Biomass Estimation of Rockfish Stocks Off the West Coast of the Queen Charlotte Islands During 1978 and 1979.

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BIOMASS ESTIMATION OF ROCKFISH STOCKS OFF THE WEST COAST OF THE QUEEN CHARLOTTE ISLANDS DURING 1978 AND 1979.

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ABSTRACT

Leaman, B. M., and D. A. Nagtegaal. 1982. Biomass estimation of rockfish stocks off the west coast of the Queen Charlotte Islands during 1978 and 1979. Can. MS Rep. Fish. Aquat. Sci. 1652: iv + 46 p.

Biomass assessment cruises of rockfish stocks off the west coast of the Queen Charlotte Islands were conducted during 1978 and 1979. Biomass of commercially important rockfishes was estimated using a swept-area trawl survey. A stratified-systematic sampling design was used in both years although the location of the sampling stations within the strata was not always fixed, but was determined by the availability of trawlable bottom. The 1979 survey was further modified by increasing sampling density in areas of greater fish abundance, as determined in 1978, and treating these areas separately in the estimation procedure. Results from the two years are not directly comparable because of these differences in survey methodology.

The 1978 cruise resulted in an estimated rockfish biomass of approximately 6400 t ± 50% if the trawlable area detected on the survey is considered solely, and of approximately 10,500 t ± 50% if all areas are considered to be equivalent to the sampled area. In contrast, the 1979 survey resulted in an estimated biomass of approximately 18,300 t. If 1979 data were not segregated by locality the biomass estimates analagous to those derived in 1978 would be approximately 9700 t ± 37% and 15,900 t ± 37%, respectively, although there is greater information content in the 1979 estimates. The 1979 biomass estimate based on locality segregation of data has an unrealistically narrow confidence interval (± 10%). This is due in part to some large hauls from individual localities which contributed significantly to the total biomass, yet had low variance. The ± 40% confidence interval of the other elements in the data set is considered more realistic. The biases in the survey methodology used are briefly reviewed.

Biological sampling of the species encountered revealed a majority of older (≥20 y) fish, particularly for Pacific ocean perch (*Sebastes alutus*), and consequently lower mortality rates than previously assumed. The possible origins of this stock and the implications of its age composition to long-term management are discussed.

Key words: Rockfishes, biomass surveys, Queen Charlotte Islands, survey methodology.

RÉSUMÉ

Leaman, B. M., and D. A. Nagtegaal. 1982. Biomass estimation of rockfish stocks off the west coast of the Queen Charlotte Islands during 1978 and 1979. Can. MS Rep. Fish. Aquat. Sci. 1652: iv + 46 p.

Des expéditions destinées à évaluer la biomasse des populations de scorpènes au large de la côte ouest des îles Reine-Charlotte ont été menées en 1978 et en 1979. On a effectué un levé par chalutage de la région pour estimer la biomasse des espèces de scorpènes importantes sur le plan commercial. Les deux années, on a utilisé une méthode d'échantillonnage stratifiée systématique même si l'emplacement des stations d'échantillonnage dans les couches n'était pas toujours fixe, mais était déterminé par la disponbilité du fond chalutable. Le levé de 1979 a été ultérieurement modifié en augmentant le nombre d'échantillons dans des zones où les poissons étaient plus nombreux, telles que déterminées en 1978, et en étudiant ces zones séparément. Étant donné ces différences dans les méthodes d'étude, on ne peut comparer directement les résultats de ces deux années.

L'expédition de 1978 a permis d'estimer la biomasse des scorpènes à 6 400 t ± 50 % si l'on tient compte uniquement de la zone chalutable décelée lors du levé, et à 10 500 t ± 50 % si l'on considère que toutes les zones ressemblaient à la zone échantillonnée. En comparaison, le levé de 1979 a permis d'evaluer la biomasse à environ 18 300 t. Si les données de 1979 n'avaient pas été séparées pour chacun des emplacements, les estimations de la biomasse correspondant à celles établies en 1978 auraient été respectivement de 9 700 t ± 37 % et 15 900 t ± 37 %, bien que les estimations de 1979 contiennent un plus grand nombre d'informations. L'étroit intervale de confiance (± 10 %) de l'estimation de la biomasse de 1979 fondée sur la séparation des données par emplacement est peu réaliste. Cela est dû en partie à de grosses prises à certains emplacements qui ont contribué notablement à la biomasse totale, mais dont la variance était faible. L'intervalle de confiance de ± 40 % des autres éléments de la série de données semble plus réaliste. On étudie brièvement les biais des méthodes d'étude.

L'échantillonnage biologique des espèces dénombrées a révélé que la majorité des poissons, particulièrement le sébaste du Pacifique (*Sebastes alutus*), étaient âgés (≥ 20 a) et par conséquent que les taux de mortalité étaient plus faibles que prévus. On discute de l'origine probable de ce stock et des répercussions de la répartition des âges sur une gestion à long terme.

Mots-clés: Scorpènes, levés sur la biomasse, Îles Reine-Charlotte, méthodes d'étude.

INTRODUCTION

Rockfish (Sebastes spp.) stocks off the west coast of the Queen Charlotte Islands have been exploited by foreign fleets since the mid-1960s. In particular, the area north of 54°N accounted for approximately 80% of the removals by the Japanese fleet from 1965-1977 (Ketchen 1980). In 1977 Canadian observer reports from Japanese vessels fishing this area indicated substantial depletion of rockfish stocks, primarily Sebastes alutus. Subsequently, the area north of 54°N was closed to all directed fishing for rockfishes.

Canadian fishermen began exploring and fishing off the west coast of the Queen Charlotte Islands in the late fall of 1976 and followed in 1977 with the development of a major fishery which has continued to date. This fishery was based primarily upon Sebastes alutus with secondary landings of S. reedi, and was therefore cause for concern because it was adjacent to areas where large removals of S. alutus had previously been made. The progress of this fishery through 1977 generated further concern due to the substantial decreases in catch rates through the year. While rockfishes may normally undergo some seasonal change in availability, the changes observed were large. Although some return to higher catch rates did occur in early 1978, they did not reach the level of the early 1977 fishery.

Rockfish populations are characterized by multiple age-groups within the fishable stock as well as very low growth, mortality and fecundity rates. Productivity of these populations is therefore low and maximal exploitation rates would generally be less than 5-10% of the fishable stock per year. The sensitivity of these populations to overexploitation, the relatively recent development of the Canadian fishery and the uncertainty of the linkages between those fish presently exploited and previously overexploited groups, was ample justification for initiating research activity in this area.

The primary objective of the cruises was to estimate biomass by species, within areas accessible to trawl gear. This information was needed to provide confirmation of Total Allowable Catches of rockfishes determined through analysis of catch statistics. The secondary objective of the cruises was to collect biological information on all species of rockfish encountered. There is almost no information available on these species in this area, due to the relatively recent development of the domestic fishery for them. Rational management of these resources cannot be accomplished without an understanding of their biology and consequent effects on available surplus production.

The domestic fishery off the west coast of the Queen Charlotte Islands has been prosecuted by less than 10 vessels, of which five vessels expended the majority of the fishing effort. Expertise at fishing this extremely rough-bottom area is limited and it was decided that a chartered, commercial vessel that had previously fished the area would be the best configuration for the surveys. The M/V BLUE WATERS, a 28-m (92-ft) stern trawler, was the successful bidder for both survey charters.

In undertaking any biomass survey, certain constraints must be recognized and, where possible, compensated for. Chief among these constraints is that such a survey is a point estimate and may not reflect abundance over time, particularly with regard to seasonal shifts in availability of fish. Another constraint is with regard to the survey design and the distribution of fish; this will be dealt with more extensively in the Methods section of this report. The limitations of surveys can be minimized if independent information on species abundance is available; fortunately, this is available through voluntary interview reports from commercial fishermen fishing this area. It is therefore possible to both confirm data obtained from the survey as well as to augment it with data from areas not covered by the survey. Further, commercial fisheries data can also be used to correct erroneous interpretations which result from the previously mentioned constraints. The latter is particularly important in the case of initial surveys of an area.

METHODS AND MATERIALS

VESSEL AND NET

The M/V BLUE WATERS is a 28-m stern trawler with 625 main engine horsepower. Main warps are wound on a double-drum towing winch. The net is wound onto a hydraulic net drum mounted on the stern; the codend is fleeted over the starboard rail amidships. The catch was split either directly into refrigerated sea water tanks or into a number of checkers for sorting/processing. The nets used for the surveys were an Atlantic Western III rigged for rough-bottom trawling and a Diamond VII midwater trawl. Detailed vessel and gear specifications are contained in Nagtegaal et al. (1980) and Nagtegaal and Farlinger (1980).

SURVEY DESIGN

A semi-systematic survey design, resulting in a regular pattern of sampling stations, was adopted for the cruises. For the first cruise (BW78-1) sample stations were established along tracklines approximately normal to the coastline, at 18.5 km (10 naut mi) intervals. The first set of 16 such lines began near Cape St. James and extended to approximately 54°00'N latitude. The base was then shifted 9.3 km (5 naut mi) and another 15 tracklines followed, resulting in a set of 31 parallel tracklines approximately 9.3 km apart. Fig. 1 illustrates these lines, each being designated by a number and its location as a LORAN 'X' rate. The second cruise utilized information from the first cruise to modify trackline density in areas of greater fish concentration so that the errors of biomass calculation could be minimized. Fig. 2 illustrates the increased density of sampling in BW79-1, where lines were 4.0 km (2.5 naut mi) apart in selected areas.

Since the precision of an estimate is strongly affected by the degree of heterogeneity within the population, the survey area was partitioned into bathymetric strata to reduce the heterogeneity within sampling units (strata). Sampling was conducted within 30-fm (55-m) strata along the survey lines beginning at 30 fm; thus 30-59 fm, 60-89 fm, etc. The 30-fm stratum was selected after an examination of commercial catch records indicated that it would incorporate the species depth variation of the majority of trawl hauls for rockfishes. Sampling locations were selected as close to the mid-point of the stratum as possible. The bathymetry of this area is such that the horizontal distance along tracklines corresponding to the appropriate depth stratum was generally <0.5 km and in many instances was less than 200 m. Within the stratum, if a tow could not be made at the mid-point, the entire vertical distance of the stratum along the line was searched, plus a distance equivalent to five LORAN microseconds (~0.5 naut mi) on both sides of the line. If this extended search did not identify an area where a tow could be made, the stratum was designated as untrawlable and the next available stratum occupied. In this sense the survey was not totally systematic since only one coordinate of the sampling stations was fixed. Trawl stations attempted to maintain starting depth although departures often resulted from the sharp relief of the bottom.

In addition to the stations occupied on the survey lines, several sounds and inlets, including Rennell Sound, Kano Inlet, Inskip Channel, Moore Channel and Bottle Inlet, were surveyed during BW78-1 (Fig. 3). When all possible stations along the survey lines had been occupied several tows were made when large aggregations of fish were encountered, primarily to obtain species composition and biological data. Positions of all sampling stations were established with LORAN-C and verified by radar bearings. Sampling stations are presented in Figs. 4 and 5.

ESTIMATION TECHNIQUES

Catch Weight

Total catch for each haul was estimated by either of two methods. If the catch was small (~0.5 t), the entire catch was sorted and weighed by species to obtain the total weight. If the catch was larger than 0.5 t, the catch in the codend of the net was weighed with an electronic load cell[1] before the catch was emptied onto the deck. After emptying the net, the codend was reweighed to obtain the weight of the catch by difference. Where multiple lifts of the net were necessary this procedure was repeated for every lift. The load cell consists of an electronic sensing unit coupled to a digital conversion/display panel. Due to the movement of the ship, no consistent value was displayed on the panel and the operator had to employ some judgement in estimating the weight of the lift. The error in this procedure was therefore dependent to some degree on the experience of the operator. The magnitude and consistency of this error was examined on a series of 13 hauls where the catch weight was estimated with the load cell and the catch subsequently separated by species and weighed on a platform scale (Appendix Table 1). A continuous, qualitative check on accuracy was maintained by comparing the load cell reading with the vessel master's visual estimate.

