Identification and Description of Assemblages of Some Commercially Important Rockfishes *(Sebastes spp.)* Off British Columbia

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ABSTRACT

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The 1977-1978 commercial catch statistics were analyzed to determine if assemblages existed among some of the commercially important rockfishes (*Sebastes* spp.) and if these assemblages persisted over time. Initially, the catch statistics were analyzed to determine bathymetric, geographic, and seasonal distribution. Cluster analysis and a relative catch proportion index were used to identify and describe assemblages, and covariance analysis was used to determine if assemblages persisted over time.

A shelf assemblage consisting of *Sebastes brevispinis*, *S. flavidus*, and *S. pinniger*, and a slope assemblage consisting of *S. alutus*, *S. proriger*, and *S. reedi* were identified.

Key words: Rockfishes, assemblage, multi-species management units.

RÉSUMÉ

Nagtegaal, D. A. 1983. Identification and description of assemblages of some commercially important rockfishes (*Sebastes* spp.) off British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1183: vi + 82 p.

L'auteur a analysé les statistiques sur les prises commerciales réalisées en 1977 et 1978 pour déterminer si des rassemblements existent chez certaines scorpènes (*Sebastes* spp.) d'importance commerciale et si ces groupements duraient pendant une certaine période. On a d'abord analysé les données pour établir les répartitions bathymétrique, géographique et saisonnière. À l'aide d'une analyse typologique et d'un indice de la proportion relative des prises, on a identifié et décrit les rassemblements et l'auteur s'est servi d'une analyse de la covariance pour déterminer si ceux-ci duraient pendant un certain temps.

On a identifié un rassemblement sur la plate-forme comprenant *Sebastes brevispinis*, *S. flavidus* et *S. pinniger*, et un groupement sur le talus regroupant S. *alutus*, *S. proriger* et *S. reedi*.

Mots-clés: scorpènes, rassemblement, unités de gestion d'espèces multiples

I. INTRODUCTION

One of the problems encountered in the management of groundfish stocks off British Columbia is a lack of information concerning the inter-relationships of different species. One of the more interesting and complex groups are the rockfishes (Sebastes spp.), comprised of a variety of species ranging from inshore to deepwater. Since these rockfishes are predominantly aggregated species, it would be advantageous to determine if we could manage this group on the basis of assemblages.

The purpose of this study is to determine if assemblages of commercially important rockfishes exist, that can be used as multi-species management units. An assemblage is defined as a closely associated group of species that covary in abundance. The identification of an assemblage therefore must include some measure of the quantitative association among the species involved and their fluctuations in abundance. Identification of an assemblage is incomplete, from a management point of view, without attempting to describe its temporal dynamics.

This study attempts to identify and describe rockfish assemblages primarily on the basis of relative catch within time (season), area, and depth. Identification of assemblages was accomplished by graphical examination of the commercial catch statistics, the use of a relative catch proportion index, and cluster analysis. Analysis of covariance was employed to determine the assemblages' persistence over time. Detailed analyses were conducted on some commercially important rockfishes (Sebastes alutus, S. brevispinis, S. entomelas, S. flavidus, S. pinniger, S. proriger, S. reedi) that occur in three major fishing areas; the west coast of Vancouver Island, Queen Charlotte Sound and the west coast of the Queen Charlotte Islands. It should be stressed that associations determined on the basis of relative abundance values from commercial data may or may not infer actual biological association. That determination is beyond the scope of the present study and will be a necessary corollary to conclusions reached in this paper.

II. MATERIALS AND METHODS

A. LITERATURE REVIEW

The concept of species associations is certainly not a new one and others have attempted to identify species assemblages (Pope 1976; May et al. 1979; Knight and Tyler 1973). There have been many different techniques employed to determine patterns or associations in both plant and animal communities (Goodall 1973). The identification of species assemblages is dependent on the relationship of certain variables, some that can be measured more easily (e.g., abundance) than others (e.g., inter-specific competition). Variables such as time (season), depth, and area are also important aspects to consider (Richardson and Pearcy 1977; Tyler 1971; Williams and Stephenson 1973).

Several studies have used rank correlation and chi-square analysis (χ^2-matrix-trellis diagram) to determine associations (Day and Pearcy 1968; Kershaw 1960; Kendall 1962). The chi-squared association index ($\Sigma\chi^2$) does not directly use the relative abundance of species and therefore cannot adequately deal with species that occur in all areas. Trellis diagrams have almost completely fallen from use because their interpretation is often confusing (Lie and Kelly 1970), although they may still be useful in an initial overview of the data. Other association studies (Shulenberger 1979; MacDonald 1969; Fager and Longhurst 1968) have used recurrent group analysis (Fager 1957) to describe distribution patterns. The major drawbacks to this type of analysis are that the Fager index only uses qualitative data (presence/absence); there is no framework to compare possible covariations in abundance of species; and the index does not consider samples in which neither of the species occurs (Hayes 1978). Recently, the various mathematical techniques of factor analysis (Echelle and Schnell 1976; Shulenberger 1980; Stevenson et al. 1974) and cluster analysis (MacDonald 1975; Borucki et al. 1975; Gabriel and Tyler 1980) have been used to determine species associations. Values of relative abundance can be incorporated in these analyses and it has been shown that the use of such values gives more meaningful results (Field and McFarlane 1968; Smith and Powell 1971).

In the literature there is also a wide variety of qualitative affinity or similarity indices designed to reflect the degree of association among species, and each of these techniques has its limitations and sources of error. In many cases the sampling properties of these affinity indices are unknown (Goodall 1973). Although similarity indices are useful tools, they are unable to comprehensively deal with any changes in the relative abundance of species.

Time-series analyses of catch data are uncommon and relatively recent in fish assemblage studies. Some studies focus on numerical and graphical analysis of the data (Tyler 1971; Stephenson and Dredge 1976; Oviatt and Nixon 1973) hoping to describe some pattern of the seasonal fluctuations in relative abundance. Similarly, cluster analysis has been used in the analysis of three-dimensional (SITES x SPECIES x TIMES) data (Williams and Stephenson 1973; McErlean et al. 1973). Classification of the data is based on three comparisons; sites with respect to times, times with respect to species, and species with respect to sites. Quinn (1980) used multiple regression techniques incorporating the Fourier transformation to determine if fish abundance conformed to a regular cyclical pattern. Results indicate that this technique would be very useful in describing known seasonal, cyclic patterns. Diversity indices have also been used to clarify interpretation of temporal patterns in fish assemblages (Haedrich and Haedrich 1974; Livingston 1976) although not all indices are applicable to this type of analysis.

It is important to note however, that the gross nature of seasonal fluctuations in many assemblages indicates that "one-time" surveys may be of limited value (Wiens 1981). If an analysis does not include time-series data then the applicability must be limited to the time period of the study.

B. IDENTIFICATION AND DESCRIPTION OF ASSEMBLAGES

1. Criteria

In this study two criteria are used to identify and describe assemblages: i) close association, and ii) covariance in abundance. Within the framework of this analysis the species involved must consistently occur together in commercial landings. It is not enough to assume that because a group of fish inhabit the same general area they are necessarily caught together. Secondly, the species involved must covary in abundance over the time when the majority of their annual catches are landed. It is essential to understand that this identification procedure is oriented toward the development of functional management units and may or may not reflect biological association.

2. Description of analyses

Several types of analyses were employed to identify and describe rockfish assemblages from the 1977-1978 commercial catch statistics. Initially catch and effort data were examined to determine the distribution of rockfishes in relation to time (season), area, and depth. Identification of assemblages was accomplished by means of cluster analysis and a relative catch proportion index. In addition, the cluster analysis was used to describe the ratios within rockfish groups relative to season and depth. Finally the analysis of covariance was used to determine if these species covaried in abundance.

a) Geographic, bathymetric, and seasonal distribution

Commercial catch statistics for 1977 and 1978 were examined by month and depth, focussing on the major commercial fishing areas off the west coast of Vancouver Island, in Queen Charlotte Sound, and off the west coast of the Queen Charlotte Islands (Fig. 1). The bathymetric distribution of rockfish was determined by plotting mean CPUE (catch per unit effort) by major area against depth. General trends in seasonal abundance were observed by comparing the catch and CPUE by month, for major areas and for study areas. To determine if seasonal catch fluctuations might be related to depth, the catch and CPUE were graphed by month for several depth intervals. As a supplement to these data, research catch statistics for 1963-1978 from the R/V G.B. REED were analyzed in a similar fashion and compared with the results from the commercial data.

Other studies suggest that most species are probably part of a community and within this community several different types of species may occur. There may be "regulars" (moderately abundant throughout the year), "seasonals" (species that are abundant at particular times of the year), and "occasionals" (inconsistent abundance).

In regard to the use of the commercial catch and effort data in this analysis, some limitations were noted. Catch per unit of effort has long been used as a measure of relative abundance for fish populations, and although a fairly reliable index, it has a number of inherent sources of error or bias

(Anon. 1976). One source of bias, particularly in the data used in this study, is the way in which catch and effort were recorded. Effort (hours fished) was recorded by depth within a vessel trip (i.e. not species specific) and consequently tends to be more accurate for target species. The CPUE index becomes less reliable at low levels of abundance when effort ceases to be directed at any given species. Catch by species was not recorded by haul (set), but summed by locality and depth interval for each vessel trip and therefore, may not necessarily reflect the species composition in any one haul.

In addition, there are other limitations of the commercial data. Firstly, the gear used in the groundfish trawl fishery is not standard and generally is selective for "bottom" rockfish species. Although they are considered a demersal species, some rockfish such as *S. flavidus* and *S. entomelas* are often found in midwater (Ketchen 1977). Secondly, the tendency for fishermen to fish the "hotspots" (targetting on particular species) may bias the true species composition and abundance of a rockfish community. For example, unusually high catches of *S. pinniger* in one small locality off the west coast of Vancouver Island during April-June, 1977 (Fig. 8b) caused the annual CPUE to be unrealistically high (4.2 t/hr). Market conditions may also have a considerable effect on the species caught (or discarded). It is thus important to note that the distribution of fishing effort influences the data, however this will also reflect management opportunities.

b) Cluster analysis

Cluster analysis (Sokal and Sneath 1963) was used to identify associations between rockfishes and to compare the relative ratios in which groups of rockfishes were caught. The ratios in which they occurred were then related to season, and the amount of rockfish caught in a given ratio was compared to the total annual rockfish catch.

This analysis, sometimes known as Q-mode clustering, produces a dendrogram which describes the hierarchical clustering of data patterns. It is based on sample by sample comparisons, in which the similarity between samples is measured on the basis of their overall species composition. The levels of similarity between samples are measured from an inter-pattern mahalanobis distance matrix. Initially, samples are paired and subsequently treated as a single point that is then compared with other samples. As more dissimilar samples are combined the distances between samples increases and natural clusters are formed.

The commercial catch data were compiled by study area and vessel such that the catch for one vessel trip could be used as the basic data element. The analysis was limited to the study areas (Fig. 2) since sufficient data by vessel trip were not available for all areas. The cluster analysis grouped the vessel catches on the basis of a relative ratio index:

$$R_{ij} = \frac{C_{ij}}{\sum_{i=1}^{N} C_{ij}}$$

where C_{ij} is defined as the catch of a rockfish species (i) in a given vessel trip (j), and $\sum_{i=1}^{N} C_{ij}$ is defined as the total rockfish catch for that vessel trip. A commercial vessel trip is defined as the total catch landed by a vessel during one fishing trip to a given study area.

As a supplement to the cluster analysis, two additional pieces of information were included in the dendrograms. Comparison of the ratios by season was accomplished by simply identifying the month when each vessel landed. Secondly, a relative catch index was applied to each cluster:

$$L_{ig} = \frac{C_{ig}}{\sum_{g=1}^{N} C_{ig}}$$

where C_{ig} is the catch of a species (i) in a given cluster (g) and $\sum_{g=1}^{N} C_{ig}$ is the total catch of that species in all clusters in the given study area. This index was necessary to quantitatively determine the catch of a given cluster relative to the total rockfish catch. On this basis, those clusters representing most of the total rockfish catch could easily be identified.

