reaching 39% of the virgin level by 2001. Even under the more optimistic assumption, spawning biomass is projected to continue to decline over the next three years unless the catch is reduced to at least 1100 mt. All STAT3 projections were dependent upon the modeled increase in recruitments during the 20-year period from 1977-1997 and may be overly optimistic if the increase was not a real event, but rather a change in fishery selectivity or noise in the indices. STAT2 expected values using only the priors were more conservative than those of STAT3; STAT2 assumed that recruitments were decreasing rather than increasing over time (Table 3 and 4).

The STAT2 table indicates that if the larger catches were taken in 1998-2000 and the more conservative model was correct, the spawning biomass would still be above or close to 35% of the unexploited level (Table 4).

## **Recommendations**

Although uncertainties about the historic fisheries can never be resolved, collection of accurate fisheries data in the future should improve the assessments. Separate landings information on the two species, including fishery length compositions and logbook landing data from each state should continue to be collected. Age composition estimates would be valuable if valid production aging is possible. Analysis of discard information from the ongoing observer program should be done as soon as it is available.



Further work could be done to refine the life history parameters used in the assessment. This could include histological examination of maturity-at-length for shortspine thornyheads, fecundity estimates, and tagging studies to provide further age validation for shortspine thornyhead. Radiochemical age validation of smaller and larger fish could supplement the work of Kline (1996) and potentially result in a more accurate growth curve.

Survey indices of abundance could be improved by extending the latitudinal range of the slope survey and continuing to provide synoptic coverage. Coastwide information in each year of the survey is important, even if this requires fewer tows per area. If the area below Pt. Conception, California cannot be sampled with trawl gear, a hook-and-line survey should be instituted.

### Sources of Additional Information

Other sources of information include:

- Brodziak, J. in prep. Standardized catch rates for the deep-water complex.
- Butler, J.L., C.Kastelle, K.Rubin, D.Kline, H.Heijnis, L.Jacobson, A.Andrews, and W.Waldo Wakefield. 1995. Age determination of shortspine thornyhead *Sebastes alascanus*, using otolith sections and  $^{210}\text{Pb}$ : $^{226}\text{Ra}$  Ratios. NMFS Admin. Rep. LJ-95-12. 22 pp.
- Ianelli, J.N., R.Lauth, and L.D. Jacobson. 1994. Status of the thornyhead (*Sebastes* sp.) resource in 1994. Appendix D. In: Status of the pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council. Portland, Oregon.
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- Jacobson, L. D. 1991. Thornyheads--stock assessment for 1991. Appendix D. In: Status of the pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1992. Pacific Fishery Management Council. Portland, Oregon.
- Jacobson, L.D. and R.D. Vetter. 1995. Bathymetric demography and niche separation of thornyhead rockfish: *Sebastes alascanus* and *Sebastes altivelis*. Can.J. Fish. Aquat.Sci. 53:600-609.
- Jacobson, L.D., J. Brodziak, J. Beyer Rogers, and P.Crone, R. Conser, R. Lauth, and R. Methot. In prep. Empirical fishery selectivity estimates for Dover sole, sablefish, and thornyheads in the deep water Dover fishery.
- Kline, D.E. 1996. Radiochemical age verification for two deep-sea rockfishes. M.S. Thesis, Moss Landing Marine Laboratories, San Jose State University, CA. 124 pp.
- Rogers, J. B., L.D. Jacobson, R. Lauth, J.N. Ianelli, and M. Wilkins. 1997. Status of the thornyhead (*Sebastes* sp.) resource in 1997. Pacific Fishery Management Council. Portland, Oregon.

Table 1. Model results for the last ten years at four values of slope survey catchability (q).