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[1]SI-2300 "SEA WEIGH" scale MSI Ltd., Seattle, WA., U.S.A.

Species Composition

The species composition of catches was determined either through sorting of the entire catch for small hauls or subsampling of the catch and prorating for large hauls. In general, hauls of >0.5 t were subsampled however there were exceptions to this procedure if hauls were only slightly larger than 0.5 t or hauls from 0.5-1.0 t showed very high species diversity. In the latter cases, the entire haul was sorted and weighed. In one instance, a haul of less than 0.5 t was subsampled because it was almost monospecific.

Subsampling of hauls varied somewhat with species diversity; more diverse hauls were sampled more intensively with the guideline of one six-tub sample for hauls of 0.5-2.5 t and two six-tub samples for hauls of larger size. Initially, three six-tub samples were taken from a 3 t haul, however, examination of the results yielded no advantage over two six-tub samples and resulted in considerably more time lost in sampling.

Subsampling of the catch was conducted so that samples would come from the top, middle and bottom of the checkers where the catch was dumped, and so that all areas of the checker would be sampled (after Westrheim 1967a, 1976). The latter was necessary because of ship movement and concomitant shifting of the catch. Where more than one lift of the net was required, the subsampling of the catch was determined in part by species diversity. Where species diversity was low, only the first and last lifts were sampled, whereas an attempt was made to sample all lifts of high diversity catches. All marketable fish were dumped into the ship's RSW tanks; all other fish and invertebrates were discarded. The weight of a species in the entire catch was prorated from its proportional weight in the subsample of the catch.

Biological sampling

The primary emphasis of sampling conducted on the cruises was to obtain representative samples of all rockfish species so that the age composition of their populations or aggregations could be estimated. These activities were intended to augment those of sampling by port observers in Prince Rupert, who have been sampling major species in the landings from this area since the inception of the fishery. The basic sample size was 100 length-sex-otolith measurements per species plus as many more length-sex-otolith or length-sex measurements as were practicable. If multiple samples of a species were taken from the same area or if an area was well represented in the commercial sampling, only one otolith sample was collected per area. For some species, e.g. *Sebastes borealis*, no one haul contained 100 fish and their samples would be necessarily smaller, however the lack of information on these species dictated that they should be sampled.

In addition to the rockfish samples described, samples were taken of species for other Program investigations as time and circumstances permitted. The Seattle, WA. laboratory of the National Marine Fisheries Service had also requested assistance in obtaining liver and muscle samples from *S. alutus* and

S. reedi (during BW78-1) to incorporate into a coastwide electrophoretic study of several rockfish species. Observations of maturity states and stomach contents of rockfishes were also made, where practicable.

Net Characteristics and Catchability

A major component of biomass calculations via any swept-area measure is the accurate estimation of certain dimensions and operating characteristics of the trawl and hence, effective path width. A number of techniques and instruments have been used in determining net dimensions (Wathne 1977; Carrothers 1968; Harling et al. 1969). The United States National Marine Fisheries Service has estimated the mean effective path width (bowed horizontal opening between wing tips) for various trawl nets using electronic sensors. This information was used to estimate the effective path width of the Atlantic Western III by applying the mean ratio of effective path width/footrope length for nets of similar dimensions, to the footrope length of the survey net. Having thus obtained an estimate of the distance between the wings of the net, the distance between the trawl doors was calculated by simple geometry.

While previous trawl surveys have assumed that the distance between the wings of the net represents the effective path width, the simultaneous use of ship and net echo sounders showed positive indication that the zone of influence of the trawl extends well forward of the net itself; the herding effect of Blaxter and Parrish (1966). It is evident that this influence may be present as far in advance of the trawl as the trawl doors. For this reason we have chosen the effective path width as the distance between the trawl doors. Associated with this we have chosen a net catching coefficent, c, equal to 1.0. While this may appear somewhat arbitrary, we believe that this more correctly describes the catching power of a trawl when the effective path width is correctly described, especially in hard-bottom trawling where the door to net distance is relatively short. It is difficult to establish the correct value for c since published papers have dealt primarily with flatfishes (e.g. Harden-Jones et al. 1977) whereas rockfishes have a more highly developed acoustico-lateralis and might be expected to be more sensitive to the herding effect of the gear. The reaction of rockfish schools to fishing certainly bears witness to this sensitivity. While Harden-Jones' work with sector-scanning sonar indicates a value of c=0.44 between the doors for plaice, the value for rockfishes would probably be higher. It is doubtful that the value would be as high as 1.0, however this value was used both because it will not overestimate biomass, and because rockfish stocks are extremely sensitive to overexploitation. Further commentary on this problem will be provided in the Discussion.

Previous studies (Alverson and Pereyra 1969; Westrheim et al. 1972) have also assumed that c=1.0, however, these studies further assumed that the effective path width of the trawl was the distance between the wing tips. We believe that such an assumption will overestimate abundance; some support for this view is derived from the fact that biomass estimates of S. alutus in Queen Charlotte Sound indicate stock sizes capable of supporting removals larger than those which have obviously reduced this stock. While the width of the trawl doors is used as the effective path width of the trawl in this report, it is acknowledged that current velocity, vessel speed and warp length will alter this and other trawl dimensions. No compensation for these changes has been made and the 'average' relationships have been used in calculations.

Although a catching coefficient of 1.0 between the doors may appear high it is pertinent to note that other assumptions of swept-area estimators will provide an overestimation bias, when applied to aggregated species (see also p. 15).

Biomass

Biomass estimates were calculated by species for each 55 m (30 fm) depth stratum with the following equation (after Westrheim et al. 1972):

$$B_i = \sum_{i=1}^{n} \left(\frac{\overline{CPUE_i}}{K_a} \right) (A_i)\ (c)$$

where B_i = estimated total biomass in the i^{th} depth stratum (t);

$\overline{CPUE_i}$ = mean catch per hour trawled in the i^{th} depth stratum (t/hr);

K_a = area of the bottom trawled in one hour (naut mi^2);

A_i = total area of the i^{th} depth interval (naut mi^2);

c = catching coefficient of trawl gear.

Biomass estimates were then summed for all strata to obtain the total biomass figure, B_i . Biomass estimates were calculated separately by strata due to the higher degree of heterogeneity among strata, and because observed distribution of fishing effort indicates some consistency in the bathymetric modes of abundance over time. K_a was calculated as the product of vessel speed and effective path width of the trawl gear. A_i values were obtained by use of a planimeter on C.H.S. charts 3853, 3854, 3865 and 3868. The low areal resolution of soundings on charts for this area should be noted.

In the case of BW78-1, the biomass estimates were calculated based on total area and for estimates of trawlable area by strata. For the BW79-1 data, biomass was calculated on the basis of sampled, trawlable area and a separate calculation made for other areas, by strata. Confidence limits for estimates were calculated using the normal root of summed error terms and the appropriate t statistic, i.e.

$$B_T \pm t_{(.95,n_e)} \quad \sqrt{varB_T}$$

where n_e = effective degrees of freedom
and

$$varB_T = \sum_{i=1}^{n} (A_i/K_a)^2 \ var\ \overline{CPUE_i}$$

In the case of a stratified survey such as this the effective degrees of freedom, n_e, to be used in the calculation of the error about B_T is not the usual

$$\sum_{i=1}^{n} n_i - 1$$

Because B_T is a linear function of independent variances the degrees of freedom term is derived by the formula of Satterthwaite (1946):

$$n_e = \frac{\left(\sum_{i=1}^{n} S_i^2\right)^2}{\sum_{i=1}^{n} \left(\frac{S_i^4}{n_i - 1}\right)}$$

As noted by Pennington and Brown (1981), "...if S_i^2 vary widely, which is often the case for trawl surveys, the effective number of degrees of freedom is much lower than the sum of degrees of freedom over all the strata.." In many trawl surveys the independence of variance among strata is not examined and confidence intervals may be broader than presented. In the case of the present survey, examination of variance among strata with a Bartlett's test showed no homogeneity, and strata variances were therefore treated separately.

AGE, MORTALITY AND GROWTH

Age structure of stocks was estimated through subsampling of catches. Sagittal otoliths were collected and preserved in either glycerine and water or 25% ethanol for subsequent ageing. The minimum sample size for estimation of age and growth was 100 fish and ranged up to 414 fish. Additionally, samples of less than 100 otoliths were collected from some species due to their low overall abundance in catches. Otoliths were read with a dissecting microscope under reflected light at 12x magnification; during 1979 those otoliths estimated to be over 20 years old were then mounted in epoxy, sectioned, and read under a compound miscroscope (Beamish 1979). Double ageing of random samples by alternate readers provided a check on consistency of reading. Age, length and sex data for all fish were collated on magnetic tape for analysis.

Subsequent to the age determination of BW78-1 samples it was discovered that significant ageing errors occur between the ages of 16-20, when ages are based on surface readings of otoliths. In consequence these samples had to be reassessed and it was decided to conduct a major review of rockfish age, growth and mortality for major species, coastwide. The results of revised age readings are included in Shaw and Archibald (1981) and the review of growth and mortality in Archibald et al. (1981). Details of processing and analysis are included in these reports.

SPECIES ASSOCIATIONS AND DISTRIBUTIONS

Catches were examined to determine if species exhibited consistent associations over depth, area or bottom type. Species were segregated by depth strata and examined over areas. The results of this review prompted a general analysis of rockfish species associations to determine if associations were sufficiently persistent to be used as functional management units. This analysis examines both research and commercial catches and uses cluster analysis and covariance analysis to detect patterns. The report of this project is currently in preparation.

RESULTS

SPECIES DISTRIBUTION AND TRAWLABLE AREAS

The precise distribution of rockfish species off the west coast of the Queen Charlotte Islands cannot be accurately delimited because it is impossible to obtain a continuum of samples along the coast. Both commercial fleet activity and research surveys (Figs. 1, 2) indicate that there are substantial segments of the coastline where trawling is not presently possible; inferences about species distribution must be made with this in mind. While these segments do cover a large latitudinal distance the actual area of bottom in depths where rockfishes are commonly found is relatively small. Table 1 presents the area of trawlable and untrawlable bottom by depth interval, for the survey area. These areas were calculated by planimetry using hydrographic charts of the area, but the paucity of soundings on some charts made interpolation necessary in order to construct isobaths. There is therefore some error associated with the area measurements for both trawlable and untrawlable areas, although it has been minimized to the extent possible.

Rockfishes were present in all depth ranges fished in the offshore areas with the greatest concentrations encountered between 219-382 m (Table 2). Both abundance and species diversity were considerably lower in those inshore waters (bays and inlets) surveyed than in comparable depths offshore. The centre of rockfish abundance identified through trawling during BW78-1 was between Buck Pt. and Kano Inlet with a mean catch rate of 3.38 t/hr. With the exception of this area there was a general decrease in both abundance and diversity of rockfish encountered in trawl hauls when moving from Frederick Island to Cape St. James. However, this is reflective of the effectiveness of the sampling gear as several areas of apparent rockfish abundance off Moresby Island were identified by echo sounder, but in areas unsuitable for bottom trawling. Sampling of these areas with longline gear is the subject of another report (McCarter 1980). Major concentrations of rockfish were encountered only off Rennell Sound during BW79-1, with minor bodies of fish being noted off Anthony Island and Flamingo Inlet.

Of those species encountered during the survey, Sebastes alutus, S. brevispinis and Sebastolobus alascanus had the greatest bathymetric range, occurring in six of the eight depth zones fished. Sebastes brevispinis exhibited the greatest vertical range, being obtained in hauls between 50-602 m. Figs. 6 and 7 present depth ranges and relative abundance of individual species by depth, for the survey area as a whole. Several species groupings by depth are suggested in this figure but associations should not necessarily be inferred due to the grouping of all hauls, the known seasonal behaviour of these species and the fact that these figures represent only one point in the seasonal cycle. A more complete treatment of species associations among the commercial scorpaenids in B. C. waters, as determined through both research and commercial catches, is near completion.

