WEST COAST NATIONAL UNDERSEA RESEARCH CENTER

Final Report

Prepared By

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Regional Information Report[1] No. 1J92-08

Alaska Department of Fish and Game
Division of Commercial Fisheries
Juneau, Alaska

May 1992

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West Coast National Undersea Research Center

FINAL REPORT

Date of Report: May 1, 1992

Inclusive dates of Mission: August 1989- June 1991

Project Titles: Evaluation of Submersibles and ROVs as Tools for Estimating Abundance of Rockfish and Inventorying Rockfish Habitat in the Gulf of Alaska. Definition of the Relationship Between Demersal Shelf Rockfish Abundance and Habitat Complexity based on in-situ Observation from a Submersible in the Eastern Gulf of Alaska.

Principal Investigator: Victoria M. O'Connell

Senior and Supporting Investigators: David W. Carlile

Undersea System Utilized: Delta II submersible

Number of Dives and days used and total cost estimate for the mission: 69 submersible dives and 17 ROV dives

Amount of co-funding provided: $118,458

Co-funding agency: Alaska Department of Fish and Game

Prior to our research, demersal shelf rockfish (DSR) was one of the few commercially important groups of fish in the Gulf of Alaska for which no reliable estimates of abundance were available. Trawl surveys are used to estimate the abundance of most other species of groundfish in the Gulf of Alaska. However, the close association of DSR with rough, rocky ocean bottom prevents the use of trawl surveys for stock assessments of these fishes. Aided by the National Undersea Research Program, the Alaska Department of Fish and Game is developing a habitat-based stock assessment program for DSR that seeks to use the association of DSR with rough, rocky bottom to aid, rather than hinder, stock assessments. This approach is based on the hypothesis that DSR abundance is positively related to certain structural habitat characteristics that can be more readily and less expensively measured than can actual abundance of DSR. Some data which may reflect useful habitat characteristics are already available. The primary goal of this project is to define a predictive model of the relationships between DSR abundance and structural habitat complexity and to use that model to estimate potential abundance of DSR, and thereby improve stock assessments for these species. Reported here are the results of three seasons of NURC-aided research supporting that goal of improved stock assessments of DSR in the eastern Gulf of Alaska.

The research was conducted in two phases. The first phase (Project Title: Evaluation of submersibles and ROVs as tools for estimating abundance of rockfish and inventorying rockfish habitat in the Gulf of Alaska) involved evaluation of two underwater vehicles, a remotely-operated vehicle (ROV), and a manned submersible. The objective of this phase was to identify the most cost-effective underwater vehicle for gathering necessary DSR abundance and habitat data and compare the usefulness of these *in-situ* tools with a mark-recapture method for estimating abundance of DSR.

The second phase (Project Title: Definition of the relationship between demersal shelf rockfish abundance and habitat complexity based on in-situ observation from a submersible in the eastern Gulf of Alaska) used the most cost-effective vehicle and approach from Phase I to simultaneously collect DSR abundance and habitat data to model the relationships between abundance and habitat complexity. The long-term goal, to which these NURP projects contribute, is the development of an improved stock assessment method for DSR and enhanced management of these species.

The specific objectives and null hypotheses addressed in Phases I and II included:

Phase I (1989)

Objective 1. To evaluate the usefulness of submersibles and/or ROVs for estimating density of adult and juvenile demersal shelf rockfish in the Gulf of Alaska.

Null hypothesis H_{01} - Demersal shelf rockfish in Southeast Alaska cannot be adequately detected, enumerated and their density estimated using a submersible or ROV.

Null hypothesis H_{02} - Rockfish density estimates derived from submersible/ROVs are less reliable and cost efficient than estimates based on tagging.

Null hypothesis H_{03} - Juvenile shelf rockfish do not co-occur spatially with adults at the time of year the dives are conducted.

Null hypothesis H_{04} - Line transect methods cannot be used int eh uneven terrain occupied by demersal shelf rockfish.
[express goals, null hypotheses, etc.]

Objective 2. To evaluate the usefulness of a submersible and/or ROV for delineating habitat of DSR in the Gulf of Alaska.

Null hypothesis H_{01} - Habitat of demersal shelf rockfish in Southeastern Alaska cannot be delineated adequately using submersibles or ROVs.

Phase II (1990 and 1991)

Objective 1. To estimate density of adult demersal shelf rockfish using line transects conducted from a manned submersible.

Null hypothesis H_{01} - The density of adult demersal shelf rockfish in Southeast Alaska cannot be determined using line transects from a manned submersible.

Null hypothesis H_{02} - There is no diel difference in observed abundance of DSR.

Objective 2. To further evaluate the usefulness of a submersible for delineating habitat of DSR in the Gulf of Alaska.

Null hypothesis H_{01} - Habitat of demersal shelf rockfish in Southeast Alaska cannot be delineated adequately using submersibles.

Objective 3. To define the relationship between habitat characteristics and DSR abundance.

Null hypothesis H_{01} - Relationships between DSR density and habitat characteristics cannot be statistically defined based on data obtained from a manned submersible.

METHODS

Phase I

We conducted strip transects (Seber 1982) along the same seafloor transects with both the ROV and the sub. Thus, each vehicle was exposed to very similar underwater conditions and the same terrain was viewed from each vehicle. Two general criteria were used for evaluating the vehicles: effectiveness (i.e. ability to collect useable data) and cost. Specific criteria used to judge the effectiveness of each vehicle included range of visibility from the vehicle, field of view (FOV), and clarity of real-time and video-recorded images and the resultant abilities to sight, identify, and count rockfish species, to demarcate strip transect boundaries, and to differentiate habitat characteristics. The ease of deployment, operation, and retrieval of each vehicle were also used to evaluate effectiveness. Our initial intent was to conduct a formal cost-benefit analysis to identify which of the two types of vehicles would be the more cost effective for collecting simultaneous rockfish abundance and habitat data.