Some general considerations should be noted concerning the commercial catch data and the analysis itself. One of the first points to consider when identifying assemblages from commercial catch statistics is the nature of the species involved. Rockfishes are predominantly aggregated species and as such are not likely to be homogeneously distributed throughout a given area. They probably exist in schools of different sizes and possibly composed of several species in varying proportions. This variability should be evident in the commercial vessel catches (Fraidenburg et al. 1979; Parsons et al. 1976). A second point to consider is the vulnerability of the fish to gear, that is the proportion of individuals encountered by the fishing gear which are caught by that gear. It is highly probable that on some occasions the fishing gear simply does not catch all species within a given school. This may partly be due to the effort expended, the bottom topography, and/or the species' ability to avoid the gear. For example, vessel catches from one particular area and depth interval may be interpreted as separate subsamples of the assemblage in that area. Although these subsamples may not always include all the species in that assemblage, they may still be considered representative for those species caught. The absence of species in the catch of any given vessel does not necessarily imply its absence in that area.

An important aspect of a cluster analysis is the basis on which the program groups the data. This type of analysis usually clusters either on the basis of a sample similarity measurement (Q-mode) or individual species similarity measurements (R-mode). One of the drawbacks of using a sample similarity measurement is that the Q-mode analysis will form groups on the basis of the overall similarity between samples rather than on the basis of a specific set of co-occurring species. However, using an index based on catch ratios in a given pattern (vessel) not only compares the overall similarity between samples, but also indirectly focuses on key species. A second aspect is the interpretation of the dendrograms. It should be understood that clustering techniques attempt only to simplify complex data sets and do not provide any ecological interpretations. A dendrogram is not an all-encompassing analysis and therefore should be presented with a detailed explanation. All too often the results of cluster analysis are presented with very little interpretation. To this end one should have some understanding of the data to recognize meaningful clusters. This is especially important in regard to the selection of an appropriate similarity level. Applying a fixed similarity level to all data sets may be less subjective but does not allow the flexibility needed to interpret different data sets. For example, high resemblance among groups may require higher similarity levels to resolve useful clusters than with distinctly different groups. Thus it may often be more useful to arbitrarily define the significance level according to the type of data. Great importance is sometimes attached to the similarity level but it is only relative and cannot be used as an absolute value for comparison among data sets.

c) <u>Catch proportion analysis</u>

As a supplement to the cluster analysis, a proportion index was calculated to determine the proportions of rockfishes caught together. From the literature it was evident that many similarity and correlation indices have been used to describe the relationships of animals. Unfortunately some indices appear to have been exclusively developed for one particular study. For this study, it was imperative to use a quantitative index since relative catch values and the proportions in which species were caught needed to be examined.

The proportions of rockfishes caught together were analyzed by vessel trip using the following index:

$$P_{ix} = \frac{C_{ix}}{\sum_{i=1}^{N} C_{ix}}$$

where C_{ix} is the catch of species (i) in a given combination (x), and $\sum_{i=1}^{N} C_{ix}$ is the total catch of all rockfishes in that combination within a given study area over a given time period. The proportions were calculated for all possible combinations of the commercially important species within each study area. In addition, each species' catch by month relative to its annual catch was examined by major area. These analyses should differentiate between those species that consistently occur together and those that only occasionally occur together.

The level of acceptance for the proportion index (P_{ix}) was arbitrarily set at 70% assuming that at least that amount of the species' annual catch should be caught with other rockfishes for an assemblage to be useful in management.

d) Analysis of covariance

An important aspect of an assemblage is the fidelity of association between species. The degree of association may vary over time and this information would be invaluable in the overall assessment of an assemblage (Wiens 1981). An analysis of covariance was used to determine the persistence of an association in terms of the covariance in abundance over time.

Commercial catch statistics were compiled by area and month so that individual species' catches by month relative to their annual catch could be analyzed. Previously identified rockfish groups were compared to determine if the species within a group covaried using the following index:

$$M_{it} = \frac{C_{it}}{\sum_{t=1}^{12} C_{it}}$$

where C_{it} is the catch of a given species (i) over some time interval (t), in this case a month. And $\sum_{t=1}^{12} C_{it}$ refers to the annual catch of that species within a given study area.

The covariance program (Lindsey 1971) fits a regression line to each data set. The program calculates the significance of all slopes being equal and for all slopes equal to zero. The associated analysis of variance, F statistic, and the probability P were also calculated. The P value represents the probability of a given F ratio (or larger one) occurring, assuming that the two slopes are equal. Comparison between data sets, for our purposes, was based on the test for all slopes being equal.

An important prerequisite for the use of this analysis is that the data should be in some form amenable to linear analyses. It was obvious from a preliminary examination of the relative catch data that they were not linear. With this in mind, a standard log transformation [$Z=\log(X+1)$] was applied to the data prior to the analysis.

Quinn (1980) analyzed the temporal changes in fish assemblages using multiple regression techniques with Fourier transformations. Stephenson (1978) reviews various approaches to periodicity studies of biological data, focussing on auto-correlation analyses. These analyses assume that the data conform to some annual cyclical pattern in abundance and therefore would not be applicable to our data. The advantage of covariance analysis is that no assumptions concerning seasonal abundance patterns are necessary.

III. RESULTS

A. GEOGRAPHIC, BATHYMETRIC, AND SEASONAL DISTRIBUTION

Table 1 lists the commercial catch data by major area for 1977-1978. In both Areas 3C and 3D the dominant species were Sebastes flavidus, S. brevispinis, and S. pinniger while in Area 5E S. alutus and S. reedi dominated the catches. In Queen Charlotte Sound (Areas 5A and 5B) a combination of shelf and slope rockfish existed.

Schematic illustrations of the relative abundance of these rockfish by depth, off the west coast of Vancouver Island, Queen Charlotte Sound, and the west coast of Queen Charlotte Islands are shown in Fig. 3, 4, and 5, respectively. The slope rockfish off the Queen Charlotte Islands and in Queen Charlotte Sound were concentrated between 182 and 291 m (100-159 fm). The shelf rockfish, in the Sound and off Vancouver Island were found between 72 and 181 m (40-99 fm).

General trends in seasonal catch and catch per unit effort (t/hr) by major area are shown in Fig. 6-8. Seasonal catch and CPUE patterns were also compiled for some study areas and are presented in Fig. 9-11. In Areas I and II (Fig. 6, 9) off the Queen Charlotte Islands, the catch and CPUE for both S. alutus and S. reedi varied considerably throughout the year. Sebastes reedi and to a lesser extent S. proriger recorded higher catch and CPUE values during the latter part of the year. This seasonal pattern was also quite evident in Area III (Fig. 10).

In Queen Charlotte Sound (Fig. 7, 11) two peaks in the catch and CPUE values for shelf rockfishes were observed, especially for S. flavidus. These peaks existed in May-June and again in August-September. From these figures there were indications that S. pinniger and S. brevispinis also follow this pattern. Although this trend may be characteristic of the shelf rockfish off the west coast of Vancouver Island (Fig. 8), there were only limited data. The highest catch and effort values for S. entomelas were recorded from August to October in Queen Charlotte Sound and from May to June off the southwest coast of Vancouver Island. It is interesting to note that S. entomelas was rarely caught during other times of the year and none was caught in Area V.

These observed fluctuations in seasonal catch rates may be attributed to several variables including fishing effort, reproductive season, and depth. In regard to effort, the greater the effort expended the better CPUE approximates abundance. During the reproductive season (insemination-parturition) rockfishes might be expected to form large schools, and it is probable that increased catch rates in the fall are associated with the reproductive season. Seasonal changes in catch rates may also be related to bathymetric migration. Gunderson (1971) noted that S. alutus migrated from the "shallows" in the summer to the "deepwater" in winter. To determine if any seasonal bathymetric movement occurred, the catch and CPUE were plotted by area, month, and depth (Fig. 12-14). Although there were minor variations among depth intervals, no major seasonal bathymetric trends were observed, as might have been expected. In Queen Charlotte Sound (Fig. 13b) the peak catch and CPUE of S. alutus shifted from 200 m during the summer to 240 m in winter. While Gunderson noted this same relatively minor movement, he also presented a greater range (200+ m) of movement off Vancouver Island than is evident in my data. This is largely accounted for by the considerable lowering of fishing effort off Vancouver Island since Gunderson's study.

Patterns of rockfish distribution observed in research catches (R/V G.B. REED, 1963-1978) generally coincided with results from the commercial data. Although some discrepancies were present, possibly due to different gears used, similar bathymetric, geographic, and seasonal patterns were evident.

Within the time frame of this study, S. reedi and S. proriger could be classified as "seasonals" within the slope community while S. alutus is a definite "regular". Within the shelf rockfish community S. entomelas, S. brevispinis, S. pinniger, and S. flavidus could all be labelled as "seasonals". S. flavidus might be considered as a "regular" over the calendar year, but during the period when most of the fishing effort was expended (early spring to late fall) a distinct peak in the catch and CPUE data was recorded.

From this preliminary analysis, rockfishes were observed to have fairly distinct bathymetric distributions and therefore, assemblages were examined separately for both shelf and slope groups, over their most productive depth ranges.

B. CLUSTER ANALYSIS

The species composition by commercial vessel trip based on the relative ratio index (R_{ij}) was analyzed by study area for 1977-1978. When data were limited, the information for several areas was combined and for the west coast of Vancouver Island it was necessary to analyze the data by study area VI and VII (Fig. 2). Hierarchical dendrogram plots were constructed for each study area and are presented in Fig. 15-21. For each dendrogram the species composition and month caught are recorded by vessel trip. A summary of the relative catch indices (L_{ig}) and mean ratios for each cluster is listed in Table 2. Natural divisions in the dendrogram defined groups of similar samples, but other criteria such as species composition and month caught were also reviewed when examining clusters. In addition, it was necessary to determine spatial patterns as well as temporal differences.

Data were analyzed from three areas off the west coast of the Queen Charlotte Islands. In Area I (Fig. 15) there were five groups at a similarity of 0.8. Within these groups there are several subdivisions but for our purposes the differences in catch ratios among these groups were not substantial and could not be related to month caught. Groups A', B', C', and D' are basically comprised of a S. alutus/S. reedi/S. proriger combination caught between May and December. The other group consists primarily of individual S. alutus catches. The relative catch index for S. alutus in this group (E') contains some anomalous catches (see footnote for Table 3).

In Area II (Fig. 16) two clusters were formed at a similarity of 0.4. Groups A_1' and A'_2 consisted of a S. alutus/S. proriger/S. reedi group caught from July to December while group B' consisted primarily of S. alutus catches from January to June. Since data were limited, little additional detail concerning assemblages could be extracted from the samples.

Vessel catches in Area III (Fig. 17) were dominated by S. alutus and S. reedi. At a similarity level of 0.7 there were three identifiable groups. The second group was further subdivided into B'_1 and B'_2 on the basis of month caught and species composition. Both groups A' and B'_1 consisted of a S. alutus/S. reedi pair caught from July to December. A third group, B'_2, was entirely comprised of individual S. alutus catches from January to June. The catch ratio of S. alutus and S. reedi in group C' was only slightly different from that in groups A' and B'_1. The reason these groups were connected at such low levels of similarity (0.4) was due to the addition of S. proriger.