Catches during both BW78-1 and BW79-1 were dominated by S. alutus and S. reedi in virtually all areas fished. Mean catch rates for the two species were 0.28 t/hr and 0.43 t/hr in 1978, and 0.14 t/hr and 0.10 t/hr in 1979, respectively. The decreases in catch rates over the two years were 50% for S. alutus and 76% for S. reedi. Over the same period the commercial fleet fishing in these areas experienced decreases in catch rates of 16% and 38% for S. alutus and S. reedi, respectively. The discrepancy between the decreases of research and commercial catch rates is largely due to the lack of effort by the commercial fleet in areas which were previously productive, whereas the research cruises occupied the same areas in both years.

SPECIES ABUNDANCE AND BIOMASS ESTIMATES

Biomass estimates for the two cruises were derived in different manners in accord with the changes in the survey design from 1978 to 1979. The abundance estimates for BW78-1 were calculated for the entire trawlable area of the west coast of the Queen Charlotte Islands, with no segregation of data for variations in relative abundance along the coast. While this variation was noted, the survey design was not amenable to the segregation of these areas. Table 3 presents estimates of the biomass of rockfish species by depth range, for BW78-1. The large error associated with these estimates was primarily an artifact of the application of a regular sampling pattern to a highly overdispersed resource, and was the major impetus to modify the design for 1979. The majority of the estimated biomass in 1978 was accounted for by S. alutus (1623t ± 45.1%) and S. reedi (2312t ± 109.0%), representing 61.4% of the total. Other major components of the total were S. brevispinis (14.0%) S. zacentrus (6.5%), S. aleutianus (5.3%), S. proriger (3.1%) and S. borealis (3.1%). While S. zacentrus did account for almost 7% of the total estimated biomass, the majority of these fish were less than 30 cm and therefore unmarketable as food fish; the same applied to S. diploproa, S. elongatus, S. helvomaculatus and all but a very small proportion of the Sebastolobus alascanus.

During BW78-1 the maximum of the estimated rockfish biomass occurred in the 274-327 m range, however distribution of total estimated biomass by depth interval did not vary from the mean by more than 20%, between 165-382 m (Table 3). Distribution of individual species varied considerably with depth; most major species exhibited some degree of skewness toward the deeper segments of the ranges over which they were encountered (Fig. 6). The bathymetric distribution of the minor species is more difficult to determine since sample sizes were generally small, although some such as Sebastolobus alascanus, Sebastes babcocki and S. brevispinis appeared to be symmetrically distributed around a mode. Others, such as S. helvomaculatus and S. proriger appeared to be more uniformly distributed.

Table 4 presents the estimated biomass of rockfish, by species and depth range during 1978, if the fish were assumed to be as abundant in untrawlable and unsampled areas as they were in sampled. Relative to the figures obtained for the trawlable areas during BW79-1, the figures in this table are probably an overestimate of the biomass of these species because concentrations of fish of magnitude similar to those sampled were not commonly observed in other locations. While some major concentrations of fish were observed in these areas, the majority were shallow of 180 m, where no sampling in any location was possible. The majority of these unsampled concentrations therefore have no correlates in the existing data. Subsequent sampling of these areas with longline gear (McCarter 1980) caught primarily S. ruberrimus (63.4%) and S. pinniger (6.7%) however the different selective properties of longline and trawl gears are acknowledged.

The estimated biomasses of rockfishes, as calculated from BW79-1 cruise data, are presented in Tables 5-9 by species, depth range and locality. Table 10 presents the estimate of biomass as derived if data were not segregated by locality. The figures in this table, although not strictly comparable to those of 1978, are calculated in a similar fashion, i.e. mean catch rates extrapolated over all trawlable areas, however the mean catch rates employed have a greater information content than those of 1978. The latter is reflected in the narrower confidence interval of the 1979 estimate (~9700 t ± 37%) compared with that of 1978 (~6400 t ± 50%).

The sum of the 1979 individual locality estimates was approximately 18,293 t ± 9.3%. The largest contribution to this total came from the Rennell Sound area (14,174 t); the error of this locality estimate (±5%) is not representative of normal variation encountered and occurs because the biomass estimate for the 165-218 m stratum arises from only a single, large haul. As such, this estimate has no error associated with it and strongly biases the total estimate. Unfortunately there are no samples in this stratum from other localities subject to the same sampling intensity. While there are samples in this stratum from the remainder of the survey area (i.e. non-localized sampling), the extrapolation of error limits from areas where fish are not abundant to those where they are, would be unrealistic. The true error limits of the 1979 biomass estimate for Rennell Sound are therefore unknown, but are assumed to lie somewhere between the 5.4% value in Table 5 and the 49.5% value of the 1978 survey. Naturally the low error limit of the Rennell Sound estimate has a concomitant effect on the error limits of the total estimate. The 38% error associated with estimates from other localities during BW79-1 is probably a more realistic figure for the error of the total estimate.

It is evident from consideration of the commercial fishery, that the survey may not have produced a realistic estimate for the Anthony Island area. The total estimated biomass for this area was 204 t ± 357% and while the error limit is large the estimate is probably somewhat low. The fishery in this area was initiated in earnest during 1978, when CPUE was almost 9 t/hr; by 1979 the CPUE had dropped by over 50%, to less than 4 t/hr. Regression analysis of this fishery suggests that the standing stock of rockfishes prior to 1977 was approximately 3200 t, although the paucity of data should be noted. Since the cumulative landings to the end of 1979 stood at almost 2500 t, it is implied that the present biomass of rockfishes at Anthony Island would be about 700 t plus the biomass of recruited fish over the interval. Considering the life history characteristics of these species, this recruitment biomass would be small (<100 t) and the error limits of the 1979 survey estimate may in fact encompass the actual biomass of rockfishes in this area. Obviously, the Anthony Island area merits close scrutiny in the future.

SIZE AND AGE COMPOSITION OF STOCKS

Although a thorough treatment of both size and age composition of rockfish stocks in this area is contained in Shaw and Archibald (1981), salient aspects of that summary are presented here. In general, rockfish stocks off the west coast of the Queen Charlotte Islands appear to have undergone relatively little exploitation. Age compositions of the major species are dominated by fish >20 y old (Fig. 8). In comparison, stocks of *S. alutus* in Queen Charlotte Sound where exploitation has been extensive, are composed almost entirely of fish in the 15-18 y range. Off the southwest coast of Vancouver Island, another area of high exploitation, the age composition of *S. alutus* is also biased to the 13-17 y range.

Sebastes alutus and *S. reedi* stocks, the primary components of the total biomass, are dominated by cohorts which arose from spawning prior to the major foreign exploitation of the mid-1960s. In decreasing order of abundance the cohorts were spawned in 1952, 1942, 1929, 1923 and 1915. The 1952 cohort was also dominant in other areas of the coast (Queen Charlotte Sound, Vancouver Island; Westrheim et al. 1972) prior to extensive foreign exploitation, although its abundance was dramatically reduced in subsequent years. The bias toward older, larger fish in the survey area, relative to other coastal areas, carries strong implications for the management of such stocks.

MORTALITY AND GROWTH

The mortality and growth of rockfishes from B. C. waters is the subject of a separate, more extensive report (Archibald et al. 1981) however the major feature of stocks in the survey area will be noted here. Chief among the opportunities presented by the cruises was that of sampling from relatively unexploited populations of rockfishes and subsequently deriving mortality estimates which would approximate natural mortality alone. A caution to this should be added, in that the biased nature of the age distribution for most species may indicate that mortality estimates derived (Z) would not represent natural mortality experienced throughout the lifespan of the fish but, rather would incorporate some degree of senescent mortality. Accordingly, those estimates derived might best be considered as upper limits of M, the instantaneous rate of natural mortality.

In general the estimates of mortality generated in this study ($Z \simeq M$) are lower than published values. This result is not unexpected, since these earlier studies did not have the benefit of sectioning techniques. The ultimate values of mortality arrived at however, do much to alter our thinking on the behaviour of rockfish populations. Additional information from commercial fishery samples in the survey area (Archibald et al. 1981) provides support and elaboration of estimates from research samples.

The highly skewed age distribution of most species sampled makes estimation of the age at full recruitment difficult. Where sufficient numbers of young fish were available (S. zacentrus) it is evident that recruitment to the gear may begin at ages 5-6. The lack of young fish in samples of other species indicates that the functional aspects of recruitment may be far more important than mere physical recruitment to the gear. Whether this delay in functional recruitment results from behavioural differences of younger fish on the fishing ground or spatial separation of this component of the stock is unknown. Limited sampling in the shallower segments of the known bathymetric range of these species revealed no abundance of pre-recruit juveniles, despite a small-mesh liner used in the net. The location of juvenile scorpaenids has proved to be very difficult. Even though some juveniles have been found (Carlson and Haight 1976; Westrheim 1967b), their abundance has never been proportional to the true abundance of the cohort, as evidenced by subsequent fishery results.

While the development of new ageing techniques has substantially altered estimates of mortality for most species, it has had relatively little effect on estimated growth parameters. Linear growth rates of rockfishes diminish greatly after ages 15-17 and since revisions of age estimates concern primarily these post-inflection fish, parameter estimates differ little from published values. Parameters were not determined for some species due either to small sample sizes or lack of convergence in estimation procedures, resulting from samples of only small segments of the length range. Subsequent examination of research and commercial data from this and other areas (Archibald et al. 1981) indicates that the lack of smaller fish in samples precludes determination of growth parameters applicable throughout life. Fortunately these data indicate only limited spatial variation in growth, other than what are evidently density-dependent changes associated with highly exploited stocks.

SPECIES ASSOCIATIONS

The limited duration of the surveys discussed here provides little opportunity for interpretation of associations among rockfish species. The more detailed examination referred to earlier was initiated largely as a result of these cruises and the anomalies noted on them. It is evident that most species have restricted and coincident bathymetric ranges (Figs. 6, 7). The summary of catches over all areas is somewhat misleading since some overlaps in depth distribution (e.g. S. alutus and S. reedi) are not spatially coincident. Similar situations exist for S. proriger, S. zacentrus, and S. brevispinis. It is possible, as suggested in Ketchen (1980), that habitat requirements (or preferences) may be highly specific.

Other authors, beginning with Alverson et al. (1964), have noted the dynamic nature of rockfish bathymetric distribution and inferences regarding associations should consider such movements. In addition, the bathymetric modes of abundance may represent the availability of suitable habitat. A further complication to such a summary presentation concerns variaton in catch rates or availability at particular survey times. For example, a shift in bathymetric abundance of S. reedi between 1978 and 1979 is suggested in Figs. 6 and 7, however the apparent mode in 1979 is the result of high catches at a single locality. Were sufficient data available to treat each locality more thoroughly, more resolution of the distribution might have indicated similar modes. It was largely due to the ambiguities evident in these and other temporally-limited data sets that the detailed species association study was initiated.

DISCUSSION

SURVEY DESIGN

The overdispersed nature of rockfish schools presents some major problems to the provision of biomass estimates with sufficient precision to render them useful for management. Existing survey methodology does not adequately address the needs of surveys for highly aggregated species, where the area to be surveyed is much larger than the size of the sampling element, and survey time is limited. Improvements in precision of estimates may be made through sample allocations proportional to variance in the strata, however some foreknowledge of the coefficients of variation within the strata is required. It has been suggested (Green 1979; Elliot 1971; Kuno 1969) that sequential sampling be conducted to obtain these coefficients but the widespread distribution of many target species often renders the time necessary to sample a 'representative' segment of the range prohibitive. A further drawback to existing survey designs are the strong constraints to adaptive sampling that arise from the assumptions upon which the subsequent analysis of the data is based (e.g., swept-area estimators). Some improvements can be made through post-stratification of the data although extreme caution in making subsequent distributional inferences is then required.

