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

Stock Assessment Teams (STATs) Summary Report

July 1998

Submitted to

Stock Assessment Review (STAR)
Oregon State University
Hatfield Marine Science Center
Newport, OR
6-10 July 1998

PREFACE

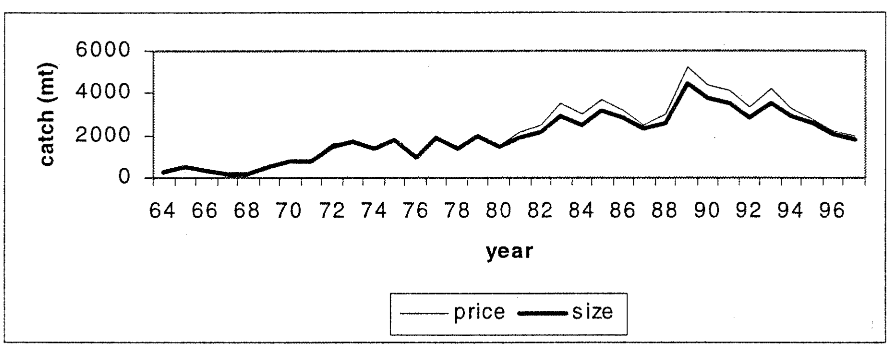
This summary report has been prepared jointly by two stock assessment teams (STAT) that evaluated the status of the shorspine thornyhead population off the U.S. Pacific coast in 1998. One STAT team (STAT 3) consisted of researchers from the Fishery Resource Analysis and Monitoring Division (FRAMD) of the Northwest Fisheries Science Center (NWFSC), 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 LaboratoryNMFS, Alaska Fisheries Science Center, Sand Point Laboratory), Lawrence Jacobson (Scientific and Statistical Committee representative, NMFS, Southwest Fisheries Science), Robert Hannah (Oregon Department of Fish and Wildlife, Marine Program, Hatfield Marine Science Center), Steven Murawski (NMFS, Northeast Fisheries Science Center, Woods Hole Laboratory), Sandra Lowe (NMFS, Alaska Fisheries Science Center, Sand Point Laboratory), and Robert Mohn (Canada Department of Fisheries and Oceans, Marine Fish Division). Jim Hastie (Groundfish Management Team representative) and Peter Leipzig (Groundfish Advisery Panel representative) were official observers.

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^{0}29'N). The choices of stock area and northern and southern stock boundaries are based on the availability of survey and fishery data, as well as traditional INPFC management areas, and are the same as in the 1997 assessment.

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 decreased over time, as markets developed 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 used by STAT3 were based on discard estimates derived by fitting a retention curve (proportion of fish caught which are retained at size) as a function of minimum market-acceptable sizes. Catch was then iteratively fit until the estimated catch values matched the observed within 2%. Catches varied slightly, with catches for the best fitting model designated "size" below. Catch estimates used by STAT2 were those used in the 1997 assessment based on price-adjusted observer data (designated as "price"). Both STAT teams applied estimates of an additional 30% management-induced discard for 1995-1997.



YEAR	Catch (mt) price	size
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 varies among states and over time. In general, fishery data are most complete for California, the state in which the fishery first developed. Length compositions for the landings are limited from Oregon and not available from Washington. New fishery data available since the 1997 assessment includes 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 fishery-independent indices are available for shortspine thornyhead (see Figure below). For the first time in 1997, a slope survey has covered 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.