In Area IV (Fig. 18) seven combinations of rockfishes were caught. Both S. brevispinis and S. pinniger were occasionally caught by themselves and S. flavidus was often caught alone. S. entomelas was only present when S. flavidus was caught. At a similarity level of 0.9, several groups were formed. Group A' is subdivided into six identifiable smaller groups, each one composed of vessel trips with similar ratios of species caught. However, the species composition of the vessel catches are not necessarily the same. This may be explained by the fact that each subgroup has a prominent group or pair of species in common and any other species are "incidentals" present in the catch. Subgroups A'_4, A'_5 and D' consist of a common pair of S. entomelas/S. flavidus caught from September to October. The three groups imply that although these two species are consistently caught together, they are not always caught in the same ratio. Subgroups A'_1, A'_3, A'_6, B' and C' consist primarily of an S. brevispinis/S. flavidus/S. pinniger combination caught from May to September. Subgroups A'_2 and C'_2 consist mostly of individual catches of S. flavidus and S. brevispinis, respectively. Group E', which consists of individual S. pinniger catches, was considered to be unimportant because the relative catch index (L_{ig}) indicated that this group only represented 3% of its annual rockfish catch (Table 2).

In Area V (Fig. 19) there were four major groups at a similarity level of 0.75. Subgroup A'_1 consists of a S. brevispinis/S. flavidus pair and groups A'_2, B' and C' also consist of this pair but have a S. pinniger component as well. S. pinniger was not caught as consistently with this pair as in Area IV. Although Group B' was subdivided in three smaller clusters, the group was analyzed as one since the divisions could not be associated with month caught. Subgroup A'_3 is primarily composed of individual S. flavidus catches from May to September. At first glance the considerable number of individual S. flavidus catches suggest that it is most often caught by itself. While the total amount of S. flavidus caught by itself was substantial, the individual catches were quite small. Very little S. entomelas was caught in Area V and again only present with S. brevispinis and S. flavidus, although the catch ratio of this group (Group D': .01/.01/.89) was quite different from Area IV.

Since data were limited for the west coast of Vancouver Island, the study area was divided into the southwest coast (Area VII) and the northwest coast (Area VI). In both areas the major species were S. flavidus and S. pinniger but their catch ratios were quite different. The dendrogram for the northwest coast of Vancouver Island was divided into three small clusters (Fig. 20). Group A' consists of a S. brevispinis/S. pinniger pair caught from August to September. Group B'consists primarily of S. pinniger catches and Group C' of S. flavidus catches. Since data were limited little information concerning assemblages could be gained from this area although the data suggest that the dominant group was S. brevispinis/S. pinniger (Table 2).

At a similarity level of 0.7 there were three groups off the southwest coast of Vancouver Island (Fig. 21). A S. entomelas/S. flavidus pair, caught mainly from May to June, was common to subgroups A'_1, A'_2 and B' although a considerable number of vessel catches in group A'_2 consisted of S. flavidus only. Groups C'_1 and C'_2 consisted of S. flavidus/S. pinniger and S. brevispinis/S. flavidus/S. pinniger groups, respectively. Similar rockfish combinations existed in Queen Charlotte Sound (Areas IV and V) but the seasonal groupings seem to be reversed. A S. entomelas/S. flavidus pair was present from May to July and a S. flavidus/S. pinniger pair was caught from August to October.

C. CATCH PROPORTION ANALYSIS

A catch proportion index (P_{ix}) was calculated and used as a supplement to the cluster analysis. The 1977 and 1978 commercial catch data were compiled by study area, and proportion indices were calculated by species combinations and are presented in Table 3. Similar results were recorded for both shelf and slope rockfishes.

Off the west coast of the Queen Charlotte Islands (Areas I, II, and III), the mean proportions of species' catches caught in a S. alutus/ S. reedi/S. proriger combination was 66% (ranging from 8-100%), slightly higher than the main shelf rockfish group. The mean proportion caught in paired combinations of these slope species was 25% (ranging from 3-92%), most of which was accounted for by a strong S. alutus/S. reedi pair in Area C. Only a small proportion of each species' annual catch was caught by itself (~9%). Although S. reedi and S. proriger were consistently caught with S. alutus, the former two species were never caught as a pair.

In Queen Charlotte Sound (Areas IV and V) and off Vancouver Island (Areas VI and VII), it was evident that the majority of a given species' annual catch was caught with other rockfishes. In this regard there are several points to note. Most of each shelf species' annual landings were caught either in a S. flavidus/S. brevispinis/S. pinniger group or as paired combinations of these three species. The mean proportion of a species' annual catch taken in this group was 37% (ranging from 1-83%) and the mean proportion caught in pairs was 42% (ranging from ~14-98%). It is important to note that only a relatively small proportion (~14%) was caught without other rockfishes. Very little of the annual catch of these three species was caught in a combination involving S. entomelas, with one notable exception, but most of the S. entomelas was caught with S. flavidus and S. brevispinis (~ 92%). Some combinations, such as S. flavidus/S. entomelas/S. pinniger, were never caught even though a considerable amount was taken as paired combinations of these species.

In addition, the species' catch by month relative to its annual catch by major area was examined (Fig. 22-24). The variability that exists among depths and the smaller study areas was greatly reduced. The data indicate that patterns in monthly proportions were quite similar for species among and within the shelf and slope rockfish groups. Some differences between 1977 and 1978 data were evident, especially in Areas IV and V, however, this may be due in part to the limited amount of data for 1977.

D. ANALYSIS OF COVARIANCE

Rockfish groups identified by the cluster and proportion analyses were further examined using an analysis of covariance to determine if the species within these groups covaried in abundance. Relative catch data [$\log(M_i)$] were plotted by month for each species and are shown in Fig. 25-29. A summary of the results of the analysis is presented in Table 4. Areas II and VI were not included in this analysis since assemblage information for these areas was limited.

The F test revealed that for both shelf and slope groups the catch-time relationships among species within a given area were not significantly different. Some differences in these relationships were evident among areas but the general level of variance and limited data precluded statistical significance.

For the shelf rockfish group similar slopes were recorded for each species within a given area except for S. entomelas. Its slope (Areas IV and VII) was quite different which may be a reflection of its highly seasonal nature. Although $F_{obs} < F_{0.05}$ there are indications that the catch-time relationship for S. entomelas (Fig. 27 and 29) may be different, but more data are required to determine if these differences are real.

IV. DISCUSSION

Migration and distribution patterns of commercially important rockfishes have been studied by several investigators (Alverson et al. 1964; Snytko and Federov 1974). Alverson et al. (1964) noted that most rockfish species were found within particular geographic and bathymetric ranges. Gunderson and Sample (1980) reviewed the distribution and abundance of some rockfishes off Washington, Oregon, and California and concluded that various rockfish communities occur within specific depth ranges. In this study, analysis of seasonal, bathymetric, and geographic data indicated that rockfishes off the coast of British Columbia also exist within specific depth ranges and areas. Monthly commercial catch and catch per unit effort data suggested that both shelf and slope rockfishes undergo considerable seasonal fluctuations in abundance, assuming that commercial catch data reflect relative abundance. In addition, when seasonal fluctuations were examined on the basis of monthly proportions of annual landings, quite similar patterns were recorded within the species of both shelf and slope groups.

The key results of the cluster and catch proportion analyses were as follows:

i) the proportion of a given species' annual catch caught with other rockfishes was greater than when it was caught by itself,

ii) at the vessel level rockfishes were not always caught in the same combination,

iii) at the vessel level the catch ratio of species within a given combination was quite variable,

iv) examination of a given species' catch by month relative to its annual catch by study area indicated that within the shelf and slope groups, rockfishes were consistently caught during the same months and in similar proportion patterns.

Results of the analysis of covariance revealed that the catch proportion over time relationships for each of the shelf and slope rockfishes were not significantly different, however the variance between and within groups was quite high. In particular, within the shelf rockfish group there are indications that the catch proportion-time regression for S. entomelas may be different from the other shelf species. A more detailed analysis of additional years of data will be required to resolve apparent differences.

As stated earlier, the criteria used to identify and describe assemblages were close association and covariance in abundance. In this study, the commercially important rockfishes were not always caught in the same combination or catch ratio, but they were consistently caught with other members of the shelf and slope groups. The average of a given shelf rockfish's annual catch caught as a S. brevispinis/S. flavidus/S. pinniger group relative to its annual catch, regardless of area was 68% (areas ranging from 19-78%). Similarily the average for a given slope rockfish caught in a S. alutus/S. proriger/S. reedi group in Area I and II was 79% (ranging from 67-95%). In Area III where very little S. proriger was caught, an average of 86% of a given species annual catch was caught in a S. alutus/S. reedi pair, and 100% of the S. proriger was caught in a S. alutus/S. proriger/S. reedi combination.

S. entomelas was not consistently caught with the S. brevispinis/ S. flavidus /S. pinniger group; only 8% was caught in that combination. It was, however, almost always caught with S. flavidus but catches were sporadic and highly seasonal. Although S. entomelas may biologically be part of the shelf assemblage, from a management point of view it could not be considered part of the assemblage unit because catches were too inconsistent.

Results of the covariance analysis indicated that each of the shelf and slope rockfish groups covaried in abundance. The analysis could only be performed on those months for which sufficient data were available and since data for some months were limited, it could not be determined whether the groups covaried over the whole year. Most importantly they did covary over the period when most of the catch was landed. It is conceivable that these rockfish groups covary on a seasonal basis only but this could not be determined from the available data.

In this paper methods to identify and describe assemblages from commercial catch statistics are presented. This management-oriented analysis was applied to the 1977-1978 commercial groundfish catch data and a shelf assemblage consisting of *S. brevispinis/S. flavidus/S. pinniger*, and a slope assemblage consisting of *S. alutus/S. proriger/S. reedi* were identified. Further analysis to determine whether these assemblage units may be functional within a multi-species management framework will be presented in a subsequent paper.

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Table 1. Commercial catches (t) by Major Area, 1977-1978. (Common names in Appendix Table 1.)

	Major Area									
	1978					1977[a]				
Species	3C	3D	5A	5B	5E	3C	3D	5A	5B	5E
S. alutus	48.88	7.05	164.56	1,134.32	2,426.91	15.02	1.13	69.35	1,004.91	1,550.81
S. aleutianus	-	0.02	-	-	193.96	-	-	-	-	-
S. babcocki	0.81	0.38	17.68	54.98	5.09	-	-	-	-	-
S. brevispinis	1.03	20.78	373.39	350.23	132.83	18.01	10.31	85.69	111.97	20.33
S. entomelas	-	1.53	1.49	142.02	56.05	-	-	-	-	-
S. flavidus	45.04	36.84	406.98	1,237.29	1.57	236.61	7.52	303.96	709.38	3.72
S. paucispinis	3.81	19.15	74.88	58.43	14.31	28.97	10.14	17.41	24.50	1.37
S. pinniger	14.52	54.09	108.54	154.08	8.30	-	-	-	-	-
S. proriger	0.38	6.64	7.60	12.05	228.81	0.33	-	33.03	0.48	155.96
S. reedi	0.27	-	10.86	97.63	973.34	-	-	308.98	2.67	1,256.72
S. ruberrimus	1.37	0.62	0.80	1.25	68.62	-	-	-	-	-
S. zacentrus	-	-	0.45	-	3.64	-	-	-	-	-

[a]Data not available for all species.

Table 2. Relative catch indices and mean catch ratios for groups in cluster analysis by study area.