It was primarily to reduce the large variance of the initial (BW78-1) stratified-systematic design that a second level of stratification (geographic or locality) was introduced in 1979. While the precision of the 1979 estimate was improved by this additional stratification, the constraints on sampling imposed by this rigid design and the general problem of extrapolation over unsampled areas continue to argue for a better survey design. In particular, more attention must be given to the biological characteristics of the target species as they relate to the assumptions of biomass estimators. Swept-area calculations are often made over large areas for species having very specific habitat requirements; the accuracy of mean values thus employed may be suspect. Elsewhere (Leaman 1981) we have suggested a different approach to estimation for highly aggregated species, which involves a sampling response for each encounter with a school. Such an approach would be successful only for overdispersed resources and where the size of the response elements are such that the sampling pattern is smaller than that specified by any fixed design. While minimum population estimates would result, their precision would be greatest and, for the survey area, their accuracy would be higher. Naturally, the search pattern for the survey vessel becomes more critical with such a design, and simulation studies to determine optimal searching algorithms have been initiated. The data base for this simulation is derived from two intensive rockfish surveys off southwest Vancouver Island and the northwest Queen Charlotte Islands, conducted during 1979. Results will be contained in future reports.

BIOMASS ESTIMATES

The species composition of biomass estimates derived from these cruises reflects that of commercial landings from the area; not unexpected in view of the sampling gear. Some of the minor species contributing to the total rockfish biomass (S. diploproa, S. helvomaculatus, S. proriger and S. variegatus) are landed commercially from this area whereas their smaller size in other areas prohibits such landings. Other species such as S. aleutianus, S. ciliatus and S. variegatus are considerably less abundant in more southerly areas, simply on the basis of their geographic distribution.

The biomass estimates for the survey area must be examined within some fishery context to assess their validity. As noted previously, the rockfish fishery in this area began in earnest during 1977; fishery statistics for this fishery are presented in Table 11. It is difficult to provide a detailed analysis of a fishery when the time series of catch data is short relative to the duration of a cohort in the fishery. Some regression techniques may be applied however, when the removals by the fishery are the dominant variable in stock biomass changes, and recruitment or natural mortality are minor components. The estimated mortality rates (0.05-0.10) and generation times (40-70 y) for rockfishes would argue that these conditions are met, at least for stocks in the early stages of exploitation. The Leslie-DeLury (Leslie and Davis 1939; DeLury 1947) regression estimator for original population size [with Braaten's (1969) adjustment for interval length] was applied to the fishery data from the survey area (Table 11). The estimated population size of all rockfishes in the fishable stock (N_o) in 1976 was approximately 15,200 t. The nature of the DeLury estimator is such that the confidence interval for N_o is not symmetric about N_o, although it does follow a standard t distribution. A measure of the sensitivity of this estimator can be seen in comparing the 95% (10,870-40,380 t) and 90% (11,830-24,510 t) confidence intervals for N_o.

The confidence intervals for the survey and the regression estimators thus overlap, and the point estimates are within 3500 t. While the point estimates cannot be interpreted too stringently they suggest a biomass in the 15,000-20,000 t range. The proximity of these two independent estimates provides a more substantial basis for management of rockfishes in the survey area.

One of the most scientifically unsatisfactory elements of the swept-area estimator is the catching coefficient, c, of the trawl gear. While a number of papers dealing with the values of c for various trawls have been published (Foster et al. 1981; Ben-Tuvia and Dickson 1969), none have dealt with the scorpaenid forms and little is known of their responses to trawls. Most of these papers have dealt with pleuronectid or gadoid forms and in the case of the former, have shown that fish usually must make contact with the fishing gear before responses are ellicited. Other demersal forms have shown greater sensitivity to the sweeplines and bridles. Simultaneous use of net and vessel sounders has shown that the Sebastes spp. are influenced by the gear well in advance of the net itself. A more elaborate system of transducer/receivers will be necessary to quantify the range and efficacy of the herding of Sebastes spp. by trawl gear. We suggest that the use of c=1.0 at the path width of the trawl doors represents a maximum of the effective trawl path. In addition to the estimation of the effective path width of the trawl, another source of error in assigning a value for c is the estimation of escapement by those individuals that encounter the trawl gear but are not retained by it, i.e. the vulnerability of the fish. In our calculations there is an implicit assumption that all fish encountered by the gear are retained by it. A number of factors argue that this assumption is not met. Firstly, the response of rockfish schools to fishing is generally observed to be a downward movement; indeed, fish are often observed with their heads wedged in the 'half-eggs' of the groundline, when the net is hauled. Secondly, the sea bed over which rockfish are found is irregular and the net cannot possibly be in contact with the bottom all the time. The combination of these two factors implies that some fish will escape below the net groundline. Added to this is the probability of fish moving away from the net; either to the sides or above. The latter is thought to be a lower probability than the former because fish are seldom observed when looking upward from the net sounder, albeit the beam width of the transducer is narrow. In conjunction, the foregoing elements suggest that the swept-area biomass estimator will tend to underestimate those fish actually encountered.

In contrast to the biases inherent in the path width/vulnerability components of the swept-area estimator, a strong bias toward overestimation of fish abundance is contained in the use of mean catch rates to extrapolate over unsampled areas. Although sampling intensity was intensified and extrapolation areas minimized during BW78-1, it was still necessary to apply average catch per nautical mile to areas larger than were sampled. This practice has as its basis the precept that random sampling within the extrapolation area will yield an average catch rate representative of the area. That rockfishes are more common around rocky bottom areas and that they are highly aggregated evidences a non-random distribution, purely as a function of the distribution of rocky bottom areas. The strong link between the variance and the sample mean is ample proof of such non-random distribution. Accordingly, strata means are strongly biased by larger tows and will tend to overestimate strata biomass, particularly when few samples are available.

As previously noted the precision of the biomass estimate generated from BW79-1 data increased over that from BW78-1, largely due to the segregation of sampling in areas of higher abundance. The biomass estimated from this survey is primarily concerned with that stock exploited by the domestic fleet; less than 20% of the total was from areas unknown to the commercial fleet. Limitations of the survey with regard to its application to commercial production are those that are common to all surveys, i.e. they are point estimates and reflect only the fish that were present and available at the time of sampling, and they do not make a series of repetitive tows at each station. The former is impossible to account for within the context of a single survey; the latter may provide considerable information if there is sufficient time available during the survey to both sample the entire area adequately and provide these repetitive tows.

We have endeavoured to present both the strengths and limitations of these two surveys. Because of the level of uncertainty attached to the estimation process the corroboration of the commercial fishery analysis becomes more important. We believe that until surveys become more adaptive to species distributions, swept-area estimators of rockfish stocks, and aggregated species in general will continue to require the verification of independent techniques.

PRODUCTIVITY OF ROCKFISH STOCKS IN THE SURVEY AREA

There are two primary components to rockfish biomass in this area: (i) the 'slope' aggregation composed of *S. aleutianus*, *S. alutus*, *S. proriger*, *S. reedi* and *S. zacentrus*; and (ii) the 'shelf' forms, *S. pinniger* and to a lesser extent *S. brevispinis* and *S. ruberrimus*. *S. alutus* and *S. reedi* are the major contributors to the first group, with the former being the most important. The late spawning of *S. alutus* in this area (May-June) relative to other areas on the B. C. coast (Westrheim 1975) indicates that the stock off the Queen Charlotte Islands is most closely allied with the Gulf of Alaska *S. alutus* stocks. If this is correct then any depletion of this stock may necessitate recruitment from the Gulf area. The absence of any substantial quantity of young (<15 y) fish off the Queen Charlotte Islands indicates either that normal recruitment from the resident stock is very low or that no recruitment from the Gulf area has occurred for some time. Lapi and Richards (1981) found in surveying the Langara Spit area (north of 54°00'N) that younger fish contributed substantially to the overall biomass of that area. The Langara Spit area was fished heavily by Soviet and Japanese trawlers in the mid-1960s and present biomass is estimated to be less than 10% of the primitive abundance (Ketchen 1980). Significantly, the young fish obtained in their survey represent only year-classes spawned prior to this extensive exploitation. Also of note is that the Gulf of Alaska experienced similarly heavy exploitation prior to and after that in the Langara Spit area.

Consideration of the foregoing suggests at least two scenarios for productivity of rockfish stocks in the area covered by this report. The lack of young fish south of 54°00'N may indicate that *S. alutus* is a relic population that remains from the previously abundant and widespread stocks centred in the Gulf of Alaska, and that the stock of *S. alutus* off the Queen

Charlotte Islands is not self-sustaining. If this is true then management of this stock will simply represent the rate at which it is acceptable (by socio-economic criteria) to deplete it. Alternately, the presence of cohorts in the Langara Spit area, which were spawned prior to extensive exploitation and invulnerable to it, may indicate that a large biomass of older fish inhibits the recruitment of young fish, and that only the removal of these older fish will permit expression of this recruitment. Whether this inhibition would be a simple density-dependence or some behavioural mechanism is open to speculation.

We believe the former of these two scenarios to be more probable on the basis that the complete absence of younger fish in the BW78-1 and BW79-1 data is implausible from a population maintenance viewpoint, and implies recruitment from elsewhere. The absence of young fish would make this population highly susceptible to catastrophic declines unless a reservoir of juveniles is available. There may well be an inhibitory effect of a large biomass of adults on juvenile expression, at least in the maturation process. Recent work on the Moresby Gully *S. alutus* stock indicates that gonadal maturation may be delayed when large numbers of adult fish are present (unpublished data, in preparation). Size at first maturity in that stock is considerably larger (38 vs 34 cm) than for the *S. alutus* stock in Goose Island Gully, where few fish older than 24 y are present. Spawning periods indicate that these two stocks are of the same 'type' relative to the Queen Charlotte Islands and Gulf of Alaska stock.

The 'shelf' rockfish (*S. pinniger*, *S. brevispinis*, *S. ruberrimus*) component of rockfish biomass off the Queen Charlotte Islands was less well assessed by these surveys, due to the shallower centres of distribution for these species. Both these surveys and that reported by McCarter (1980) identified substantial rockfish aggregations shallow of 180 m. While the exact composition of these aggregations is uncertain, their magnitude and distribution suggests a total biomass of these three species at least equal to that of the 'slope' forms discussed earlier. Since most of the area where these species occur is presently considered untrawlable, assessment of these stocks awaits the development of such a shallow-water fishery.

The low estimated mortality rates for these species (Archibald et al. 1981) imply low productivity and management recommendations will continue to reflect this. While the *S. alutus* stock may be a relic, unrestrained exploitation will not be recommended unless the present policy of controlled fishing truncates the age distribution and reduces the stock without evidence of long-term recruitment. In this regard such reductions in the stock may permit greater expression of recruitment, if adult biomass is indeed inhibitory.

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Table 1. Trawlable areas (naut mi^2) by depth strata and locality.[a]

Depth Interval(m)	Rennell Sound	Buck Point	Flamingo Inlet	Anthony Island	Other[b] Areas	Total[c] Area
0- 55	-	-	-	-	-	219.4
55-108	-	-	1.53	-	1.28	212.5
109-163	-	-	1.75	-	1.15	234.6
164-218	26.92	2.90	2.52	-	40.37	224.2
219-272	6.10	2.96	1.51	8.07	45.56	107.0
273-327	7.24	2.76	1.54	2.10	113.28	149.2
328-382	7.27	2.66	1.59	2.88	46.27	81.2
383-437	5.85	4.14	.54	1.10	1.37	81.5
438-491	7.69	.79	.54	.77	2.21	80.7
491-547	5.32	.79	.54	.88	4.97	80.0
Total	66.39	17.00	12.06	15.80	256.46	1470.3

[a]From Frederick Is.(54°00'N) to Cape St. James (51°52').
[b]Areas other than Rennell Sd., Buck Pt., Flamingo Inlet, and Anthony Is.
[c]Trawlable and untrawlable.

Table 2. Rockfish catch rates (kg/hr) by depth interval and locality.

