Shortspine thornyhead (*Sebastolobus alascanus*) abundance and habitat associations in the Gulf of Alaska

Page Else
Lewis Haldorson
School of Fisheries and Ocean Sciences
University of Alaska
11120 Glacier Highway
Juneau, Alaska 99801
E-mail address (for L. Haldorson, contact author): lew.haldorson@uaf.edu

Kenneth Krieger
Auke Bay Laboratory
National Marine Fisheries Service
Juneau, Alaska 99802

Abstract–Shortspine thornyhead (*Sebastolobus alascanus*) abundance was estimated from 107 video transects at 27 stations recorded from a research submersible in 1991 off southeast Alaska at depths ranging from 165 to 355 m. Numbers of invertebrates in seven major taxa were estimated, as was substrate type. Thornyhead abundance ranged from 0 to 7.5/100 m^2, with a mean of 1.22/100 m^2, and was positively correlated with depth and amount of hard substrate. Invertebrate abundances were not significantly correlated with numbers of thornyheads. Shortspine thornyhead abundance estimates from this study were several times higher than estimates produced by bottom trawl surveys off southeast Alaska in 1990 and 1993, the two years of survey that encompassed the submersible transects; however, the trend of increasing abundance with depth was similar in the trawl surveys and in the submersible transects, suggesting that trawl surveys systematically underestimate abundance of shortspine thornyheads.

Manuscript accepted 24 August 2001.
Fish. Bull. 100:193–199 (2002).

Fish distributions are affected by physical conditions such as depth, temperature and substrate type and by biotic variables such as prey distribution, predator presence, and habitat features (e.g. kelp forests). Patterns of habitat use are important factors in resource assessments, and stratification based on habitat characteristics are common features of survey design. For example, trawl surveys in the Gulf of Alaska are stratified by depth and general bottom type (flats, gullies, shelf break, slope) (Stark and Clausen, 1995). Assessment of fish populations based on traditional fishing gear, such as trawls or longlines, provide relatively economical surveys with broad geographic coverage; however, they provide limited detailed information on species associations or habitat preferences (Matlock et al., 1991).

Shortspine thornyhead (*Sebastolobus alascanus*) is a member of the family Scorpaenidae, which includes the rockfishes (*Sebastes*—over 60 species in the northeast Pacific) and three species of thornyheads (*Sebastolobus*). Shortspine thornyhead range from Baja California, Mexico, to the Bering Sea and are found at depths to 1500 m (Moser, 1974). Off southeast Alaska, most fish sampled from 200–310 m depths were between 15 and 30 years old and had lengths of 25–35 cm (Miller, 1985). The maximum age observed by Miller (1985) was 62 years, and age at 50% maturity was 12 years for both sexes. These life-history features are similar to those of rockfishes, and such long-lived fishes are difficult to manage because they are easily overexploited and recover slowly from overfishing (Adams, 1980). Shortspine thornyhead have been commercially valuable in the Gulf of Alaska, where catch (including discards) ranged from 1298 to 2020 metric tons from 1991 to1996 (Ianelli and Ito[1]). Bycatch of thornyhead has the potential of forcing closure of other high-value fisheries (Ianelli and Ito[2]). Estimates of their abundance and size distribution are currently based on bottom trawl and longline surveys (Ianelli and Ito[2]); however, direct observations from submersibles can provide an alternate method for assessing abundance (Krieger, 1993). Assessments of thornyheads and rockfishes often result in population estimates with high variances; resulting in considerable uncertainty for assigning

---

[1] Ianelli, J. N., and D. H. Ito. 1998. Status of Gulf of Alaska thornyheads (*Sebastolobus* sp.) in 1998. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 371–402. [Available from North Pacific Fishery Management Council, 605 West 4th St., Anchorage, Alaska 99501.]

[2] Ianelli, J. N., and D. H. Ito. 1994. Thornyheads. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 1995. [Available from North Pacific Fishery Management Council, 605 4th St., Anchorage, Alaska 99501.]