Study area	Figure	Species[a]	Group no.	Month	Relative catch index (L_{ig})	Mean catch ratio
I	15	Al/PR/RE	A'	Jun-Nov	.17/.02/.12	.51/.05/.43
		Al/PR/RE	B'	May-Nov	.23/.43/.46	.08/.06/.85
		Al/PR/RE	C'	Jul-Dec	.17/.28/.16	.23/.25/.48
		Al/PR/RE	D'	May-Oct	.01/.24/.09	.04/.50/.40
		Al/PR/RE	E'	Jan-Jun	.42/.03/.17	.97/.01/.01
II	16	Al/PR/RE	A_1'	Jul-Dec	.30/.41/.25	.48/.19/.33
		Al/PR/RE	A_2'	Jul-Dec	.23/.12/.62	.23/.07/.70
		Al/PR/RE	B'	Jan-Jul	.47/.47/.12	.96/.03/.04
III	17	Al/RE	A'	Jul-Dec	.46/.70	.79/.20
		Al/RE	B_1'	Jul-Dec	.33/.19	.90/.09
		Al	B_2'	Jan-Jun	.07	-
		Al/PR/RE	C'	Jul-Nov	.14/1.0/.11	.89/.01/.09
IV	18	BR/Fl/PI	A_1'	May-Jul	.01/.11/.15	.02/.78/.19
		BR/Fl/PI	A_2'	May-Jun	.08/.15/.12	.02/.93/.05
		BR/Fl/PI	A_3'	Aug-Oct	.14/.26/.04	.19/.79/.02
		BR/EN/Fl	A_4'	Sep-Oct	.07/.32/.11	.04/.20/.75
		BR/EN/Fl/PI	A_5'	Aug-Oct	.09/.09/.04/.08	.05/.11/.60/.23
		BR/Fl/PI	A_6'	May-Jul	.01/.04/.15	.01/.71/.27
		BR/Fl/PI	B'	May-Jun	.01/.02/.19	.25/.27/.47
		BR/Fl/PI	C_1'	Aug-Sep	.40/.12/.20	.51/.37/.08
		BR/Fl/PI	C_2'	Aug-Sep	.19/.04/.04	.95/.02/.02
		EN/Fl	D'	Aug-Sep	.59/.10	.57/.40
		PI	E'	Mau-Jun	.03	-
V	19	BR/Fl	A_1'	Jul-Oct	.13/.34	.23/.76
		BR/Fl/PI	A_2'	May-Jun	.01/.01/.08	.07/.65/.27
		BR/Fl/PI	A_3'	May-Sep	.01/.38/.05	.01/.97/.01
		BR/Fl/PI	B'	Aug-Oct	.83/.14/.71	.71/.22/.06
		BR/Fl/PI	C'	May-Nov	.01/.01/.17	.32/.04/.62
		BR/EN/Fl	D'	May-Jul	.01/1.0/.12	.06/.01/.89
VI	20	BR/PI	A'	Aug-Sep	.82/.07	.74/.25
		BR/Fl/PI	B'	Apr-Sep	.13/.38/.92	.02/.04/.93
		BR/Fl/PI	C'	May-Aug	.05/.62/.01	.13/.84/.02
VII	21	BR/EN/Fl/PI	A_1'	Aug-Sep	.03/.01/.01/.01	.16/.13/.46/.15
		EN/Fl	A_2'	May-Jul	.72/.86	.17/.82
		EN/Fl	B'	May	.26/.07	.50/.50
		Fl/PI	C_1'	Aug-Oct	.05/.75	.16/.83
		BR/Fl/PI	C_2'	Aug-Sep	.96/.01/.24	.31/.08/.46

[a]Al: S. alutus — BR: S. brevispinis
PR: S. proriger — EN: S. entomelas
RE: S. reedi — FI: S. flavidus
PI: S. pinniger

Table 3. Proportion indices by species groups and study area.

Area I

	Al[b]	Al/RE	Al/PR	Al/PR/RE
%	36.4	3.7	6.5	53.2
(with deletions[a])	19.4	4.0	8.3	67.8
	RE	Al/RE	RE/PR	Al/PR/RE
%	-	19.0	-	80.8
	PR	Al/PR	RE/PR	Al/PR/RE
%	-	3.9	-	95.7

Area II

	Al	Al/RE	Al/PR	Al/PR/RE
%	50.4	2.2	-	47.3
(with deletions[a])	27.6	3.1	-	69.1
	RE	Al/RE	RE/PR	Al/PR/RE
%	-	12.0	-	87.9
	PR	Al/PR	RE/PR	Al/PR/RE
%	23.2	-	-	76.8

Area III

	Al	Al/RE	Al/PR	Al/PR/RE
%	7.2	81.4	-	11.3
	RE	Al/RE	RE/PR	Al/PR/RE
%	-	91.8	-	8.1
	PR	Al/PR	RE/PR	Al/PR/RE
%	-	-	-	100.0

Table 3 (cont'd)

Area IV

	F1	F1/BR	F1/PI	F1/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	15.7	9.1	7.9	10.7	39.8	11.8	4.9
	BR	F1/BR	BR/PI	BR/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	9.3	24.2	-	-	53.5	3.3	9.6
	PI	F1/PI	BR/PI	EN/PI	F1/BR/PI	F1/EN/PI	F1/EN/BR/PI
%	2.8	37.5	-	-	50.4	-	9.2
	EN	EN/F1	EN/PI	EN/BR	F1/EN/BR	F1/EN/PI	F1/EN/BR/PI
%	-	58.2	-	-	32.3	-	9.5

Area V

	F1	F1/BR	F1/PI	F1/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	28.7	34.6	5.5	-	23.2	10.7	1.0
	BR	F1/BR	BR/PI	BR/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	25.3	17.9	4.7	-	51.6	-	-
	PI	F1/PI	BR/PI	EN/PI	F1/BR/PI	F1/EN/PI	F1/EN/BR/PI
%	1.1	3.9	10.9	-	82.8	-	1.1
	EN	EN/F1	EN/PI	EN/BR	F1/EN/BR	F1/EN/PI	F1/EN/BR/PI
%	-	-	-	-	88.4	-	11.6

Area VI

	F1	F1/BR	F1/PI	F1/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	34.9	3.8	9.9	-	51.3	-	-
	BR	F1/BR	BR/PI	BR/EN	F1/BR/PI	F1/EN/BR	F1/EN/BR/PI
%	4.3	1.3	79.8	-	14.6	-	-
	PI	F1/PI	BR/PI	EN/PI	F1/BR/PI	F1/EN/PI	F1/EN/BR/PI
%	58.9	10.8	9.6	-	20.7	-	-
	EN	EN/F1	EN/PI	EN/BR	F1/EN/BR	F1/EN/PI	F1/EN/BR/PI
%					(No catch)		

Table 3 (cont'd)

	Area VII						
	Fl	Fl/BR	Fl/PI	Fl/EN	Fl/BR/PI	Fl/EN/BR	Fl/EN/BR/PI
%	6.0	-	1.6	90.7	1.0	-	-
	BR	Fl/BR	BR/PI	BR/EN	Fl/BR/PI	Fl/EN/BR	Fl/EN/BR/PI
%	-	3.5	50.4	-	41.9	-	4.1
	PI	Fl/PI	BR/PI	EN/PI	Fl/BR/PI	Fl/EN/PI	Fl/EN/BR/PI
%	33.1	41.1	7.4	-	16.6	-	1.6
	EN	EN/Fl	EN/PI	EN/BR	Fl/EN/BR	Fl/EN/PI	Fl/EN/BR/PI
%	1.0	97.8	-	-	-	-	1.5

[a]In Area I, but especially in Area II, cluster analysis and the proportion index show that a considerable amount of _S. alutus_ was caught by itself. This is primarily due to a few unusually large and irregular catches in 1977 that accounted for approximately 50% of the individual catches. In this analysis those catches have been deleted and the index recalculated.

[b]Al: _S. alutus_ BR: _S. brevispinis_
PR: _S. proriger_ EN: _S. entomelas_
RE: _S. reedi_ FI: _S. flavidus_
PI: _S. pinniger_

Table 4. Results of the analysis of covariance by study area.

Area	Assemblage unit	Time interval	Equality of slopes: Mean SS	Equality of slopes: Mean Residual SS	Slope	F ratio: F_{OBS}	F ratio: $F_{0.05}$	Probability
I	S. alutus S. reedi S. proriger	April-December	.0260	.2881	.0117 -.0225 .0178	.0901	4.35	.50>P>.40
III	S. alutus S. reedi	May-December	.0012	.1400	-.0574 -.0498	.0086	6.55	.40>P>.30
IV	S. brevispinis S. flavidus S. entomelas S. pinniger	April-November	.1213	.6160	.0793 .0827 .3577 .0805	.1970	3.90	.30>P>.20
V	S. brevispinis S. flavidus S. pinniger	May-December	.1400	.2269	.0637 -.1394 -.1804	1.2845	4.69	.20>P>.10
VII	S. brevispinis S. flavidus S. entomelas S. pinniger	May-October	1.4859	.6148	.0263 .0403 -.6111 .0930	2.4168	3.95	.10>P>.05

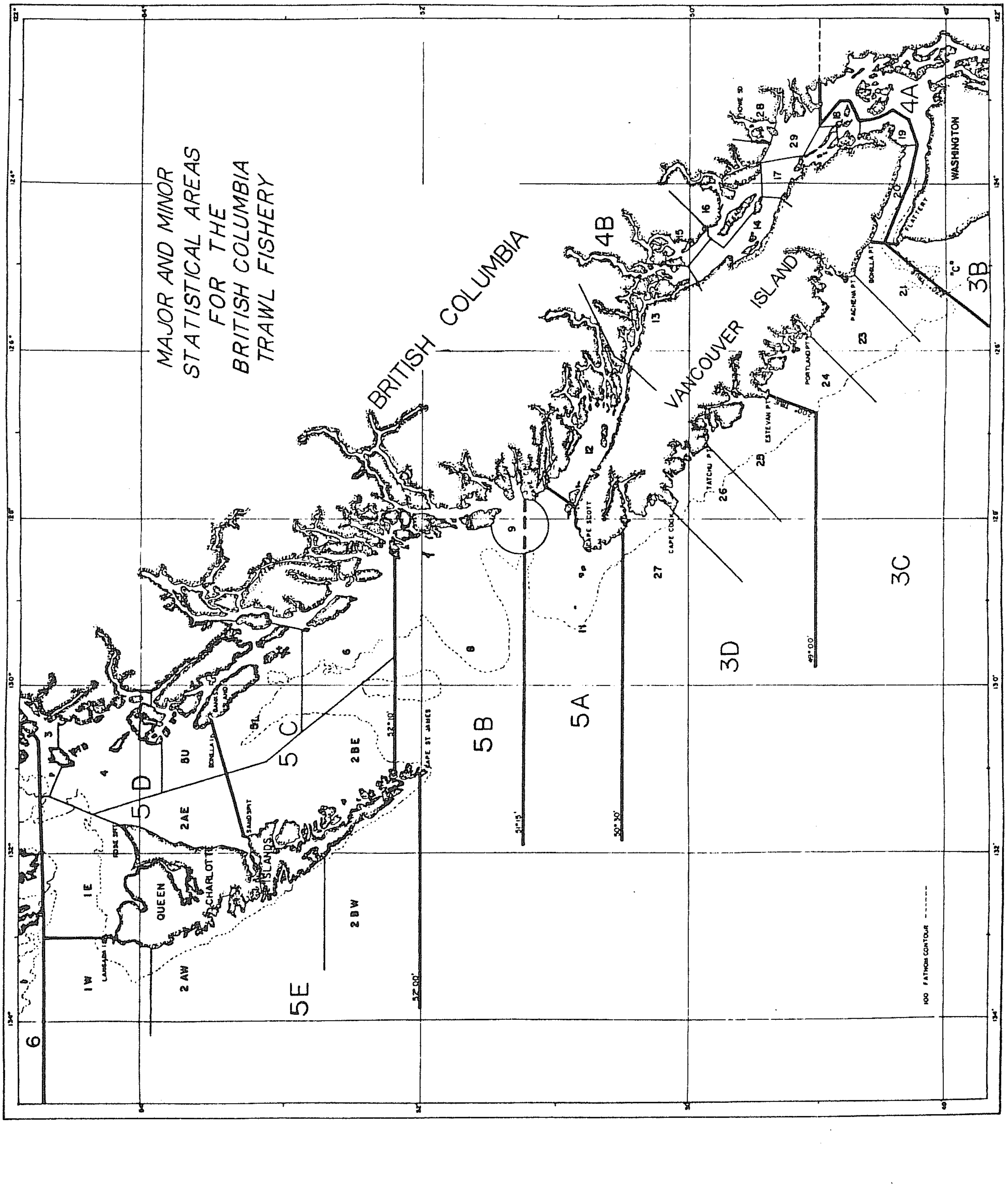


Fig. 1. Major and minor statistical areas.