To improve the accuracy and precision of abundance estimates, we attempted to maximize counts of rockfish by conducting many transects at historically productive commercial fishing locations in the vicinity of Sitka Sound (Fig 1). Transects were conducted over soft and cobble bottoms as well as rugged, high relief areas in depths from 35 to 169 meters. Eighteen sub transects and 15 ROV transects were attempted. Initially a chartered fishing vessel set a groundline along the seafloor at a transect location to serve as a reference line along which to conduct the strip transects. However, the rough terrain often caused the line to be suspended off the bottom. As an alternative, we established transect lines by anchoring a buoy and flag at the beginning of each transect and used compass headings from the buoy to maintain the transect course. Transect locations were marked on nautical charts and located in the field using Loran C. The usual sequence of operations was to conduct a sub transect followed by an ROV transect. All transects were conducted during June 1989.

Submersible Operation

We used General Oceanographic's two-person sub, *Delta II*. The M/V *Wm. A. McGaw* served as a support vessel to transport, deploy, track and retrieve the sub.

To conduct a transect the sub was launched from the support vessel and descended near the anchored buoy. Once the sub was on the bottom, the transect was run from the buoy anchor line on a pre-selected gyro-compass heading for approximately 30 minutes. Compass headings were chosen to maximize vertical relief encountered. We tried to maintain an operating speed of approximately 0.5 knots and a height off bottom of one meter. The location of the sub was pinpointed periodically from the support ship using a Track Point®[3] telemetry system to monitor the progress of the sub along the transect. All dives were conducted in daylight between 0700 and 1900 hours.

The sub carried a pilot and an observer. The observer sat or laid in the forward portion of the sub and made observations through three viewing ports on the right side of the sub. These ports, rather than the bow or left-side ports, were used because of the overall wider FOV afforded from the right-side ports, and because the lights, video and still cameras were mounted on the right side of the sub.

An externally-mounted CCD video camera on the right side of the sub and 1 m above the keel bottom, video-recorded each strip transect. The viewing area was illuminated by three, 150-watt, halogen lamps. A 35 mm Photosea®[3] still camera with strobe was also mounted externally. The observer used a cassette tape recorder to record species, maturity and numbers of fish seen outside the video camera FOV, and to record habitat types encountered.

ROV Operation

We used a Benthos Undersea Systems Technology *MiniROVER MKI*® ROV, owned and operated by Eastern Oceanographics. The ROV was deployed from a commercial longliner, the F/V *Haley Christine*. The ROV was equipped with a high-resolution color video camera with a lens that could pan and tilt, thereby expanding the potential FOV. Two 150 watt quartz halogen lights provided illumination. The magnetic compass mounted on the forward end of one skid and visible at the edge of the camera FOV provided the ability to orient the ROV on a constant compass heading. An 11 kg lead ball was suspended 0.5 m from the bottom of the ROV to keep the ROV near the bottom and to dampen erratic motion of the ROV caused by surge and current.

To run an ROV transect, the support vessel anchored immediately down-current from the buoy marking the beginning of the transect. The ROV was then deployed over the stern of the support vessel and hand-lowered to the seafloor (usually two people) with a nylon support line independent of the ROV umbilical. The transect conducted by slowly letting out anchor rode and allowing the support vessel and the ROV to drift down current, roughly along the path of the transect run initially by the sub. were accomplished from the operator control panel aboard the support vessel. The ROV was connected by umbilical to a video monitor and ROV control panel in the wheelhouse of the support vessel. The ROV operator aboard the support vessel manipulated joysticks on the control panel to activate thrusters on the ROV to control horizontal and vertical movements of the ROV over small areas of seafloor. Larger vertical movements of the ROV, often necessitated by high topographic relief, involved the support vessel deck crew hand raising and lowering the ROV with the support line. Commands to the deck crew to raise or lower the ROV were given by the ROV operator as he monitored the progress of the ROV on a video monitor. In addition to having real-time images of the seafloor from the video monitor, each transect was video-taped.

Phase II

Based on results from Phase I, we used the sub to collect DSR abundance and habitat data for Phase II. Although strip transects were originally proposed for Phase II, we used line transect methods (Burnham et al. 1980) instead. Valid application of strip transect methods requires the assumption of 100% detectability of all DSR within the transect boundaries. The rough, rocky bottom occupied by DSR would have necessitated a very narrow strip transect width to insure 100% detectability. However, narrow strip widths would probably have reduced the number of DSR counted, thereby potentially increasing the variability in DSR density estimates. Therefore, we conducted line transects along the seafloor to simultaneously collect habitat and rockfish abundance data. Transect locations were chosen systematically to try to include sites with a range of habitat complexity. The principal parameter we used to assess habitat complexity was topographic relief. We used topographic relief as the most readily apparent and measurable metric of structural habitat complexity. Bathymetric data from the National Ocean Service (NOS) hydrographic and marine geophysical data bases were used to aid in placing transects. We attempted to orient each transect along the ocean bottom to maximize the topographic relief to be encountered along the transect.

Transects were conducted by navigating the sub along a predetermined course. Occasionally it was necessary to alter the predetermined course because of adverse ocean currents. Periodic locational fixes of the sub along each transect were obtained using a *Trak Point®* telemetry system aboard the support vessel. The sub pilot strove to maintain straight transects using headings on a gyrocompass aboard the sub, supplemented by course corrections based on *Trak Point®* locational fixes. The length of each transect (l_i) was measured as the sum of the distances between locational fixes.

While conducting transects, the sub pilot attempted to maintain a speed of approximately 0.5 nm/hr and a height off the ocean bottom of 1 m. In practice, the speed and height off bottom varied somewhat due to ocean currents and the often high topographic relief encountered. Per standard line transect sampling procedure (Burnham et al. 1980), an observer aboard the sub counted each individual DSR sighted along a transect and measured or estimated the perpendicular distance from the transect line to the point where the rockfish was originally sighted. Distances to rockfish were measured using modified sonar guns deployed from inside the sub. The usual procedure for line transect sampling entails counting objects on both sides of a transect line. However, we counted rockfish only on the right side of each transect. We departed from the normal procedure because of the much better visibility afforded from the right side of the sub, due to a greater number of viewing ports and better illumination than on the left side. In addition, video and Photosea® still cameras were mounted on the right side of the sub and recorded only the right side of each transect. A video tape of the terrain along each transect was recorded. The species and perpendicular distance of each fish sighted was recorded by the observer on a hand held cassette tape recorder, with a simultaneous backup audio recording on the video cassette which was recording the terrain along the transect. In addition to species and perpendicular distances, the observer periodically recorded information on the type of habitat being traversed, visibility, and a general indication of topographic relief.