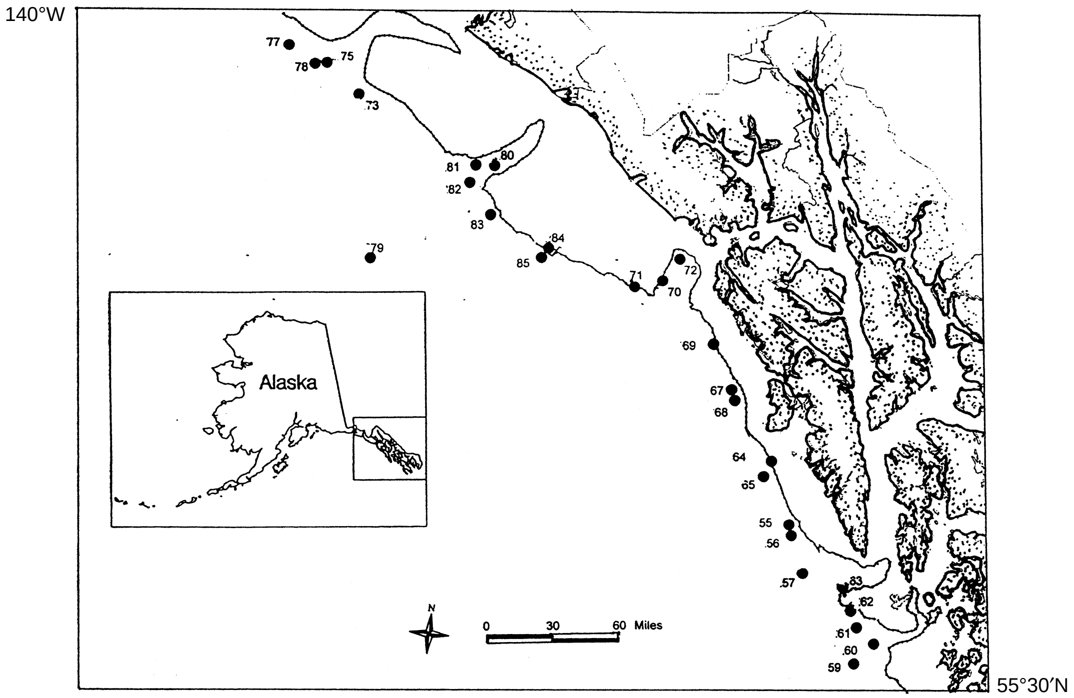

Figure 1

Locations of stations (•) where transects were run off southeast Alaska. The offshore line marks the 200-m isobath near the edge of the continental shelf.

harvest levels. Submersible observations with line-transect methods have been used in attempts to improve estimates of rockfish abundance and to understand rockfish habitat associations (Richards, 1986; Pearcy et al., 1989; Krieger, 1992; Stein et al., 1992; O'Connell and Carlile, 1993).

Our goal was to assess abundance and habitat use by shortspine thornyhead in the eastern Gulf of Alaska, based on data from existing video records taken during submersible transects. We estimated abundance of fish and invertebrates and quantified substrate type. We explored the relationships between thornyhead abundance and both physical and biotic environmental variables and compared abundance estimates from submersible transects with those from trawl surveys in the same area.

Materials and methods

Sources of data were video tapes of 107 bottom transects recorded at 27 stations during submarine dives in June 1991 on the outside coast of northern southeast Alaska from Cape Ommaney to Yakatat (Fig.1). All transects were conducted with the Delta submersible. This battery-powered two-man submersible is 4.7 m long, dives to 365 m, and travels 2–6 km/h. It is equipped with ten 150 W external halogen lights, internal and external video cameras, a 35-mm external camera, magnetic compass, directional gyro compass, and underwater telephone and transponder that allowed the submersible to be tracked from the surface support vessel. The surface vessel recorded LORAN fixes at the beginning and end of each transect. A pilot and observer formed the crew of the submersible: the pilot attempted to maintain the submersible within 0.5 m above the bottom at 3–4 km/h while the observer made observations through a starboard porthole.