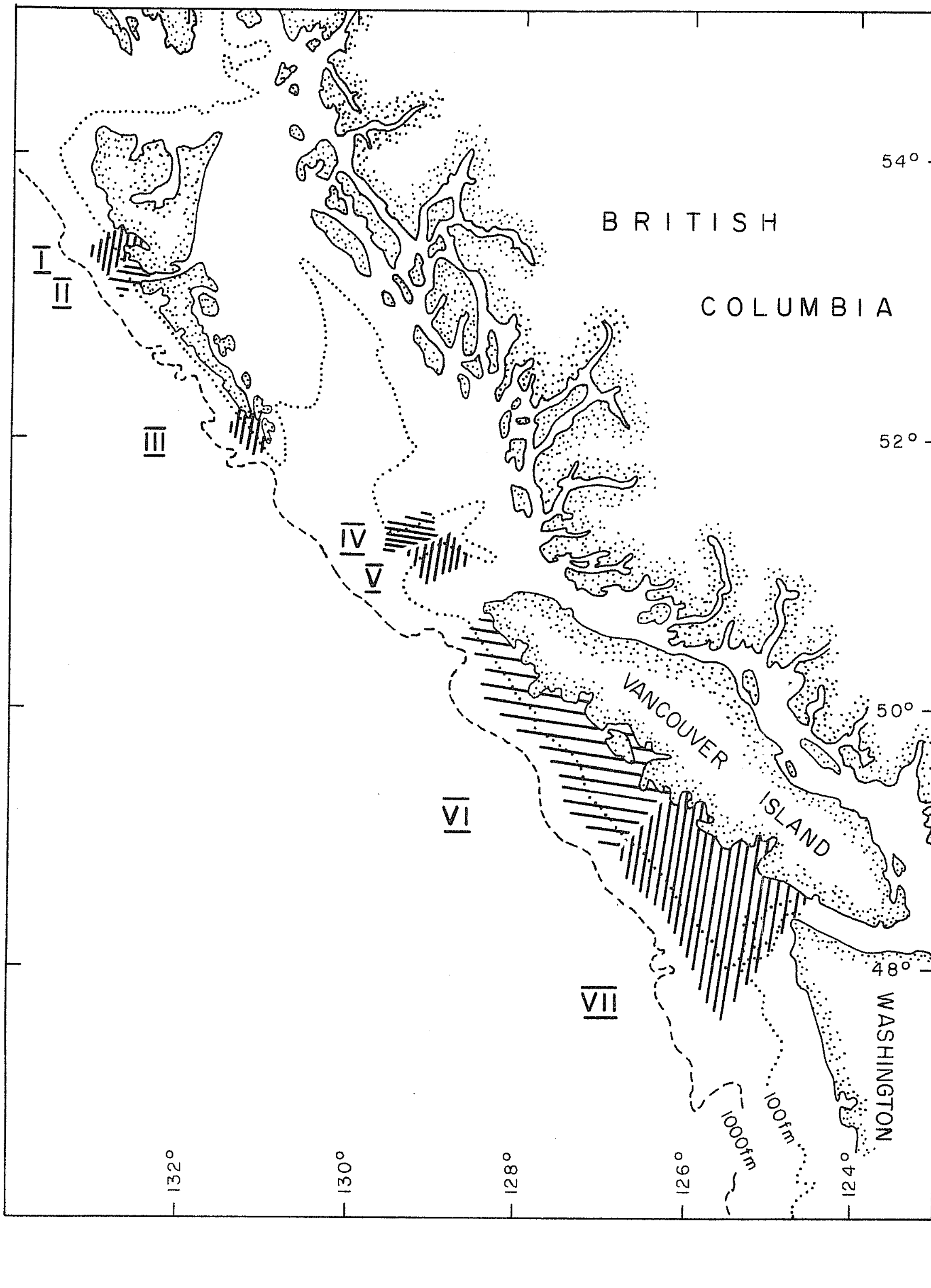


Fig. 2. Study Areas.

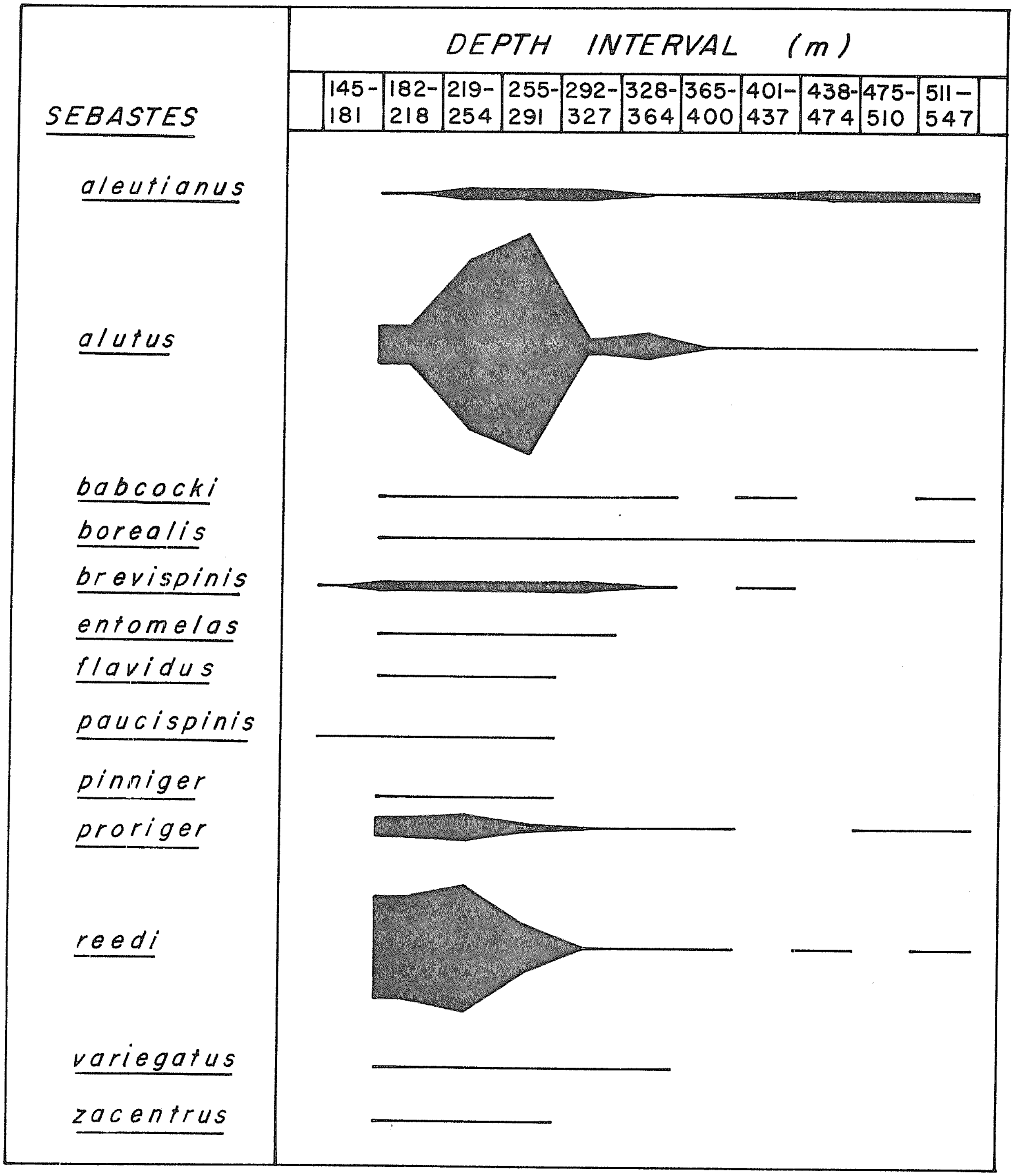


Fig. 3. Schematic illustration of relative abundance by depth, Major Area 5E.

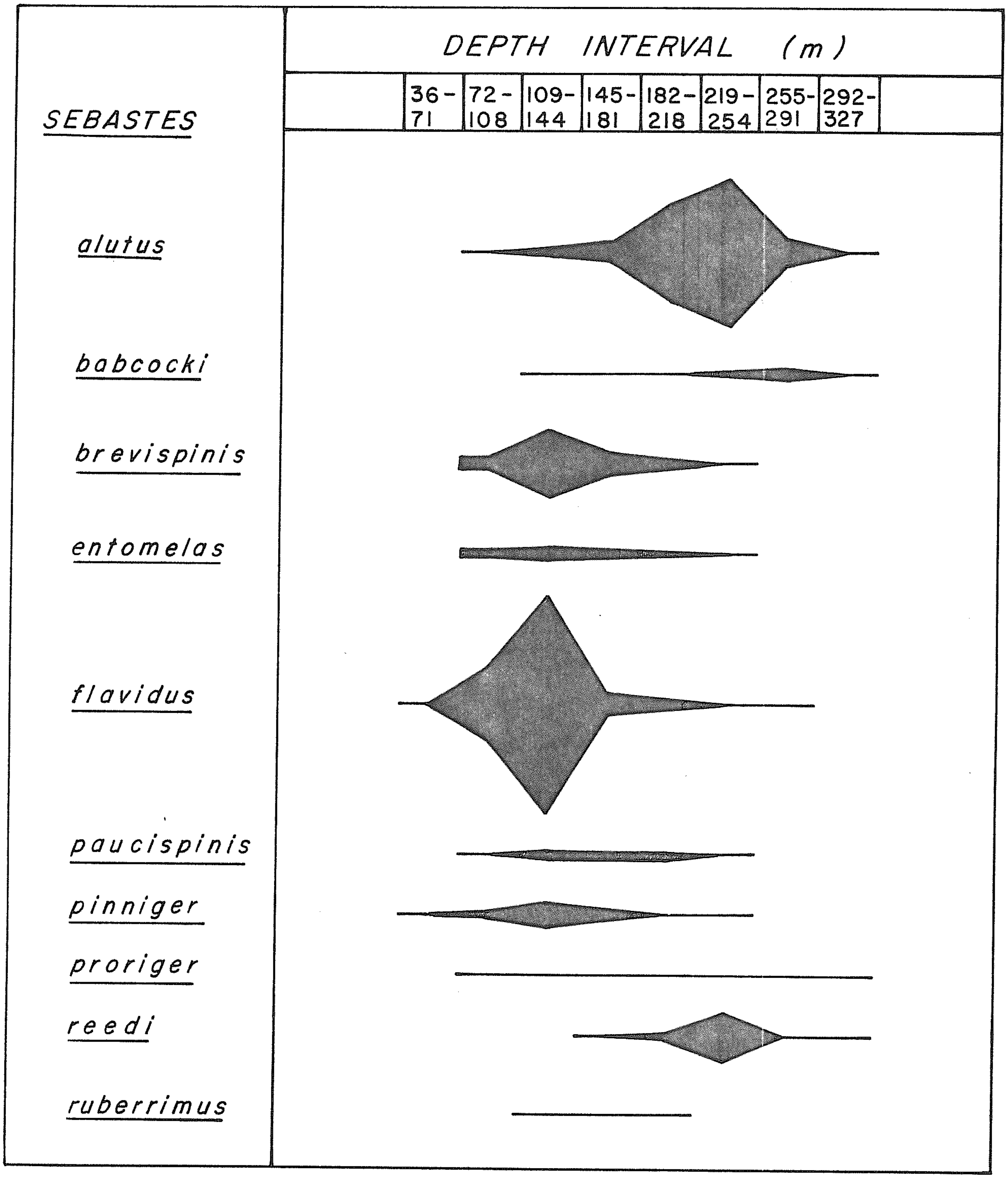


Fig. 4. Schematic illustration of relative abundance by depth, Major Areas 5A and 5B.