The depth of the sub below the surface was measured with an onboard pressure gauge and encoded onto the video cassette through a *Pisces Box®*. The height of the sub off the bottom was measured by a down-looking sonar and also digitally recorded onto the video tape. Depth and height off bottom were automatically recorded every second.

Transects were conducted in 1990 in the vicinity of Sitka Sound and on the Fairweather Ground (Fig 2). In 1991 transects were completed only in the Sitka Sound area. For each transect, densities of DSR, were estimated as:

$$\hat{D}_{T_i}=\frac{n_i\hat{f}(0)_i}{l_i} \qquad (1)$$

where: $\hat{D}T_i$ = total density of four species of demersal shelf rockfish for transect i.

n_i = total number of demersal shelf rockfish along transect i

$\hat{f}(0)_i$ = value of a probability density function of perpendicular distance data at a distance of 0 from transect i (i.e. on the transect line)

l_i = length of transect i

This is the density estimator advanced by Burnham et al. (1980), except that "l" rather than "2l" is used in the denominator, since we were only able to count fish on one side of each line transect. Estimates of $\hat{f}(0)$ were obtained using the hazard-rate model of Hayes and Buckland (1983).

For each transect, the density of each species was estimated as:

$$\hat{D}_{s_i}=\hat{D}_{T_i}\hat{p}_{s_i} \qquad (2)$$

where: $\hat{D}s_i$ = estimated density of species s for transect i

$\hat{p}s_i$ = estimated proportion of DSR counted along transect i that were species s

Given the estimates of $\hat{D}s_i$, a weighted mean density for each species was estimated as:

$$\hat{D}_s = \frac{\sum_{i=1}^{R} l_i \hat{D}_{s_i}}{\sum_{i=1}^{R} l_i} \qquad (3)$$

where: R = the total number of transects

This approach is similar to that used by Holt and Powers (1982) for estimating the density of different species of dolphins in multi-species dolphin schools.

RESULTS AND DISCUSSION

For 1990 in Sitka Sound, 18 transects were completed in 9 dives. In the Fairweather Ground, 15 transects were completed in 11 dives. In 1990 dives occurred from August 17 to August 25. In 1991 33 transects were conducted during the course of 18 dives from May 27 to June 3. Submersible transect lengths during 1990 and 1991 varied from 0.2 to 3.6 nm. Dive durations ranged from 15 to 150 minutes.

Phase I

Objective 1. To evaluate the usefulness of submersibles and/or ROVs for estimating density of adult and juvenile demersal shelf rockfish in the Gulf of Alaska.

Hypothesis H_{01} - We rejected the null hypothesis that DSR in southeast Alaska cannot be adequately detected, enumerated and their density estimated using a submersible or ROV.

Both the ROV and the sub were good vehicles for detecting DSR. Image clarity was comparable and usually very good from both vehicles. However, the visibility from the sub tended to be better than the ROV due to the generally wider FOV, higher vantage point, better illumination and greater maneuverability of the sub. Demersal shelf rockfish could be adequately enumerated and densities estimated using the sub, but not the ROV.

Accurate DSR enumeration with the ROV was difficult because of the often erratic motion of the ROV due to surge, currents and the motion of the support vessel. Because of this motion, and the apparent tendency for some fish to swim around the ROV and back and forth in front of the ROV camera, there was a high probability of multiple counts of individual fish. This potential for double counts may have been exacerbated by the relatively slow speed of the ROV along the bottom. It appeared that some DSR may have been attracted to the ROV, perhaps partly due to the slow speed and small size of the ROV. Because of the difficulties inherent in counting DSR, it would be difficult to estimate densities of DSR using data acquired from the ROV. Such estimates might be biased high because of the probability of multiple counts of individuals. Also, the slow speed of the ROV, relative to the submersible, reduced the amount terrain covered and tended to minimize counts of DSR. The reduced counts of DSR would be expected to decrease the precision of density estimates. The danger of snagging the ROV or its umbilical on the bottom or lost longline fishing gear, or lodging the ROV on the bottom also reduced the effectiveness of the ROV, compared to the submersible. Rock outcrops, boulders and overhangs, characterize much of the habitat occupied by DSR. Lost groundline, from longline fishing operations, may stretch for hundreds of meters along the bottom, often suspended several meters above the bottom due to the high relief. Because the ROV operator could not normally see the umbilical above the ROV, there was a potential danger in snagging the umbilical on rock overhangs, outcrops or longline gear. Large crevices, holes and spaces between boulders are also characteristic of DSR habitat. Because of the relatively small size of the ROV and the often quick, erratic movements of the ROV, the chance of lodging the ROV on the bottom was also a concern.

In contrast to the ROV, we encountered few difficulties in enumerating DSR from the sub. There was little or no concern with multiple counts of the same fish. This may have been due to the faster speed of the sub and the tendency of fish to show little overt attraction to or avoidance of the sub. Further discussion on the suitability of the sub for aiding in density estimation is provided under Phase II results.

Hypothesis H_{02} - We tend to reject the null hypothesis that "Rockfish density estimates derived from submersible/ROVs are <u>less</u> reliable and cost efficient than estimates based on tagging". This is based on the results from Phase I, and results from an independent trial study of remote-tagging of DSR. As indicated, adequate density estimates appear to be achievable using line-transect derived counts obtained from a sub. While minimal tag returns from remotely-tagged yelloweye rockfish are encouraging (O'Connell, 1992), uncertainties regarding numbers of fish tagged, potential tag loss, the assumption of population closure and problems in deploying and retrieving adequate numbers of tags make this approach more uncertain than the line transect approach. While the cost of deploying and retrieving tags may be less than operating the submersible, the reliability of the data would be much lower than line-transect data, making the line-transect-based density estimates more cost efficient.