BW78-1

Depth Interval (m)	Frederick Is.	Tian Hd.	Louis Pt.	Rennell Sd.	Kano In.	Marble Is.	Buck Pt.	Englefield Bay	Bottle In.	Barry In.	Mike In.	Gowgaia Bay	Flamingo In.	Anthony Is.
164-218	113.4	526.6	-	1833.9	-	2402.2	98.0	-	-	27.2	-	-	-	-
219-272	160.1	148.8	273.1	102.1	-	-	1073.2	11537.2	1332.7	-	395.5	-	-	399.2
273-327	460.4	487.2	471.7	2107.4	-	-	5344.2	1046.9	788.3	-	400.1	640.9	626.9	-
328-382	178.3	258.5	643.2	637.8	10208.1	-	313.0	1691.2	-	-	429.6	-	-	-
383-239	-	-	-	651.4	-	-	-	-	-	-	-	-	-	-
549-602	-	-	48.5	-	-	-	-	-	-	-	-	-	-	-

BW79-1

Depth Interval (m)	Frederick Is.	Tian Hd.	Louis Pt.	Rennell Sd.	Kano In.	Marble Is.	Buck Pt.	Englefield Bay	Bottle In.	Barry In.	Mike In.	Gowgaia Bay	Flamingo In.	Anthony Is.
164-218	54.0	-	-	22286.0	-	-	-	-	-	148.0	-	-	-	-
219-272	175.4	694.9	424.0	1235.5	-	-	998.0	893.3	300.0	-	-	-	3356.4	277.7
273-327	463.0	1678.0	460.0	2733.3	-	-	-	1303.0	-	405.0	-	-	951.0	-
328-382	308.7	270.0	400.6	1124.5	2368.5	-	200.0	489.1	-	-	-	-	-	344.5
383-437	-	-	408.2	-	-	-	500.0	297.0	532.0	120.0	-	-	-	-
438-492	564.0	305.3	-	76.0	-	-	-	-	-	-	-	-	-	-

Table 3. Biomass estimates (t) extrapolated over trawlable areas only, BW78-1.

	Depth interval (m)					
	164-218	219-272	273-327	328-382	383-437	Total
Sebastes aleutianus	18.8± 18.8	0.7± 1.1	15.7± 9.9	314.1± 351.0	10.7± 42.5	341.2± 353.7
S. alutus	-	184.4± 215.2	1002.5± 620.6	342.2± 297.7	75.1± 123.3	1623.0± 731.9
S. babcocki	4.5± 7.0	16.2± 19.9	23.6± 11.5	4.2± 3.3	2.5± 10.7	51.0± 26.5
S. borealis	-	6.6± 14.8	66.9± 64.4	110.9± 93.6	11.8± 50.6	196.2± 125.3
S. brevispinis	90.1± 118.4	722.6±1522.3	82.3± 100.9	5.8± 5.6	-	900.8±1530.2
S. ciliatus	1.9± 4.5	-	-	-	-	1.9± 4.5
S. crameri	-	0.8± 1.9	22.8± 39.6	10.7± 19.3	0.1± 0.3	34.4± 44.1
S. diploproa	-	0.9± 1.7	18.9± 30.1	0.5± 0.9	-	20.3± 30.2
S. elongatus	3.3± 7.2	-	-	0.1± 0.3	-	3.4± 7.2
S. entomelas	-	3.0± 6.7	-	0.1± 0.3	-	3.1± 6.7
S. flavidus	0.9± 2.1	0.5± 1.1	-	-	-	1.4± 2.4
S. helvomaculatus	1.8± 2.6	0.6± 0.8	4.8± 2.9	4.2± 8.1	0.8± 3.4	12.2± 9.6
S. paucispinis	1.9± 2.9	85.8± 156.7	12.9± 19.4	-	-	100.6± 157.9
S. pinniger	4.2± 7.1	1.7± 3.9	0.5± 0.7	0.5± 0.9	-	6.9± 8.1
S. proriger	57.2± 112.1	77.4± 120.8	59.9± 99.5	2.2± 4.0	0.1± 0.3	196.8± 192.5
S. reedi	180.3± 423.7	183.9± 383.7	1006.1±1587.2	939.4±1870.6	2.0± 7.7	2311.7±2519.0
S. ruberrimus	-	-	0.4± 0.9	1.6± 3.4	-	2.0± 3.5
S. variegatus	5.3± 12.6	-	-	0.03± 0.1	-	5.33± 12.6
S. zacentrus	356.5± 787.2	47.8± 62.7	13.2± 15.2	0.1± 0.2	-	417.6± 789.8
Seb. alascanus	0.9± 0.14	28.3± 28.4	91.0± 54.6	46.7± 30.4	10.0± 12.2	176.9± 69.7
Total	727.6± 909.1 (±124.9%)	1361.2±1598.6 (±117.4%)	2421.5±1713.1 (±70.7%)	1783.3±1929.0 (±108.2%)	113.1± 141.1 (±124.8%)	6406.7±3171.4 (±49.5%)

Table 4. Biomass estimates (t) extrapolated over trawlable and untrawlable areas, BW78-1.

	Depth interval (m)					
	164-218	219-272	273-327	328-382	383-437	Total
Sebastes aleutianus	58.8± 57.8	1.1± 1.9	18.5± 11.6	420.3± 469.8	67.1± 267.2	507.0± 540.6
S. alutus	-	307.4± 358.7	1178.5± 729.5	458.0± 398.4	471.6± 774.6	2473.6±1192.9
S. babcocki	13.8± 21.7	27.1± 33.1	27.8± 13.5	5.6± 4.4	15.6± 67.1	89.9± 79.2
S. borealis	-	11.1± 24.7	78.7± 75.8	148.4± 125.3	73.9+ 318.0	312.1± 351.0
S. brevispinis	277.8± 365.2	1204.3±2537.2	96.7± 118.7	7.8± 7.5	-	1586.6±2566.1
S. ciliatus	5.9± 14.0	-	-	-	-	5.9± 14.0
S. crameri	-	1.4± 3.1	26.8± 46.6	14.3± 25.8	0.5± 2.2	43.0± 53.4
S. diploproa	-	1.4± 2.9	22.2± 35.4	0.7± 1.2	-	24.3± 35.5
S. elongatus	10.1± 22.3	-	-	0.1± 0.4	-	10.2± 22.3
S. entomelas	-	5.0± 11.2	-	0.1± 0.4	-	5.1± 11.2
S. flavidus	2.8± 6.5	0.8± 1.8	-	-	-	3.6± 6.7
S. helvomaculatus	5.7± 8.0	1.0± 1.3	5.7± 3.4	5.7± 10.8	5.0± 21.6	23.1± 25.7
S. paucispinis	5.9± 9.0	143.0± 261.1	15.2± 22.8	-	-	164.1± 262.2
S. pinniger	13.0± 22.0	2.9± 6.5	0.6± 0.8	0.7± 1.3	-	17.2± 23.0
S. proriger	176.5± 345.8	128.9± 201.3	70.4± 117.0	3.0± 5.4	0.5± 2.2	397.3± 416.9
S. reedi	555.9±1306.5	306.5± 639.6	1182.7±1965.8	1257.3±2503.5	12.8± 48.7	3315.1±3444.9
S. ruberrimus	-	-	0.5± 1.0	2.1± 4.6	-	2.6± 4.7
S. variegatus	16.3± 38.7	-	-	0.05± 0.2	-	16.4± 38.7
S. zacentrus	1099.3±2427.3	79.6± 104.6	15.6± 17.9	0.1± 0.3	-	1194.6±2429.6
Seb. alascanus	2.8± 4.3	47.1± 47.3	170.0± 64.2	62.5± 40.7	63.1± 76.8	282.5± 118.0
Total	2243.9±2803.3 (±124.9%)	2268.6±2664.4 (±117.4%)	2846.9±2013.9 (±70.7%)	2386.8±2581.7 (±108.2%)	710.1± 886.4 (±124.8%)	10456.3±5144.3 (±49.2%)

Table 5. Biomass estimates (t) for Rennell Sd., extrapolated over trawlable areas only, BW79-1.

	Depth Interval (m)					
	164-218	219-272	273-327	328-382	438-491	Total
Sebastes aleutianus	-	1.0± 1.9	34.4± 84.4	31.3± 49.5	10.3	77.0± 97.9
S. alutus	399.7	21.7± 30.7	261.9± 578.4	119.5± 55.8	2.1	804.9± 581.9
S. babcocki	-	0.2± 0.4	0.5± 0.8	0.5± 0.8	-	1.2± 1.2
S. borealis	-	-	3.9± 12.3	11.3± 10.3	-	15.2± 16.0
S. brevispinis	266.9	4.3± 8.7	4.6± 14.6	-	-	275.8± 17.0
S. crameri	-	-	0.5± 1.1	0.6± 0.7	-	1.1± 1.3
S. diploproa	-	0.1± 0.1	-	-	-	0.1± 0.1
S. entomelas	134.0	1.3± 2.0	1.5± 4.9	-	-	136.8± 5.3
S. helvomaculatus	-	1.6± 2.7	1.1± 0.9	2.8± 6.4	-	5.5± 7.0
S. paucispinis	-	1.1± 2.5	2.6± 5.4	0.3± 0.7	-	4.0± 6.0
S. proriger	2933.1	31.8± 62.8	14.3± 44.2	0.2± 0.3	-	2979.4± 76.8
S. reedi	9467.2	100.1± 157.2	143.1± 453.5	2.6± 4.4	-	9713.0± 480.0
S. variegatus	134.0	-	-	-	-	134.0
Seb. alascanus	-	1.3± 2.0	10.7± 13.5	13.3± 15.1	0.7	26.0± 20.4
Total	13334.9	164.5± 172.3	479.1± 741.5	182.4± 77.2	13.1	14174.0± 765.2 (± 5.4%)

Table 6. Biomass estimates (t) for Buck Pt., extrapolated over trawlable areas only, BW79-1.

	Depth interval (m)			
	219-272	328-382	383-437	Total
Sebastes aleutianus	0.9	0.4	12.7	14.0
S. alutus	35.9	8.0	17.1	61.0
S. babcocki	-	0.5	0.7	1.2
S. borealis	-	2.2	1.8	4.0
S. brevispinis	11.3	-	-	11.3
S. diploproa	-	-	0.4	0.4
S. entomelas	0.3	-	-	0.3
S. paucispinis	1.8	-	-	1.8
S. proriger	0.9	-	-	0.9
S. reedi	14.2	-	-	14.2
Seb. alascanus	0.3	0.7	13.3	14.3
Total	65.6	11.8	46.0	123.4

Table 7. Biomass estimates (t) for Anthony Is., extrapolated over trawlable areas only, BW79-1.

	Depth interval (m)		
	219-272	328-382	Total
Sebastes aleutianus	-	6.9	6.9
S. alutus	28.6	7.4	36.0
S. babcocki	2.8	1.1	3.9
S. borealis	-	2.6	2.6
S. brevispinis	5.2	-	5.2
S. crameri	0.9	1.1	2.0
S. helvomaculatus	0.6	0.2	0.8
S. proriger	0.6	0.1	0.7
S. reedi	2.5	0.2	2.7
S. zacentrus	0.6	-	0.6
Seb. alascanus	8.0	2.0	10.0
Total	49.8	21.6	71.4

Table 8. Biomass estimates (t) for Flamingo Inlet, extrapolated over trawlable areas only, BW79-1.

	Depth interval (m)		
	219-272	328-382	Total
Sebastes aleutianus	1.5± 3.5	1.1± 3.1	2.6± 4.7
S. alutus	91.7±354.3	26.3±305.4	118.0±467.8
S. babcocki	0.4± 5.1	-	0.4± 5.1
S. borealis	-	4.6± 57.9	4.6± 57.9
S. helvomaculatus	0.6± 7.2	0.3± 4.0	0.9± 8.2
S. reedi	4.7± 60.1	0.8± 9.9	5.5± 60.9
S. zacentrus	0.1± 1.3	-	0.1± 1.3
Seb. alascanus	0.4± 0.3	0.5± 4.0	0.9± 4.0
Total	99.4±359.5	33.6±311.1	133.0±475.4

Table 9. Biomass estimates (t) for areas other than Rennell Sd., Buck Pt., Anthony Is., and Flamingo Inlet, extrapolated over trawlable areas only, BW79-1.