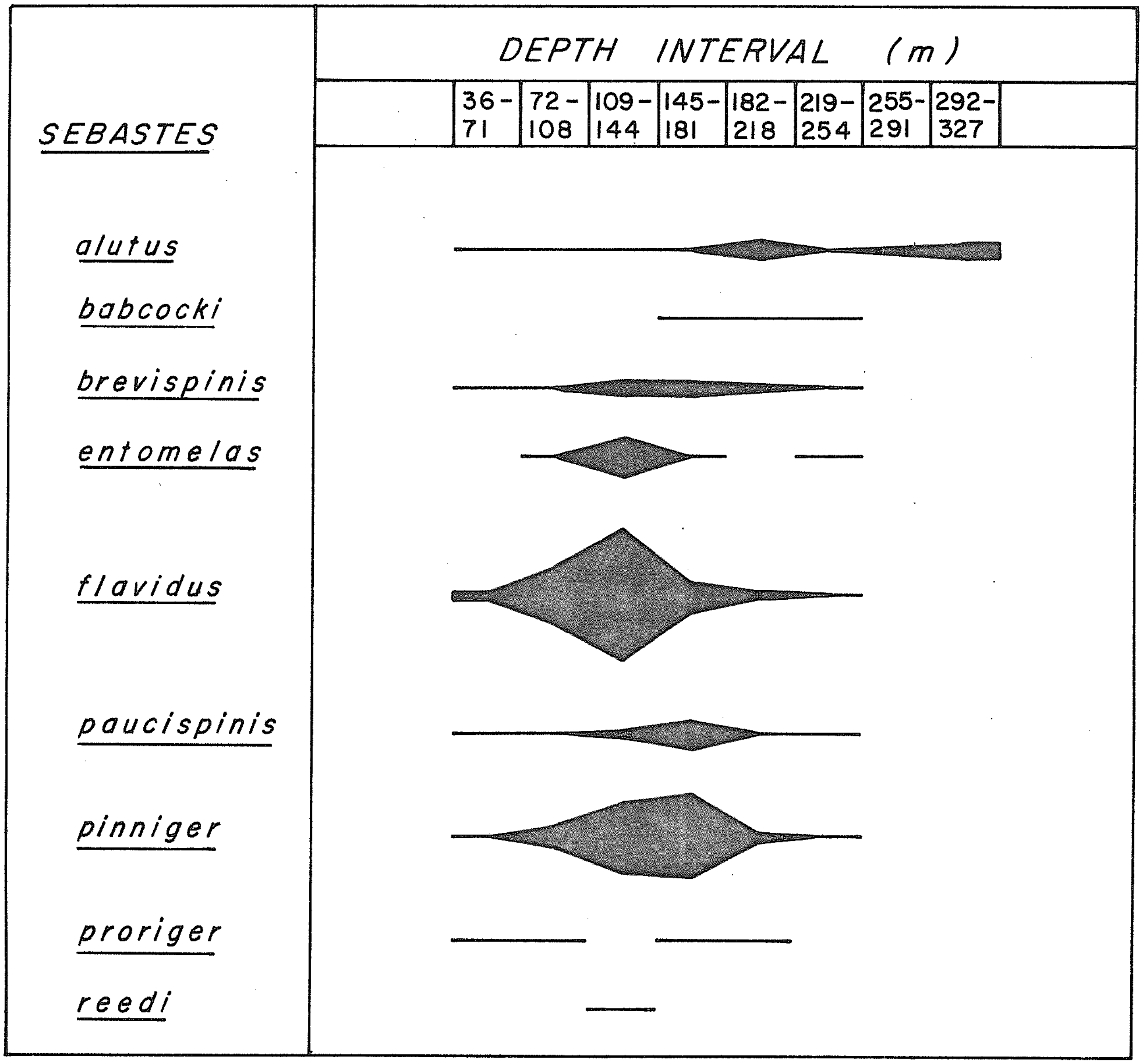


Fig. 5. Schematic illustration of relative abundance by depth, Major Areas 3C and 3D.

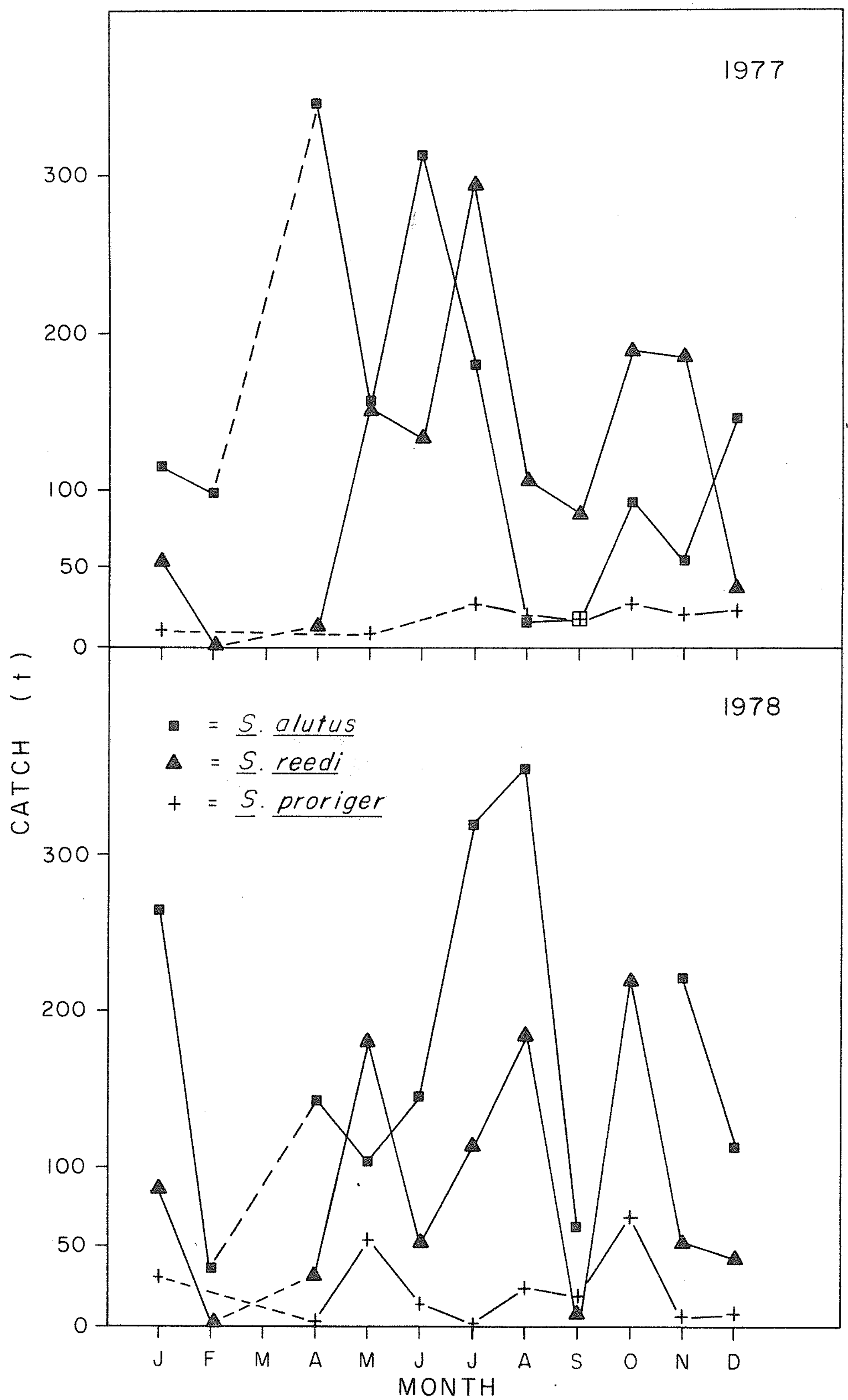


Fig. 6a. General trends in seasonal catch, 1977-1978, Major Area 5E.

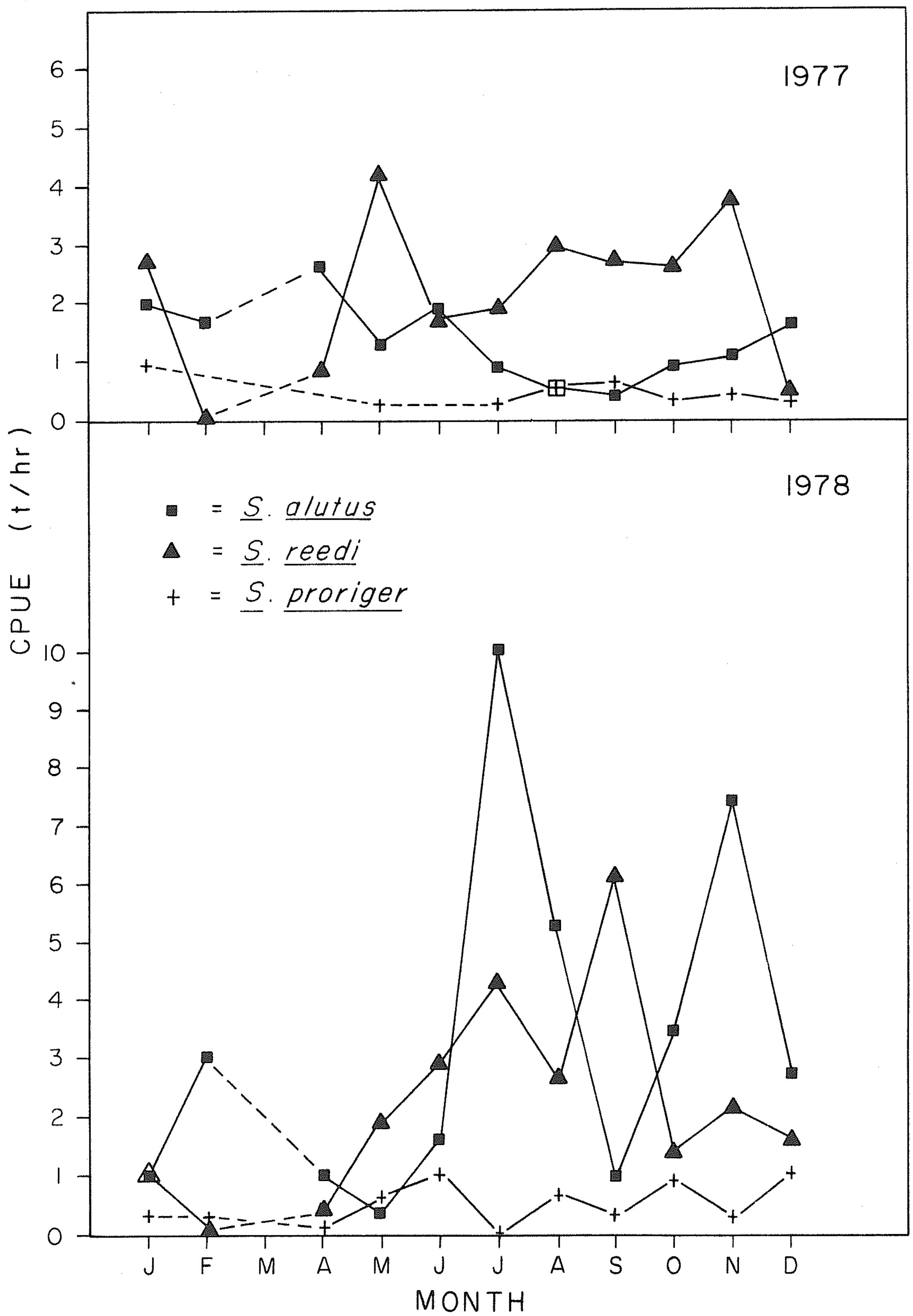


Fig. 6b. General trends in seasonal CPUE, 1977-1978, Major Area 5E.

