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ROCKFISH INVESTIGATIONS OFF THE COAST OF WASHINGTON

ANNUAL REPORT FOR FY 1980

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National Marine Fisheries Service

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INTRODUCTION

In July 1979 the University of Washington entered into a 3-year contract with NMFS/NOAA to evaluate the utility of several new techniques in assessing shelf rockfish stocks. Toward this end, alternative types of survey equipment were evaluated during FY 79, and a detailed plan of field research was developed for FY 80. The field survey has been successfully implemented since then, and the results are summarized in this report.

The most useful results from the survey arose from the unanticipated encounter of large concentrations of widow rockfish (Sebastes entomelas) off the southern coast of Washington. The information on widow rockfish is quite timely, however, since a large fishery for this species began in 1979. Participation in this fishery requires midwater trawling capability, and it is only in recent years that United States fishermen have geared their vessels for this type of fishing. Since 1976, foreign trawlers have been limited to incidental catches of widow rockfish under the provisions of the Governing International Fishing Agreement between the United States and the nations involved in the whiting and jack mackerel fisheries.

The development of the domestic fishery for widow rockfish has been most impressive in Pacific Marine Fisheries Commission (PMFC) areas 2C and 3A, encompassing the region between Cape Perpetua (44°18′) and Cape Elizabeth (47°20′). Based on status reports prepared for meetings of the International Groundfish Technical Subcommittee, domestic landings of widow rockfish from this area increased from about 578 mt (1,274,000 lb) in 1978 to 2,890 mt (6,372,000 lb) in 1979. In PMFC area 2C (Cape Perpetua-Cape Falcon) alone, landings increased from about 6 mt (13,000 lb) in 1978 to 1,985 mt (4,377,000 lb) in 1979. Preliminary statistics for 1980, suggest that this fishery has continued its rapid growth (Jack Tagart, Washington State Dept. of Fisheries, personal communication).

In view of the importance and rapid development of the widow rockfish resource, and the applicability of sonar mapping/echosounder survey techniques to this species, several options have been proposed for modifying the FY 81 survey to accommodate more intensive research on widow rockfish.

OBJECTIVES

The primary objective of this study was to evaluate the effectiveness of alternative resource assessment methodologies, and improve on current techniques as much as possible. Two steps must be taken to achieve a higher degree of accuracy in rockfish resource assessment.

The first of these involves detailed examination of the microdistribution and schooling behavior of shelf rockfish, so as to be able to control the impact of these factors on resource surveys. This impact is determined by the temporal (diel, seasonal, and annual variations in distribution) and spatial (bathymetric and substrate preference) characteristics of the rockfish populations. The description of these characteristics and incorporation of such information into the survey design is the first order of business in developing accurate estimates (or indices) of rockfish biomass.

The second step involves improvement of survey technology and statistical design. Equipment development was viewed as an essential requirement in this regard.

Conventional echosounders transmit and receive sound from a single transducer. The angle of the sound beam is dependent on the ratio of the wave length to the transducer size and for any given frequency, the larger the transducer, the smaller the beam angle. Since there is only a single transducer with a fixed beam angle, there is always a tradeoff between resolution and sampling volume.

The sector scanning sonar used in this study reduces this limitation since the transducer is made up of several independent elements. Sound is transmitted simultaneously through all elements to form a 200° transmitted beam, but the individual elements are electronically scanned at a high rate (within one pulse length). In effect, the receiver functions as many narrow-beam transducers which integrate the received echo information. This allows both large sampling volume and high angular resolution to be achieved.

Sector scanning sonar allows more effective studies of rockfish distribution and schooling behavior than conventional echosounders or sonars, and is an invaluable tool in employing line transect and line intercept methods (Hewitt et al. 1976; Seber 1980; Burnham et al. 1980) of density estimation to rockfish. By using the sector scanning sonar in conjunction with a conventional echosounder/hydroacoustic data acquisition system, the two systems complimented each other, and their relative utility in rockfish stock assessment could be evaluated directly.

METHODS

Survey Design

All field work was carried out during March 19-April 2, aboard the fishing vessel MUIR MILACH. The MUIR MILACH is an 26 m (86 ft) midwater/demersal trawling vessel that was chartered for 10 fishing days after it became apparent that the University of Washington research vessel ALASKA would not be available for our survey. The vessel characteristics, electronic equipment, and fishing gear are described in Table 1, and it is clear that we were fortunate to obtain a vessel so well-suited to our needs. The midwater trawling experience of the crew and availability of an effective midwater trawling system proved invaluable in helping us to attain our objectives.

The vessel was allowed to fish commercially when not required for survey work, with the stipulation that fishing and unloading days would not be counted as part of the charter period. This worked out well for both parties, since the scientists were able to collect a substantial amount of information during those periods when the vessel was engaged in commercial fishing activities. In addition, unloading days provided an opportunity to make necessary repairs to the sonar equipment, yet not be penalized by loss of research days. The itinerary for the MUIR MILACH is shown in Table 2.

The survey design followed the plan outlined in the FY 79 report, with most of the work being conducted in the survey area off Willapa Bay (Fig. 1). Only one trackline was run in the Cape Flattery Spit area. Extensive concentrations of widow rockfish, herring, and anchovy necessitated a substantial number of mapping runs perpendicular to the trackline to determine the north-south extent of these aggregations. This, together with the frequent need for net sampling for target identification purposes, precluded any significant amount of work outside the Willapa Bay area.

During the period from March 20-25, all research operations were conducted during daylight hours (Table 3). Acoustic sampling was conducted with echosounding and sonar equipment along preplanned tracklines (Fig. 1) until a significant aggregation of fish was detected. The extent of the aggregation along the trackline was then determined, followed by several mapping runs perpendicular to the trackline. Net sampling usually followed, the Polish rope trawl being employed for pelagic concentrations of fish and the Nor′ Eastern otter trawl being employed for near-bottom concentrations. The acoustic sign sampled with the Nor′ Eastern trawl typically consisted of a diffuse but extensive layer near bottom. On March 27, large schools of widow rockfish were encountered near dusk and they become more dense and numerous as the night progressed. Acoustic sampling of these schools continued during the night of March 27/28, until the schools dispersed at dawn. In view of the striking abundance of widow rockfish in the survey area, and their tendency to school at night, nighttime transecting was subsequently intensified, with further work being conducted during the nights of March 28/29 and March 31/April 1 (Table 3).

Tracklines 10, 11, and 16 were all run twice, and both day and night censusing was completed for each.

Acoustic Equipment

All echosounder data were collected using a conventional echosounder/data acquisition system (Fig. 2). An EK-38 scientific sounder was used in conjunction with a 38 kHz transducer with a full beam angle of 11° at -3dB. The transducer was housed in a 2-ft Braincon V fin and towed from a stabilizer pole on the port midships. A pulse length of 0.6 ms was used throughout the survey, and the data collection rate was two transmissions per second. The acoustic signal was monitored with an oscilloscope, recorded in real-time on chart paper and stored on magnetic tape with a TEAC 3440 recorder for subsequent analysis and biomass estimation. Transect paths and fish school locations were recorded on an EPSCO Loran-C plotter.

Sonar data were collected using the C-Tech LSS-68 sector scanning sonar under long-term lease for this project. This sonar has an operating frequency of 75 kHz, and the pulse-length employed usually varied from 0.5 to 2 ms, depending on the depth range selected. The shortest possible pulse length was always used in order to obtain the greatest possible near-bottom resolution of fish targets.

The LSS-68 was always deployed at a 90° tilt angle, perpendicular to the bottom, when collecting transect data (Fig. 3). During fishing operations the sonar was used to locate and track fish schools, and a variety of forward tilt angles were employed. The sonar insonifies a 200° by 9° wedge-shaped field with 10° by 9° angular resolution, and as fine as 15 cm range resolution. Real-time acoustic data are displayed on a 10-inch cathode ray tube (CRT) screen giving the range and bearing of all acoustic targets. This information was recorded on magnetic tape using an RCA CC004 video camera and a video tape recorder.

The LSS-68 frequently malfunctioned during the survey, and it was often necessary to put into port for repairs. The sonar could seldom be operated at full power. After the survey had been completed, the transducer was thoroughly checked at Sound Marine Electronics, and found to be defective. The transducer was subsequently replaced under the warranty provided by C-Tech.

Although the LSS-68 is capable of operating at shorter pulse lengths than the EK-38, increased near-bottom detection will require the development of a more sensitive data recording system. The CRT display was not designed with high near-bottom resolution in mind. In addition, a "ring" of interference was usually present near-bottom on the CRT display, and the near-bottom resolution of the sonar was generally inferior to that of the echosounder. This could have been due to a malfunction in the sonar transducer, however, and the situation may be different on future cruises.

Despite all problems, the sector scanning sonar gave useful results for pelagic schools, and allowed us to continuously census a rectangular area 200-280 m wide, and extending from the surface to about 5 m from the bottom. This contrasts sharply with the cone-like region insonified by the echosounder, which was 11-35 m wide (at 30 and 100 fathoms, respectively) near the base (i.e., the sea bed).

Data Analysis

Echosounding Data

The technique used to estimate biomass from the echosounder data was based on the principle that the acoustic intensity of a signal reflected from fish targets is proportional to the mean individual scattering cross-section of the targets times the number of targets.

The echosounder data were processed with a digital echo integration system (Fig. 4). At "echo integration" (step 5) the data processor was set to measure echo voltages from the surface to bottom in approximately 20 depth intervals of variable thickness. Several near-bottom depth intervals were used to process the data, and rapid changes in bottom slope and/or rolling and pitching by the towed body required manual editing of the integrated output. The limited number of integration depth intervals provided by the INTEG program necessitated varying their thickness. Density estimates were averaged over 12.5 second intervals. The relative densities were converted to absolute values using post-cruise calibration data and assuming a -35 dB target strength. All calculations were based upon the system gain measured with the calibration oscillator at 100 ms (75 m depth). Calibration oscillator data were used to correct deviations of the echo sounders' time varied gain (TVG) from ideal, but bias in the process (approximately 1 dB) may have resulted in slight overestimates of the measurements of fish density below 75 m depth.

Following integration, the acoustic data were reduced to density observations and stored on the PDP 11/45 disk. All erroneous data points (e.g., bottom and surface reverberation) were deleted from the file with the use of a CRT editing routine. Echograms and integration logs were employed to identify measurements which were suspected to contain bottom and/or surface reverberation, etc.

The nekton biomass data were grouped by three categories: total, layer, and school. Echograms were used to determine length and thickness (in meters) of the layer and school concentrations. The integration output was time-linked to the echogram record for density estimation. Often, integration categories (depth or length) did not correspond to the school or layer dimensions, requiring interpolation between adjacent estimates. This process was carried out manually and was very time consuming. A computer-based school data processing system should be developed for future work of this nature.

The final echosounder data file included date, time, transect/mapping run I.D. number, vessel speed, compass bearing, bottom depth, bottom slope, mean school depth, school thickness, total density (g/m^3), density within schools, and density within layers. The information was coded by 12.5 sec intervals, and for 20 variable depth strata. This file was created using computer cards and was placed on a CDC 6400 disk file for further analysis.

Sonar Data

The LSS-68 sonar display gives a CRT representation of the range and bearing of all targets (Fig. 3). Video tapes of the sonar display gave a permanent record of the survey data, which was analyzed on a video monitor using the slow motion and stop action features available with the Panasonic 404 video recorder.

The video tape information enabled us to measure school depth, distance off bottom, thickness, width, radial distance from vessel, perpendicular distance off transect, degrees off transect and bearing (Fig. 5). Measurements were made for all schools identified as widow rockfish which had a length greater than 10-15 m. School length was calculated by relating the number of pulses received from each target to the number number of sonar pulses per minute and the corresponding vessel speed at a particular time.

Data were also collected on schools other than widow rockfish, particularly if net sampling led to conclusive target identification. This was done in an effort to explore the usefulness of sector scanning sonar in discriminating the school characteristics of those species.

Biomass Estimates

Several estimates of widow rockfish biomass were made using echosounder and sonar information collected in the "widow rockfish subarea" delineated in Fig. 1. This area was selected because it encompassed the bathymetric range (70-100 fm) occupied by widow rockfish and was the only region in the Willapa Bay study area where this species was censused during darkness, the period when widow rockfish schools were encountered most frequently.

A substantial part of the sampling in this area was conducted during daylight hours, and the survey design would have to be changed substantially to obtain widow rockfish biomass estimates that are accurate. The estimates in this report were made only to evaluate the applicability and precision of several alternative methods of determining the biomass of shoaling pelagic rockfish.

Biomass estimates were obtained from echosounder data by the traditional approach of extrapolating integration data on density (g/m^2) along the tracklines to the entire "widow rockfish subarea." Echosounder data were also employed to estimate the biomass of individual schools for use in conjunction with sonar estimates of school density (i.e., schools/nm^2).

Two subsets of sonar measurements were identified to maximize usage of these data: 26 nighttime sightings of widow rockfish schools located on transects 10 and 11, (Fig. 1), and 73 sightings obtained during a single mapping run during the night of March 27/28. Although the mapping run (Fig. 6) was not randomly located, the large number of sonar sightings made along it allowed a comparison of line transect and line intercept methods of estimating school density.

Biomass estimates were obtained using line transect methods (Appendix 1) to estimate school density (schools/nm^2) along the transects, multiplying this by an estimate of mean school biomass, then extrapolating the result to the entire "widow rockfish subarea." Mean school biomass was determined by using echosounder data on school thickness, school length, and density within schools (kg/m^3) in conjunction with a mean school width estimate from the sector scanning sonar. The exact relation used was:

$$\hat{b}_i = 12.5 \, v n_i \, t_i \, \bar{w} \, d_i$$

where $\hat{b}_i$ = biomass of school i (g)

v = vessel speed (m/sec)

n_i = number of 12.5 sec intervals integrated for school i

t_i = thickness (m) of school i, as determined from echogram

$\bar{w}$ = mean school width (m) as determined from sonar data

d_i = mean integration density (g/m^3) over the n_i intervals integrated.

Only those schools which intersected the vessel's path were used to estimate mean school width.

Biological Data

All catches of less than 2,000 pounds were completely sorted by species, then weighed on a platform scale. The entire catch of the dominant rockfish species was usually retained for a biological sample when catches were small.

Deck sampling proved difficult for larger catches since the net reel for the midwater trawl was located forward of the MUIR MILACH's deck area, and the deck had to be clear when setting or retrieving the net. Catch estimates for hauls greater than 2,000 pounds were obtained from the vessel captain. A biological sample consisting of four baskets of widow rockfish from the first, middle, and last part of the catch brought aboard was collected from haul 10, but on all other widow rockfish hauls the biological sample consisted of 1-2 baskets selected from the catch at random.

Size and sex data were collected for all fish in the biological sample, and a sample of otoliths (stratified by size-sex group) was collected from the widow rockfish in haul 10. The otoliths collected were subsequently sent to the NMFS Southwest Fisheries Center, Tiburon lab, where they were read by Dr. W. H. Lenarz.

The number of individuals sampled for length, sex and age composition studies is shown below:

Species	No. of length-sex observations	No. otoliths collected
Widow rockfish	508	109
Yellowtail rockfish	37	
Black rockfish	100	
Greenstriped rockfish	46	
Sablefish	161	

Stomachs were collected from widow, yellowtail, and black rockfish on an opportunistic basis. The methods used in post-survey analysis of gut contents, together with a preliminary report on the results, are outlined in Appendix 2.

RESULTS

Catch Data

Information on the date, time, and location of each haul, together with the catch data for that haul is given in Table 4. Widow rockfish clearly dominated the total trawl catch (Table 5), but were never captured with the Nor′ Eastern trawl.