		YEAR										
		87	88	89	90	91	92	93	94	95	96	97
Total age 1+ biomass (mt)												
q	0.25	113234	111742	110060	106649	104067	101942	100586	98677	97498	96789	96737
	0.5	66999	65222	63208	59416	56402	53793	51903	49409	47594	46204	45426
	0.75	52300	50410	48268	44325	41144	38346	36252	33532	31474	29824	28772
	1	45099	43187	41005	37011	33779	30912	28744	25940	23795	22050	20896
Biomass Available to the Fishery (mt)												
q	0.25	67956	70397	77270	87340	77915	83161	80552	83882	87426	83305	83261
	0.5	37483	38351	41452	45439	39512	41050	38915	39259	39811	37079	36418
	0.75	26825	27210	29092	31177	26550	26962	25056	24539	24219	22007	21195
	1	22738	22933	24338	25655	21482	21417	19569	18676	17986	15964	15085
Spawning Biomass index												
q	0.25	26198	25727	25110	24234	23544	22997	22568	22098	21799	21634	21622
	0.5	15570	15080	14435	13521	12775	12154	11629	11043	10608	10291	10110
	0.75	12215	11713	11051	10116	9342	8686	8117	7482	6992	6614	6368
	1	10571	10067	9398	8454	7671	7000	6414	5761	5251	4851	4580
Exploitation Rate (catch/available biomass)												
q	0.25	0.02	0.02	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.02	0.02
	0.5	0.03	0.04	0.07	0.06	0.06	0.05	0.07	0.06	0.05	0.04	0.04
	0.75	0.04	0.05	0.09	0.09	0.08	0.07	0.10	0.09	0.08	0.07	0.06
	1	0.05	0.06	0.11	0.10	0.10	0.09	0.12	0.11	0.11	0.09	0.08
Recruits in 1000's of age 1 fish												
q	0.25	36659	36659	36659	36659	36659	36659	36659	36659	36659	36659	36659
	0.5	19123	19123	19123	19123	19123	19123	19123	19123	19123	19123	19123
	0.75	13490	13490	13490	13490	13490	13490	13490	13490	13490	13490	13490
	1	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080	11080

**Table 2. Management performance for the thornyhead species on the Pacific West Coast. All HGs are expressed in terms of catch to ease comparison. Actual HGs had an assumed 8% discard subtracted in 1994 (thornyheads) and 30% discard subtracted in 1998 . Discard rates assumed for 1994-1997 are 8%. Unspecified thornyhead landings were allocated to species using the proportion in known landings by year and state. Landings (and catch) in 1995-1997 include landings south of Point Conception. According to PacFin, in 1995, 80 mt of unspecified thornyheads, and in 1996, 17 mt shortspine and 64 mt unspecified thornyheads were landed south of Point Conception. The tigerbase data base indicates that in 1995 south of Point Conception, 171 mt of shortspine and 178 mt of unspecified thornyheads were landed.**

Species	Year	Area	ABC (mt)	HG (mt)	Landings (mt)	Catch (mt)
Thornyhead	1991	Columbia	3,200	-	2,957	
	1991	Eureka	1,300	-	2,119	
	1991	Monterey	1,400	-	660	
Shortspine	1992-1994	Columbia, Eureka, Monterey.	1,900	7,000	1992 - 7,184 1993 - 7,365 1994 - 6,172	1992 - 7,184 1993 - 7,365 1994 - 6,709
Longspine	1992-1994	Columbia, Eureka, Monterey	10,100			
Shortspine	1995-1997	north of Point. Conception.	1,000	1,500	1995 - 2,006 1996 - 1,552 1997 - 1,417	1995 - 2,180 1996 - 1,687 1997 - 1,540
Shortspine	1998	north of Point Conception	1,000			
		U.S. Vancouver - Monterey		1546		
		Conception area north of Point Conception		161		

**Table 3a. Model projections and decision table for the next three years (1999-2001).**

Slope survey catchability(q)	0.25	0.5	0.75	1		
virgin age 1+ biomass	143026	97998	83933	76434		
1998 Age 1+ Biomass	97074	45013	28075	20076		
virgin available biomass	74053	47022	36715	32746		
1998 available biomass	83610	36079	20667	14471		
virgin spawn	34014	23480	20228	18502		
1998 spawn	21703	10009	6198	4383		
total log-likelihood	-598	-590	-585	-581		
slope log-likelihood	1.725	5.2	6.926	6.745		
normalized likelihood	0	0	0.02	1		
prior	0.1	0.4	0.4	0.1	expected	expected
posterior	0.00	0.00	0.07	0.93	posterior	prior
F35% yield	3597	1706	1080	790	811	1553
F40% yield	3051	1451	920	674	692	1321