Video recordings were made from a downward projecting external Hi-8 color video camera tilted obliquely forward on the starboard side and included a digital readout of depth, temperature, and height above bottom. Data were collected either in strip transects by using the entire length of each transect, or in quadrats by freezing individual frames from the video. The width of the strip transect was calculated from the height above bottom and field of view of the camera. The field of view formed a trapezoid on the seafloor beginning almost directly beneath the camera and projecting forward; its maximum width (W) was estimated by calibrations performed on a subsequent cruise that had the same camera and camera configuration (Zhou and Shirley, 1997). When the submarine was resting on the bottom, the camera height (H) was 0.93 m and the width of the field of view (i.e. longest side of trapezoidal field) was 1.78 m. Transect width (W) was estimated by

$$W = (1.78/0.93)\,H, \qquad \text{[(Zhou and Shirley, 1997)].}$$

The height above bottom (H) was recorded at one minute intervals during each transect and mean height was used to estimate width (W) of that transect. All dives were made during daylight between 0600 and 1900 h. At each station a series (usually 4) of parallel transects was run, and spacing between transects was about 200 m. Transect lengths were calculated from the position fixes taken from the surface vessel.

The entire length of each transect was viewed and all thornyheads in the field of view were counted. Invertebrates were also counted in seven categories: starfish, seapens, sea urchins, anemones, corals, sponges, and sea cucumbers. Depth and temperature were recorded once every minute during each transect and averaged over the complete transect. Substrate type was estimated by scoring video quadrats at one-minute intervals during the transect. A mylar grid of about twenty-five 50-mm squares was placed on the screen over the freeze-framed image, and substrate within the squares was scored in three categories of soft (mud, sand, and gravel), cobble, and rock-boulder, the latter two of which were then combined into a single category, hard-bottom. The proportions of each category (soft and hard) for each transect were estimated as the mean from the one-minute quadrats. Abundance (number/100 m^2) of shortspine thornyheads and invertebrate categories was estimated for each transect by dividing the number counted by the area estimate ($W \times$ *Transect length* $\times$ 100).

To evaluate variables that may have affected thornyhead densities, we assembled a correlation matrix and a partial correlation matrix of three physical variables (depth, substrate, temperature) and transformed (log(x+1)) biotic variables (shortspine thornyheads and seven invertebrate categories). Based on those matrices, we selected depth and substrate for further analyses.

We used nonparametric procedures (Kruskal-Wallis and Mann-Whitney) to determine if thornyhead densities varied among sampling stations and to evaluate the effects of substrate and depth. Substrate and depth were coded into nominal categories for use as independent variables in those analyses. We used Scheffe's (Zar, 1984) *post-hoc* test to evaluate between-category differences when Kruskal-Wallis results were significant.

An ANOVA factorial model was used to explore the joint effects depth and substrate on shortspine thornyhead abundance (transformed by log(x+1)). In addition, we used stepwise linear regression with thornyhead abundance as the dependent variable to evaluate the relative importance of all possible independent variables.