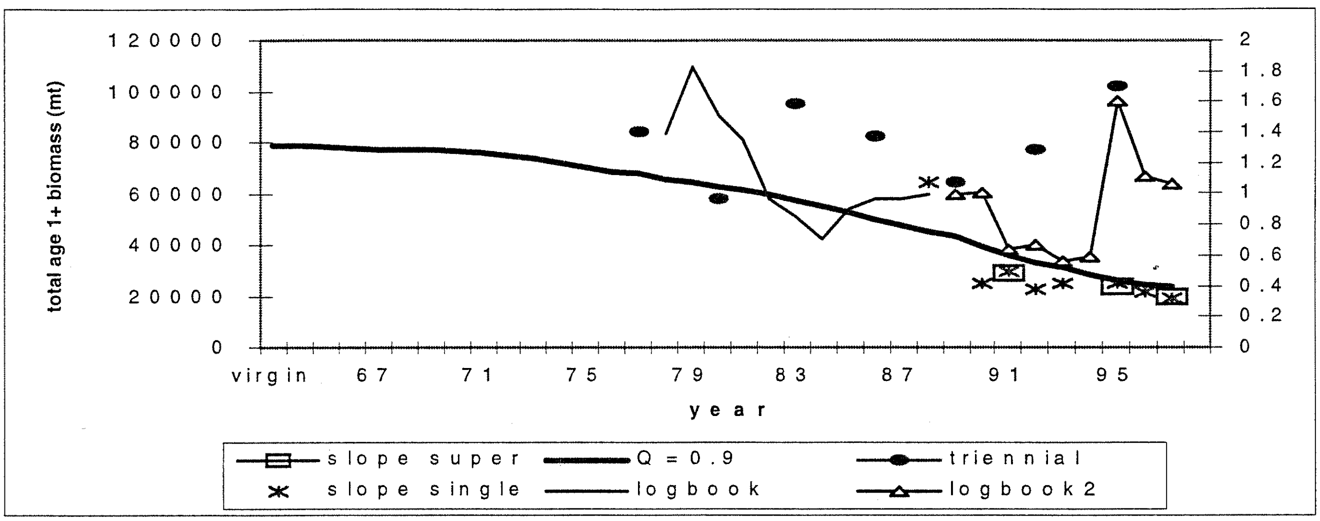


Figure above shows the indices described in the STAT3 document. The single year slope survey and logbook indices were not used in the STAT3 models. The indices are presented for the trends only the absolute values of each point are not relevant. The line represents the estimates of total biomass from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

The two STATs 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 '). In this approach, surveys were combined across particular years to develop a more 'spatially' representative index than possible using the 'single years' or 'expanded CPUE index'. This was important for shortspine thornyhead because relative biomass and length compositions at depth changed from north to south. The super year index both reduced the north-south differential, which introduced noise into the single year approach, and did not require the assumption that the 1988 central Columbia survey was representative of the entire stock biomass (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 single year approach, which was one of three methods of analyses compared in the 1997 assessment conducted by NMFS.

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 the processor minimum 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 Bertanlaffy age-length relationship within the model.

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 triennal 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 have been identified by the STATs:

1. Lack of reliable index of stock size due to poor spatial coverage and other sources of bias.

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 of the uncertainty. 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 are made based on available information and sensitivity of the results to those assumptions is explored when possible.

The STAR panel requested that each STAT team compare four values of slope survey catchability coefficients (q=.25; q=.5; q=.75, q=1.0) for a given model. For STAT3, they selected a model which allowed the von-Bertalanffy growth parameter (k) to be fit within the model (given a fixed size-at-age 8 and age 63), fixed natural mortality (M) at 0.06, and fit recruitment in two stanzas (before 1977 and 1977 and later). This model had 18 paramaters and fit the data best (highest log-likelihood) at a q between .75 and 1.0 (q= .9). It should be recognized that the estimated status of the stock and projections may vary based on the model selected as well as the value of q. STAT3 used a simple age-structured model with M= 0.06 and k=0.037. Recruitment was assumed deterministic with spawner-recruit steepness =0.72.

Reference Points

1998 Exploitation rates (catch/total biomass) corresponding to F35% in the STAT3 model were:

Slope survey q	STAT3 1998 catch/available biomass	STAT2 1998 catch/available biomass
.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 table below and figure 1:

Slope survey q	STAT3 1998/ virgin spawning biomass	STAT2 1998/virgin spawning biomass
.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). 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 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. The STAT3 model indicated increasing recruitments after 1977, but the amount of the increase varied with the value of q selected (Table 1, Figure 1). Recruitments in 1998 and in the projections were assumed to be average based on a STAR panel recommendation.

Exploitation Status

Similarly, the exploitation rates for shortspine 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 ABC, but there was no 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).

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 a 3 and 10 year time span. The expected value was to be a weighted sum at q levels equal to 0.25, 0.5, 0.75, or 1.0. The weights were to be either: prior probabilities or posterior probabilities calculated by multiplying the normalized likelihood profile (reflecting the model fit to the data) by the prior 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.

STAT3 expected values using the posteriors indicate that over a range of catch levels from 700 mt to 1700 mt the spawning biomass will be at most 30% of the unexploited level, and this would be after holding catches at 700 mt for 10 years (Table 3). On the other hand, using only the prior values, the spawning biomass was estimated to fall to 35% of the virgin level only after holding catches at 1700 mt for 10 years (Table 3). It must be considered, however, that the projections are dependent upon the modeled increase in recruitments and may be optimistic of the increase is not a real event, but rather a change in fishery selectivity or noise in the indices. This is especially true for the 10 year projections. At the end of the three year timespan, using only the priors resulted in spawning biomass estimates at 37-39% of the virgin level. Use of the posterior values resulted in estimates of spawning biomass in 2001 which were 22-25 % of the virgin level.

The Ocean Trust STAT team 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 deemed 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 and tagging studies to provide age validation for shortspine thornyhead. Radiochemical age validation of larger fish could supplement the validation conducted by Kline (1996) and allow the fitting of 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}Pb:^{226} Ra Ratios. NMFS Admin. Rep. LJ-95-12. 22 pp.