Annual Catch	spawning biomass in 2001					
700	22690	10387	6351	4455	4595	9410
900	22581	10277	6240	4344	4484	9299
1100	22472	10167	6130	4233	4374	9189
1300	22362	10058	6019	4121	4262	9079
1500	22253	9948	5908	4010	4151	8969
1700	22144	9838	5798	3898	4039	8859
ratio of spawning biomass in 2001 to virgin spawning biomass						
700	0.67	0.44	0.31	0.24	0.25	0.39
900	0.66	0.44	0.31	0.23	0.24	0.39
1100	0.66	0.43	0.30	0.23	0.23	0.38
1300	0.66	0.43	0.30	0.22	0.23	0.38
1500	0.65	0.42	0.29	0.22	0.22	0.37
1700	0.65	0.42	0.29	0.21	0.22	0.37
ratio of spawning biomass in 2001 to 1998 spawning biomass						
700	1.05	1.04	1.02	1.02	1.02	1.03
900	1.04	1.03	1.01	0.99	0.99	1.02
1100	1.04	1.02	0.99	0.97	0.97	1.00
1300	1.03	1.00	0.97	0.94	0.94	0.99
1500	1.03	0.99	0.95	0.91	0.92	0.97
1700	1.02	0.98	0.94	0.89	0.89	0.96
average exploitation rate (catch/available biomass) over the three year period						
700	0.01	0.02	0.02	0.04	0.03	0.02
900	0.01	0.02	0.03	0.05	0.04	0.03
1100	0.01	0.02	0.04	0.06	0.06	0.03
1300	0.01	0.03	0.05	0.07	0.07	0.04
1500	0.02	0.03	0.06	0.08	0.08	0.04
1700	0.02	0.04	0.06	0.09	0.09	0.05

**Table 3b. Model projections and decision table for the next ten years (1999-2008).**

Slope survey catchability(q)	0.25	0.5	0.75	1		
virgin total biomass	143026	97998	83933	76434		
1998 total biomass	97074	45013	28075	20076		
virgin available biomass	74053	47022	36715	32746		
1998 available biomass	83610	36079	20667	14471		
virgin spawn	34014	23480	20228	18502		
1998 spawn	21703	10009	6198	4383		
total log-likelihood	-598	-590	-585	-581		
slope log-likelihood	1.725	5.2	6.926	6.745		
normalized likelihood	0	0	0.02	1		
prior	0.1	0.4	0.4	0.1	<b>expected</b>	<b>expected</b>
posterior	0.00	0.00	0.07	0.93	<b>posterior</b>	<b>prior</b>
F35% yield	3597	1706	1080	790	811	1553
F40% yield	3051	1451	920	674	692	1321

Annual Catch	spawning biomass in 2008					
700	26096	12190	7599	5508	5663	11076
900	25637	11717	7108	4998	5154	10594
1100	25179	11244	6617	4487	4645	10111
1300	24721	10771	6126	3976	4135	9629
1500	24262	10297	5634	3465	3626	9145
1700	23804	9824	5142	2953	3115	8662
	ratio of spawning biomass in 2008 to virgin spawning biomass					
700	0.77	0.52	0.38	0.30	0.30	0.46
900	0.75	0.50	0.35	0.27	0.28	0.44
1100	0.74	0.48	0.33	0.24	0.25	0.42
1300	0.73	0.46	0.30	0.21	0.22	0.40
1500	0.71	0.44	0.28	0.19	0.19	0.38
1700	0.70	0.42	0.25	0.16	0.17	0.35
	ratio of spawning biomass in 2008 to 1998 spawning biomass					
700	1.20	1.22	1.23	1.26	1.25	1.22
900	1.18	1.17	1.15	1.14	1.14	1.16
1100	1.16	1.12	1.07	1.02	1.03	1.09
1300	1.14	1.08	0.99	0.91	0.91	1.03
1500	1.12	1.03	0.91	0.79	0.80	0.97
1700	1.10	0.98	0.83	0.67	0.69	0.90
	average exploitation rate (catch/available biomass) over the ten year period					
700	0.01	0.01	0.02	0.03	0.03	0.02
900	0.01	0.02	0.03	0.04	0.04	0.03
1100	0.01	0.02	0.04	0.06	0.05	0.03
1300	0.01	0.03	0.05	0.07	0.07	0.04
1500	0.01	0.03	0.06	0.08	0.08	0.05
1700	0.02	0.04	0.07	0.10	0.10	0.05

Table 4a. STAT2 three year decision table.