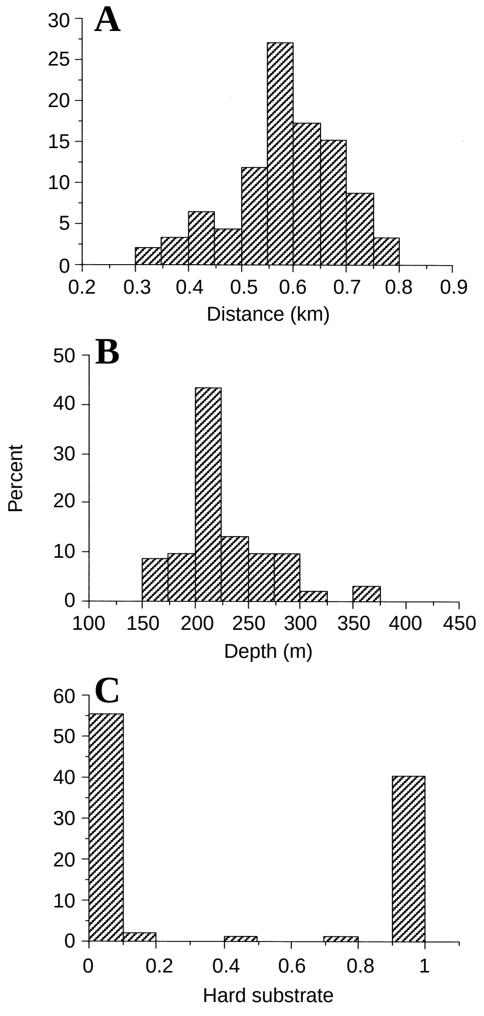

Figure 2

Distribution of transects by (**A**) distance (km), (**B**) average depth, and (**C**) the proportion of bottom categorized as hard.

Results

Transect lengths ranged from 320 to 800 m and had a mean of 580 m (Fig. 2A). The mean transect depth ranged from 165 to 355 meters, and the highest numbers of transects were at 200–250 m (Fig. 2B). Most transects (85%) had substrate that was completely soft (silt, sand, and gravel) or hard (cobble and rock-boulder) (Fig. 2C). Abundance of shortspine thornyheads per transect ranged from 0 to 13.6/100 m^2; and the mean abundance at the 27 stations ranged from 0 to 7.5/100 m^2 (Table 1). Difference in abundance among stations was very highly significant (P <0.0001, Kruskal-Wallis).

A correlation matrix of all variables indicated that depth, substrate, and sponge abundance were related to variation in thornyhead abundance; however, the partial correlation matrix indicated that among those three variables, substrate type and depth were most strongly related to shortspine thornyhead abundance (Table 2). The high correlation of sponge and thornyhead abundances was apparently spurious because of the relationship between sponge abundance and substrate type (Table 2).

For further analyses of the relationship between thornyhead abundance, depth, and substrate, we coded depth into three nominal categories, <200 m, 200–300 m, and >300m, chosen to correspond to the depth intervals used in National Marine Fisheries Service (NMFS) triennial trawl surveys (Stark and Clausen, 1995). We also coded substrate into two nominal categories, soft bottom (>90% sand, mud, and gravel) and hard bottom (>40% cobble and rock-boulder). Abundance increased with depth (Table 3), and differences that were highly significant occurred among three depth categories (P<0.001, Kruskal-Wallis). Significant differences exist-

Table 1

Mean numbers, with standard deviation, of shortspine thornyheads (*Sebastolobus alascanus*) per 100 m^2 at transect stations, with means of depth, bottom temperature, and proportion of the bottom categorized as hard substrate.