Widow and yellowtail rockfish represented nearly 100% of the midwater trawl catch, making up 99 and 1% of the total, respectively. Widow rockfish were caught in hauls 10, 18, 20, and 21, all located in the "widow rockfish subarea" (Fig. 1). All four hauls were made in the evening or at night over bottom depths ranging from 76 to 100 fathoms. The fish were encountered in numerous, densely packed midwater schools ranging from 15 to 40 fm off bottom.

Limited quantities of yellowtail rockfish were also caught with the midwater trawl, the largest of these catches (400 lb), being associated with the 60,000 lb widow rockfish catch made on haul 10. For the most part, species of rockfish other than widows did not appear to form large aggregations that were far enough off bottom to be detected acoustically and sampled with a midwater trawl.

Spiny dogfish was the dominant species in haul 14, indicating that significant midwater concentrations of this species were present during the day. The relative efficiency of the midwater trawl in capturing and retaining the diverse species comprising the total nekton biomass is unknown, and the relative abundance of these species cannot be assessed quantitatively. However, field observations and catch data suggest that the northern anchovy, *Engraulis mordax*; Pacific herring *Clupea harengus pallasi*; eulachon, *Thaleicthys pacificus*; and squid *Loligo opalescens*, represented substantial portions of the total nekton biomass.

Spiny dogfish was the leading species in bottom trawl catches (Table 5), and there were small catches of black and yellowtail rockfish. The Nor′ Eastern bottom trawl was deployed in areas where near-bottom concentrations of fish had been detected acoustically, and the catches obtained suggest that near-bottom aggregations of rockfish were sparse and scattered during the survey period.

Biomass Estimates

Echo integration data collected with the echosounder (Table 6) indicated that mean nekton density on transects 10 to 14, weighted by transect length, was 16.5 g/m^2 during the day (1507-1648) and 9.3 g/m^2 at night (1947-2123). Comparisons of school, layer and total biomass indicate that the distribution of the nekton underwent a substantial change at night, with the proportion of the total biomass found in schools declining from 88% to 41%.

Midwater trawl catches for the Willapa area as a whole suggest that many species including herring, anchovy, squid and dogfish are aggregated in the pelagic zone during daylight hours, while nighttime midwater trawl catches were dominated by widow rockfish. A realistic survey design for widow rockfish would have restricted all survey activities to the hours of darkness, when widow rockfish are schooled and the other species constitute a relatively small proportion of the biomass sampled acoustically.

Since only a limited amount of nighttime sampling took place during this survey, the biomass estimates for widow rockfish must be suspect. Estimates for the widow rockfish subarea have been developed, however, so that echosounder and sonar results can be compared. These estimates are obtained by using night-time data collected on transects 10 and 11, then extrapolating the results to the entire widow rockfish subarea.

The biomass estimate from the echosounder data was obtained from:

$$\hat{D} = \frac{\sum_{i=1}^{R} \ell_i \hat{D}_i}{\sum_{i=1}^{R} \ell_i} = \frac{\sum_{i=1}^{R} \ell_i \hat{D}_i}{L}$$

where ℓ_i = length of transect i

$\hat{D}_i$ = density estimate (g/m^2) for transect i

R = number of transects

L = total transect length for the R transects censused

$$\text{and } (\hat{B}) = \left(\frac{A}{10^6}\right) \quad (\hat{D}) \; .$$

$\hat{B}$ = biomass in metric tons

A = total area in widow rockfish subarea = 83,436,700 m^2

The variance of this estimate was estimated from:

$$\text{Var } (\hat{D}) = \frac{\sum_{i=1}^{R} \ell_i \, (D_i - \hat{D})^2}{L(R-1)}$$

and

$$\text{Var } (\hat{B}) = \left(\frac{A}{10^6}\right)^2 \quad \text{Var } (\hat{D}).$$

The resulting estimate of widow rockfish biomass $(\hat{B})$ was 778 metric tons and the coefficient of variation $\left(\frac{\sqrt{\text{Var}(\hat{B})}}{\hat{B}}\right)$ for this estimate was 0.16 or 16% of $\hat{B}$.

The nighttime schools of widow rockfish that were examined with the sonar were all distributed well off-bottom, and were generally small enough that the entire school was encompassed within the sonar beam (Table 7).

Sonar data for transects 10 and 11 gave a school density estimate of 110.7 widow rockfish schools per nm^2 (Table 8). This was combined with the mean of the biomass estimates for 34 schools censused at night in the widow rockfish subarea (0.27 mt per school) to estimate biomass per nm^2. This was then extrapolated to the entire widow rockfish subarea to obtain a biomass estimate of 726 metric tons. This compares favorably with the biomass estimate obtained from the echosounder data, although it is on the high side if only 41% of the biomass censused with the echosounder was concentrated in schools. If this is considered, the estimate of school biomass from the echosounder data becomes .41 x 778 = 319 metric tons. The number of schools that the sonar estimates were based on was quite low however, and the resulting school density estimate had a relatively high variance. This, together with the substantial variance that is probably associated with the estimate of mean school biomass is such that the discrepancy between echosounder and sonar estimates of biomass are well within the limits of sampling error.

The school density estimates for the nonrandom run data were based on a greater number of schools, and the variability associated with these density estimates is far lower than that associated with the transect data (Table 8). In addition, there was relatively good agreement between line transect and line intercept estimates of density. These results indicate that the precision of sonar density estimates may be quite high if a more extensive nighttime survey is conducted.

Biological Studies

The size composition (Fig. 7) and age composition (Fig. 8) of widow rockfish catches made during the MUIR MILACH survey were determined from biological data collected from hauls 10, 18, 20, and 21. Length frequency samples for individual hauls were weighted by the total catch from which the samples were taken to obtain the information shown in Fig. 7.

The otolith collections were stratified by size and sex, and an age-length key was used in conjunction with the weighted size composition data to determine age composition. A separate age-length key was constructed for each sex, and the results combined to obtain the age composition data shown in Fig. 8.

Both size and age composition data show that the catches were dominated by the older, adult portion of the stock. Widow rockfish males mature at about 37 cm, while females mature at 38 cm (Westrheim 1975), so that few juveniles were captured in the survey area. Like most of the other rockfish species inhabiting the continental shelf and slope in this area (e.g., yellowtail rockfish, canary rockfish, silvergray rockfish, Pacific ocean perch), the juveniles are spatially isolated from the adults. Nine-year-olds (1971 year-class) and ten-year-olds

(1970 year-class) constituted the bulk of the catches made during the survey.

The results from food habit studies initiated during the survey (Appendix 2) were quite informative despite the relatively low level of effort that went into them. It was found that widow rockfish fed largely on zooplankton (primarily euphausiids), while black and yellowtail rockfish were more piscivorous. The food habit studies also indicated that widow rockfish did not feed significantly at night, indicating that the nocturnal schooling behavior that characterized this species during the survey had little to do with feeding strategy.

DISCUSSION

The field work and analysis carried out in 1980 have demonstrated that sonar mapping, line transect, and line intercept methods are all applicable to stock assessment of pelagic fishes. Substantial improvement in the methods used to obtain school by school estimates of biomass should be considered, however, if the techniques employed are to be implemented on a larger scale.

The results have also shown that separating the total nekton biomass into its species components is a difficult problem, requiring intensive study of diurnal changes in distribution and behavior. Unless a single species survey situation can be created, net sampling techniques are inadequate in quantifying the relative abundance of species such as herring, anchovies, and squid in the nekton biomass. Analysis of this problem using the 1980 survey data is still in progress, and a time-linked merging of the echosounder, sonar, and net sampling data for the entire Willapa survey area is planned. Analysis of this merged data will allow a more detailed examination of school characteristics by species, and direct comparisons of measurements obtained with sonar and echosounder data.

Several modifications in survey design are suggested by the 1980 survey results, depending on the objectives forseen in 1981. If widow rockfish are to become the main target of the survey, nighttime surveys need to receive greater emphasis, and the survey should be restricted to the continental slope region between 70 and 120 fathoms. Daytime surveys aimed at yellowtail and canary rockfish could be continued, but the relatively low encounter rate for off-bottom schools of these species suggests that this work should be de-emphasized. On the other hand, large off-bottom schools of these species definitely occur (Bob Demory, ODF&W; Marty Nelson, NMFS; personal communication), and the survey period (or area) may not have been broad enough to provide a representative portrayal of their schooling behavior.

If further investigation of these species indicates that they are located in the near-bottom region most of the time, then modification of the sonar equipment so that it is more effective in the near-bottom region and/or development of a deep-towed, high frequency hydroacoustic system may be necessary to survey them properly.

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Table 1. Vessel characteristics for the MUIR MILACH.

Length:	26 m (86').
Power:	Two 340 hp GMC engines, two Kort nozzles. Effective power is approximately 800 hp.
Electronics:	Krupp-Atlas Fischfinder 701 (33 kHz). Si-Tex sounder (backup). Furuno netsounder system. Northstar 6000 Loran C. Epsco Loran C with plotter.
Winches:	Marco WT 202 "Tuf-trawler" winches.
Midwater Trawl:	Polish rope trawl (No. 7 Gourock Rope Wing). 233'8" headrope and footrope. 171'4" breastline. 60' vertical opening. 4.5" mesh in cod-end. 4.5 square meter Superbrub doors. 40 fm bridles.
Bottom Trawl:	NWAFC "Nor' Eastern" Otter Trawl. Construction and rigging similar to that described in Gunderson and Sample (1980), but middle bridle 9" longer. 6' x 9' (2500 lb) trawl doors.

Table 2. Vessel itinerary for the MUIR MILACH rockfish survey.

3/15-3/18	Installed sonar and loaded vessel.
3/19	Left Bellingham, checked out EK-38 echosounder and LSS-68 sonar.
3/20	Ran transect 1 on Cape Flattery spit.
3/21-3/23	Ran transects 2-6 in Willapa area.
3/24	Unloaded catch and repaired LSS-68.
3/25	Ran transects 7 and 8 in Willapa area.
3/26	Exchanged vessel crew in Westport.
3/27	Ran transects 6, 9, and 10 in Willapa area.
3/28	Ran transect 16 in Willapa area, put into Ilwaco to unload catch and repair LSS-68.
3/29	Ran transects 15 and 16 in Willapa area.
3/30	Unloaded catch, exchanged scientific crew, and repaired LSS-68 in Ilwaco.
3/31-4/2	Ran transects 10-14 in Willapa area.
4/2	Unloaded vessel.

Table 3. Dates and times of day that transects were run during MUIR MILACH rockfish survey.

Transect	Date run	Time span	Day/night
1	3/20	1030-1440	day
2	3/21	0740-1217	day
3	3/21, 3/22	1345-1711, 0755-1220	day
4	3/22	1240-1800	day
5	3/23	0700-1048	day
6	3/23, 3/27	1100-1730, 1020-1300	day
7	3/25	1200-1840	day
8	3/25	0900-1120	day
9	3/27	1500-1700	day
10	3/27, 3/27, 3/31	1720-2000, 2000-2123, 1507-1648	dusk, night, day
11	3/31, 4/1	0640-1648, 2020-0130	day, night
12	4/1	0825-1127	day
13	4/1	1127-1630	day
14	4/2	0900-1111	day
15	3/29	1417-1616	day
16	3/28-29, 3/29	2340-0529, 0630-1340	night, day

Table 4. Summary of trawl station and catch data for MUIR MILACH rockfish survey. Trawl type 1 - midwater trawl, trawl type 2 - bottom trawl.

Haul no.	Date	Start position Lat (N)	Start position Long (W)	Trawl type	Time of day	Average depth (fm) gear/bottom	Duration (min)	Catches (lb) of rockfish: Widow	Yellow-tail	Redstripe	Canary	Black	Green striped
1	3-20	48°10' 4"	125°35'5"	1	1555	75/88	24			15.0			
2	3-21	46°46' 0"	124°36'0"	2	1740	67/67	2[1]						
3	3-22	46°44' 2"	124°38'2"	1	0940	60/73	41		14.0				
4	3-22	46°44' 1"	124°48'2"	1	1404	114/114	29		3.0				
5	3-23	46°40 1"	124°17'3"	2	1303	33/33	20		32.0		13.0	23.0	
6	3-23	46°40' 4"	124°37'1"	1	1819	70/82	48			7.0			
7	3-25	46°36' 5"	124°29'3"	1	1544	40/60	75		9.0				
8	3-25	46°38' 0"	124°17'5"	2	1900	37/37	25		76.0			93.0	
9	3-27	46°39' 6"	124°39'4"	1	1135	68/80	28			.3			
10	3-27	46°31' 3"	124°30'2"	1	2238	60/100	43	60,000.0	400.0				
11	3-29	46°19' 4"	124°33'2"	1	0438	42/75	18						
12	3-29	46°19' 6"	124°34'4"	1	0829	70/82	19			1.5			
13	3-29	46°20' 0"	124°18'0"	1	1233	32/42	8		27.0			5.5	
14	3-31	46°30' 1"	124°29'5"	1	0807	70/90	20						
15	3-31	46°28' 0"	124°27'0"	2	1057	64/64	20						.5
16	3-31	46°28' 8"	124°27'0"	2	1153	60/60	37		2.5		13.0		35.0
17	3-31	46°29' 5"	124°24'2"	1	2125	20/51	10						
18	4-1	46°30' 4"	124°29'2"	1	0025	45/76	35	2,000.0					
19	4-1	46°25' 0"	124°17'5"	2	1229	36/36	35		23.0			258.0	
20	4-1	46°23' 5"	124°34'8"	1	1802	65/95	45	7,500.0					
21	4-1	46°24'58"	124°32'4"	1	2030	70/85	15	7,500.0					
Total								77,000.0	586.5	23.8	26.0	379.5	35.5

[1] Net damaged.

Table 4. Summary of trawl station and catch data for MUIR MILACH rockfish survey. Trawl type 1 - midwater trawl, trawl type 2 - bottom trawl - continued.

Haul no.	Date	Start position Lat (N)	Start position Long (W)	Trawl type	Time of day	Average depth (fm) gear/bottom	Duration (min)	Anchovies	Herring	Pacific tomcod	Chinook salmon	Dogfish	Sablefish	Lingcod	Sand sole	Petrale sole	Sanddabs	English sole	Rex sole	Dover sole	Big skate	Eulachon	Loligo opalescens	Misc.
								Catches (lbs) of selected species																
1	3-20	48°10' 4"	125°35'5"	1	1555	75/88	24		2.0															
2	3-21	46°46' 0"	124°36'0"	2	1740	67/67	2[1]																	
3	3-22	46°44' 2"	124°38'2"	1	0940	60/73	41		.5														.1	5.0
4	3-22	46°44' 1"	124°48'2"	1	1404	114/114	29		2.0														.1	
5	3-23	46°40 1"	124°17'3"	2	1303	33/33	20	7.0		4.0		54.0			12.0	3.0	16.0	29.0	2.0		21.0			2.0
6	3-23	46°40' 4"	124°37'1"	1	1819	70/82	48		39.0														8.0	
7	3-25	46°36' 5"	124°29'3"	1	1544	40/60	75	52.0	1.0				1.0									.1	1.0	
8	3-25	46°38' 0"	124°17'5"	2	1900	37/37	25			2.0	6.0	100.0			1.0	2.0	11.0	19.0	7.0		37.0			
9	3-27	46°39' 6"	124°39'4"	1	1135	68/80	28		9.0														.1	
10	3-27	46°31' 3"	124°30'2"	1	2238	60/100	43																	
11	3-29	46°19' 4"	124°33'2"	1	0438	42/75	18		3.0															
12	3-29	46°19' 6"	124°34'4"	1	0829	70/82	19		.1		9.0		.5										.1	9.5
13	3-29	46°20' 0"	124°18'0"	1	1233	32/42	8	4.0			7.0												.1	
14	3-31	46°30' 1"	124°29'5"	1	0807	70/90	20					48.0												
15	3-31	46°28' 0"	124°27'0"	2	1057	64/64	20		3.0			6.0				4.0	5.0	2.0	4.5	6.0		.1		
16	3-31	46°28' 8"	124°27'0"	2	1153	60/60	37	115.0	143.0			752.0	126.0	156.0		230.0	12.0	29.0	33.0	13.0		7.0	11.0	4.0
17	3-31	46°29' 5"	124°24'2"	1	2125	20/51	10																	
18	4-1	46°30' 4"	124°29'2"	1	0025	45/76	35																	
19	4-1	46°25' 0"	124°17'5"	2	1229	36/36	35	54.0	.1	11.0	2.0	357.0			65.0	3.0	35.0	45.0	46.0	1.0	84.0	.5		2.7
20	4-1	46°23' 5"	124°34'8"	1	1802	65/95	45																	
21	4-1	46°24'58"	124°32'4"	1	2030	70/85	15																	
Total								232.0	202.7	17.0	24.0	1,317.0	127.5	156.0	78.0	242.0	79.0	124.0	92.5	20.0	142.0	7.7	20.5	23.2

[1] Net damaged.