Ianelli, J.N., R.Lauth, and L.D. Jacobson. 1994. Status of the thornyhead (*Sebastelobus 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.

Jacobson, L. D. 1990. Thornyheads--stock assessment for 1990. Appendix D. *In*: Status of the pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991. Pacific Fishery Management Council. Portland, Oregon.

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: *Sebastolobus alascanus* and *Sebastolobus 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 (Sebastolobus sp.) resource in 1997. Pacific Fishery Management Council. Portland, Oregon.

Table 1. NMFS STAT team model results - the results for Q=1 had the size (a) catches, while the other runs fit to size (b) catches.

	YEAR										
	87	88	89	90	91	92	93	94	95	96	97
Total age 1+ biomass (mt)											
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)											
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											
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)											
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											
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). 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.

<table>
<tr><th>Species</th><th>Year</th><th>Area</th><th>ABC (mt)</th><th>HG (mt)</th><th>Landings (mt)</th><th>Catch (mt)</th></tr>
<tr><td>Thornyhead</td><td>1991</td><td>Columbia</td><td>3,200</td><td>-</td><td>2,957</td><td></td></tr>
<tr><td></td><td>1991</td><td>Eureka</td><td>1,300</td><td>-</td><td>2,119</td><td></td></tr>
<tr><td></td><td>1991</td><td>Monterey</td><td>1,400</td><td>-</td><td>660</td><td></td></tr>
<tr><td>Shortspine</td><td>1992-1994</td><td>Columbia, Eureka,Monterey.</td><td>1,900</td><td rowspan="2">7,000</td><td rowspan="2">1992 - 7,184
1993 - 7,365
1994 - 6,172</td><td rowspan="2">1992 - 7,184
1993 - 7,365
1994 - 6,709</td></tr>
<tr><td>Longspine</td><td>1992-1994</td><td>Columbia, Eureka,Monterey</td><td>10,100</td></tr>
<tr><td>Shortspine</td><td>1995-1997</td><td>north of Point. Conception.</td><td>1,000</td><td>1,500</td><td>1995 - 2,006
1996 - 1,552
1997 - 1,417</td><td>1995 - 2,180
1996 - 1,687
1997 - 1,540</td></tr>
<tr><td>Shortspine</td><td>1998</td><td>north of Point Conception</td><td>1,000</td><td>1,300</td><td></td><td></td></tr>
</table>

Table 3a. STAT3 model projections and decision table for the next three years (1999-2001).

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
posterior	0.00	0.00	0.07	0.93
F35% yield	3597	1706	1080	790
F40% yield	3051	1451	920	674

Annual Catch					expected posterior	expected prior
	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. NMFS STAT team model projections and decision table for the next ten years (1999-2008).

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
posterior	0.00	0.00	0.07	0.93
F35% yield	3597	1706	1080	790
F40% yield	3051	1451	920	674

Annual Catch					expected posterior	expected prior
	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**	**2008**	
row count			**Real state of Nature**				
2	q	0.25	0.5	0.75	1		
	SB1998	94,002	42,342	25,555	17,465		
	deplete	0.61	0.41	0.29	0.22		
	- log likelih	5.64	4.33	7.41	14.57		
	SP Virgiin	155,159	104,303	88,072	80,381		
	VB 1998	91,644	41,418	25,070	17,175		
0.042	F35% yield	3,849	1,740	1,053	721		
0.0345	F40% yield	3,162	1,429	865	593		
	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 catc	Spawning stock biomass				using prior	using posterior
700	95,399	43,378	26,302	17,974	39,209	45,834
900	94,800	42,773	25,690	17,356	38,601	45,228
1100	94,202	42,167	25,077	16,737	37,992	44,623
1300	93,604	41,561	24,465	16,119	37,383	44,017
1500	93,006	40,956	23,853	15,501	36,774	43,412
1700	92,407	40,350	23,241	14,883	36,165	42,806

					Expected Value	
	inal ratio of spawning biomass to virgin biomas				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	1.01	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 Sbmsy				using prior	using posterior
700	1.92	1.30	0.93	0.70	1.16	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	1.89	1.25	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. Ten year decision table - Ocean trust STAT team

	Thornyhead simple model				**final year**	**2008**	
row count			**Real state of Nature**				
2	q	0.25	0.5	0.75	1		
	SB1998	94,002	42,342	25,555	17,465		
	deplete	0.61	0.41	0.29	0.22		
	- log likelih	5.64	4.33	7.41	14.57		
	SP Virgiin	155,159	104,303	88,072	80,381		
	VB 1998	91,644	41,418	25,070	17,175		
0.042	F35% yield	3,849	1,740	1,053	721		
0.0345	F40% yield	3,162	1,429	865	593		
	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 catc		Spawning stock biomass			using prior	using posterior
	700	99,955	47,077	29,247	20,250	42,550	49,553
	900	97,973	45,007	27,091	18,006	40,437	47,486
	1100	95,991	42,935	24,929	15,752	38,320	45,416
	1300	94,008	40,861	22,762	13,487	36,199	43,343
	1500	92,024	38,784	20,589	11,208	34,072	41,268
	1700	90,039	36,705	18,409	8,913	31,941	39,190