Station	*n*	No./100 m^2	SD	Mean depth (m)	Temp.	Proportion of bottom as hard substrate	Lat.	Long.
55	4	0.4	0.002	210.1	4.00	0.27	56°37′11″	135°57′50″
56	4	0.5	0.002	209.0	4.33	0.00	56°32′19″	135°54′39″
57	4	2.7	0.007	319.9	3.83	1.00	56°06′06″	135°39′72″
59	4	0.2	0.002	280.1	4.51	0.00	55°46′03″	134°77′97″
60	4	0.0	0	227.9	4.83	0.00	55°61′28″	134°55′86″
61	4	0.0	0	202.9	4.90	0.00	55°71′53″	134°76′89″
62	4	0.0	0	165.5	5.42	1.00	55°86′00″	134°84′00″
63	4	0.9	0.004	355.9	4.04	0.04	55°98′36″	134°93′97″
64	4	3.8	0.011	220.3	4.86	0.78	56°80′97″	135°80′97″
65	4	2.5	0.007	237.9	4.73	0.54	56°69′22″	135°87′69″
67	3	2.6	0.012	247.9	3.95	0.11	57°24′72″	136°29′31″
68	4	3.6	0.02	246.2	4.50	0.75	57°21′67″	136°25′03″
69	4	7.5	0.045	242.7	4.53	0.72	57°55′33″	136°55′22″
70	4	0.7	0.01	217.7	4.84	0.20	57°95′94″	137°21′61″
71	4	0.1	0.002	177.4	4.95	1.00	58°02′00″	137°10′00″
72	4	0.1	0.001	289.9	4.02	0.00	58°10′92″	136°98′39″
73	4	1.2	0.007	210.8	4.79	1.00	59°03′75″	141°13′75″
75	4	0.1	0.001	208.4	4.25	0.86	59°24′50″	141°62′14″
77	4	2.9	0.015	299.8	3.76	0.71	59°31′44″	142°11′42″
78	4	0.0	0	205.8	4.25	0.77	59°22′22″	141°70′86″
79	4	0.0	0	183.9	4.67	0.51	58°00′00″	140°50′00″
80	4	0.4	0.001	251.4	4.43	0.00	58°66′81″	139°37′33″
81	4	0.3	0.002	208.4	5.04	0.00	58°65′61″	139°56′08″
82	4	0.3	0.001	262.8	4.59	0.00	58°53′81″	139°61′56″
83	4	0.0	0	218.9	4.81	0.00	58°35′00″	139°32′89″
84	4	0.0	0	172.4	5.32	0.76	58°22′00″	139°00′00″
85	4	2.4	0.016	215.2	5.26	0.74	58°10′17″	138°65′33″

ed between the shallowest depth category and both deeper depth groups (Table 3, Sheffe test). Substrate type also affected abundance (Table 3); transects with hard substrate had a significantly higher density of thornyheads than transects on soft bottom (P=0.016, Mann-Whitney). There was a significant interaction (P=0.01) of depth and substrate in the ANOVA factorial analysis (Table 4) due to the sharp increase in thornyhead abundance in depths >200 m on the hard substrate than on the soft substrate (Fig. 3).

Stepwise multiple regression with all variables resulted in a model that incorporated two variables: substrate type and depth, with substrate type entered first. The final two-variable regression model was

$$A = 0.017\,S + 0.00016\,D - 0.033, \qquad [r^2=0.208]$$

where A = thornyhead abundance;
S = proportion of bottom that is hard substrate; and
D = depth (m).

Thornyhead abundance increased with depth and amount of hard substrate, although there was an indication that abundance may have reached maximum levels at depths of 200–300 m (Fig. 3).

Discussion

Film (still or motion) and videotape recordings of transects have been used to assess abundance of aquatic organisms (Auster et al., 1989; Butler et al.[3]). Potential biases in such data include systematic underestimation

---

[3] Butler, J. L., W. W. Wakefield, P. B. Adams, B. H. Robison, and C. H. Baxter. 1991. Application of line transect methods to surveying demersal communities with ROVs and manned submersibles. Proceedings of the IEEE Oceans ‘91 Conference, p. 689–696. Institute of Electrical and Electronic Engineers, Piscataway, NJ.

Table 2

Correlation (lower left diagonal) and partial correlation matrices (upper right diagonal) for shortspine thornyhead (SSTH), depth, substrate type, temperature, and invertebrates. Significant correlations are indicated in bold.