Table 5. The species of fish (and other nekton) captured by subsampling acoustic targets with midwater and bottom trawls, ranked by percent weight in catch.

Scientific name	Common name	Midwater trawl		Bottom trawl		Total	
		kg	%	kg	%	kg	%
Sebastes entomelas	Widow rockfish	34,926	99	0	0	34,926	95
Squalus acanthias	Spiny dogfish	22	*	576	38	598	2
Sebastes flavidus	Yellowtail rockfish	204	1	62	4	266	1
Sebastes melanops	Black rockfish	3	*	170	11	173	*
Eopsetta jordani	Petrale sole	0	0	110	7	110	*
Engraulis mordax	Northern anchovy	25	*	80	5	105	*
Clupea harengus pallasi	Pacific herring	25	*	67	5	92	*
Ophiodon elongatus	Lingcod	0	0	71	5	71	*
Raja binoculata	Big skate	0	0	64	4	64	*
Anoplopoma fimbria	Sablefish	1	*	58	4	59	*
Parophrys vetulus	English sole	0	0	56	4	56	*
Glyptocephalus zachirus	Rex sole	0	0	42	3	42	*
Citharichthys sordidus	Pacific sanddab	0	0	36	2	36	*
Psettichthys melanostictus	Sand sole	0	0	35	2	35	*
Sebastes elongatus	Greenstriped rockfish	0	0	16	1	16	*
Sebastes pinniger	Canary rockfish	0	0	12	1	12	*
Sebastes proriger	Redstripe rockfish	11	*	0	0	11	*
Oncorhynchus tshawytscha	Chinook salmon	7	*	4	*	11	*
Loligo opalescens	Squid	4	*	5	*	9	*
Microstomus pacificus	Dover sole	0	0	9	1	9	*
Microgadus proximus	Pacific tomcod	0	0	8	1	8	*
	Jellyfish and Salps	*	*	4	*	4	*
Thaleichthys pacificus	Eulachon	*	*	3	*	3	*
Torpedo californica	Pacific electric ray	0	0	3	*	3	*
Platichthys stellatus	Starry flounder	0	0	2	*	2	*
Atheresthes stomias	Arrowtooth flounder	0	0	1	*	1	*
Cymatogaster aggregata	Shiner perch	0	0	1	*	1	*
Peprilus simillimus	Pacific pompano	0	0	1	*	1	*
Sebastes spp.	Unidentified juv. rockfish	0	0	1	*	1	*
----	Miscellaneous	0	0	1	*	1	*
Total catch		35,228	100	1,498	98	36,726	98

*Trace (less than 1 kg or 1%)

Table 6. Density estimates from echo integration data, by transect.

Diel period	Transect number	Length (m)	Density (g/m^2)
Day	10	4,540	1.69
Day	11	2,594	34.55
Day	12	3,891	5.20
Day	13	4,002	1.19
Day	14	5,374	39.92
Night	10	4,540	8.19
Night	11	2,594	11.30

Table 7. Width, length, and thickness of widow rockfish schools intersecting the "run" line (Figure 6), together with information on their location in the water column.

School No.	Width (m)	Length (m)	Thickness (m)	Dist. off bottom (fm)	Bottom depth (fm)	Dist. from surface (fm)
1	44	21.3	16	20	93	73
2	18	38.3	8	35	103	68
3	50	49.7	16	36	98	62
4	60	71.0	22	37	103	66
5	34	38.3	8	56	98	42
6	36	66.7	10	38	106	68
7	48	65.3	10	41	102	61
8	64	22.7	10	36	113	77
9	56	45.4	16	22	93	71
10	96	141.9	20	24	93	69
11	48	71.0	14	38	98	60
12	30	53.9	12	44	98	54
13	46	212.8	12	49	98	49
14	42	46.8	8	25	99	74
15	64	343.4	28	36	99	63
16	52	141.9	24	56	107	51
17	46	99.3	20	54	107	53
$\bar{x}(s)$	49.1(17.1)	90.0(82.2)	14.9(6.1)	38.1(11.3)	100.5(5.5)	62.4(9.8)
Coefficient of variation	.35	.91	.41	.30	.05	.16

Table 8. Summary of estimates of school density ($\hat{D}$) for widow rockfish, based on sonar data.

	$\hat{D}$ (schools/nm^2)	Standard error	Coefficient of variation
Transect data			
26 schools, 2 transects			
Line transect estimate	110.7	95.1	.86
Non-random run data			
73 schools, 1 transect			
Line transect estimate	338.6	54.4	.16
Line intercept estimate	248.9	25.3	.10

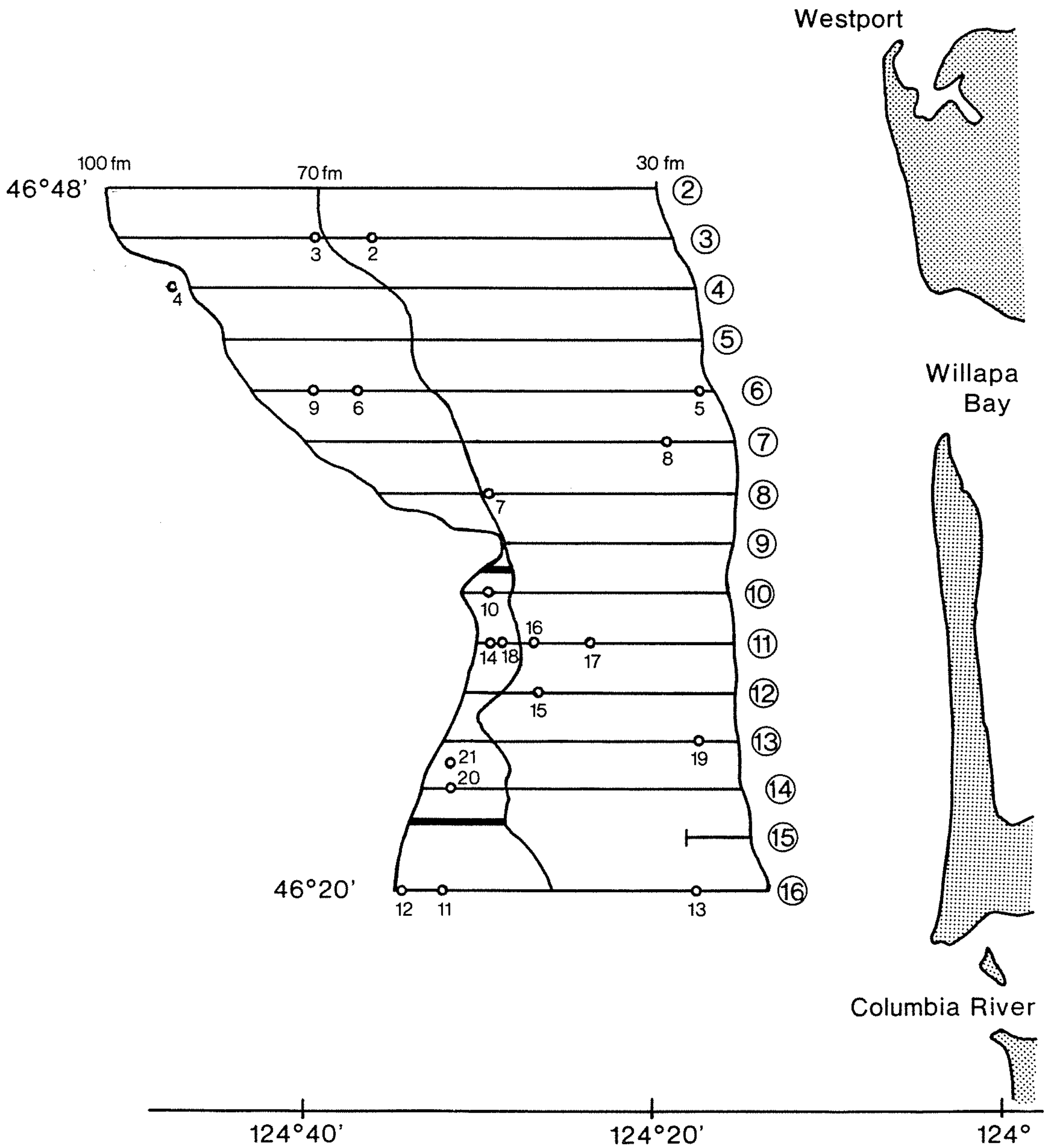

Figure 1. Chart showing transect lines run during the MUIR MILACH rockfish survey. The location of each sampling haul is indicated by an open circle, and the "widow rockfish subarea" is delineated by heavy lines.

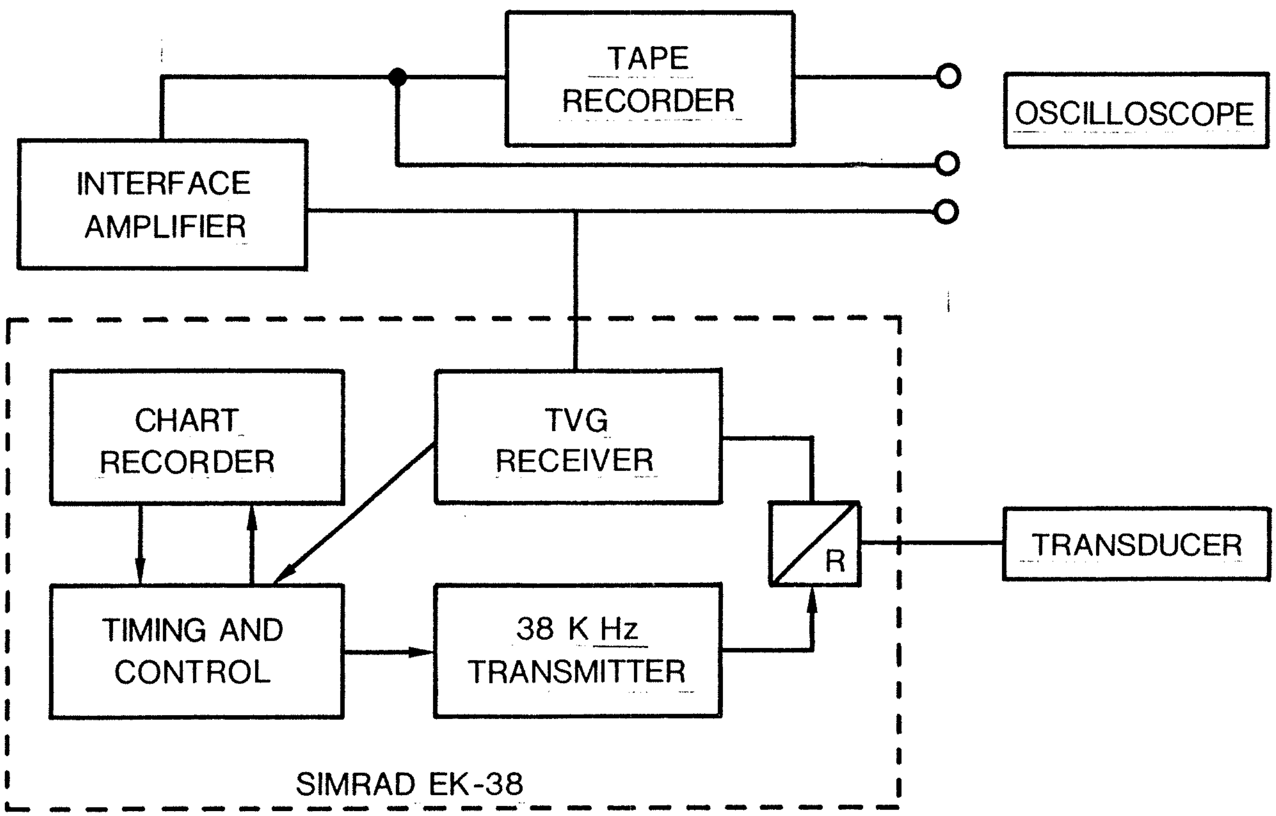

Figure 2. Block diagram of the echosounder data acquisition system.

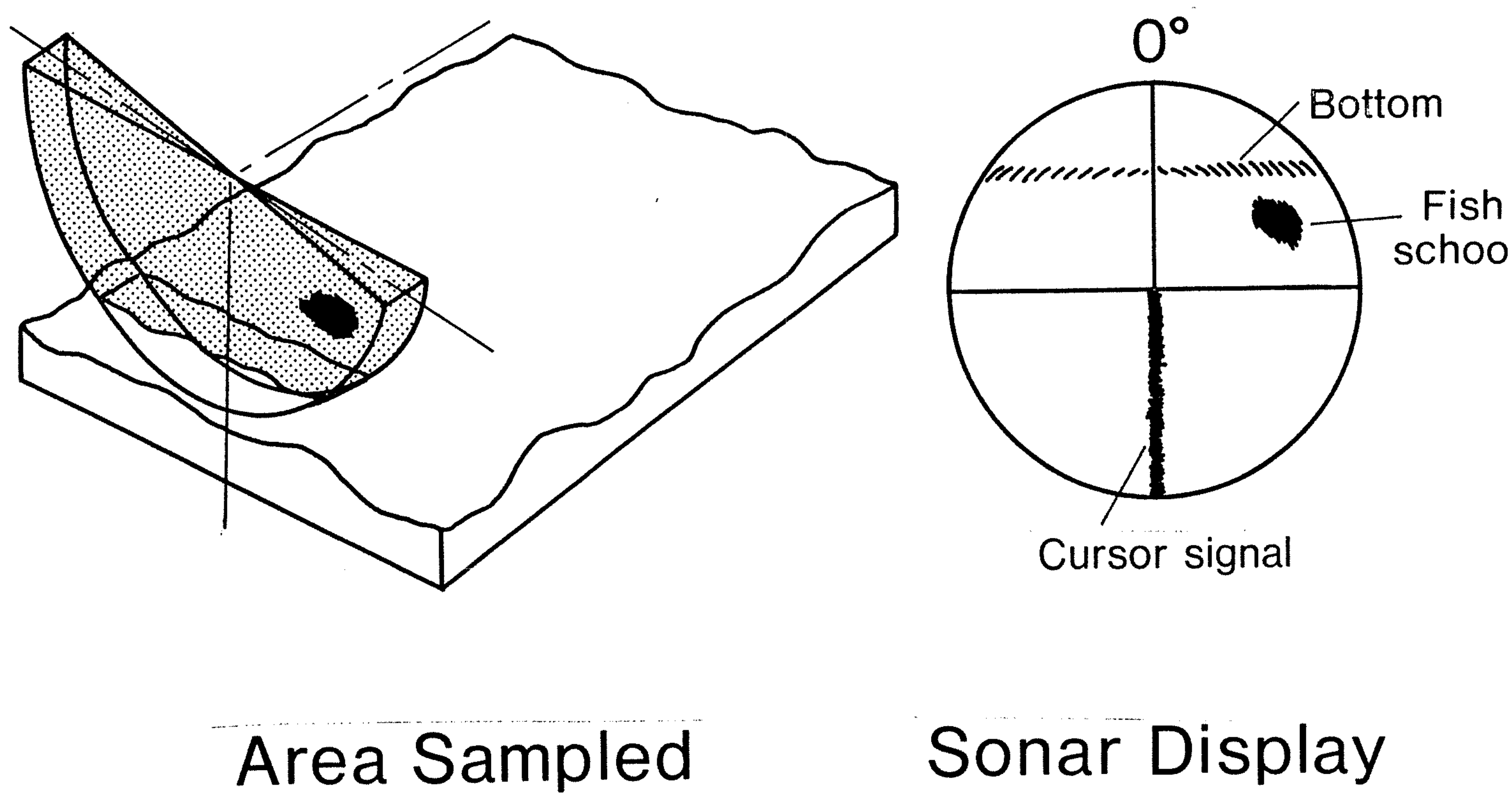

Figure 3. Area sampled by the LSS-68 sonar, showing the location of a fish school in the beam pattern and the corresponding CRT display for that school.