Hypothesis H_{03} - We rejected the null hypothesis that "Juvenile shelf rockfish do not co-occur spatially with adults at the time of year the dives are conducted". We conducted our dives from June 17 to June 21, 1989. During these dives we observed juveniles of yelloweye rockfish, tiger rockfish and rosethorn rockfish as well as large schools of small (< 5 cm) unidentified juvenile rockfishes.

Hypothesis H_{04} - We rejected the null hypothesis that "Line transect methods cannot be used in the uneven terrain occupied by demersal shelf rockfish". While final confirmation of this conclusion was not made until after our first field season under the Phase II studies, Phase I studies strongly indicated that line-transect methods could be used with the sub.

Successful application of line transect methods in the field requires establishment of straight lines of travel, accurate measurements of distances to objects sighted, and assurance that objects on and very near the transect line are seen with certainty (Burnham et al. 1980). We plotted the paths of the sub using periodic fixes from the *Trak Point*® system. Based on these transect paths, we concluded that sufficiently straight transect segments could be accomplished from the sub to allow successful application of line transect methods (Fig. 3.). During Phase I, we had no method of measuring distances to rockfish sighted, and therefore conducted strip, rather than line, transects. We overcame this problem during Phase II, using a modified sonar gun, operated from inside the sub, to measure distances to rockfish. The assumption that rockfish on or close to the transect line were seen with certainty was probably violated to a small extent. The high relief and many cracks, crevices, and holes characteristic of habitat favored by rockfish undoubtedly hid some rockfish that were on or near the transect line. However, we believe that the probability of rockfish on or close to the line being undetected was extremely low and that resulting density estimates were not seriously, if at all, biased. The degree of on-line non-detection probably varied among the four main species sighted. Among the four most abundant DSR species the least cryptically behaved was yelloweye rockfish. This species generally exhibited little or no aversion or attraction to the sub and rarely appeared to take refuge in holes or cracks as the sub passed. The most cryptically-behaved species was tiger rockfish. This species was often seen taking refuge in cracks or holes as the submersible advanced. The chance of missing tiger rockfish on the line was probably greater than the chance of missing yelloweye rockfish.

Objective 2. To evaluate the usefulness of a submersible and/or ROV for delineating habitat of DSR in the Gulf of Alaska.

Hypothesis H_{01} - We rejected the null hypothesis that "Habitat of demersal shelf rockfish in southeastern Alaska cannot be delineated adequately using submersibles or ROVs". For our purpose, adequate delineation required the ability to differentiate habitat categories, such as sand, cobble and boulders, and the ability to measure ocean depth over the length of each transect. The sub met both of these requirements, the ROV did not. Because of the excellent image clarity and adequate FOV from both vehicles, we could categorize habitat from either vehicle. However, the relatively slow speed and often erratic motion of the ROV would have made accurate measurement of ocean depth along each transect difficult, if not impossible. During Phase II, we accurately measured ocean depth along each transect at one second intervals.

Phase II

Objective 1. To estimate density of adult demersal shelf rockfish using strip transects conducted from a manned submersible.

Hypothesis H_{01} - We did not test the hypothesis that "The density of adult demersal shelf rockfish in Southeast Alaska cannot be determined using strip transects from a manned submersible". Between the time our proposal was submitted and the research conducted, we modified a hand-held sonar gun that allowed us to measure distances to individual fish and therefore use line transects rather than strip transects. Therefore, we substituted the word "line" for "strip" in the null hypothesis and rejected the null hypothesis. We were able to satisfactorily apply line transect methods to estimate the density of demersal shelf rockfish. As an example, the density of yelloweye rockfish ranged from 2174 to 2676 yelloweye/km^2 (Table 1).

Hypothesis H_{02} - We failed to reject the null hypothesis that "There is no diel difference in observed abundance of DSR". We found little difference in the count of DSR between transects conducted during the day and night along the same transect path although there were differences in counts within species. We conducted this test to determine whether we may have underestimated density based on fish counts obtained during daylight dives. Such underestimation could have occurred if DSR tended to hide more during daylight hours and this behavior subsequently increased the probability of missing DSR on or close to the transect line. There does not appear to be a significant diel effect on behavior with this group of fishes however a larger sample size is needed to reject or accept the null hypothesis.

Objective 2. To further evaluate the usefulness of a submersible for delineating habitat of DSR in the Gulf of Alaska.

Hypothesis H_{01} - We rejected the null hypothesis that "Habitat of demersal shelf rockfish in southeastern Alaska cannot be delineated adequately using submersibles." Expanding our approach for delineating habitat beyond what was used for Phase I, we quantified a characteristic of habitat, topographic relief, that may be correlated with DSR abundance. Use of the depth gauge and sonar in combination with the *Pisces Box*® allowed us to accurately measure ocean depth from which we can generate a variety of parameters associated with both micro- and macro-topographic relief (see Figure 4 for an example of the seafloor profile along a representative transect). Beyond normally sparse occurrence of sea anemones, sponges, and corals, there was little biotic cover over 5 cm in height.

Objective 3. To define the relationship between habitat characteristics and DSR abundance.

Hypothesis H_{01} - Analyses to date suggest that there may be a statistically definable relationship between DSR abundance and topographic relief. However, analyses are continuing and additional data are needed to fully address this hypothesis. At this time we can neither reject or fail to reject the hypothesis that "Relationships between DSR density and habitat characteristics cannot be statistically defined based on data obtained from a manned submersible". Linear and non-linear regression of DSR abundance on one measure of habitat complexity (variance in depth differences between sequential points on the transect) suggest a positive, statistically definable relationship between DSR density and habitat complexity (Fig 5). However, a few data points, those with the highest estimates of density and mean depth difference, strongly influence the apparent relationships. One point is particularly influential. In addition, the majority of data points are densely clustered at the lower end of the range of mean depth change with single data point from a high vertical relief pinnacle at the high end of the range. There is a notable absence of mean depth change estimates between these two extremes. Additional transects with depth change variances intermediate between the extremes recorded so far, are needed to determine whether a relationship exists, and if so, what the shape of that relationship is.