Thornyhead simple model					final year	2001	
					Real state of Nature		
q	0.25	0.5	0.75	1			
SB1998	93,998	42,340	25,554	17,464			
deplete	0.61	0.41	0.29	0.22			
- log likelihood	5.63	4.33	7.42	14.58			
SP Virgin	155,169	104,313	88,083	80,392			
VB 1998	91,641	41,415	25,068	17,174			
F35% yield	3,849	1,739	1,053	721			
F40% yield	3,162	1,429	865	592			
prior	0.100	0.400	0.400	0.100			
like*prior	0.03	0.40	0.02	0.00			
posterior	0.06	0.90	0.04	0.00			
					Expected Value		
Annual catch	ing stock biomass				using prior	using posterior	
700	95,388	43,369	26,293	17,966	39,200	45,837	
900	94,790	42,763	25,681	17,348	38,591	45,232	
1100	94,192	42,157	25,069	16,730	37,983	44,626	
1300	93,593	41,552	24,456	16,111	37,374	44,021	
1500	92,995	40,946	23,844	15,493	36,765	43,415	
1700	92,397	40,340	23,232	14,875	36,156	42,810	
					Expected Value		
ral ratio of spawning biomass to virgin biomass					using prior	using posterior	
700	0.61	0.42	0.30	0.22	0.37	0.42	
900	0.61	0.41	0.29	0.22	0.36	0.42	
1100	0.61	0.40	0.28	0.21	0.36	0.41	
1300	0.60	0.40	0.28	0.20	0.35	0.41	
1500	0.60	0.39	0.27	0.19	0.34	0.40	
1700	0.60	0.39	0.26	0.19	0.34	0.39	
					Expected Value		
ratio of final SB to 1998 SB					using prior	using posterior	
700	1.01	1.02	1.03	1.03	1.03	1.02	
900	1.01	1.01	1.00	0.99	1.01	1.01	
1100	1.00	1.00	0.98	0.96	0.99	1.00	
1300	1.00	0.98	0.96	0.92	0.97	0.98	
1500	0.99	0.97	0.93	0.89	0.95	0.97	
1700	0.98	0.95	0.91	0.85	0.93	0.95	
					Expected Value		
Catch/average vulnerable biomass					using prior	using posterior	
700	0.01	0.02	0.03	0.04	0.02	0.02	
900	0.01	0.02	0.04	0.05	0.03	0.02	
1100	0.01	0.03	0.04	0.07	0.04	0.03	
1300	0.01	0.03	0.05	0.08	0.04	0.03	
1500	0.02	0.04	0.06	0.10	0.05	0.04	
1700	0.02	0.04	0.07	0.11	0.06	0.04	
					Expected Value		
ratio of final SB to Sbm <sub>sy</sub>					using prior	using posterior	
700	1.92	1.30	0.93	0.70	1.15	1.32	
900	1.91	1.28	0.91	0.67	1.14	1.30	
1100	1.90	1.26	0.89	0.65	1.12	1.29	
1300	1.88	1.24	0.87	0.63	1.10	1.27	
1500	1.87	1.23	0.85	0.60	1.08	1.25	
1700	1.86	1.21	0.82	0.58	1.06	1.23	

Table 4b. STAT2 ten year decision table.

Thornyhead simple model					final year	2008	
					Real state of Nature		
q	0.25	0.5	0.75	1			
SB1998	93,998	42,340	25,554	17,464			
deplete	0.61	0.41	0.29	0.22			
- log likelihood	5.63	4.33	7.42	14.58			
SP Virgin	155,169	104,313	88,083	80,392			
VB 1998	91,641	41,415	25,068	17,174			
F35% yield	3,849	1,739	1,053	721			
F40% yield	3,162	1,429	865	592			
prior	0.100	0.400	0.400	0.100			
like*prior	0.03	0.40	0.02	0.00			
posterior	0.06	0.90	0.04	0.00			
					Expected Value		
Annual catfing stock biomass					using prior	using posterior	
700	99,916	47,034	29,203	20,205	42,507	49,524	
900	97,934	44,965	27,047	17,962	40,394	47,457	
1100	95,952	42,894	24,886	15,709	38,278	45,387	
1300	93,969	40,820	22,720	13,444	36,157	43,315	
1500	91,985	38,743	20,547	11,166	34,031	41,240	
1700	90,000	36,664	18,368	8,873	31,900	39,163	
					Expected Value		
ratio of spawning biomass to virgin biomass					using prior	using posterior	
700	0.64	0.45	0.33	0.25	0.40	0.46	
900	0.63	0.43	0.31	0.22	0.38	0.44	
1100	0.62	0.41	0.28	0.20	0.36	0.42	
1300	0.61	0.39	0.26	0.17	0.34	0.40	
1500	0.59	0.37	0.23	0.14	0.32	0.38	
1700	0.58	0.35	0.21	0.11	0.29	0.36	
					Expected Value		
ratio of final SB to 1998 SB					using prior	using posterior	
700	1.06	1.11	1.14	1.16	1.12	1.11	
900	1.04	1.06	1.06	1.03	1.06	1.06	
1100	1.02	1.01	0.97	0.90	0.99	1.01	
1300	1.00	0.96	0.89	0.77	0.92	0.96	
1500	0.98	0.92	0.80	0.64	0.85	0.91	
1700	0.96	0.87	0.72	0.51	0.78	0.87	
					Expected Value		
Catch/average vulnerable biomass					using prior	using posterior	
700	0.01	0.02	0.03	0.04	0.02	0.02	
900	0.01	0.02	0.03	0.05	0.03	0.02	
1100	0.01	0.03	0.04	0.07	0.04	0.03	
1300	0.01	0.03	0.06	0.09	0.05	0.03	
1500	0.02	0.04	0.07	0.11	0.06	0.04	
1700	0.02	0.04	0.08	0.14	0.07	0.04	
					Expected Value		
ratio of final SB to Sbm <sub>sy</sub>					using prior	using posterior	
700	2.01	1.41	1.04	0.79	1.26	1.43	
900	1.97	1.35	0.96	0.70	1.19	1.37	
1100	1.93	1.29	0.88	0.61	1.12	1.31	
1300	1.89	1.22	0.81	0.52	1.05	1.25	
1500	1.85	1.16	0.73	0.43	0.98	1.19	
1700	1.81	1.10	0.65	0.34	0.92	1.12	