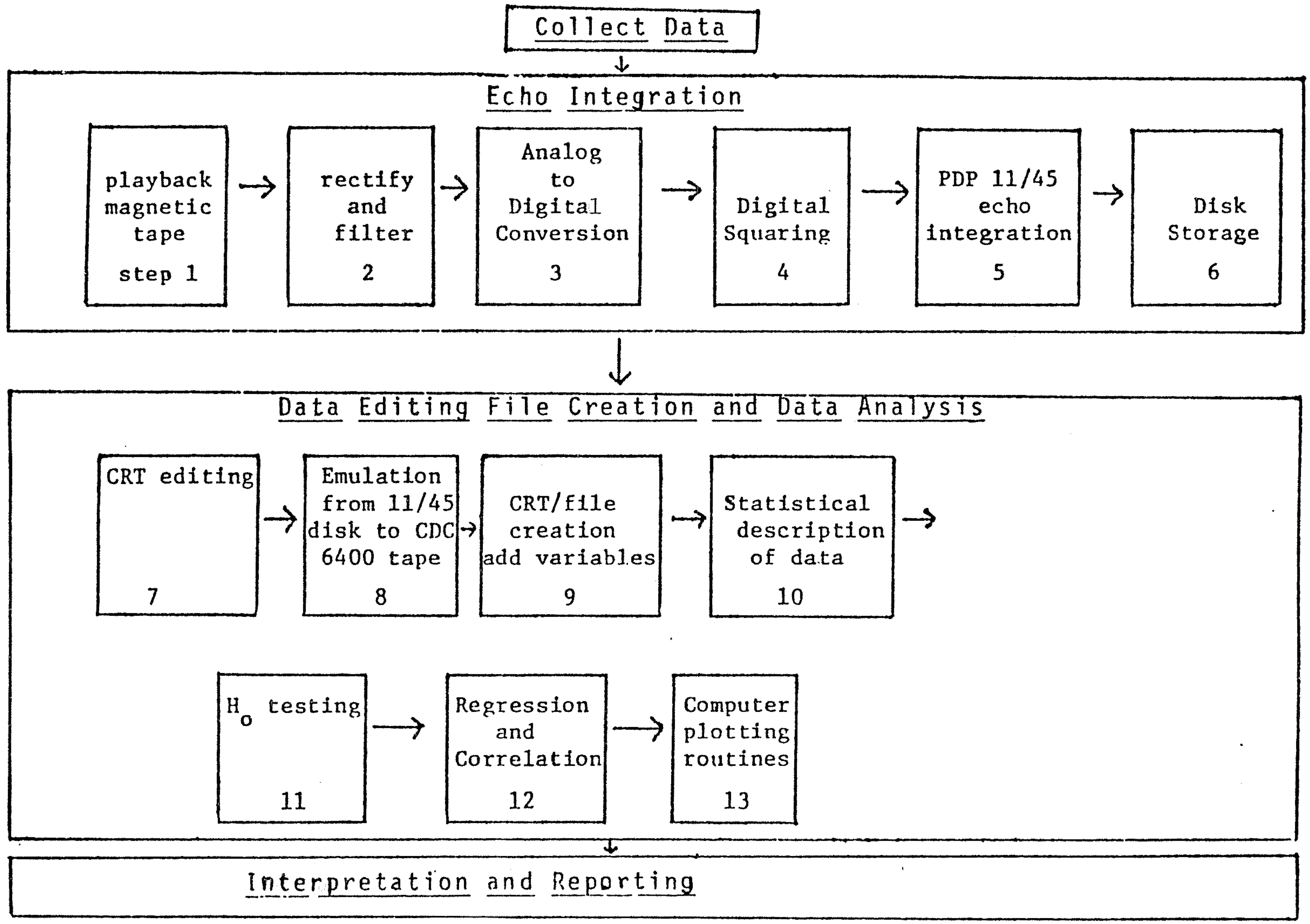

Figure 4. Block diagram of the reduction, editing, file creation, and statistical analyses of acoustic data.

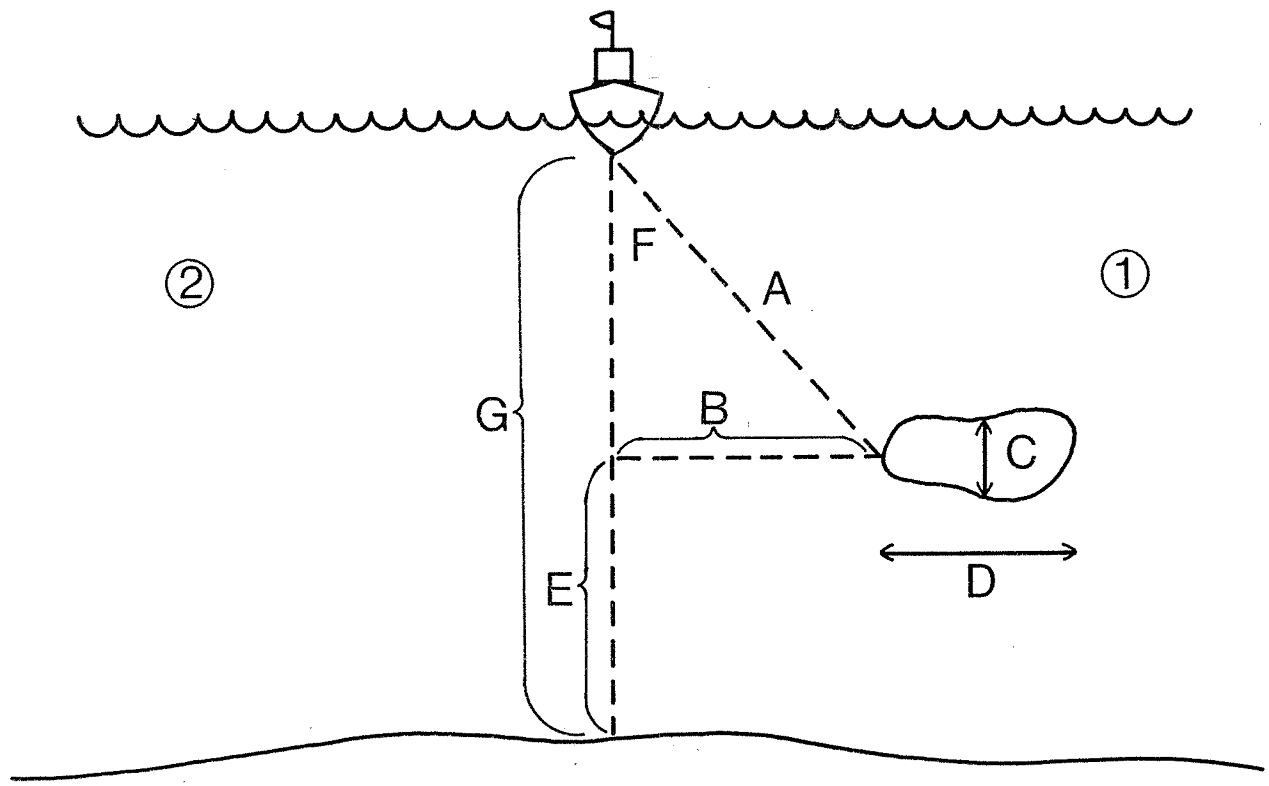

Figure 5. Data collected from video tape recording of the sector scanning sonar display: A = radial distance from vessel, B = perpendicular distance off transect, C = thickness at center of school, D = maximum school width, E = distance off bottom, F = degrees off transect, G = bottom depth, 1 = port side bearing, 2 = starboard side bearing.

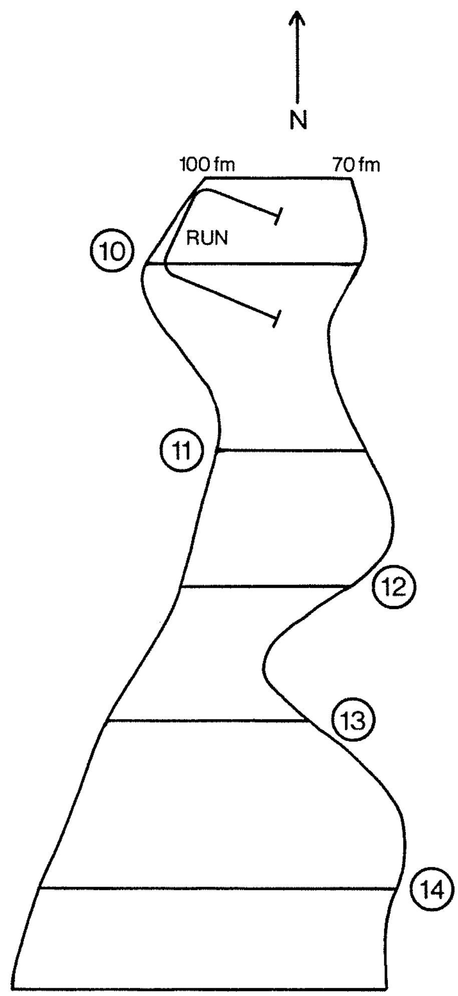

Figure 6. Expanded diagram of the "widow rockfish subarea," showing the location of the mapping run made during the night of March 27/28.

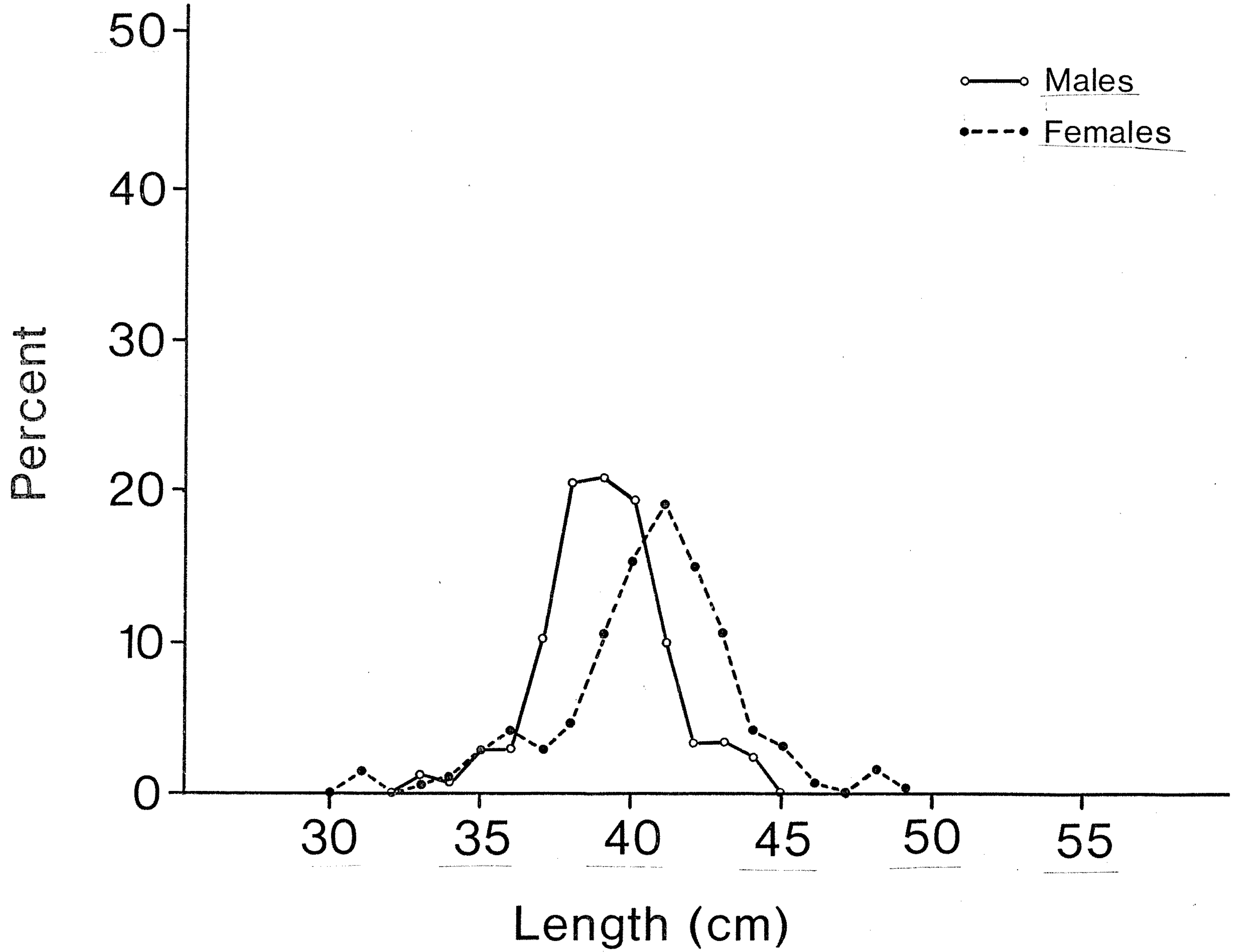

Figure 7. Size composition of widow rockfish caught during the MUIR MILACH survey.