	SSTH	Depth	Substrate	Temperature	Sea star	Urchin	Sea pen	Anemone	Coral	Sponge	Cucumber
SSTH		0.35	0.37	0.08	–0.13	0.24	0.04	–0.13	0.04	0.27	–0.12
Depth	**0.23**		–0.34	–0.56	0.02	0.03	0.00	0.09	–0.16	–0.08	0.11
Substrate	**0.32**	**–0.31**		0.00	–0.12	–0.16	–0.01	0.39	–0.15	0.23	0.25
Temp.	–0.10	**–0.62**	0.17		–0.02	–0.07	0.24	0.04	–0.05	–0.15	–0.22
Seastar	–0.18	0.05	–0.16	–0.04		0.23	0.18	0.24	0.04	–0.06	0.01
Urchin	0.11	0.18	**–0.21**	–0.12	**0.35**		0.19	0.04	0.08	–0.13	–0.04
Sea pen	–0.01	–0.09	0.04	0.13	**0.36**	**0.33**		–0.06	0.35	0.10	0.43
Anemone	0.00	–0.07	**0.38**	0.03	**0.22**	0.04	0.15		0.07	0.07	0.09
Coral	–0.05	–0.09	–0.03	0.03	**0.30**	**0.27**	**0.61**	0.16		0.05	0.27
Sponge	**0.37**	–0.08	**0.41**	–0.02	–0.18	–0.16	–0.02	0.14	–0.04		–0.17
Cucumber	–0.06	0.08	0.13	–0.15	0.27	0.20	**0.59**	**0.24**	**0.53**	–0.09	

Table 3

Mean abundance (number/100 m^2) of shortspine thornyheads in three depth categories (Kruskal-Wallis, $P<0.0001$), and in two substrate categories (Mann-Whitney, $P=0.016$), with sample sizes and standard errors. Results of nonparametric analyses are included.

	Abundance	*n*	SE
Depth			
100–200	0.1	18	0.1
200–300	1.4	80	0.2
>300	1.9	9	0.4
Substrate			
soft	0.6	57	0.1
hard	1.9	50	0.4

Table 4

Factorial analysis of effect of depth and substrate (proportion of bottom categorized as hard substrate) on shortspine thornyhead abundance (number/100 m^2, $\log(x+1)$ transformed).

Variable	df	Sum of squares	*F*-value	*P*
Depth	2	1.01	10.28	<0.0001
Substrate	1	0.35	7.10	0.009
Depth-substrate interaction	2	0.41	4.17	0.018
Residual	101	4.96		

due to gear avoidance or overestimation due to attraction of fish to the submersible. The behavior of shortspine thornyheads observed in the videotapes from our study indicated that they were not affected by the submersible. They typically remained relatively motionless unless the submersible came very close (almost touching the fish). It is also unlikely that they had moved away, or toward, the submersible, before coming into the camera field. On all dives there was an observer and another video camera recording a broader area, and there was no indication that shortspine thornyheads were responding to the submarine. The passive behavior of shortspine thornyheads in response to submersibles has been noted previously (Krieger, 1992).

In transect assessments, the probability of detecting organisms typically is not equal over the entire field of view. Detection is affected by such factors as lighting, orientation of the organism and its reflectivity, sea floor relief, suspended particles, and size of the organism. Butler et al.[3] examined the detection functions for three types of fish (flatfish, hagfish, and thornyhead) from data collected off California. For thornyheads, the probability of detection was relatively constant to a distance of about 180 cm. This distance is larger than the width of the transects in our study, indicating that our use of a constant detection function (probability of 1.0) was appropriate.

We found that shortspine thornyheads preferred habitat with hard substrate. Submersible transects have been used to identify habitat used by rockfishes and thornyheads in the northeast Pacific Ocean (Richards, 1986; Pearcy et al., 1989; Stein et al., 1992; O'Connell and Carlile, 1993; Krieger and Ito, 1999). Off Oregon, thornyheads were included in an assemblage of fishes associated with mud bottom (Stein et al., 1992), and Pearcy et al. (1989) observed that in deep water they occurred on mud bottom, but in shallower water were found over both rock and mud. We have no explanation for the differences in habitat association between Oregon and southeast Alaska.