					Expected Value	
	inal ratio of spawning biomass to virgin biomas				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	0.98	0.90	0.99	1.01
1300	1.00	0.97	0.89	0.77	0.92	0.96
1500	0.98	0.92	0.81	0.64	0.85	0.92
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 Sbmsy				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	0.44	0.99	1.19
1700	1.81	1.10	0.65	0.35	0.92	1.12

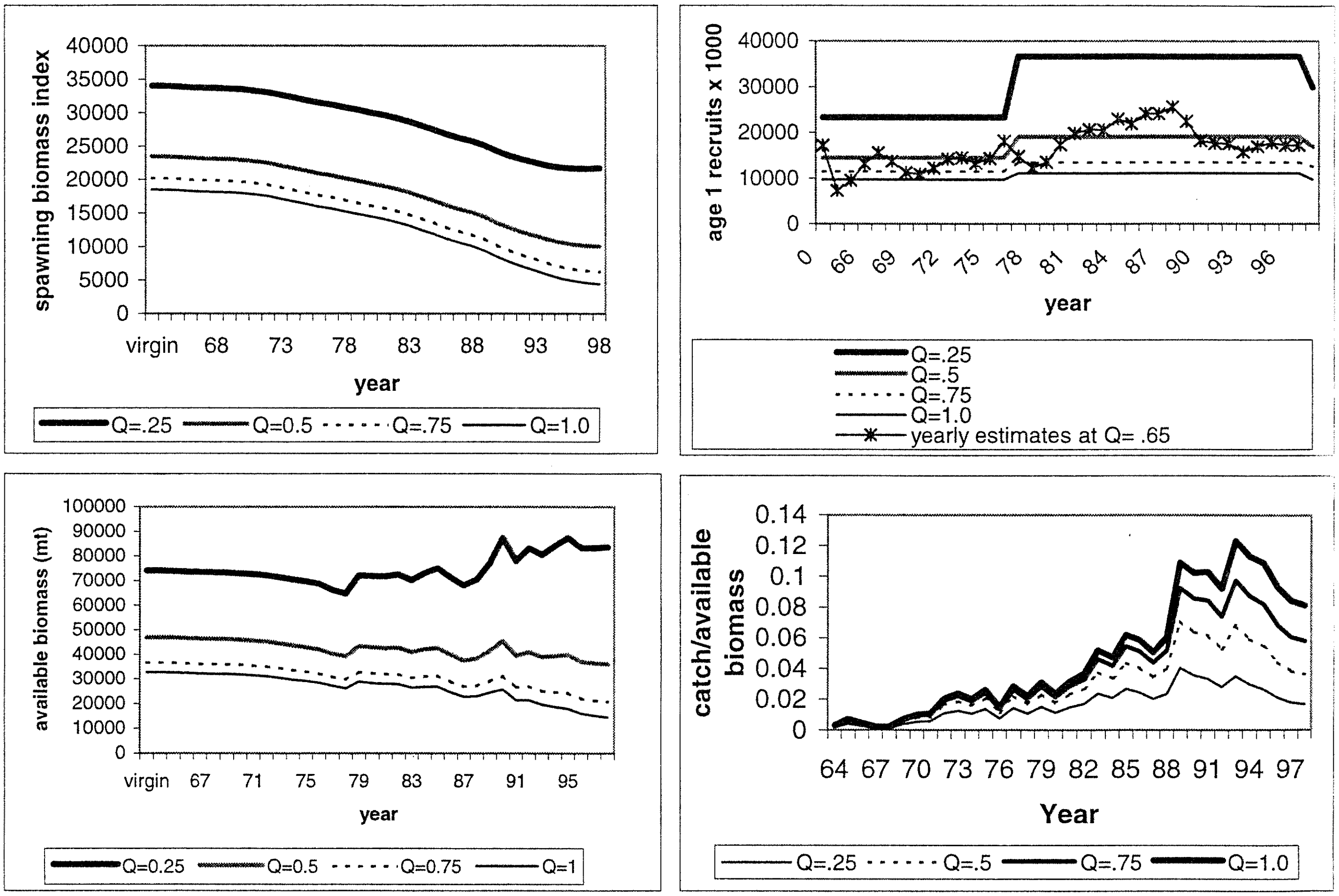


Figure 1. Comparison of the NMFS model estimates at the four selected values for Q. The yearly estimated recruitments are from a sensitvitiy run done using a different model with Q= .65.