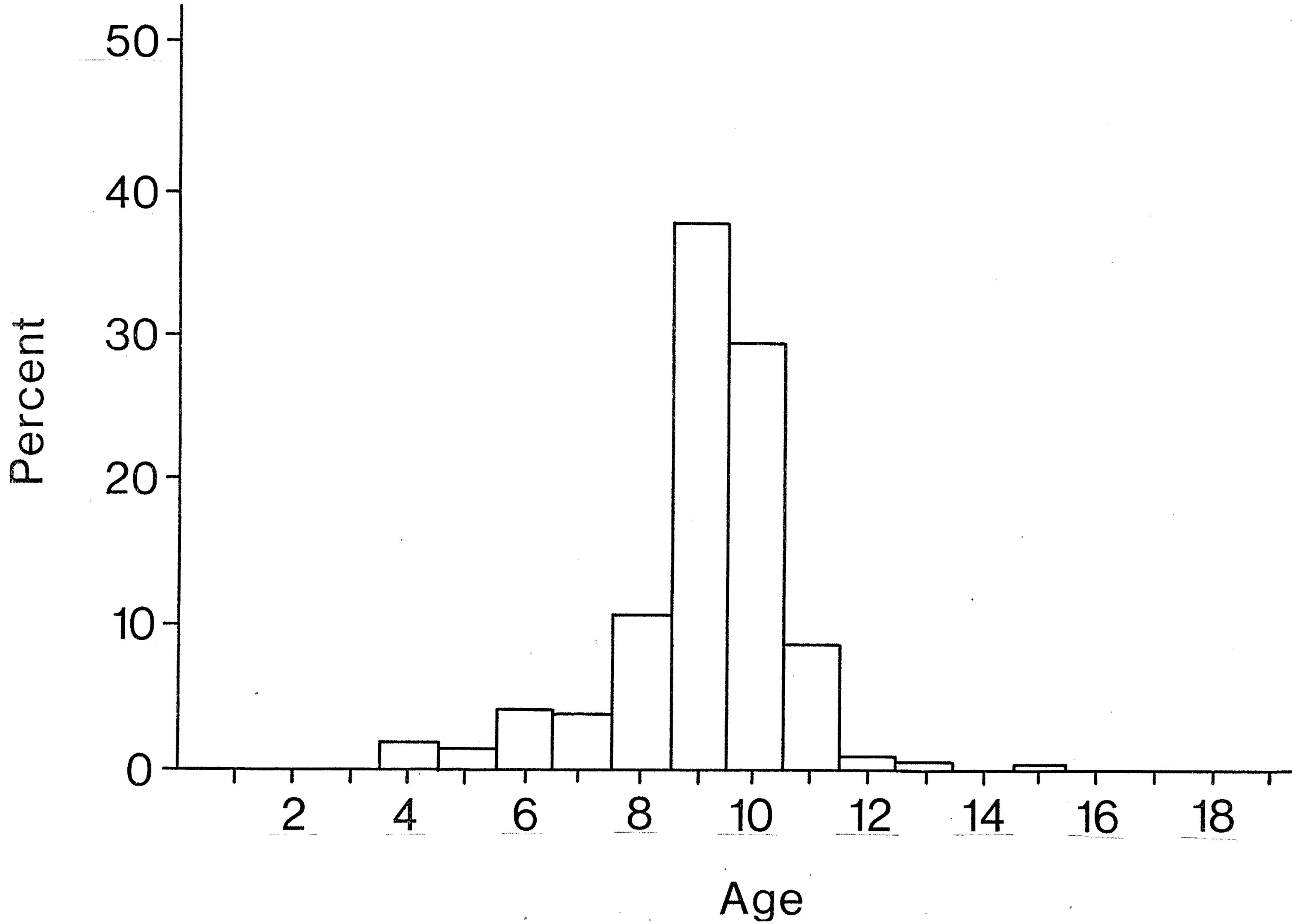

Figure 8. Age composition of widow rockfish caught during the MUIR MILACH survey, sexes combined.

Appendix 1. Estimation of School Density Using Line Transect and Line Intercept Techniques.

<u>Line Transect Method</u>. Line transect theory is based on the fact that the probability of sighting a given school varies with distance from the vessel. Seber (1973) has shown that school density can be estimated from:

$$D = \frac{nf(o)}{2L}$$

where D = number of schools per unit area

n = number of schools sighted

L = length of transect

and f(o) = A parameter estimated from the probability density function for the perpendicular distances of the schools sighted.

Three main assumptions are necessary concerning data collection to insure a reliable density estimate using the line transect method:

1) Schools directly on the transect plane will always be sighted.

2) Schools are sighted at the position they occupied prior to the approach of the vessel and there is no avoidance of the vessel.

3) Perpendicular distances off transect are measured precisely, particularly near the transect line.

The basic problem in estimation of density using the line transect method is choosing a model for the sighting function f(x). Numerous parametric and nonparametric estimators have been developed to fit the sighting function to a given data set including the exponential, logistic and half-normal. Work by Quinn (1979) and Burnham et al. (1980) suggests that the nonparametric Fourier model is a robust, flexible estimator, and provides the best fit to the sighting function in most applications. Quinn (1979) has shown that there is theoretical justification for pooling the data for several size-classes of schools, even though the sighting function varies with school size. This is because the sighting model that results from the pooled model is self-weighted by the relative abundances of the school size classes.

The Fourier model is based on a Fourier series expansion of the probability density function, f(x). The estimator of the probability density function at zero distance is:

$$f(o) = \frac{1}{w^*} + \sum_{k=1}^{m} \hat{a}_k$$

where w^* = truncation width, beyond which all observations are discarded. A value of 135 m was used for the run data, while 93 m was used for the data from transects 10 and 11.

$$\hat{a}_k = \frac{2}{nw^*}\left[\sum_{i=1}^{n} \cos\left(\frac{k\pi x_i}{w^*}\right)\right]$$

and n = number of schools observed

x_i = perpendicular distance off transect for the i^{th} school

k = term number = 1, 2, 3, ... m

The number of terms employed (k) was determined by a stopping function in the computer program TRANSECT used in this study. Bias in the estimation of f(o) and D is reduced by increasing the number of terms employed, but this reduction comes at the cost of reduced precision.

The FORTRAN program TRANSECT (Burnham et al. 1980) was used to estimate f(o) and D, using the Fourier series. This program is documented in Laake et al. (1979) and was made available for use on the CDC 6400 computer at the University of Washington. Program output includes frequency histograms of perpendicular distances, together with graphical illustrations of the resulting Fourier model fit to these data (Fig. A1).

Sonar data collected from 26 schools sighted on transects 10 and 11 were used to obtain a pooled estimate of f(o) and D. The variance of $\hat{D}$ was estimated by using the equation:

$$\hat{var}\ \hat{D} = (\hat{D})^2\ [(\hat{cv}(n))^2 + (\hat{cv}(\hat{f}(o))^2]$$

The squared coefficient of variation for $\hat{f}(o)$ is given by

$$(\hat{cv}(\hat{f}(o)))^2 = \frac{\hat{var}\ \hat{f}(o)}{(\hat{f}(o))^2}$$

and was determined by using equation 2.6 from Burnham et al. (1980) to estimate the sampling variance of $\hat{f}(o)$. The squared coefficient of variation for n = $(\hat{cv}(n))^2 = \frac{\hat{var}(n)}{\hat{n}^2}$, and was obtained by treating the two transect lines as replicates, and using equation 1.23 from Burnham et al. to estimate $\hat{var}(n)$.

School density estimates were made for the data collected during the run made on the night of March 27/28, largely because a large number of schools were sighted during this period and it enabled us to compare results from line transect and line intercept estimates of their density. The line transect estimate of density was straightforward, and a variance estimate was obtained by dividing the run into 5 equal segments which were treated as replicates. Bias may result when correlation exists between segments, and we used the estimator developed by Burnham et al. (p. 55) to avoid this problem.

Line Intercept Method. As outlined previously, this method was applied only for the data collected during the run made on the night of March 27/28. The technique is based on the fact that for a randomly located transect, the probability of intersection of a school equals w_i/W, where w_i equals the width of the i^{th} school and W equals the total width of a rectangular area surrounding the transect. Seber (1980) shows that this relation can be used to derive an estimate of school density:

$$\hat{D} = \sum_{j=1}^{n} \frac{1}{w_j L}$$

where n = number of schools measured on a transect line of length L

w_j = width of j^{th} school

In our application, the data from the mapping run was subdivided into two artificial transect lines (Fig. A2) of unequal length, and the jackknife method used to obtain $\hat{D}$ and its variance (Seber, pp. 40- 41). The pooled estimate for the K=2 transects combined gives the pooled estimate of density, defined as $\tilde{D}$. $\tilde{D}_{-k}$ values are then obtained, where the data from transect k have been omitted. Then:

$$\hat{D}_{(k)} = K\tilde{D}-(K-1)\tilde{D}_{-k}$$

$$\text{and } \tilde{D}_j = \sum_{k=1}^{K} D_{(k)}/K$$

where $\tilde{D}_j$ is the jackknife estimate of school density.

The variance of this estimate is given by:

$$\hat{\text{var}}\,(\tilde{D}_j) = \sum_{k=1}^{K} (D_{(k)} - \tilde{D}_j)^2/K(K-1)$$

PROGRAM TRANSECT -- LINE TRANSECT DATA ANALYSIS PROGRAM DEVELOPED BY THE UTAH COOPERATIVE WILDLIFE RESEARCH UNIT. METHODS AND TESTS FROM BURNHAM ET AL. (1980). PROGRAM VERSION 1.1. 4/1/80. PAGE = 34
WIDOW ROCKFISH DATA

ILLUSTRATION OF THE ESTIMATED PDF OF PERPENDICULAR DISTANCES(F) FIT TO THE SHAPE OF THE HISTOGRAM OF THE DATA(*)
CUT POINT SET 1

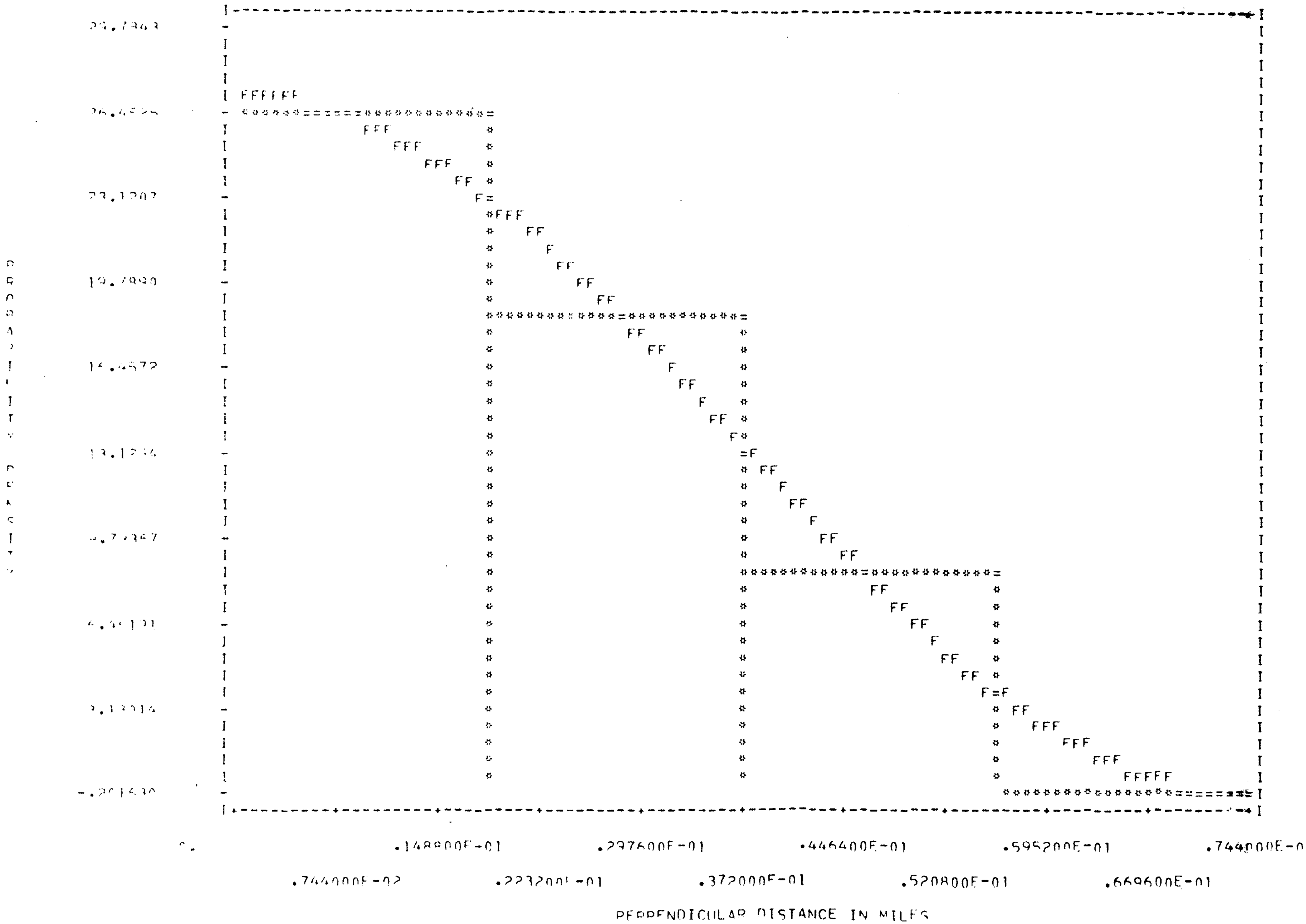

Figure A1. Example of graphical output provided by program TRANSECT.

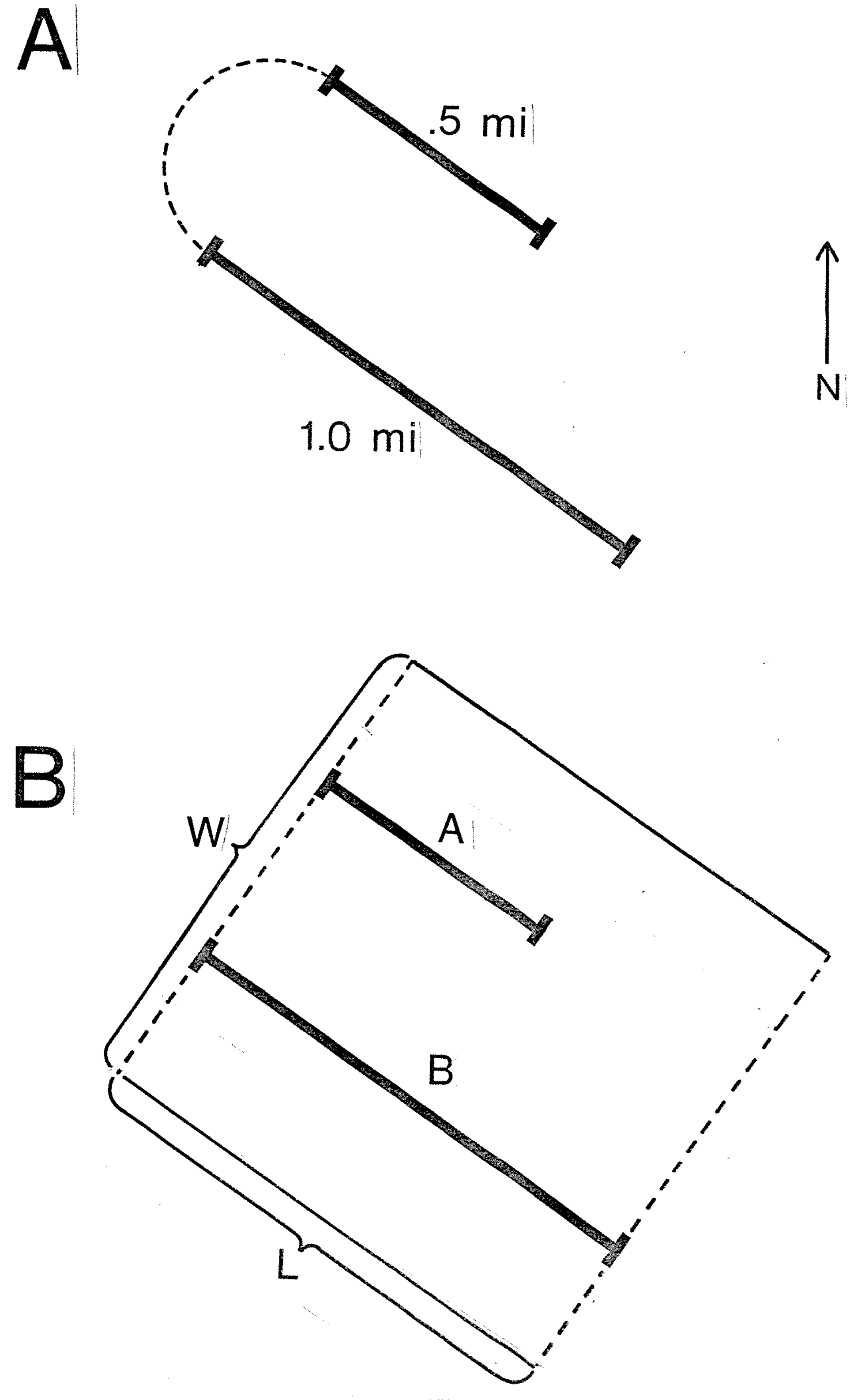

Figure A2. Application of the line intercept method of estimating school density. The entire mapping run for the night of March 27/28 (Figure 6) is shown in A, and B shows the definition of two artificial transect lines of unequal length.