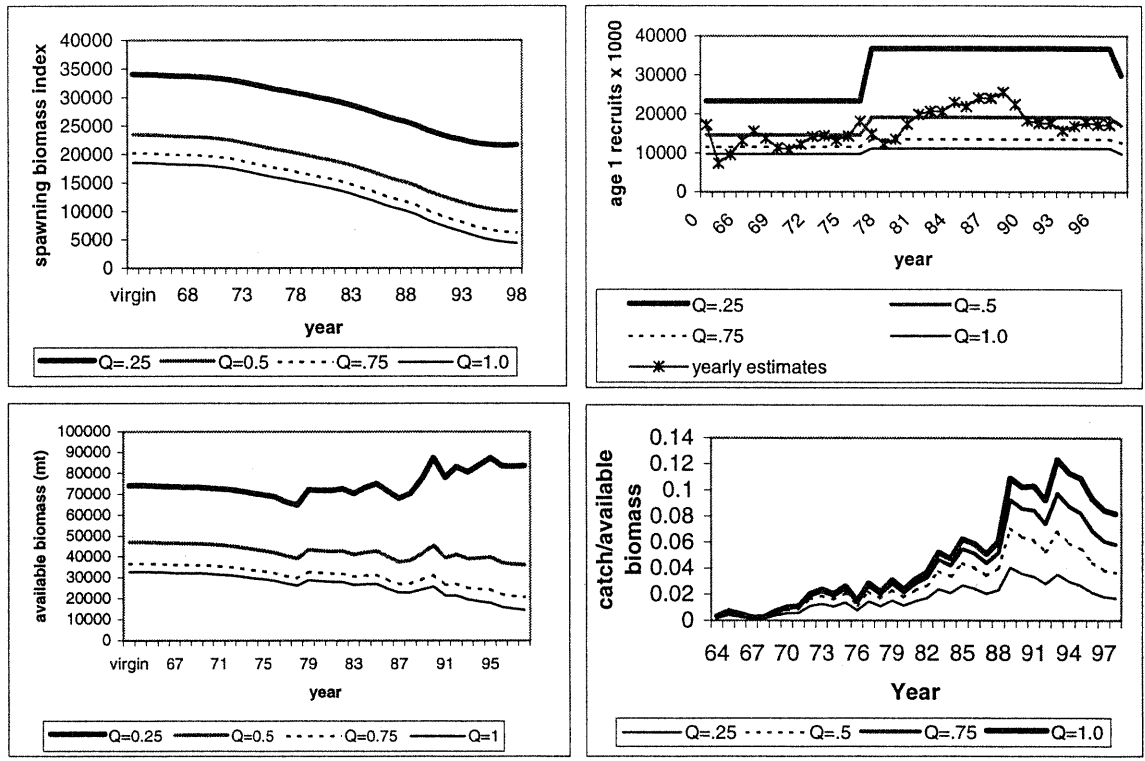


Figure 1. Comparison of the NMFS model estimates at the four selected values for  $q$ . The yearly estimated recruitments are from a differently configured model.