Our observations are based on a larger number of transects than those surveyed off Oregon, but the consistency of results from the two Oregon studies suggests that the difference is not due to a low sample size there. Our observation that abundance of shortspine thornyheads increases with depth is consistent with results from trawl surveys off Alaska, Oregon, and California (Martin and Clausen, 1995, Stark and Clausen, 1995, Jacobson and Vetter, 1996). Off Oregon, their abundance was highest in the 200–400 m depth zone, and decreased sharply between 400 m and 1400 m (Jacobson and Vetter, 1996). Off California, the highest abundance of shortspine thornyheads occurred at 400–600 m, probably because of the warmer waters off California (Jacobson and Vetter, 1996). Thus, our sampling depths covered the most important depth zones for this species in the waters off southeast Alaska, which are colder than those off Oregon.

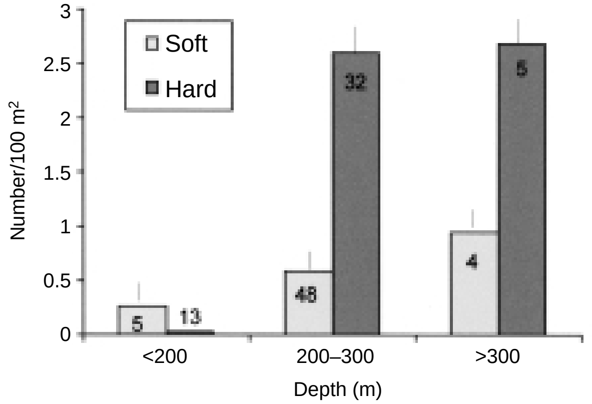

Figure 3

Mean abundance of shortspine thornyhead on soft and hard bottom substrates in three depth intervals. Sample size (number of transects) and standard errors are indicated in the number and vertical line over each bar.

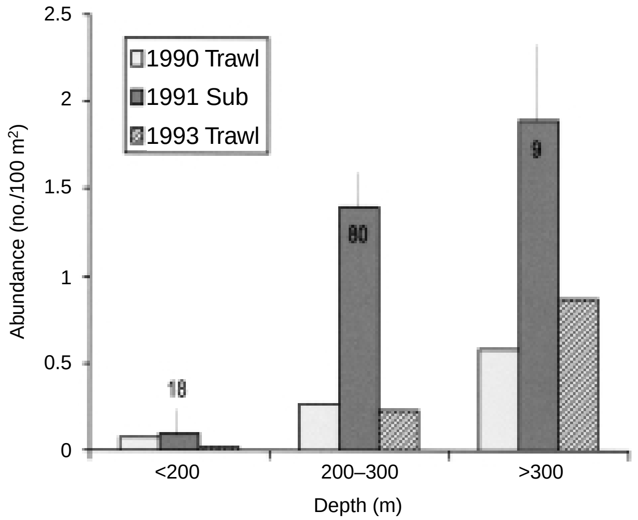

Figure 4

Mean abundance of shortspine thornyhead in three depth intervals from submersible transects in 1991 and from the 1990 and 1993 trawl surveys off southeast Alaska. Sample size (number of transects) and standard errors of the submersible estimates are indicated in the number and vertical line with each bar.

Bottom trawl surveys of fishes in the Gulf of Alaska are conducted triennially, and occurred one year before (1990) and two years after (1993) our submersible survey (Martin and Clausen, 1995; Stark and Clausen, 1995). For many species, trawl survey results may be biased because some species may be herded by the trawl doors into the path of the net, resulting in overestimates of abundance when the "area-swept" method is applied (Krieger, 1992). Other fish in the water column above the bottom may swim over the net and be underestimated by the survey (Balsiger et al., 1985). Escape routes under the foot rope and through the larger meshes in the trawl wings are also possibilities.