	Depth intervals (m)						
	164-218	219-272	273-327	328-382	383-437	438-492	Total
Sebastes aleutianus	40.6+152.5	1.8± 8.2	11.3± 15.9	224.9±228.7	24.9±23.2	44.3± 45.4	347.8± 280.1
S. alutus	5.9± 25.8	89.3± 70.6	1038.1±1081.2	361.9±267.8	5.1± 4.1	1.5± 19.6	1501.8±1116.6
S. babcocki	-	1.3± 2.9	127.7± 96.9	9.7± 8.3	0.4± 0.7	-	139.1± 97.3
S. borealis	-	-	9.1± 21.9	26.4± 27.5	9.5±13.7	11.5±131.4	56.5± 136.7
S. brevispinis	11.9± 27.3	174.3±181.2	163.7± 203.7	0.3± 0.8	-	0.4± 5.8	350.6± 274.1
S. ciliatus	-	1.2± 3.0	0.3± 1.0	-	-	-	1.5± 3.2
S. crameri	-	8.6± 14.1	203.7± 366.6	16.9± 28.2	-	-	229.2± 368.0
S. diploproa	-	-	4.3± 5.8	0.5± 1.0	0.2± 0.4	0.4± 4.3	5.3± 7.3
S. elongatus	-	2.4± 3.7	-	-	-	-	2.4± 3.7
S. entomelas	-	4.1± 4.8	3.3± 4.5	-	-	-	7.4± 6.6
S. helvomaculatus	-	2.6± 4.2	9.6± 10.3	5.7± 6.1	-	-	17.9± 12.7
S. melanops	-	0.2± 0.6	-	-	-	-	0.2± 0.6
S. paucispinis	2.3± 10.3	15.6± 11.2	71.3± 79.3	0.8± 2.0	-	-	90.0± 80.8
S. pinniger	4.8± 13.6	5.7± 7.5	2.5± 5.0	-	-	-	13.0± 16.3
S. proriger	12.6± 54.0	94.5±144.8	194.1± 410.2	0.1± 0.2	-	0.3± 3.8	301.6± 438.4
S. reedi	12.6± 54.0	57.3±102.9	103.0± 125.4	280.7±515.6	-	-	453.6± 543.2
S. ruberrimus	3.6± 15.4	-	-	-	-	-	3.6± 15.4
S. zacentrus	-	10.4± 12.2	78.8± 125.4	-	-	0.2± 1.9	89.4± 126.0
Seb. alascanus	-	0.8± 1.2	103.7± 88.1	60.6± 21.6	8.2± 7.7	7.1± 16.7	180.4± 92.6
Total	94.3±176.1 (±186.7%)	470.1±264.7 (±56.3%)	2124.5±1252.6 (±58.9%)	988.5±626.1 (±63.3%)	48.3±28.3 (±58.6%)	65.6±141.6 (±215.8%)	3791.3±1443.2 (±38.1%)

Table 10. Biomass estimates (t) extrapolated over trawlable areas only, BW79-1

	Depth intervals (m)						
	164-218	219-272	273-327	328-382	383-437	438-492	Total
Sebastes aleutianus	54.9+ 58.5	13.0± 15.6	150.6± 271.1	237.7±170.2	52.7±37.6	51.4± 57.2	560.3± 332.9
S. alutus	278.0±320.8	671.6±716.1	1901.7±1978.4	654.7±274.3	18.5±18.4	2.7± 4.5	3527.2±2146.0
S. babcocki	-	4.9± 5.3	252.2± 312.9	9.6± 5.8	1.2± 1.1	-	267.9± 313.0
S. borealis	-	-	23.1± 36.1	68 5± 42.2	18.6±22.7	12.0± 35.3	122.2± 69.6
S. brevispinis	196.4±209.9	154.8±124.4	148.4± 149.2	0.4± 0.5	-	0.5± 1.5	500.5± 286.0
S. ciliatus	-	0.9± 1.9	0.3± 0.6	-	-	-	1.2± 2.0
S. crameri	-	6.6± 9.1	163.1± 260.7	13.6± 17.3	-	-	183.3± 261.4
S. diploproa	-	0.1± 0.4	3.4± 4.2	0.3± 0.4	0.6± 0.7	0.3± 1.1	4.7± 4.4
S. elongatus	-	1.7± 2.4	-	-	-	-	1.7± 2.4
S. entomelas	90.5±108.6	7.1± 6.1	9.0± 13.3	-	-	-	106.6± 109.6
S. helvomaculatus	-	10.3± 9.1	12.4± 7.9	12.1± 13.4	-	-	34.8± 18.0
S. melanops	-	0.1± 0.4	-	-	-	-	0.1± 0.4
S. paucispinis	3.2± 3.9	17.3± 10.4	67.1± 57.8	1.8± 2.2	-	-	89.4± 58.9
S. pinniger	6.5± 5.5	4.0± 5.1	2.3± 3.7	-	-	-	12.8± 8.3
S. proriger	1997.5±2370.7	94.8± 96.5	212.7± 326.7	0.7± 0.8	-	0.3± 1.0	2306.0±2395.1
S. reedi	355.1±389.8	390.7±444.9	673.7±1233.9	193.9±314.7	-	-	1613.4±1404.1
S. ruberrimus	4.8± 5.8	-	-	-	-	-	4.8± 5.8
S. variegatus	90.5±108.6	-	-	-	-	-	90.5± 108.6
S. zacentrus	-	8.1± 8.3	62.3± 96.2	-	-	0.2± 0.5	70.6± 96.6
Seb. alascanus	-	11.1± 9.4	126.1± 77.3	78.2± 34.7	22.1±15.5	7.8± 11.3	245.3± 87.4
Total	3077.4±2438.5 (±79.2%)	1397.1±858.0 (±61.4%)	3808.4±2413.5 (±63.4%)	1271.5±454.7 (±35.8%)	113.7±50.1 (±44.1%)	75.2± 68.3 (±90.8%)	9743.3±3566.8 (±36.6%)

Table 11. Statistics of the rockfish fishery for the west coast of the Queen Charlotte Islands, 1977-1980 with regression estimators of biomass in 1976 (N_{76}) and MSY at various mortality levels.

	Year			
	1977	1978	1979	1980[a]
Catch (t)	2824	4097	1375	1824
Effort (h)	613	1337	495	986
C/E (t/h)	4.61	3.06	2.78	1.85
% *Sebastes alutus*	45	60	63	53
% *S. reedi*	43	26	20	27

[a]Preliminary data

Regression estimate of N_{76} = 15,190 t (r=0.973)

95% conf. interval N_{76} = 10,915 - 39,867 t

90% conf. interval N_{76} = 11,872 - 24,448 t

$MSY_{.05}$ = 380 t

$MSY_{.08}$ = 608 t (where $MSY_i = 0.5\ M_i\ N_{76}$)

$MSY_{.10}$ = 760 t

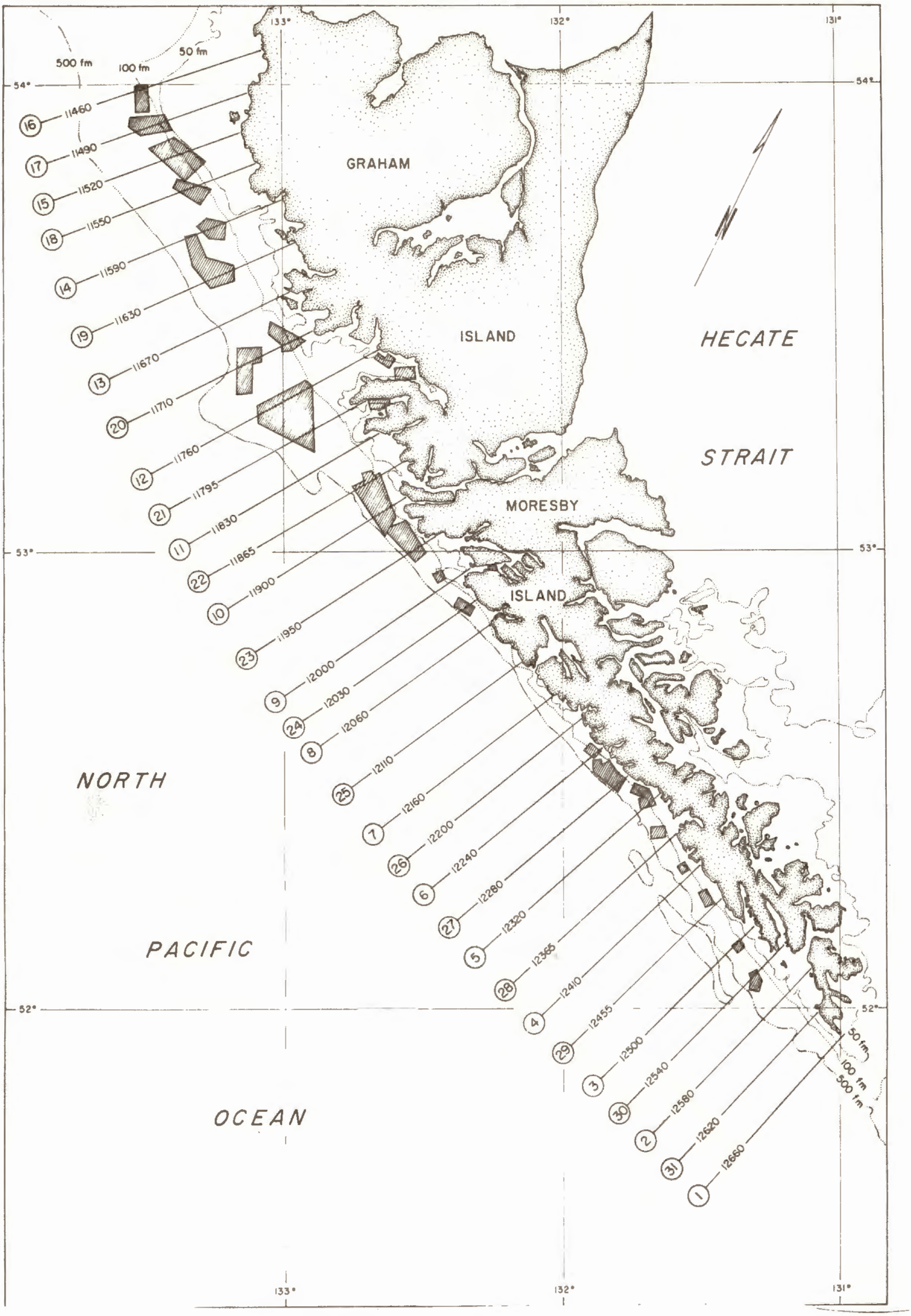

Fig. 1. Locations of tracklines and trawlable areas (hatched) for the west coast of the Queen Charlotte Islands, as estimated on BW 78-1, June 19-July 8; July 15-21, 1978.