In 1991, we intended to conduct transects at sites which may have had topographic relief intermediate between the extremes shown in Figure 5, to determine the nature of a possible relationship. However, marginal weather in the intended dive area (Fairweather Ground) prevented us from diving. Intended dive sites were identified using National Ocean Service bathymetry data.

In addition to the mean and variance in depth changes, for future analysis we will be using other parameters derived from the high resolution depth data to explore the relationship between DSR abundance and habitat complexity. These parameters will include the error variances from polynomial models fit to depth data and a substrate rugosity index (Luckhurst and Luckhurst 1978) computed from the high resolution depth data.

We have not completed all analyses to define the relationships between DSR abundance and habitat complexity. There does appear to be a relationship between density and habitat type - i.e. yelloweye density is highest in boulder areas and broken rock and lowest over soft bottom. We have not yet successfully translated qualitative habitat typing into a quantifiable measure of habitat complexity. However, our analyses to date provide the first reliable density estimates for four species of DSR in the eastern Gulf of Alaska (Table 1). These estimates are being used by the North Pacific Fishery Management Council to recommend total allowable catches of DSR in the Gulf of Alaska.

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Luckhurst, B.E. and K. Luckhurst. 1978. Analysis of the influence of substrate variables on coral reef fish communities. Marine Biology 49:317-323.

O'Connell, V.M. 1992. A preliminary examination of breakaway tagging for demersal rockfishes. Fish Res Bull 91-06. 8 pp. Alaska Department of Fish and Game, Commercial Fisheries, Juneau, Alaska.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd ed. MacMillan Pub. Co., Inc. New York 654 p.

APPENDIX I.
PRODUCTS RESULTING FROM PROJECT

Refereed publications:

O'Connell, V.M. and D.W. Carlile. (Submitted to Fishery Bulletin). Comparison of a remotely-operated vehicle and a submersible for estimating abundance of demersal shelf rockfish in the eastern Gulf of Alaska.

O'Connell, V.M. and D.W. Carlile. (Presently in in-house review at ADF&G prior to submission for publication). Habitat specific density of adult yelloweye rockfish in the eastern Gulf of Alaska.

Non-refereed publications:

O'Connell, V.M., B.E. Bracken and D.W. Carlile. 1991. Demersal shelf rockfish in Stock Assessment and Fishery Evaluation for the 1992 Gulf of Alaska Groundfish Fishery. GOA Plan Team NPFMC, Anchorage, Alaska, September 1991.)

Presentations:

Carlile, D.W. and V.M. O'Connell. Relationships between rockfish (*Sebastes* spp.) abundance and habitat complexity. Presented at American Fisheries Society Meeting, San Antonio, September 1991 (published abstracts) and at the American Institute of Fisheries Research Biologists, Southeast Alaska Chapter Meeting, Juneau, AK February 1992.

O'Connell, V.M. and D.W. Carlile. Investigations of Demersal Shelf Rockfish in the Eastern Gulf of Alaska Using a Manned Submersible.
Presented at Western Groundfish Conference, Union, WA, January 1992 (published abstracts).