Appendix 2. Rockfish Diet Studies

Stomachs were collected with the goal of examining the role of shelf rockfish in the continental shelf ecosystem. Feeding was to be examined in relation to vertical migrations, degree of aggregation, and diel periodicity.

Methods

Selected fish were retained from the biological samples on an opportunistic basis. Fish stomach contents analyses were conducted once ashore, according to an established systematic standardized procedure which quantifies the frequency of occurrence and numerical and gravimetric composition of prey organism, as well as the degree of fullness of the stomach and the state of digestion of its contents (Terry 1977).* After dissection of the stomach, the total stomach contents weight was determined to 0.01 g by subtracting the emptied stomach lining weight from the whole stomach weight. At the time of emptying the stomach, the state of stomach fullness was evaluated and ranked according to a 7-number scale: 1 = empty, 2 = trace, 3 = 25% full, 4 = 50% full, 6 = full, 7 = distended (MESA** code N). After the

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*Terry, C. 1977. Stomach analysis methodology: Still lots of questions. Pages 87-92 *in* C. A. Simenstad, and S. J. Lipovsky, eds. Proc. 1st Pacific Northwest Technical Workshop, Fish Food Habits Studies. University of Washington, Washington Sea Grant, WSG-WO77-2.

**Marine Ecosystem Analysis Program, NOAA.

stomach contents were emptied into a petri dish, the stage of digestion was evaluated and ranked according to a 6-number scale: 1 = all contents unidentifiable, 2 = similar to 1, but traces of prey organisms identifiable, 3 = less than 50% identifiable, 4 = 50-75% identifiable, 5 = 75-100% identifiable, 6 = no digestion evident (MESA Code 0). The contents were sorted, enumerated, and identified under a dissecting microscope to species and life history stage whenever digestion stage and state of taxonomy permitted. Each taxon was weighed to the nearest milligram.

Type specimens of all species and life history stages of prey organisms found in the stomachs were maintained in a catalogued reference collection (preserved in 70% ethanol). The identification of each species was later verified by experts on each taxon.

All field and laboratory recording of collection and fish examination data employed MESA/NODC* formats. This data management system is currently in use in similar ecosystem studies at a number of locations in the Northeast Pacific: In OCSEAP** studies in the Gulf of Alaska, the Bering and Beaufort seas, and the Kodiak Island vicinity; in NOAA/MESA studies in central and northern Puget Sound and the Strait of Juan de Fuca; in Washington State Department of Fisheries studies in Puget

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*National Oceanographic Data Center.

**Outer Continental Shelf Environmental Assessment Program.

Sound; and in Fisheries Research Institute (University of Washington) investigations in Puget Sound and the Aleutian Islands. Use of this system enhances comparability with other data sets gathered under similar objectives, hypotheses, and sampling designs.

Tabulation and basic statistical analysis of the data were performed using a computer program (GUTBUGS) specifically developed for the MESA/NODC-formatted stomach analysis data.

Results

A total of 49 yellowtail, 12 black, and 134 widow rockfish stomachs were examined (Appendix Table 1). The stomach contents by haul-rockfish species units are summarized in Appendix Tables 2-8. The stomachs were then pooled by rockfish species, and prey grouped by higher taxonomic categories. Dietary information was summarized by percent composition by numbers and biomass, percent frequency of occurrence, and index of relative importance (IRI) (Appendix Figs. 1-3).

Yellowtail rockfish were feeding primarily on fish (Appendix Fig. 1). Macrozooplankton were also common in the stomachs taken in haul 1A and haul 3. Haul 1A was a commercial midwater trawl taken at 0530-0630. The dominant invertebrates from those stomachs examined were Loligo (squid), Sergestidae (shrimp), and Pasiphaea (shrimp) (Appendix Table 2). These are water column forms commonly associated with the deep scattering layer (DSL). Some Pleuronectidae (flounder) were also found suggesting that some bottom feeding had occurred. Haul 3 was also a midwater trawl taken at 0940-1021. Although the sample size was small (2 fish) the diet consisted of herring and benthic and epibenthic invertebrates (Polychaeta and Pandalus) (Appendix Table 3). These data suggested that yellowtail rockfish are opportunistic feeders in both midwater and near-bottom habitats.

Both yellowtail and black rockfish were examined from haul 8 (a bottom haul made at 1900-1925). Stomach contents of both rockfish species consisted entirely of northern anchovy (Appendix Tables 4-5) or unidentifiable fish which were most likely the anchovy. There also was a large catch of northern anchovy in the bottom trawl and feeding in the net cannot be ruled out although the stomachs were highly digested (2.7 digestion index for yellowtails and 2.0 digestion index for blacks) which would indicate that feeding had occurred prior to capture.

Widow rockfish were feeding primarily on Euphausiacea (Appendix Fig. 3). However, there was quite an array of incidental prey items. They included many macrozooplankton associated with the deep scattering layer as well as several fish. These latter included larval and juvenile Scorpaenidae, Perciformes, Pleuronectidae, and Myctophidae (Appendix Tables 6-7). Widow rockfish fed strictly in the midwater habitat.

All samples of widow rockfish were taken at night at a time when the fish were in schools. A time series of stomach fullness and degree of digestion was constructed (Appendix Table 9). These data are by no means definitive as the pre-dawn sample was taken on a different day than the post-dusk sample. The data indicated that little night feeding by widow rockfish was occurring. All of the nighttime samples showed a high degree of digestion with most prey being unidentifiable (Appendix Table 9). The degree of digestion as well as the percent empty stomachs increased through the night. There were no inverted stomachs due to airbladder expansion noted at the time of stomach removal. The amount of material in the stomachs showed no clear trend with time but the 0310 sample showed the smallest amount of material in the gut. These data indicated that school formation during darkness was not a feeding response and that most prey were captured during diurnal periods.

Appendix Table 1. Summary of hauls from which stomachs were taken.

Haul No.	Date	Latitude	Longitude	Trawl type	Depth(fm) gear/ bottom	Time of day	Duration (min)	No. of stomachs examined: Widow	Yellowtail	Black
3	3-22	46°44′2"	124°38′2"	1	60/73	0940	41	0	2	0
1A	3-24	46°15′5"	124°30′5"	1	72/85	0530	60	0	30	0
8	3-25	46°38′0"	124°17′5"	2	37/37	1900	25	0	17	12
10A	3-28	46°31′3"	124°30′2"	1	60/100	0218	52	42	0	0
20	4- 1	46°23′5"	124°34′8"	1	65/95	1802	45	67	0	0
21	4- 1	46°24′58"	124°32′4"	1	70/85	2030	15	25	0	0

Appendix Table 2. Stomach contents analysis and prey composition of yellowtail rockfish from haul 1A.

FROM COLLECTIONS: FILE ID.	SAMPLE NO.	STATION LOC. NO.	SPECIMENS	COLLECTION TIME (PST)
24MR80	01A	13801	30	630

LIFE HISTORY STAGE:
30 ADULT
TOTAL SAMPLE SIZE: 30

NUMBER OF EMPTY STOMACHS: 18
PERCENTAGE OF EMPTY STOMACHS: 60.0
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 12

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	6.0	3-7	1.3
DIGESTION FACTOR (1-5, COMPLETE-NONE)	3.1	2-5	1.4
TOTAL CONTENTS WEIGHT (GRAMS)	16.46	1.79-59.89	15.58
TOTAL CONTENTS ABUNDANCE (NUMBERS)	1.7	1.0-5.0	1.2
NO. PREY CATEGORIES (PER STOMACH)	1.3	1-2	.5
LENGTH (MM)	421.7	360-500	50.60
WEIGHT (GRAMS)	1316.67	700.00-2300.00	521.94
PCT RATIO OF CONTENTS WT TO PREDATOR WT	1.20	.20-2.99	.77

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
LOLIGO SP.	C-J/A NOSEX	8.3	1	.1	1-1	.3	7.21	.60	7.21-7.21	2.08	7.2130	.0000	5.00	3.65	4.36
DECAPODA	C-J/A NOSEX	16.7	3	.3	1-2	.6	1.18	.10	.51-.66	.23	.4225	.1294	15.00	.60	.71
SERGESTIDAE	C-J/A NOSEX	8.3	1	.1	1-1	.3	.48	.04	.48-.48	.14	.4760	.0000	5.00	.24	.29
PASIPHAEA PACIFICA	C-J/A NOSEX	8.3	4	.3	4-4	1.2	9.05	.75	9.05-9.05	2.61	2.2632	.0000	20.00	4.58	5.47
TELEOSTEI	C-J/A NOSEX	50.0	6	.5	1-1	.5	97.23	8.10	5.26-38.52	11.94	16.2048	*.4993	30.00	49.20	58.71
ALLOSMERUS ELONGATUS	8-ADULT	8.3	1	.1	1-1	.3	10.30	.86	10.30-10.30	2.97	10.3000	.0000	5.00	5.21	6.22
ALLOSMERUS ELONGATUS	C-J/A NOSEX	16.7	2	.2	1-1	.4	20.63	1.72	9.58-11.05	4.03	10.3150	1.0394	10.00	10.44	12.46
PLEURONECTIDAE	C-J/A NOSEX	8.3	1	.1	1-1	.3	5.44	.45	5.44-5.44	1.57	5.4420	.0000	5.00	2.75	3.29
PLEURONECTIDAE	C-J/A NOSEX	8.3	1	.1	1-1	.3	14.10	1.17	14.10-14.10	4.07	14.1000	.0000	5.00	7.14	8.51

Appendix Table 2. Stomach contents analysis and prey composition of yellowtail rockfish from haul 1A - cont.

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
UNIDENTIFIED MATERIAL							31.98	3.55	.00-21.27	6.72				16.18	

TOTAL NUMBER OF PREY CATEGORIES 9

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS 2.81
BIOMASS 2.04

BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS 2.21

Appendix Table 3. Stomach contents analysis and prey composition of yellowtail rockfish from haul 3.

FROM COLLECTIONS: FILE ID.	SAMPLE NO.	STATION LOC. NO.	SPECIMENS	COLLECTION TIME (PST)
22MR80	003	13801	2	1021

LIFE HISTORY STAGE:
2 ADULT

TOTAL SAMPLE SIZE: 2

NUMBER OF EMPTY STOMACHS: 0
PERCENTAGE OF EMPTY STOMACHS: .00
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 2

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	6.0	6-6	.0
DIGESTION FACTOR (1-5, COMPLETE-NONE)	4.0	4-4	.0
TOTAL CONTENTS WEIGHT (GRAMS)	35.11	17.28-52.93	25.21
TOTAL CONTENTS ABUNDANCE (NUMBERS)	6.5	5.0-8.0	2.1
NO. PREY CATEGORIES (PER STOMACH)	2.0	1-3	1.4
LENGTH (MM)	490.0	480-500	14.14
WEIGHT (GRAMS)	9360.00	8800.00-9920.00	791.96
PCT RATIO OF CONTENTS WT TO PREDATOR WT	.36	.20-.53	.24

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
POLYCHAETA C-J/A NOSEX		50.0	1	.5	1-1	.7	.13	.06	.13-.13	.09	.1290	.0000	7.69	.18	.28
PANDALUS SP. C-J/A NOSEX		100.0	11	5.5	5-6	.7	18.69	9.35	7.67-11.02	2.37	1.6855	.2143	84.62	26.62	41.26
CLUPEA HARENGUS PALLASI C-J/A NOSEX		50.0	1	.5	1-1	.7	26.49	13.24	26.49-26.49	18.73	26.4850	.0000	7.69	37.72	58.46
UNIDENTIFIED MATERIAL							24.90	12.45	9.61-15.29	4.02				35.47	

TOTAL NUMBER OF PREY CATEGORIES 3

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS .77
BIOMASS 1.00
BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS .58

Appendix Table 4. Stomach contents analysis and prey composition of yellowtail rockfish from haul 8.

FROM COLLECTIONS:	FILE ID.	SAMPLE NO.	STATION LOC. NO.	SPECIMENS	COLLECTION TIME (PST)
	25MR80	008	13801	17	1925

LIFE HISTORY STAGE:
17 ADULT

TOTAL SAMPLE SIZE: 17

NUMBER OF EMPTY STOMACHS: 3
PERCENTAGE OF EMPTY STOMACHS: 17.7
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 14

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	6.6	5-7	.7
DIGESTION FACTOR (1-5, COMPLETE-NONE)	2.7	1-4	.9
TOTAL CONTENTS WEIGHT (GRAMS)	84.79	14.12-269.81	67.01
TOTAL CONTENTS ABUNDANCE (NUMBERS)	5.4	.0-14.0	4.4
NO. PREY CATEGORIES (PER STOMACH)	1.6	1-2	.5
LENGTH (MM)	474.3	330-560	59.58
WEIGHT (GRAMS)	2121.43	700.00-3000.00	629.01
PCT RATIO OF CONTENTS WT TO PREDATOR WT	3.97	.61-9.99	2.63

PREY ORGANISM PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
TELEOSTEI C-J/A NOSEX		71.4	55	3.9	1-10	3.6	637.12	45.51	15.60-168.90	48.24	11.96804.2761	72.37	53.67	63.54
ENGRAULIS MORDAX C-J/A NOSEX		71.4	21	1.5	1-5	1.5	365.64	26.12	12.88-77.57	26.05	17.35302.6657	27.63	30.80	36.46
UNIDENTIFIED MATERIAL							184.29	13.16	2.47-23.50	7.18			15.53	

TOTAL NUMBER OF PREY CATEGORIES 2

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS .85
BIOMASS .95
BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS .81

Appendix Table 5. Stomach contents analysis and prey composition of black rockfish from haul 8.

FROM COLLECTIONS:	FILE ID.	SAMPLE NO.	STATION LOC. NO.	SPECIMENS	COLLECTION TIME (PST)
	25MR80	008	13801	12	1925

LIFE HISTORY STAGE:
12 ADULT

TOTAL SAMPLE SIZE: 12

NUMBER OF EMPTY STOMACHS: 6
PERCENTAGE OF EMPTY STOMACHS: 50.00
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 6

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	3.7	2-7	2.6
DIGESTION FACTOR (1-5, COMPLETE-NONE)	2.0	1-4	1.1
TOTAL CONTENTS WEIGHT (GRAMS)	32.67	.31-158.35	62.44
TOTAL CONTENTS ABUNDANCE (NUMBERS)	2.8	.0-13.0	5.0
NO. PREY CATEGORIES (PER STOMACH)	1.2	1-2	.4
LENGTH (MM)	473.3	430-550	44.12
WEIGHT (GRAMS)	1866.67	1500.00-2800.00	496.66
PCT RATIO OF CONTENTS WT TO PREDATOR WT	1.98	.02-9.90	3.92

PREY ORGANISM PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUN-DANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
TELEOSTEI	C-J/A NOSEX	66.7	14	2.3	1-10	3.8	122.77	20.46	1.19-103.63	41.10	5.58074.0284		82.35	62.64	76.47
ENGRAULIS MORDAX	C-J/A NOSEX	16.7	3	.5	3-3	1.2	37.77	6.29	37.77-37.77	15.42	12.5900	.0000	17.65	19.27	23.53
UNIDENTIFIED MATERIAL							35.46	5.91	.31-16.95	7.35				18.09	

TOTAL NUMBER OF PREY CATEGORIES 2

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS .67
BIOMASS .79
BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS .56

Appendix Table 6. Stomach contents analysis and prey composition of widow rockfish from haul 20.