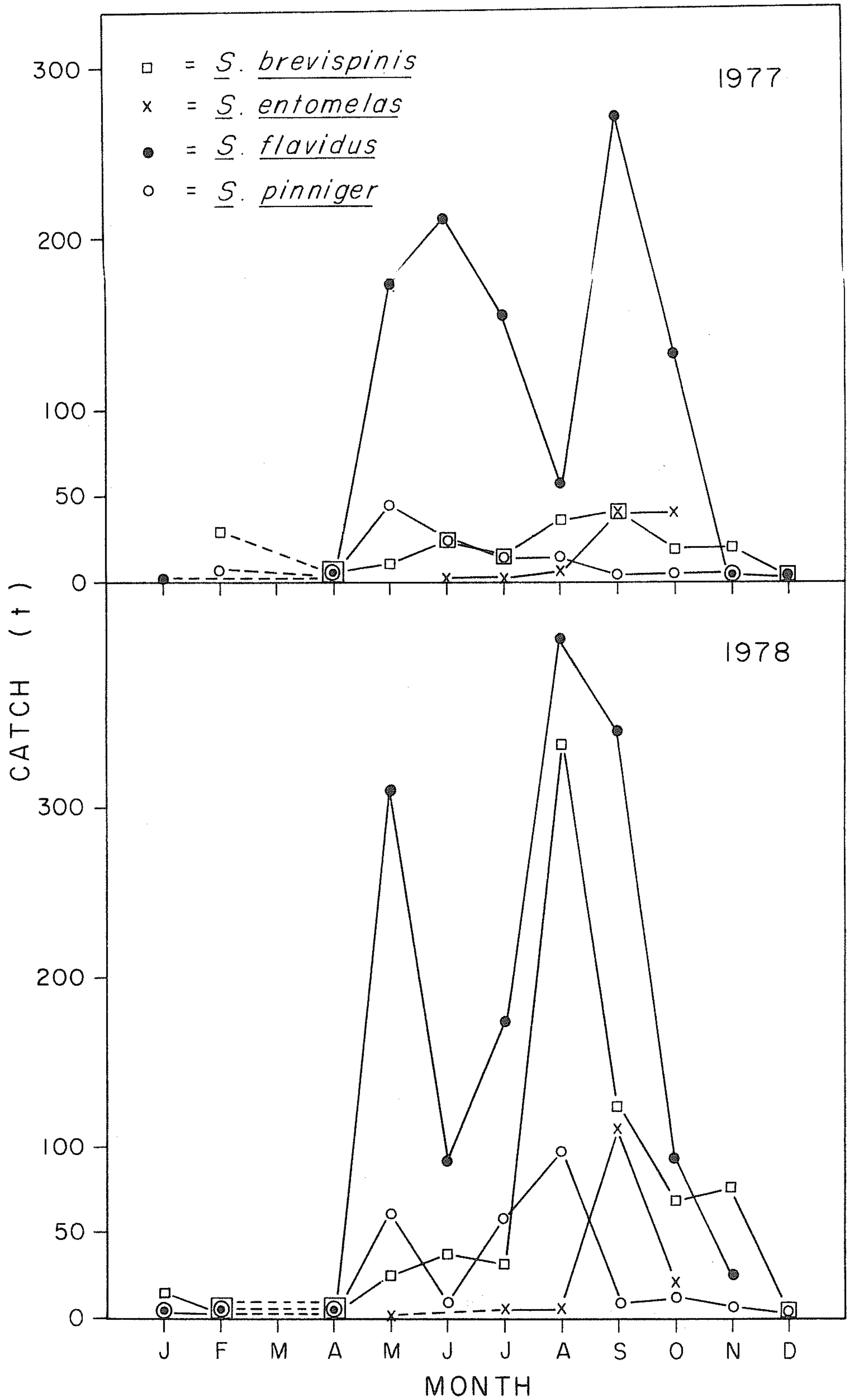


Fig. 7a. General trends in seasonal catch, 1977-1978, Major Areas 5A and 5B.

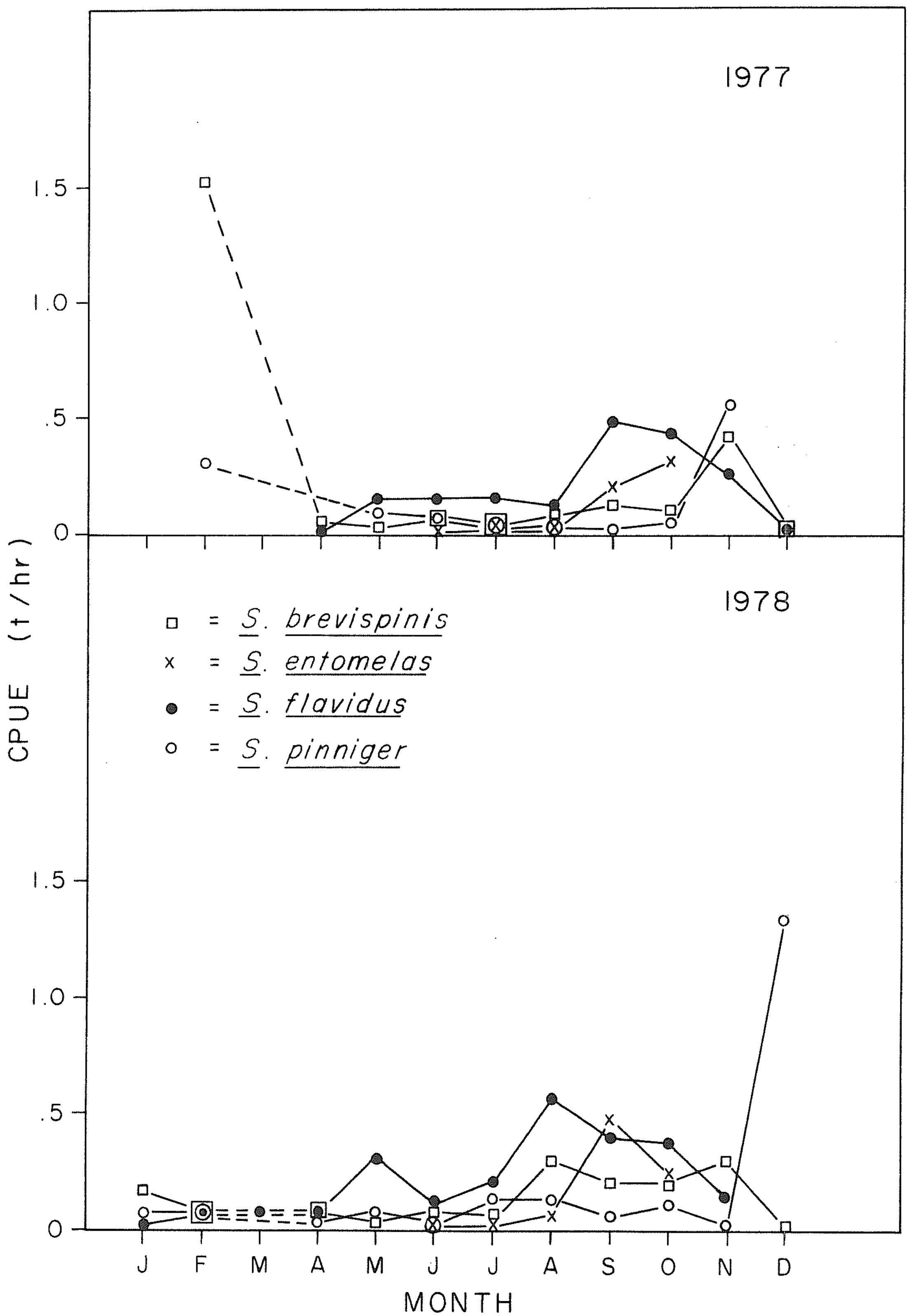


Fig. 7b. General trends in seasonal CPUE, 1977-1978, Major Areas 5A and 5B.

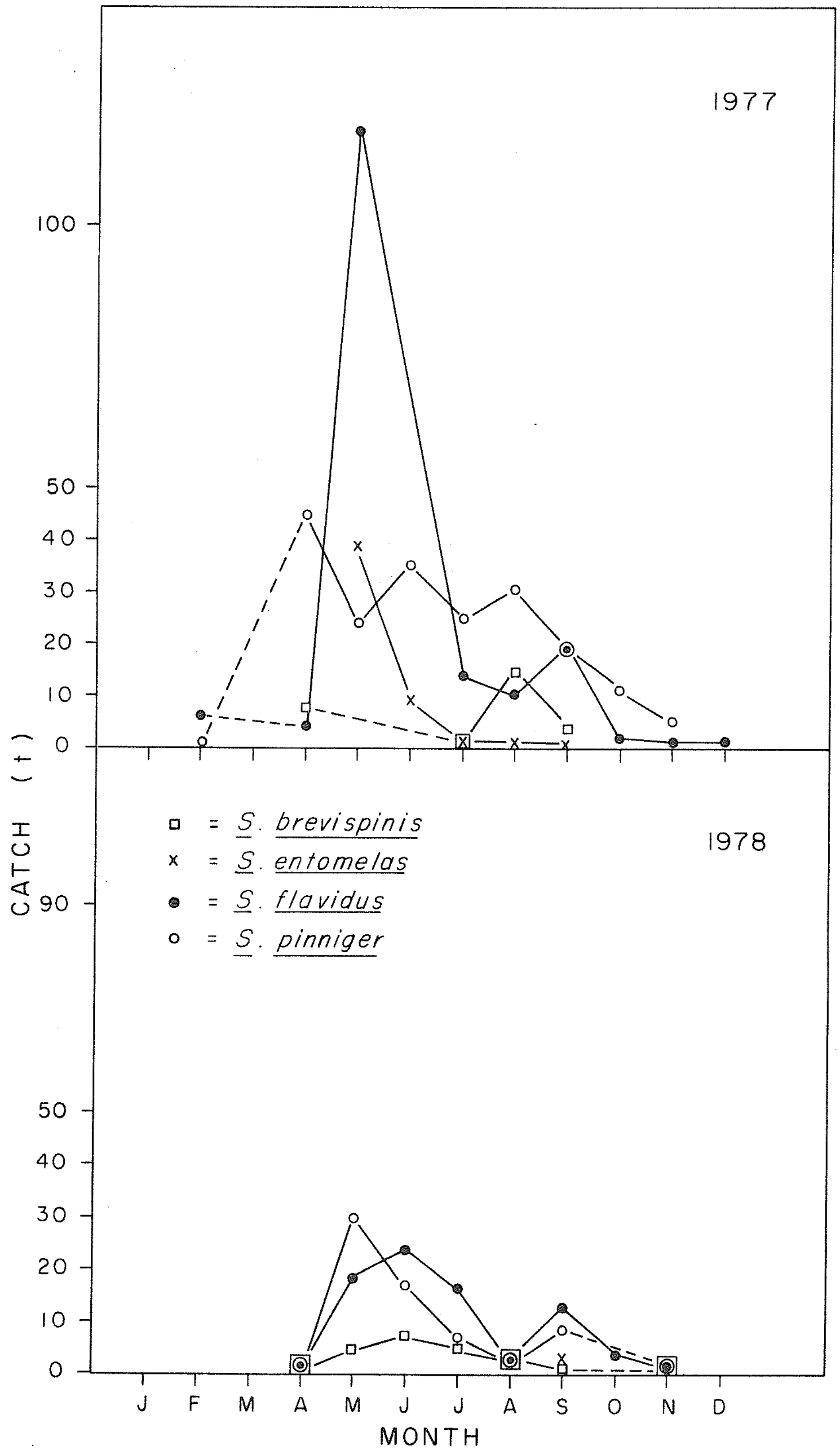


Fig. 8a. General trends in seasonal catch, 1977-1978, Major Areas 3C and 3D.