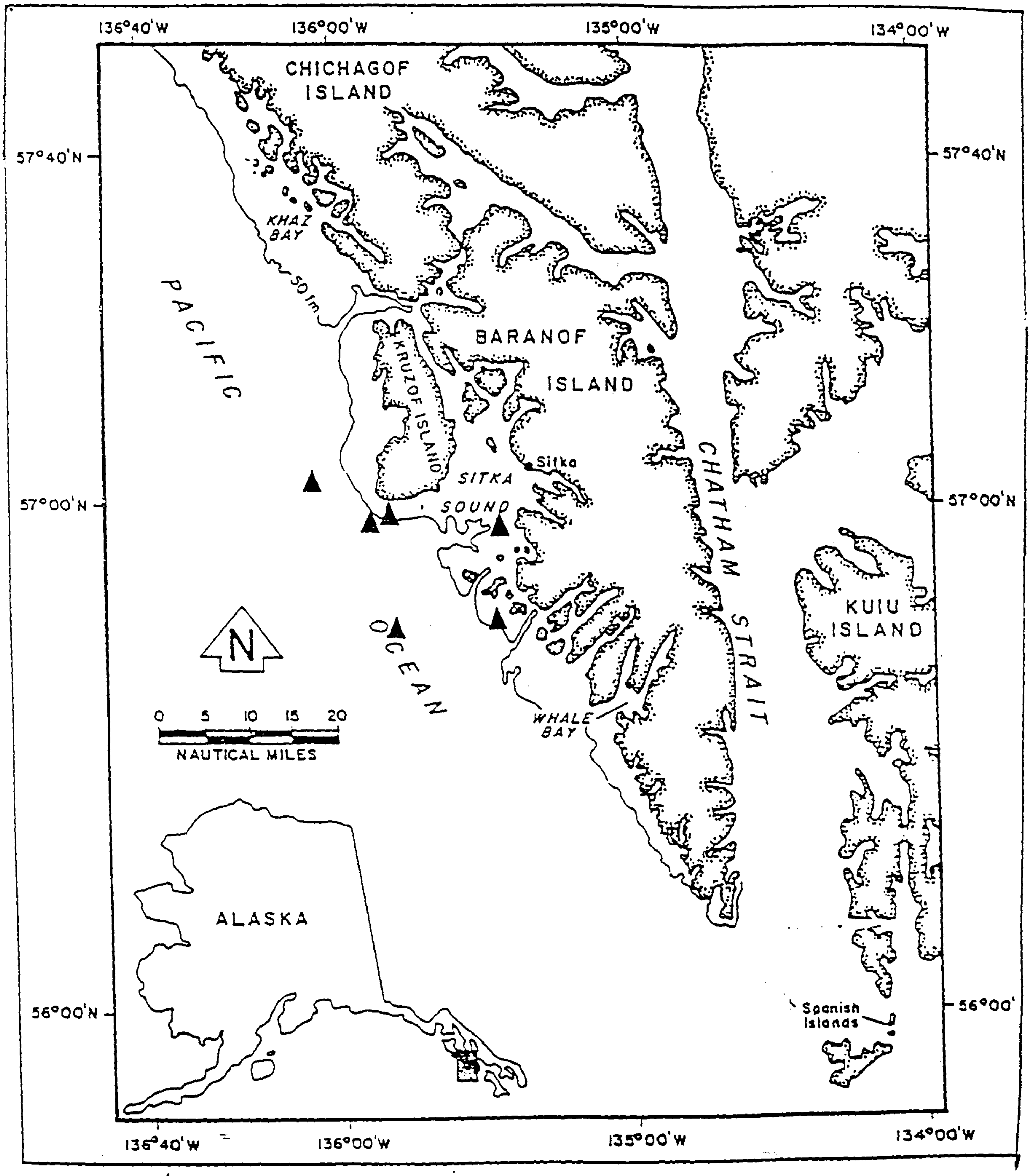

Figure 1. Study site for ROV and submersible comparison study, eastern Gulf of Alaska, 1989.

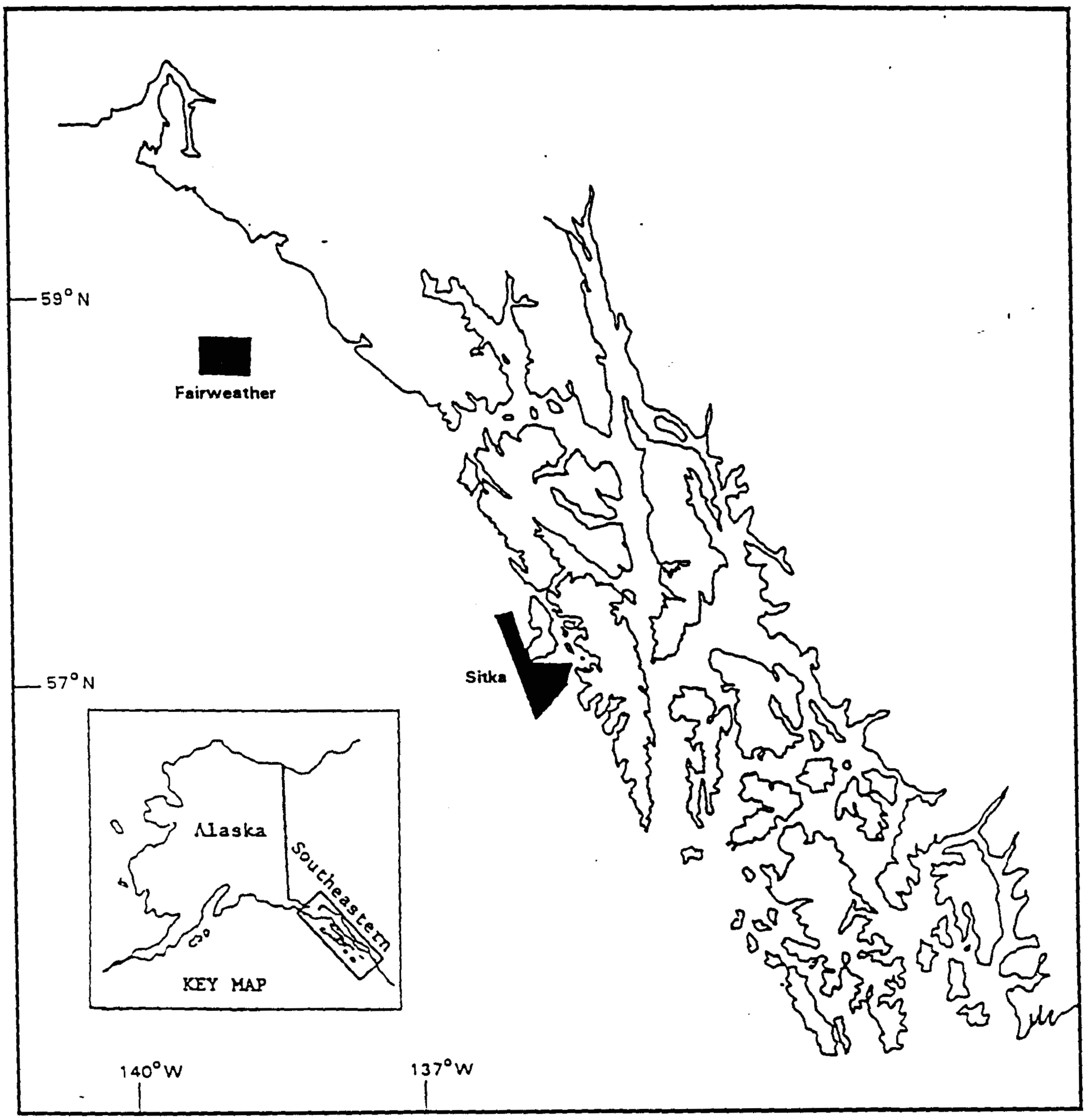

Figure 2. Study sites for submersible survey of DSR, eastern Gulf of Alaska, 1990 and 1991.