FROM COLLECTIONS: FILE ID.	SAMPLE NO.	STATION LOC.	NO. SPECIMENS	COLLECTION TIME (PST)
80AP01	020	13801	67	1847

LIFE HISTORY STAGE: 67 ADULT

TOTAL SAMPLE SIZE: 67

NUMBER OF EMPTY STOMACHS: 5
PERCENTAGE OF EMPTY STOMACHS: 7.46
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 62

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	4.6	2-7	1.9
DIGESTION FACTOR (1-5, COMPLETE-NONE)	2.7	1-4	.7
TOTAL CONTENTS WEIGHT (GRAMS)	11.52	.09-39.47	9.47
TOTAL CONTENTS ABUNDANCE (NUMBERS)	87.4	.0-483.0	95.9
NO. PREY CATEGORIES (PER STOMACH)	3.6	1-8	1.9
LENGTH (MM)	387.4	330-490	29.31
WEIGHT (GRAMS)	199999.90-	.00	.00
PCT RATIO OF CONTENTS WT TO PREDATOR WT	1	*99.90-.00	.00

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
CTENOPHORA	C-J/A NOSEX	1.6	3	.0	3-3	.4	2.69	.04	2.69-2.69	.34	.8950	.0000	.06	.38	.73
POLYCHAETA	C-J/A NOSEX	3.2	6	.1	1-5	.6	.09	.00	.04-.06	.01	.0326	.0359	.11	.01	.03
THECOSOMATA	UNKNOWN	1.6	4	.1	4-4	.5	.04	.00	.04-.04	.01	.0102	.0000	.07	.01	.01
THECOSOMATA	C-J/A NOSEX	48.4	190	3.1	1-40	6.7	1.54	.02	.00-.32	.06	.0096	.0122	3.51	.22	.42
CEPHALOPODA	C-J/A NOSEX	19.4	24	.4	1-5	1.0	2.66	.04	.02-.57	.13	.0948	.0482	.44	.37	.73
THEUTHIDIDA	7-JUVENILE	1.6	1	.0	1-1	.1	.22	.00	.22-.22	.03	.2200	.0000	.02	.03	.06
THEUTHIDIDA	C-J/A NOSEX	6.5	5	.1	1-2	.3	1.65	.03	.04-1.14	.15	.3942	.5146	.09	.23	.45
THEUTHIDIDA MYOPSIDA	C-J/A NOSEX	1.6	1	.0	1-1	.1	.22	.00	.22-.22	.03	.2200	.0000	.02	.03	.06

Appendix Table 6. Stomach contents analysis and prey composition of widow rockfish from haul 20 - cont.

PREY ORGANISM PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
OCTOPODIA	7-JUVENILE	3.2	4	.1	2-2	.4	.64	.01	.24-.40	.06	.1593	.0555	.07	.09	.17
OCTOPODIA	C-J/A NOSEX	1.6	1	.0	1-1	.1	.05	.00	.05-.05	.01	.0490	.0000	.02	.01	.01
COPEPODA	C-J/A NOSEX	1.6	1	.0	1-1	.1	.00	.00	.00-.00	.00	.0010	.0000	.02	.00	.00
CALANOIDA	8-ADULT	1.6	1	.0	1-1	.1	.00	.00	.00-.00	.00	.0030	.0000	.02	.00	.00
CALANOIDA	C-J/A NOSEX	3.2	2	.0	1-1	.2	.01	.00	.00-.01	.00	.0050	.0028	.04	.00	.00
AMPHIPODA	C-J/A NOSEX	3.2	4	.1	2-2	.4	.11	.00	.04-.07	.01	.0280	.0106	.07	.02	.03
AMPHIPODA-HYPERIIDEA	C-J/A NOSEX	6.5	4	.1	1-1	.2	.08	.00	.00-.03	.01	.0192	.0127	.07	.01	.02
HYPERIA SP.	C-J/A NOSEX	8.1	5	.1	1-1	.3	.13	.00	.01-.05	.01	.0266	.0128	.09	.02	.04
PARATHEMISTO SP.	C-J/A NOSEX	9.7	7	.1	1-2	.4	.04	.00	NEG.-.02	.00	.0069	.0087	.13	.01	.01
PARATHEMISTO PACIFICA	8-ADULT	1.6	2	.0	2-2	.3	.01	.00	.01-.01	.00	.0055	.0000	.04	.00	.00
PARATHEMISTO PACIFICA	C-J/A NOSEX	3.2	2	.0	1-1	.2	.01	.00	.01-.01	.00	.0060	.0014	.04	.00	.00
PHRONIMA SP.	C-J/A NOSEX	17.7	14	.2	1-2	.5	.54	.01	.01-.11	.02	.0399	.0287	.26	.08	.15
PRIMNO MACROPA	C-J/A NOSEX	6.5	4	.1	1-1	.2	.07	.00	.01-.02	.00	.0165	.0044	.07	.01	.02
AMPHIPODA-HYPERIIDEA	C-J/A NOSEX	11.3	9	.1	1-2	.4	.06	.00	.00-.04	.01	.0087	.0138	.17	.01	.02
AMPHIPODA-HYPERIIDEA	C-J/A NOSEX	1.6	2	.0	2-2	.3	.03	.00	.03-.03	.00	.0170	.0000	.04	.00	.01
EUPHAUSIACEA	C-J/A NOSEX	95.2	4197	67.7	2-279	69.6	240.87	3.88	.05-15.15	3.96	.0544	.0164	77.44	33.65	65.79
THYSANOESSA SP.	C-J/A NOSEX	1.6	10	.2	10-10	1.3	1.61	.03	1.61-1.61	.20	.1610	.0000	.18	.22	.44
SERGESTIDAE	C-J/A NOSEX	1.6	2	.0	2-2	.3	.30	.00	.30-.30	.04	.1500	.0000	.04	.04	.08
SERGESTIDAE	C-J/A NOSEX	33.9	221	3.6	1-59	10.1	56.78	.92	.04-14.44	2.56	.2513	.0945	4.08	7.93	15.51
PLEOCYEMATA-CARIDEA	C-J/A NOSEX	6.5	12	.2	1-5	.8	3.25	.05	.24-1.45	.24	.2608	.0234	.22	.45	.89
PASIPHAEIDAE	C-J/A NOSEX	1.6	1	.0	1-1	.1	.14	.00	.14-.14	.02	.1390	.0000	.02	.02	.04
DECAPODA-BRACHYURA	C-J/A NOSEX	1.6	1	.0	1-1	.1	.03	.00	.03-.03	.00	.0280	.0000	.02	.00	.01
CHAETOGNATHA	C-J/A NOSEX	8.1	10	.2	1-5	.7	.81	.01	.06-.43	.06	.0848	.0426	.18	.11	.22
SALPIDAE	C-J/A NOSEX	4.8	626	10.1	23-343	54.2	5.55	.09	.18-2.94	.48	.0086	.0007	11.55	.78	1.52
TELEOSTEI	7-JUVENILE	3.2	2	.0	1-1	.2	1.23	.02	.45-.78	.11	.6150	.2333	.04	.17	.34
TELEOSTEI	C-J/A NOSEX	12.9	14	.2	1-5	.8	18.91	.30	.08-6.87	1.24	1.1043	1.1718	.26	2.64	5.17

Appendix Table 6. Stomach contents analysis and prey composition of widow rockfish from haul 20 - cont.

PREY ORGANISM PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
MYCTOPHIDAE	C-J/A NOSEX	8.1	10	.2	1- 3	.6	18.79	.30	.31- 9.31	1.40	1.5826	1.0944	.18	2.62	5.13
SCORPAENIDAE	7-JUVENILE	1.6	1	.0	1- 1	.1	.32	.01	.32- .32	.04	.3200	.0000	.02	.04	.09
SCORPAENIDAE	B-LARVA+JUV	3.2	4	.1	1- 3	.4	1.84	.03	.26- 1.59	.20	.3917	.1933	.07	.26	.50
SCORPAENIFORME COTTOIDEI	B-LARVA+JUV	1.6	1	.0	1- 1	.1	.16	.00	.16- .16	.02	.1580	.0000	.02	.02	.04
PERCIFORMES	B-LARVA+JUV	1.6	1	.0	1- 1	.1	.21	.00	.21- .21	.03	.2090	.0000	.02	.03	.06
PLEURONECTIFORMES	3-ZOEA	1.6	4	.1	4- 4	.5	2.21	.04	2.21- 2.21	.28	.5525	.0000	.07	.31	.60
PLEURONECTIFORMES	7-JUVENILE	1.6	1	.0	1- 1	.1	.34	.01	.34- .34	.04	.3420	.0000	.02	.05	.09
PLEURONECTIFORMES	B-LARVA+JUV	1.6	3	.0	3- 3	.4	1.40	.02	1.40- 1.40	.18	.4653	.0000	.06	.20	.38
PLEURONECTIFORMES	C-J/A NOSEX	1.6	3	.0	3- 3	.4	.46	.01	.46- .46	.06	.1543	.0000	.06	.06	.13
UNIDENTIFIED MATERIAL							349.76	5.73	.05- 20.68	4.52				48.86	

TOTAL NUMBER OF PREY CATEGORIES 43

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS 1.33
BIOMASS 1.90

BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS 1.31

Appendix Table 7. Stomach contents analysis and prey composition of widow rockfish from haul 21.

FROM COLLECTIONS:	FILE ID.	SAMPLE NO.	STATION LOC.	NO. SPECIMENS	COLLECTION TIME (PST)
	01AP80	021	13801	25	2045

LIFE HISTORY STAGE:
25 ADULT

TOTAL SAMPLE SIZE: 25

NUMBER OF EMPTY STOMACHS: 4
PERCENTAGE OF EMPTY STOMACHS: 16.0
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 21

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	4.0	2-7	1.7
DIGESTION FACTOR (1-5, COMPLETE-NONE)	2.8	2-3	.4
TOTAL CONTENTS WEIGHT (GRAMS)	15.54	.17-59.64	15.83
TOTAL CONTENTS ABUNDANCE (NUMBERS)	100.6	2.0-424.0	97.9
NO. PREY CATEGORIES (PER STOMACH)	3.9	1-9	2.1
LENGTH (MM)	400.0	370-450	23.02
WEIGHT (GRAMS)	I99999.90	-.00	.00
PCT RATIO OF CONTENTS WT TO PREDATOR WT	I	*99.90-.00	.00

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
POLYCHAETA	C-J/A-NOSEX	9.5	4	.2	1-3	.7	.37	.02	.02-.35	.08	.1780	.2447	.19	.11	.25
THECOSOMATA	C-J/A-NOSEX	47.6	171	8.1	1-128	27.7	2.63	.13	.00-1.95	.43	.0160	.0179	8.10	.76	1.92
CEPHALOPODA	C-J/A-NOSEX	33.3	7	.3	1-1	.5	.36	.02	.00-.09	.03	.0521	.0336	.33	.11	.25
PODOCOPA	C-J/A-NOSEX	9.5	26	1.2	2-24	5.2	.27	.01	.02-.26	.06	.0091	.0022	1.23	.08	.19
CALANOIDA	C-J/A-NOSEX	4.8	1	.0	1-1	.2	.00	.00	NEG.-NEG.	.00	.0001	.0000	.05	.00	.00
AMPHIPODA	C-J/A-NOSEX	9.5	2	.1	1-1	.3	.07	.00	.02-.05	.01	.0360	.0240	.09	.02	.05
HYPERIA SP.	C-J/A-NOSEX	4.8	1	.0	1-1	.2	.03	.00	.03-.03	.01	.0270	.0000	.05	.01	.02
PARATHEMISTO SP.	C-J/A-NOSEX	38.1	27	1.3	1-10	2.7	.32	.02	.00-.21	.05	.0305	.0730	1.28	.09	.22
PHRONIMA SP.	C-J/A-NOSEX	19.0	4	.2	1-1	.4	.25	.01	.03-.11	.03	.0625	.0340	.19	.07	.17

Appendix Table 7. Stomach contents analysis and prey composition of widow rockfish from haul 21 - cont.

PREY ORGANISM / PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
AMPHIPODA-HYPERIIDEA	C-J/A NOSEX	4.8	1	.0	1-1	.2	.00	.0C	.00-.00	.00	.0C1C	.0000	.05	.CC	.00
AMPHIPODA-HYPERIIDEA	C-J/A NOSEX	4.8	1	.0	1-1	.2	.02	.00	.02-.02	.01	.0240	.000C	.05	.C1	.02
EUPHAUSIACEA	C-J/A NOSEX	90.5	1552	73.9	2-416	93.1	68.83	3.28	.05-9.81	2.71	.0776	.C878	73.48	19.82	47.76
SERGESTIDAE	C-J/A NOSEX	33.3	54	2.6	1-30	6.7	23.54	1.12	.35-10.17	2.80	.4372	.3752	2.56	6.78	16.33
CHAETOGNATHA	C-J/A NOSEX	4.8	5	.2	5-5	1.1	.24	.01	.24-.24	.05	.0486	.0000	.24	.07	.17
SALPIDAE	C-J/A NOSEX	9.5	184	8.8	20-164	35.8	2.31	.11	.14-2.17	.47	.0100	.0046	8.71	.67	1.60
GNATHOSTOMATA	C-J/A NOSEX	4.8	2	.1	2-2	.4	.42	.02	.42-.42	.09	.2120	.0000	.09	.12	.29
TELEOSTEI	C-J/A NOSEX	28.6	19	.9	1-8	2.1	29.43	1.40	.04-24.76	5.39	.8820	1.1718	.90	8.47	20.42
MYCTOPHIDAE	C-J/A NOSEX	4.8	1	.0	1-1	.2	2.60	.12	2.60-2.60	.57	2.6010	.0000	.05	.75	1.80
SCORPAENIDAE	B-LARVA+JUV	4.8	1	.0	1-1	.2	.39	.02	.39-.39	.09	.3940	.000C	.05	.11	.27
SCORPAENIDAE	C-J/A NOSEX	4.8	5	.2	5-5	1.1	1.71	.08	1.71-1.71	.37	.3418	.0000	.24	.49	1.19
SCORPAENIFORME COTTOIDEI	B-LARVA+JUV	4.8	1	.0	1-1	.2	.03	.0C	.03-.03	.01	.0330	.C000	.05	.01	.02
PLEURONECTIFORMES	B-LARVA+JUV	4.8	19	.9	19-19	4.1	10.26	.49	10.26-10.26	2.24	.5402	.000C	.90	2.96	7.12
UNIDENTIFIED	1-EGG	4.8	24	1.1	24-24	5.2	.01	.00	.01-.01	.00	.0004	.CCCC	1.14	.00	.01
UNIDENTIFIED MATERIAL							203.20	9.68	.12-41.60	9.60				58.51	

TOTAL NUMBER OF PREY CATEGORIES 23

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS 1.57
BIOMASS 2.23

BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS 1.55

Appendix Table 8. Stomach contents analysis and prey composition of widow rockfish from haul 10A.