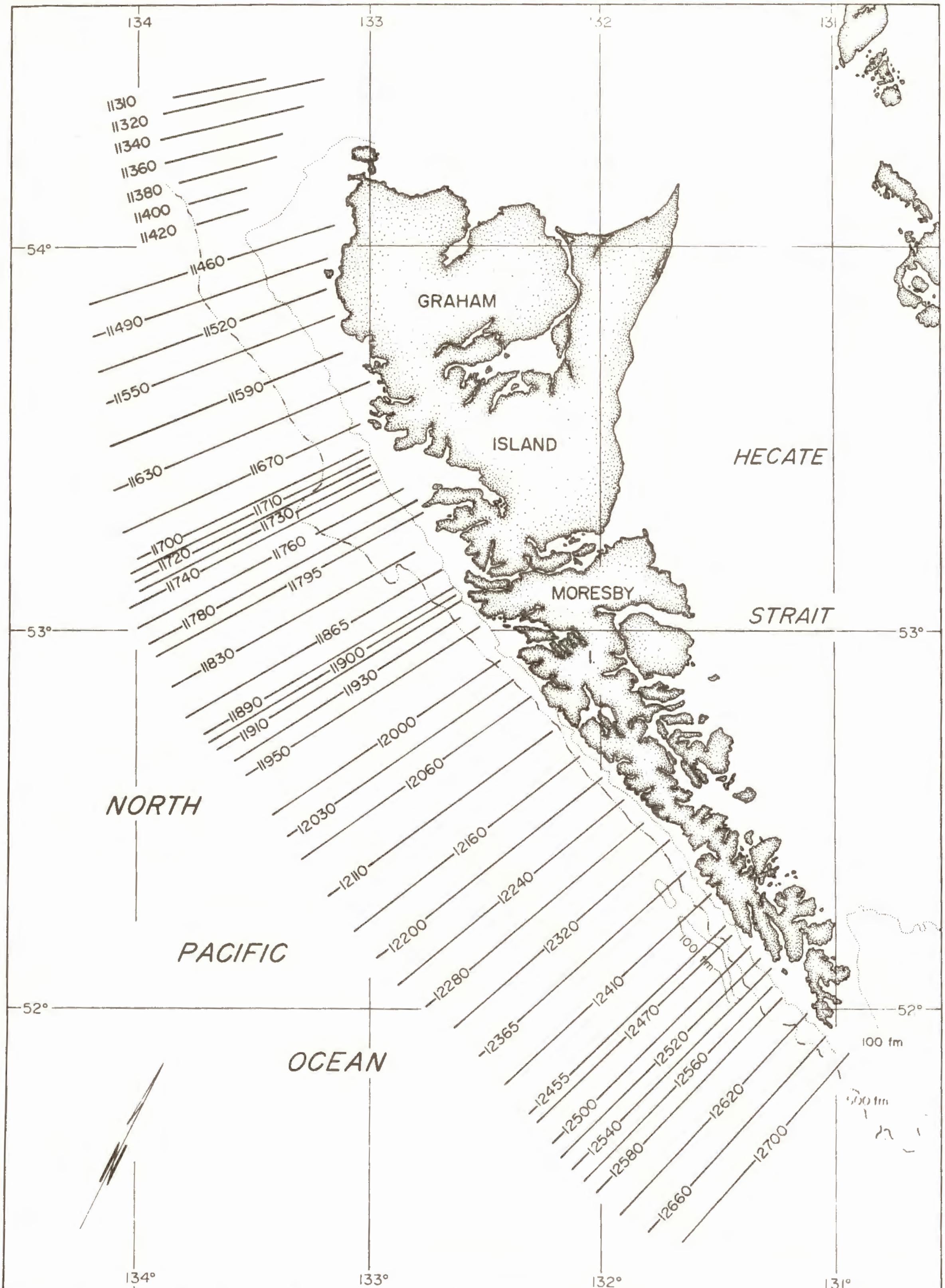

Fig. 2. Locations of tracklines, M/V BLUE WATERS rockfish cruise, May 22-June 13, 1979.

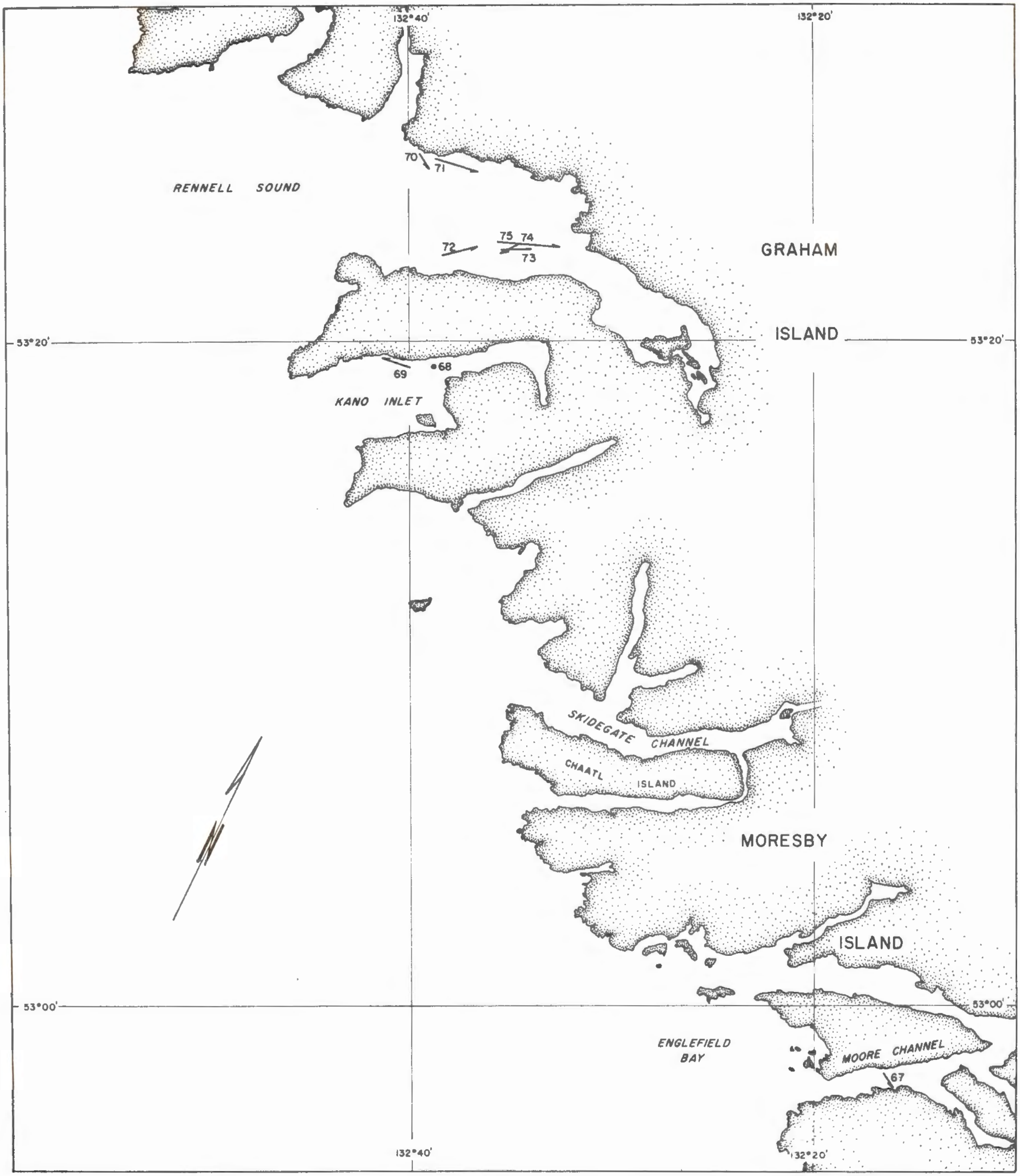

Fig. 3. Locations of hauls in inlets and bays made by M/V BLUE WATERS, June 19-July 8; July 15-21, 1978.

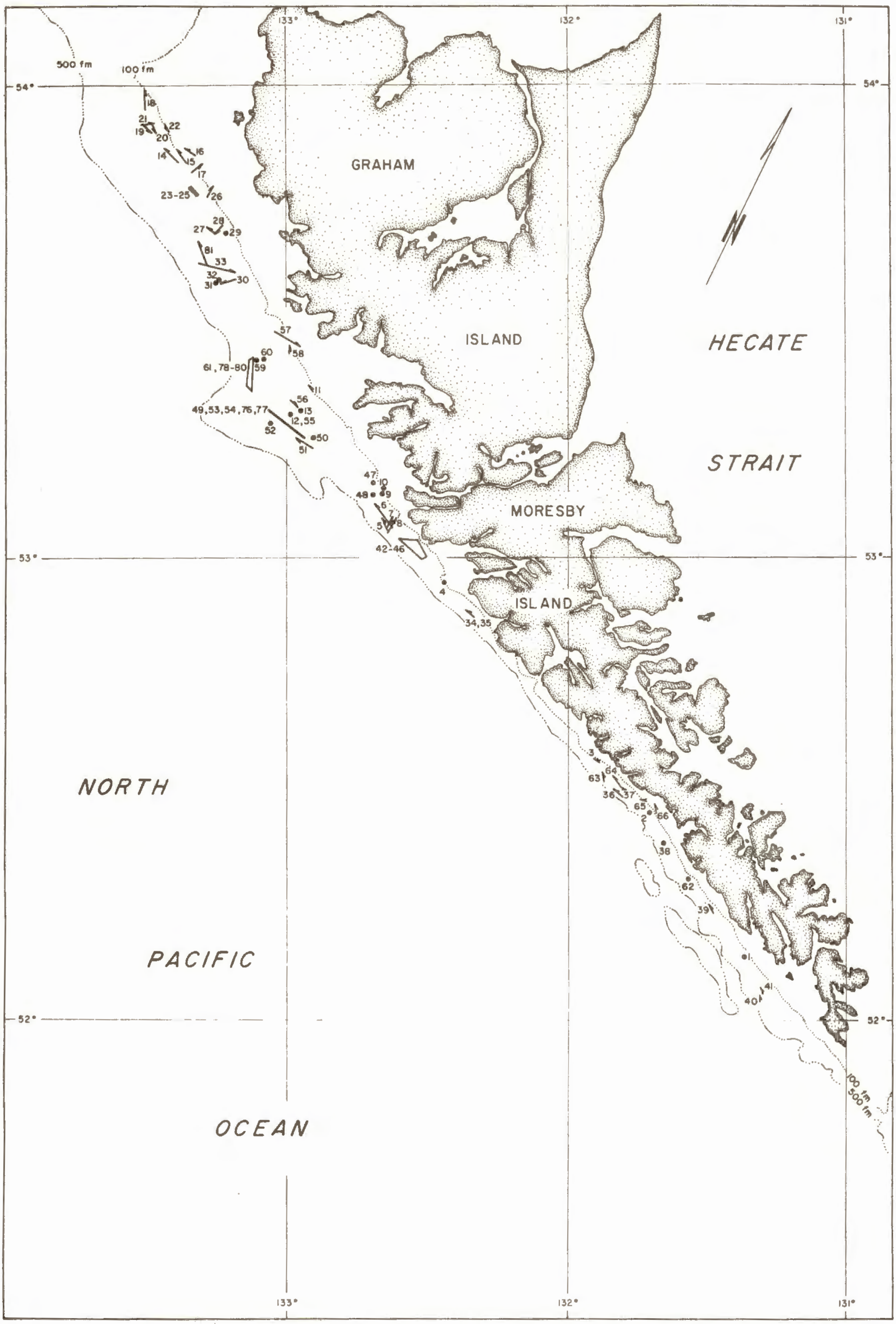

Fig. 4. Locations of trawl hauls, BLUE WATERS rockfish cruises, June 19-July 8; July 15-21, 1978.