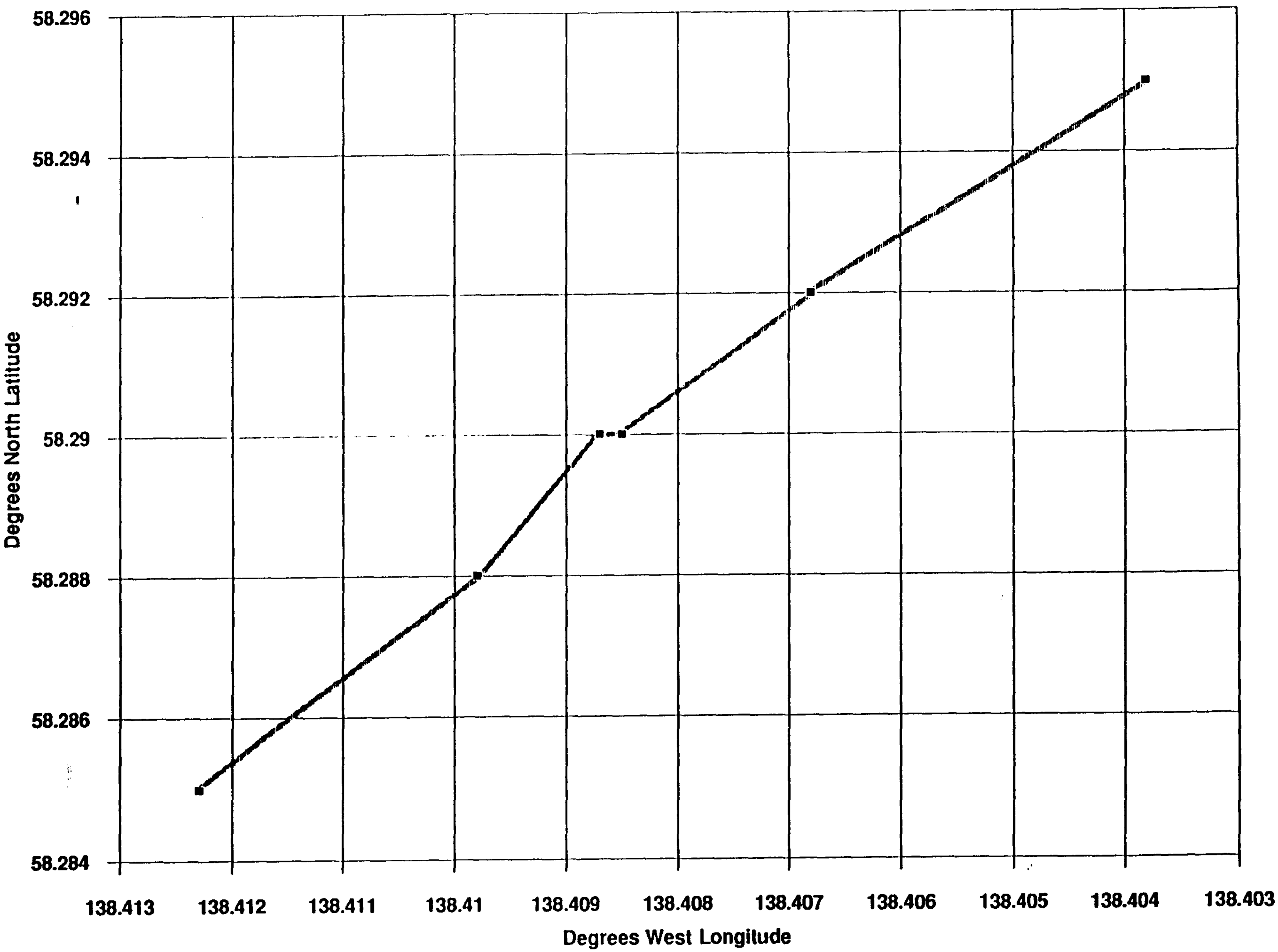

Figure 3. Representative example of a submersible path along a line transect. Transect No. 14, Fairweather Ground, 1990.