FROM COLLECTIONS:	FILE ID.	SAMPLE NO.	STATION LOC. NO.	SPECIMENS	COLLECTION TIME (PST)
	28MR80	010	13801	42	310

LIFE HISTORY STAGE:
42 ADULT

TOTAL SAMPLE SIZE: 42

NUMBER OF EMPTY STOMACHS: 25
PERCENTAGE OF EMPTY STOMACHS: 59.5
ADJUSTED SAMPLE SIZE(STOMACHS CONTAINING PREY): 17

	MEAN	RANGE	S.D.
CONDITION FACTOR (1-7, EMPTY-DISTENDED)	4.0	2-7	1.8
DIGESTION FACTOR (1-5, COMPLETE-NONE)	1.7	1-3	.6
TOTAL CONTENTS WEIGHT (GRAMS)	12.69	2.27-39.18	11.89
TOTAL CONTENTS ABUNDANCE (NUMBERS)	49.8	.0-316.0	82.5
NO. PREY CATEGORIES (PER STOMACH)	1.2	1-3	.5
LENGTH (MM)	410.6	350-450	29.26
WEIGHT (GRAMS)	1123.53	800.00-1500.00	185.50
PCT RATIO OF CONTENTS WT TO PREDATOR WT	1.17	.20-4.46	1.20

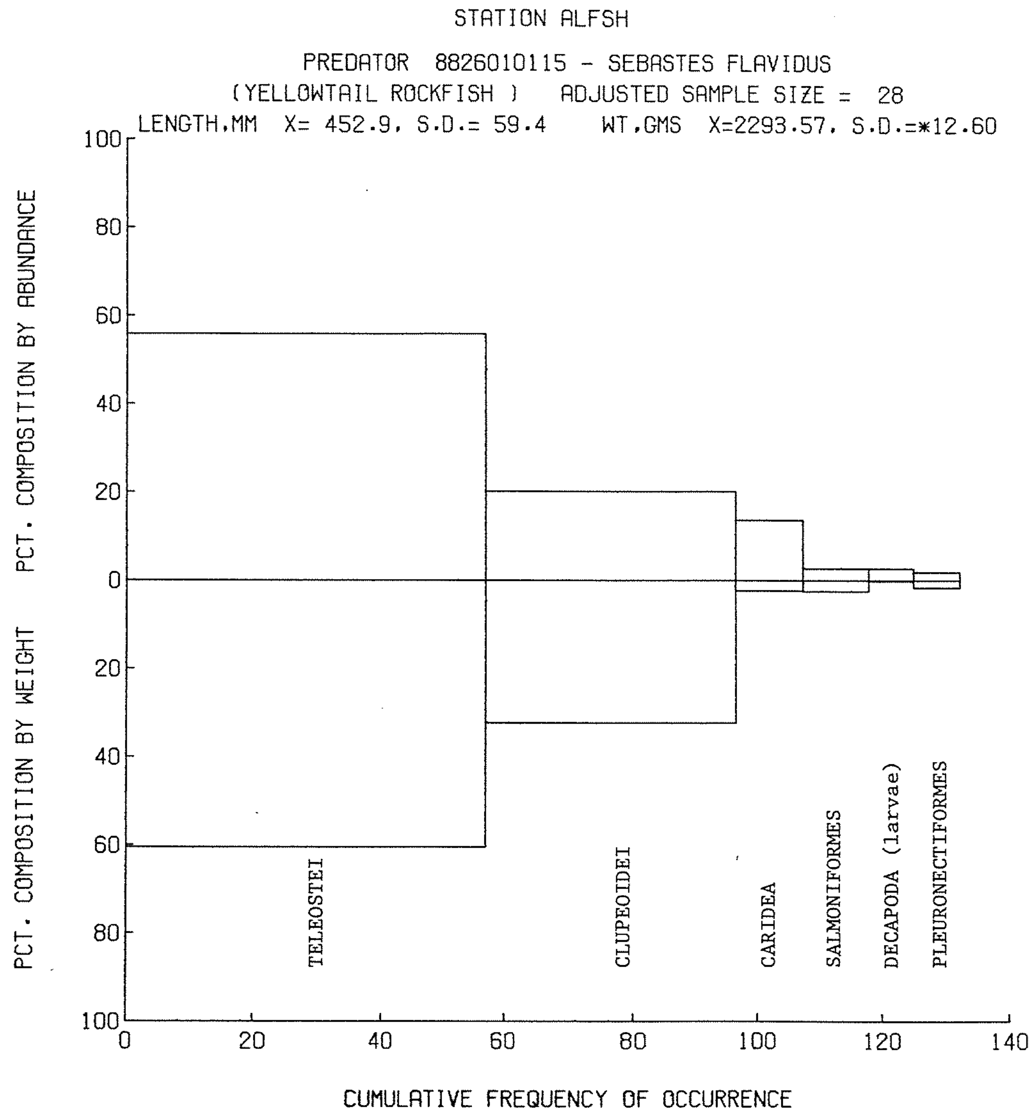
PREY ORGANISM PARTS CODE	LIFE HISTORY STAGE	FREQ OCCUR	NUMBER TOTAL	NUMBER MEAN	NUMBER RANGE	NUMBER S.D.	BIOMASS TOTAL	BIOMASS MEAN	BIOMASS RANGE	BIOMASS S.D.	AVE. BIOMASS MEAN	AVE. BIOMASS S.D.	PERCENTAGES ABUNDANCE	PERCENTAGES BIOMASS	PERCENTAGES NORM. BIOMASS
EUPHAUSIACEA	C-J/A NOSEX	64.7	782	46.0	1-316	80.7	81.49	4.79	.17-33.09	8.43	.1094	.0232	92.33	37.76	98.09
CANCER SP.	3-ZOEA	5.9	53	3.1	53-53	12.9	.82	.05	.82-.82	.20	.0155	.0000	6.26	.38	.99
CANCER SP.	4-MEGALOP	5.9	4	.2	4-4	1.0	.01	.00	.01-.01	.00	.0028	.0000	.47	.01	.01
TELEOSTEI	C-J/A NOSEX	5.9	8	.5	8-8	1.9	.76	.04	.76-.76	.18	.0945	.0000	.94	.35	.91
UNIDENTIFIED MATERIAL							132.72	7.81	1.87-23.88	6.74				61.50	

TOTAL NUMBER OF PREY CATEGORIES 4

SHANNON-WEINER DIVERSITY INDEX (NORMALIZED) NUMBERS .46
BIOMASS * .16
BRILLOUIN-S DIVERSITY INDEX BASED ON NUMBERS .45

Appendix Table 9. Summary of nocturnal sampling of widow rockfish stomachs.

Date	Haul-in time	Sample size	No. empty	Pct. empty	Mean stomach contents(g) fish w/food	Mean stomach contents(g) all fish	Mean digestion factor	Mean fullness factor
4/01/80	1847	67	5	7	11.52	10.66	2.7	4.6
4/01/80	2045	25	4	16	16.54	13.89	2.8	4.0
3/28/80	0310	42	25	60	12.69	5.14	1.7	4.0

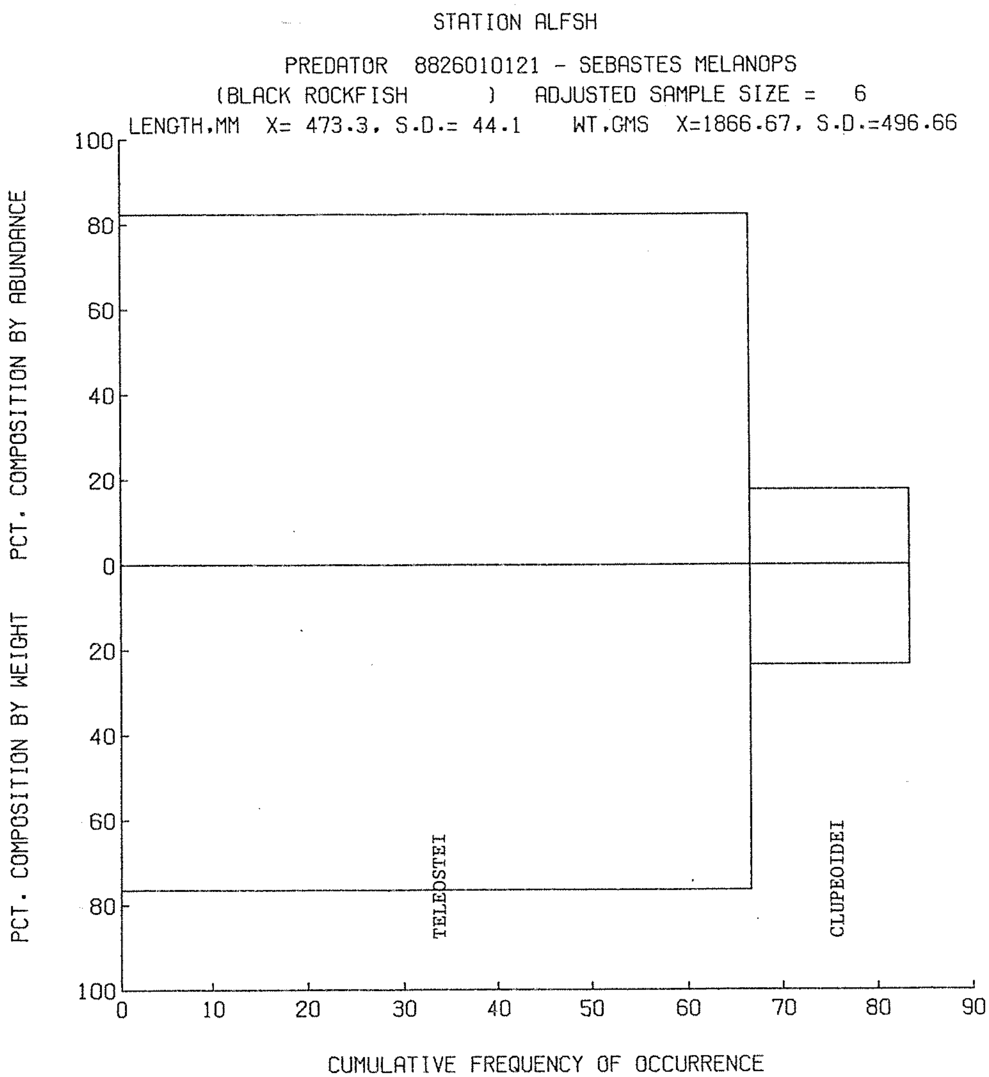


PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
TELEOSTEI	57.14	55.96	60.51	6655.4	73.92
CLUPEIFORMES-CLUPEOIDEI	39.29	20.18	32.31	2062.2	22.90
PLEOCYEMATA-CARIDEA	10.71	13.76	2.29	171.9	1.91
SALMONIFORMES	10.71	2.75	2.55	56.8	.63
DECAPODA	7.14	2.75	.10	20.4	.23
PLEURONECTIFORMES	7.14	1.83	1.61	24.6	.27

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.37	.47	.60
SHANNON-WEINER DIVERSITY	1.91	1.38	1.02
EVENNESS INDEX	.60	.44	.32

Appendix Fig. 1. Index of relative importance (IRI) diagram for yellowtail rockfish. All samples were pooled, prey taxon were truncated to order, and life history stages pooled.

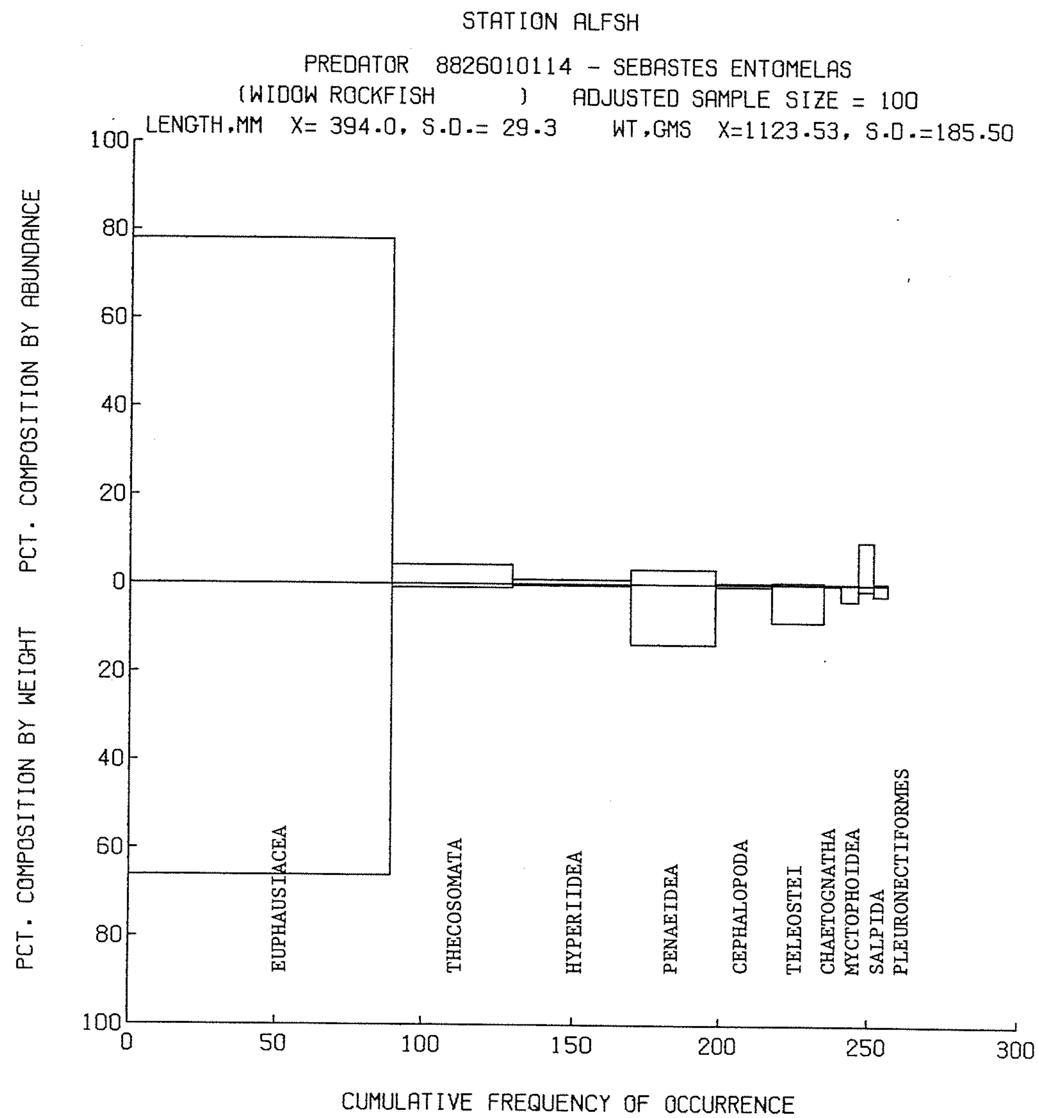


PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
TELEOSTEI	66.67	82.35	76.47	10588.4	93.91
CLUPEIFORMES-CLUPEOIDEI	16.67	17.65	23.53	686.2	6.09

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.71	.64	.89
SHANNON-WEINER DIVERSITY	.67	.79	.33
EVENNESS INDEX	.67	.79	.33

Appendix Fig. 2. Index of relative importance (IRI) diagram for black rockfish. All samples were pooled, prey taxon were truncated to order, and life history stages pooled.



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
EUPHAUSIACEA	89.00	78.06	66.21	12840.1	92.61
THECOSOMATA	41.00	4.36	.71	207.7	1.50
AMPHIPODA-HYPERIIDEA	39.00	.99	.27	49.1	.35
PENAEIDEA	29.00	3.31	13.59	489.9	3.53
CEPHALOPODA	19.00	.37	.51	16.7	.12
TELEOSTEI	17.00	.51	8.48	152.9	1.10
CHAETOGNATHA	6.00	.18	.18	2.1	.02
SALMONIFORMES-MYCTOPHOIDEI	6.00	.13	3.61	22.4	.16
THALIACEA-SALPIDA	5.00	9.67	1.32	55.0	.40
PLEURONECTIFORMES	5.00	.36	2.47	14.2	.10

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

	NUM. COMP.	GRAV. COMP.	PERCENT TOTAL IRI
PERCENT DOMINANCE INDEX	.62	.47	.86
SHANNON-WEINER DIVERSITY	1.34	1.82	.55
EVENNESS INDEX	.28	.38	.12

Appendix Fig. 3. Index of relative importance (IRI) diagram for widow rockfish. All samples were pooled, prey taxon were truncated to order, and life history stages pooled.