The NMFS trawl survey does not cover exceptionally rugged rocky habitats that would destroy equipment; consequently, species that select high-relief habitats may be underestimated by the survey, whereas species that select low-relief soft-bottom habitats may be overestimated. Submersible observations provide a means to quantify the biases inherent in bottom trawl surveys. The depth categories we used to analyze the submersible data matched the depth strata used in the NMFS triennial trawl surveys. Mean abundance of shortspine thornyheads in submersible surveys were several times higher that those in the 1990 and 1993 trawl surveys; however, the ratios of abundance in the three depth zones were very similar (Fig. 4). We suggest that trawl surveys underestimate the abundance of shortspine thornyheads in the Gulf of Alaska but may be good indicators of relative abundance, patterns of distribution, and stock trends.

Acknowledgments

We thank Dan Ito for his encouragement and support for this project. This research was supported by a grant (43ABNF401902) from the U.S. Dept. of Commerce, National Marine Fisheries Service, Auke Bay Laboratory, Juneau, Alaska.

Literature cited

Adams, P. B.
1980. Life history patterns in marine fishes and their consequences for fisheries management. Fish. Bull. 78:1–12
Auster, P. J., L. L. Stewart, and H. Spunk.
1989. Scientific imaging with ROVs: tools and techniques. Mar. Technol. Soc. J. 23:16–20.
Balsiger, J. W., D. H. Ito, D. K. Kimura, D. A. Somerton, and J. M Terry.
1985. Biological and economic assessment of Pacific ocean perch (*Sebastes alutus*) in waters of Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-72,

NMFS Alaska Fish. Sci. Cent., Seattle, WA, 210 p.

Jacobson, L. D., and R. D. Vetter.
1996. Bathymetric demography and niche separation of thornyhead rockfish: *Sebastolobus alascanus* and *Sebastolobus altivelis*. Can. J. Fish. Aquat. Sci. 53:600–609.

Krieger, K. J.
1992. Shortraker rockfish, *Sebastes borealis*, observed from a manned submersible. Mar. Fish. Rev. 54(4):34–36.
1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91: 87–96.

Kreiger, K. J., and D. H. Ito.
1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, S. *aleutianus*, determined from a manned submersible. Fish. Bull. 97:264–272.

Martin, M. H., and D. M. Clausen.
1995. Data report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-59, 217 p.

Matlock, G. C., W. R. Nelson, R. S. Jones, A. W. Green, T. J. Cody, E Gutherz, J. Doerzbacher.
1991. Comparison of two techniques for estimating tilefish, yellowedge grouper and other deepwater fish populations. Fish. Bull. 89:91–99.

Miller, P.
1985. Life history of the shortspine thornyhead, *Sebastolobus alascanu*s, at Cape Omnaney, S.E. Alaska. M.S. thesis. Univ. Alaska, Juneau, AK, 75 p.

Moser, H. G.
1974. Development and distribution of larvae and juveniles of *Sebastolobus* (Pisces; Family Scorpaenidae). Fish. Bull. 72:865–884.

O'Connell, V. M., and D. W. Carlile.
1993. Habitat-specific density of adult yelloweye rockfish *Sebastes ruberrimus* in the eastern Gulf of Alaska. Fish. Bull. 91:304–309.

Pearcy, W. G., D. L. Stein, M. A. Hixon, E. K. Pikitch, W. H. Barss, and R. M. Starr.
1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fish. Bull. 87:955–965.

Richards, L. J.
1986. Depth and habitat distributions of three species of rockfish (*Sebastes*) in British Columbia: observations from the submersible PISCES IV. Environ. Biol. Fishes 17: 13–21.

Stark, J. W., and D. M Clausen.
1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-49, 221 p.

Stein, D. L., B. N. Tissot, M. A. Hixon, and W. Barss.
1992. Fish-habitat associations on a deep reef at the edge of the Oregon continental shelf. Fish. Bull. 90:540–551.

Zar, J. H.
1984. Biostatistical analyses. Prentice-Hall, Englewood Cliffs, NJ, 718 p.

Zhou, S., and T. C. Shirley.
1997. Distribution of red king crabs and Tanner crabs in the summer by habitat and depth in an Alaskan fjord. Invest. Mar. Valparaiso 25:59–67.