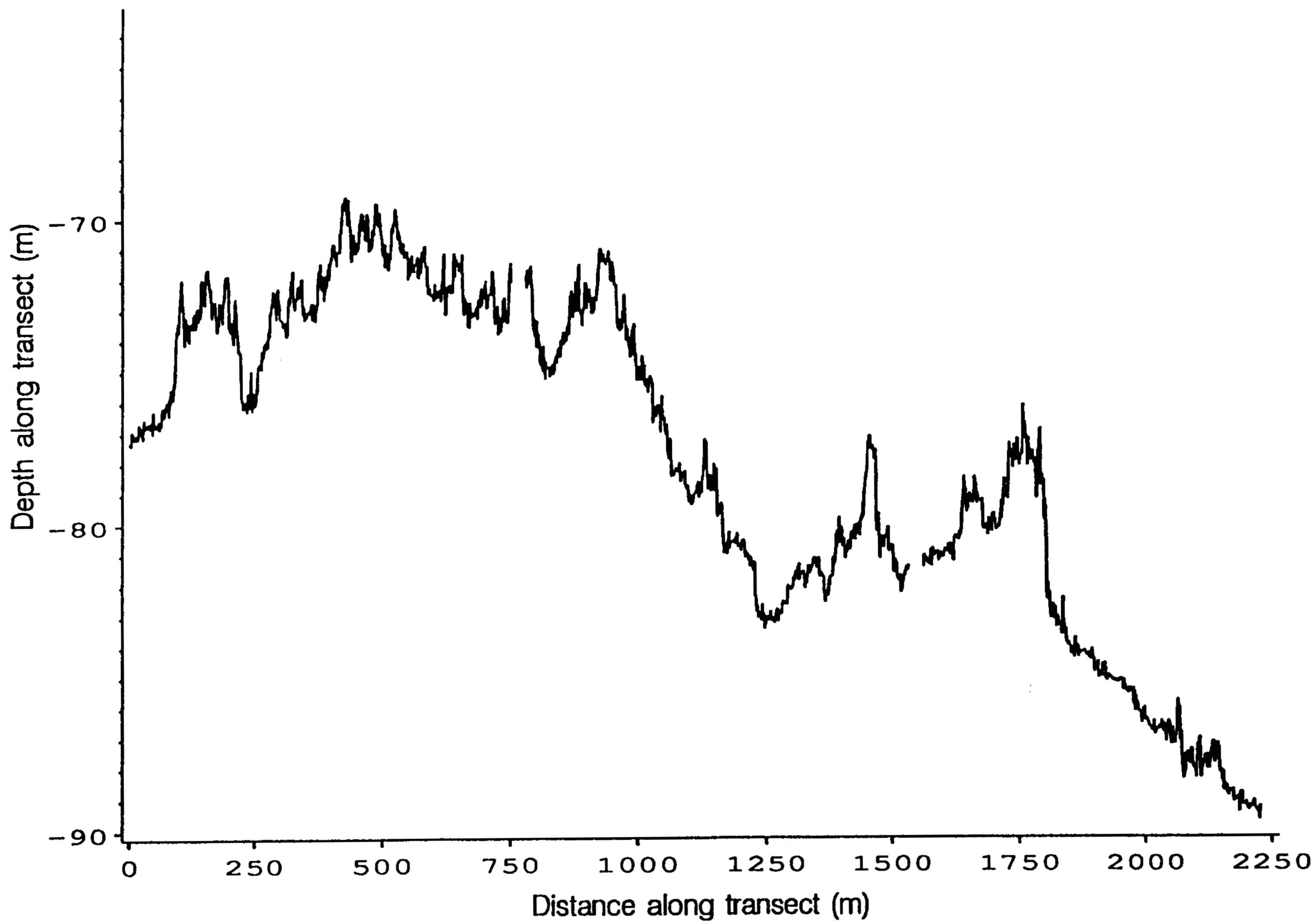

Figure 4. An example of a transect depth profile. Transect 17, Fairweather Ground, 1990.

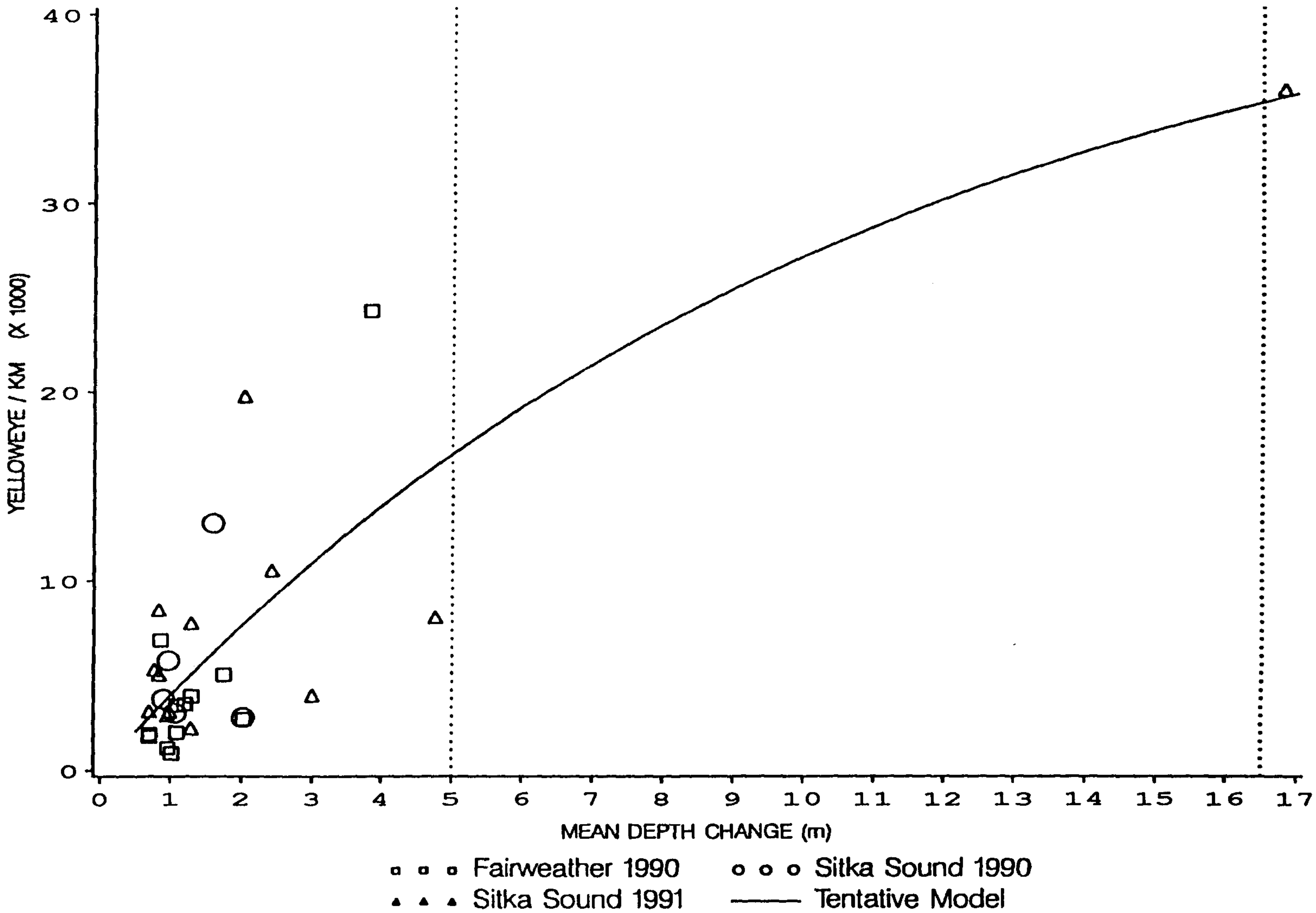

Figure 5. Possible relationship between yelloweye rockfish density and habitat complexity (mean depth difference between points separated by 20 m). Added sampling from areas of intermediate habitat complexity (between dotted lines) is needed.

Table 1. Density of four species of demersal shelf rockfish in Southeast Alaska.

Year	Area	Species	Density (no./km)	95% Confidence Limits	
				Lower	Upper
1990	Fairweather Ground	Quillback	250.36	131.25	369.47
		Rosethorn	3244.20	1811.84	4676.57
		Tiger	927.62	660.39	1194.85
		Yelloweye	2174.36	1461.29	2887.44
	Sitka Sound	Quillback	1585.17	390.58	2779.76
		Rosethorn	10317.18	3635.06	16999.30
		Tiger	392.91	179.79	606.04
		Yelloweye	2675.58	1052.14	4299.03
1991	Sitka Sound	Quillback	2138.04	508.23	3767.85
		Rosethorn	5842.41	3053.75	8631.08
		Tiger	902.64	0.00	1895.09
		Yelloweye	2531.02	1608.57	3453.47