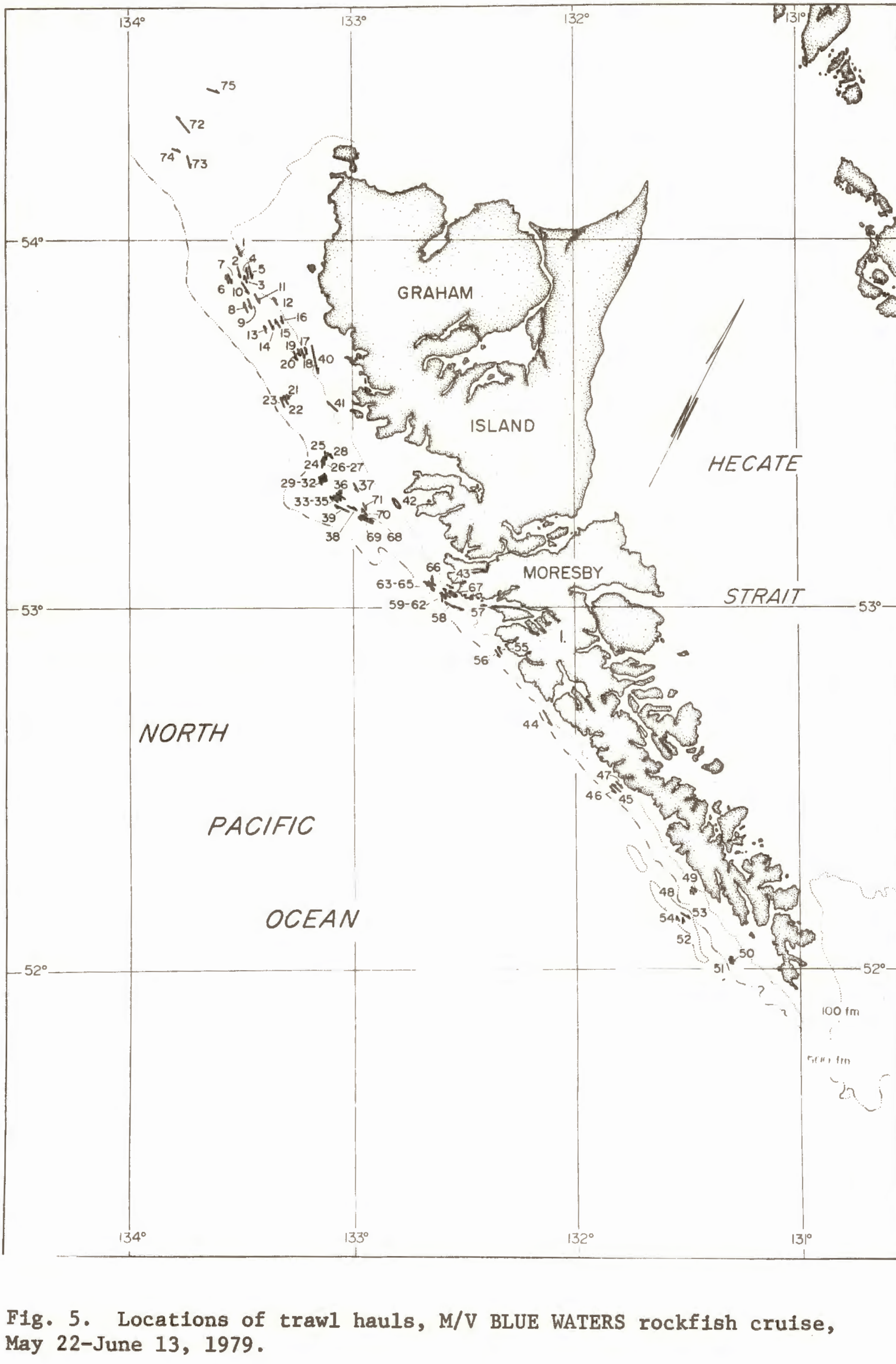

Fig. 5. Locations of trawl hauls, M/V BLUE WATERS rockfish cruise, May 22-June 13, 1979.

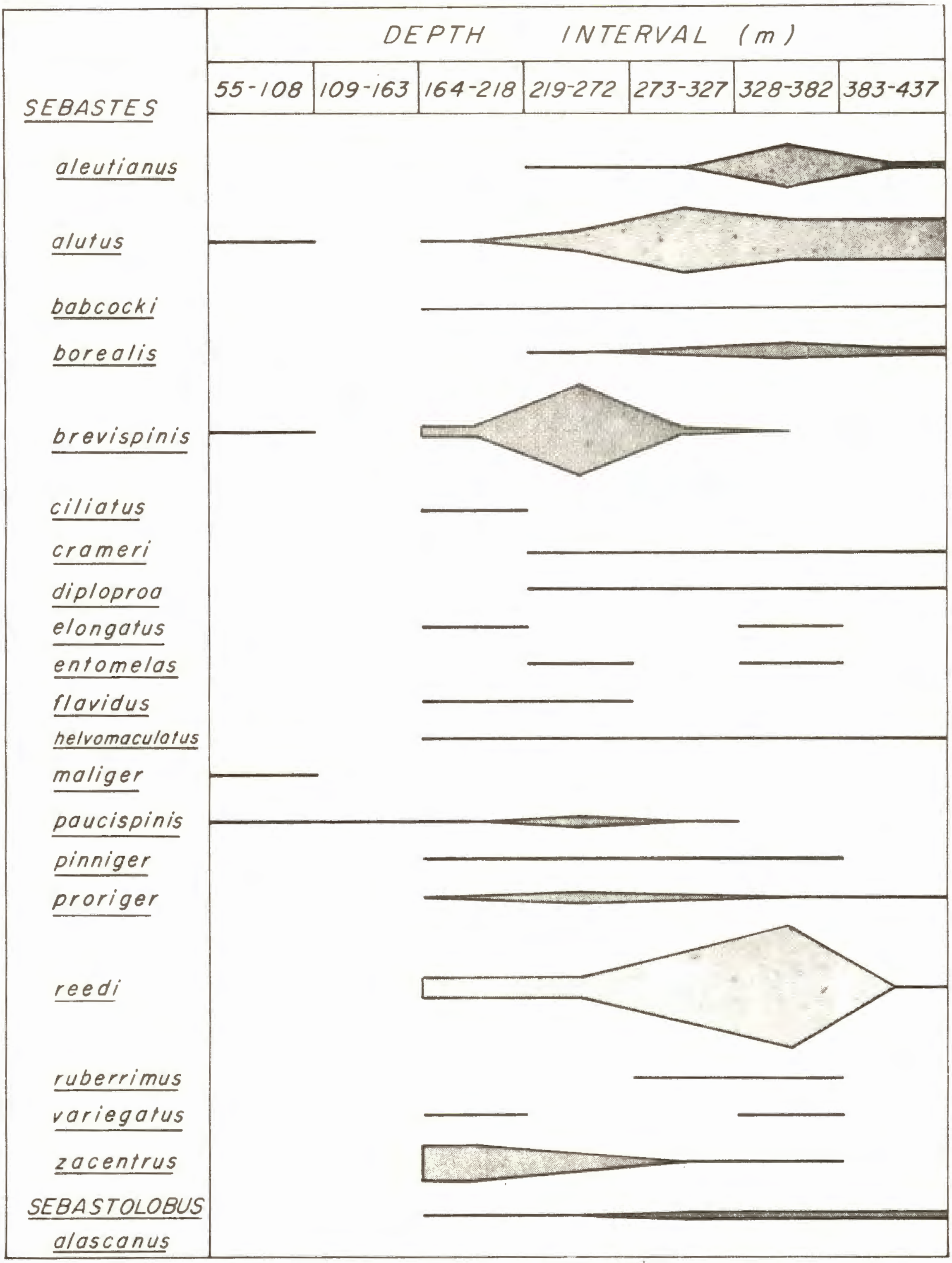

Fig. 6. Schematic illustration of the relative abundance of rockfishes off the west coast of the Queen Charlotte Islands, BW 78-1, June 19-July 8; July 15-21, 1978.

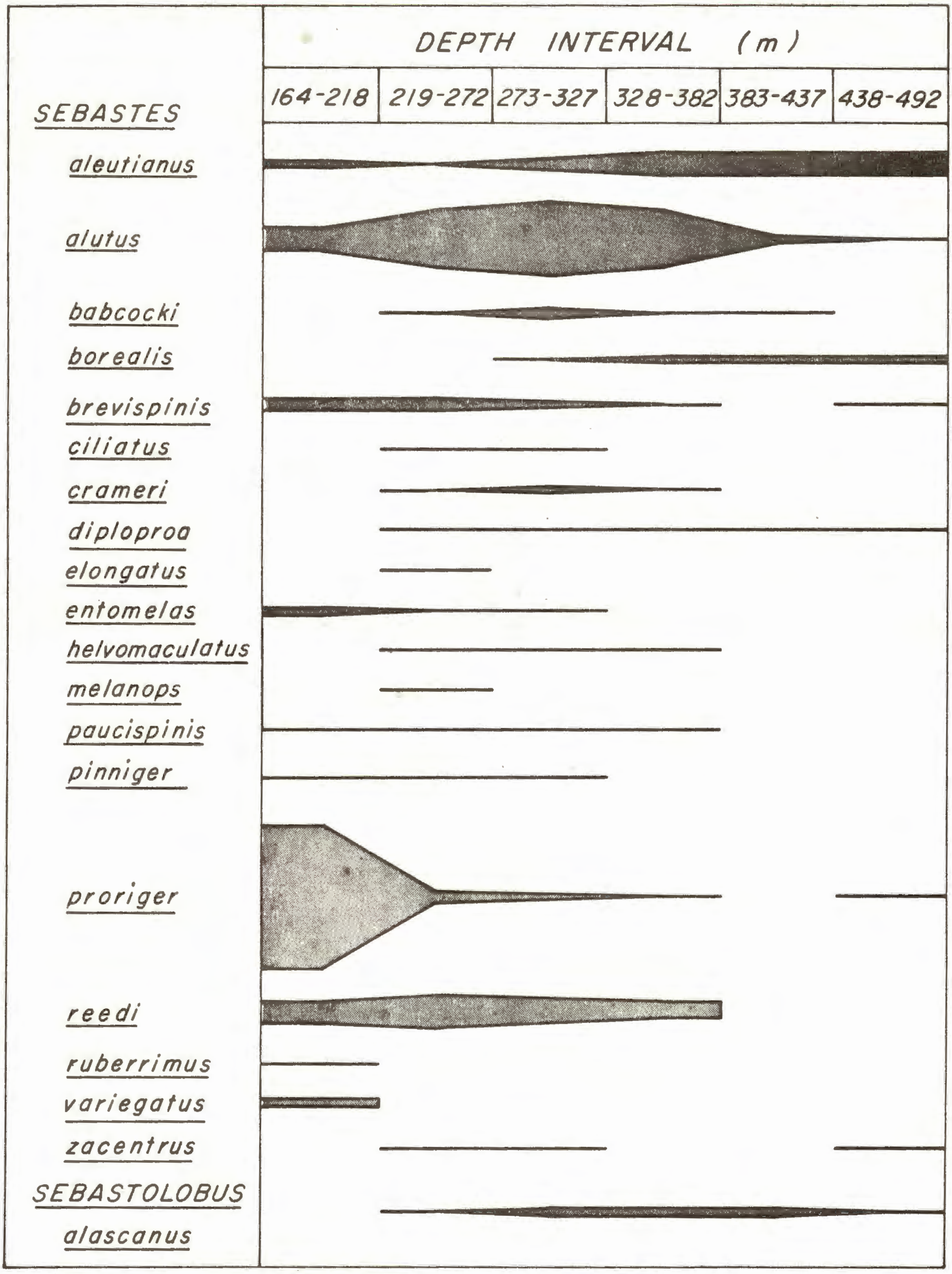

Fig. 7. Schematic illustration of the relative abundance of rockfishes off the west coast of the Queen Charlotte Islands, BW 79-1, May 22-June 13, 1979.

Appendix Table 1. Comparison of load cell estimates of catch with weight determined through weighing of entire catch.

Date	Tow no.	(1) Load cell weight (lb)	(2) Weighed catch (lb)	% Deviation of (1) from (2)
June 26 1978	18	800	752	+ 6.0
28	20	720	660	+ 8.3
	24	1030	912	+11.5
	26	900	823	+ 8.6
29	27	480	451	+ 6.0
	28	670	641	+ 4.3
	30	830	838	- 1.0
	31	1070	1117	- 4.4
30	34	1200	1160	+ 3.3
	36	560	488	+12.9
	37	840	808	+ 3.8
July 7 1978	39	740	769	- 3.9
17	63	860	866	- 0.7
		$\bar{X}$ = 824	$\bar{X}$ = 791	$\bar{X}$ = +4.2%
		$\pm$ 2 S. E.= 114	$\pm$ 2 S. E.= 115	$\pm$ 2 S. E.= 3.1%