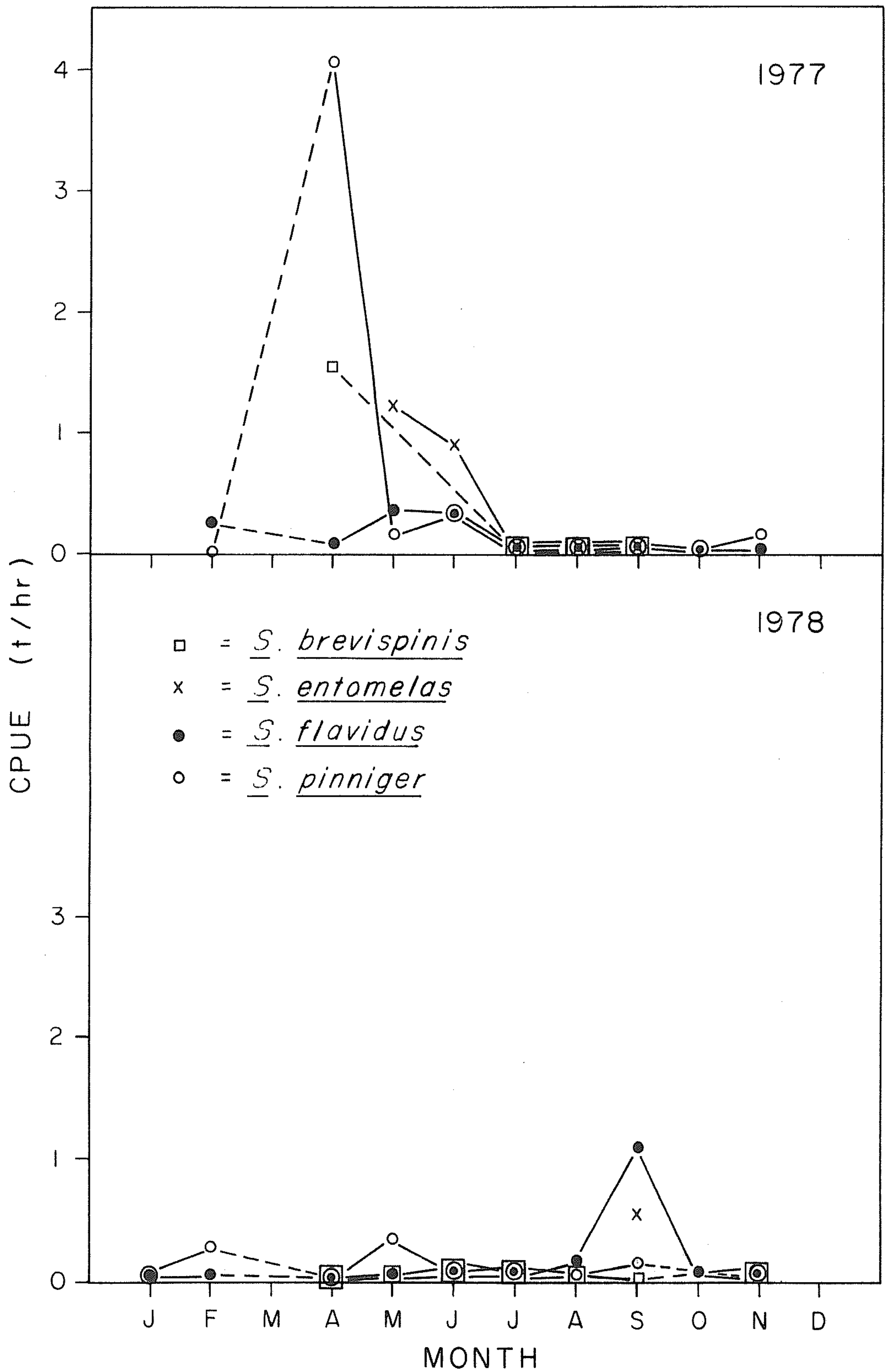


Fig. 8b. General trends in seasonal CPUE, 1977-1978, Major Areas 3C and 3D.

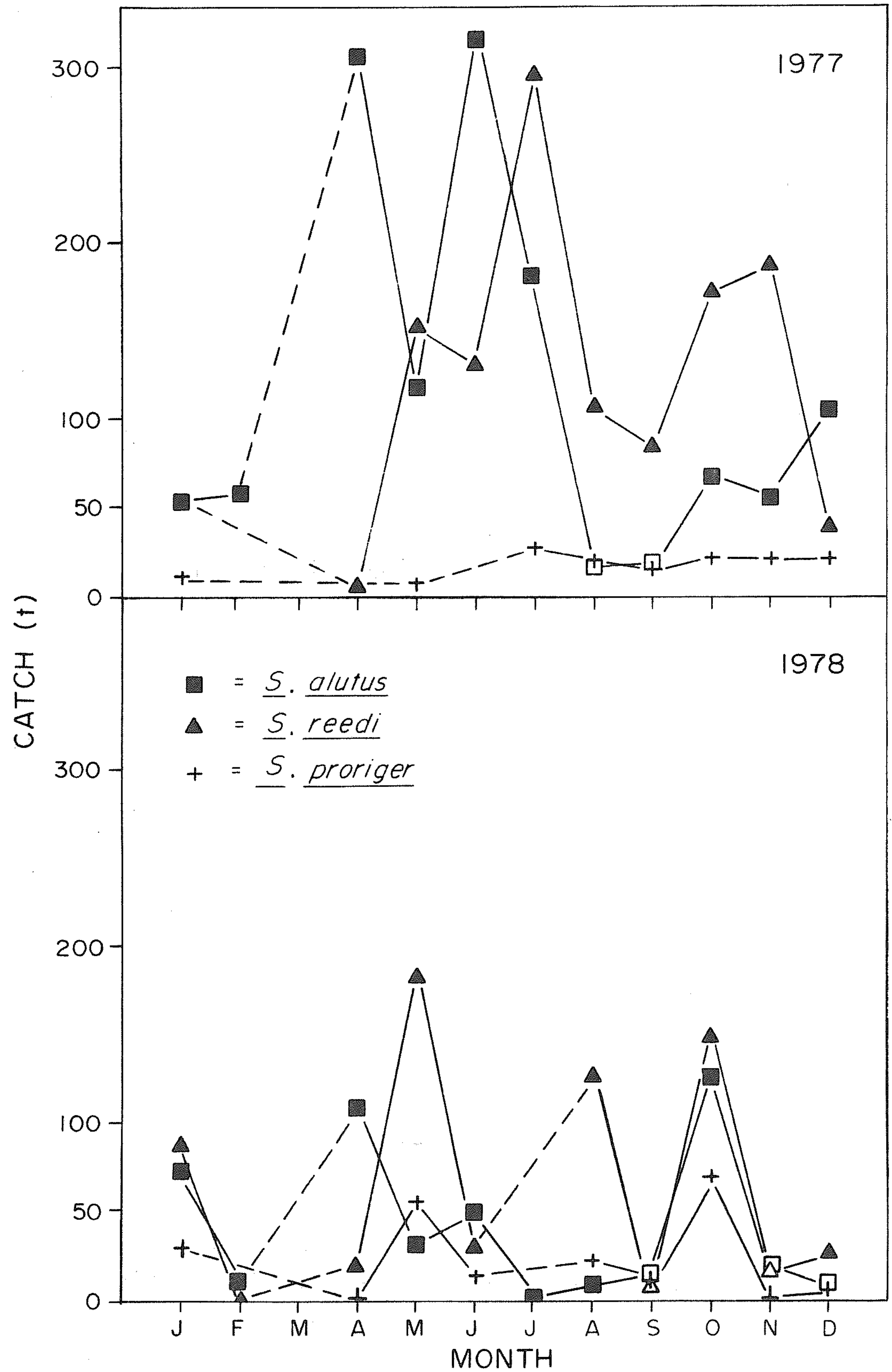


Fig. 9a. Seasonal trends in catch 1977-1978, Study Areas I and II.

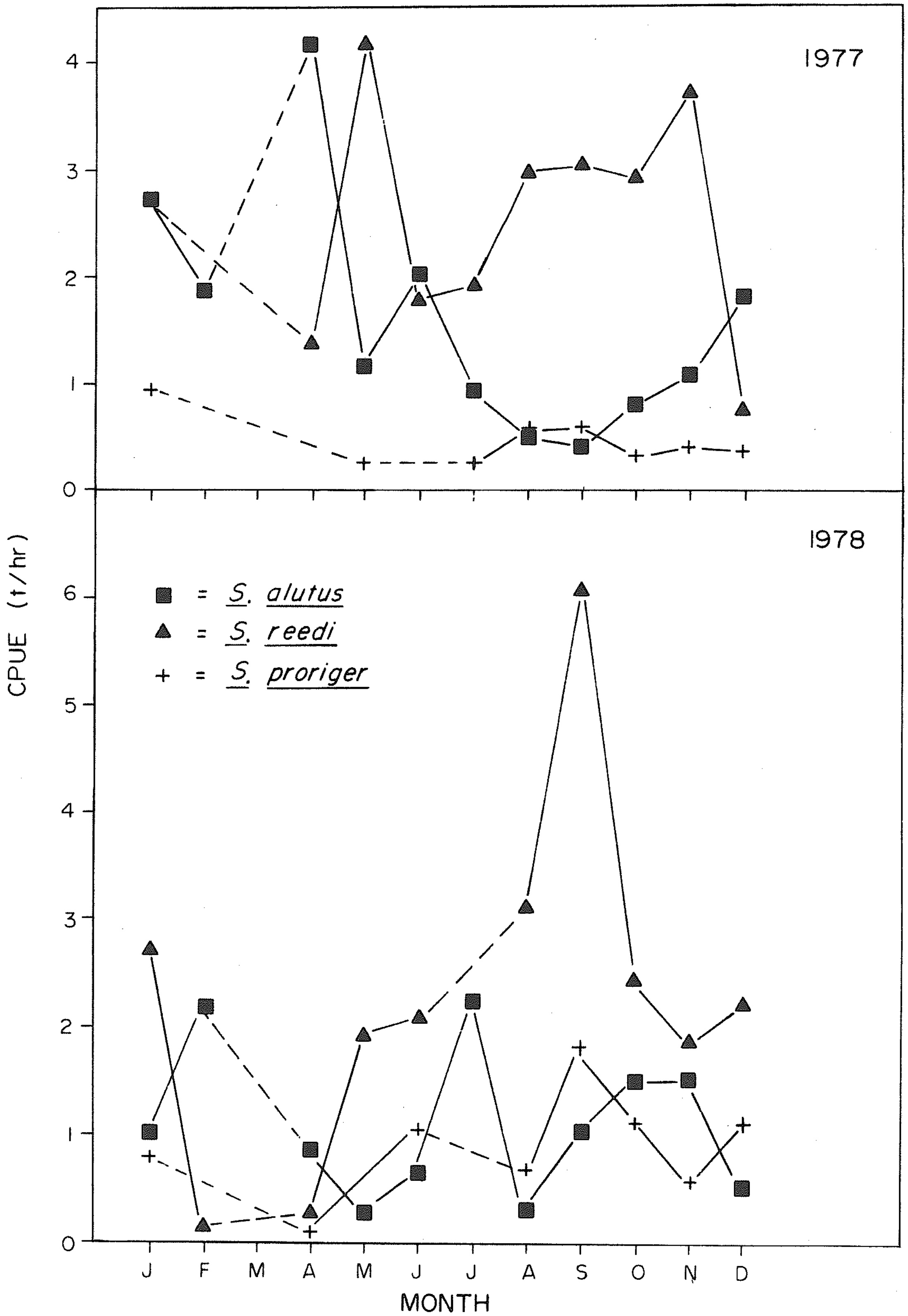


Fig. 9b. Seasonal trends in CPUE, 1977-1978, Study Areas I and II.

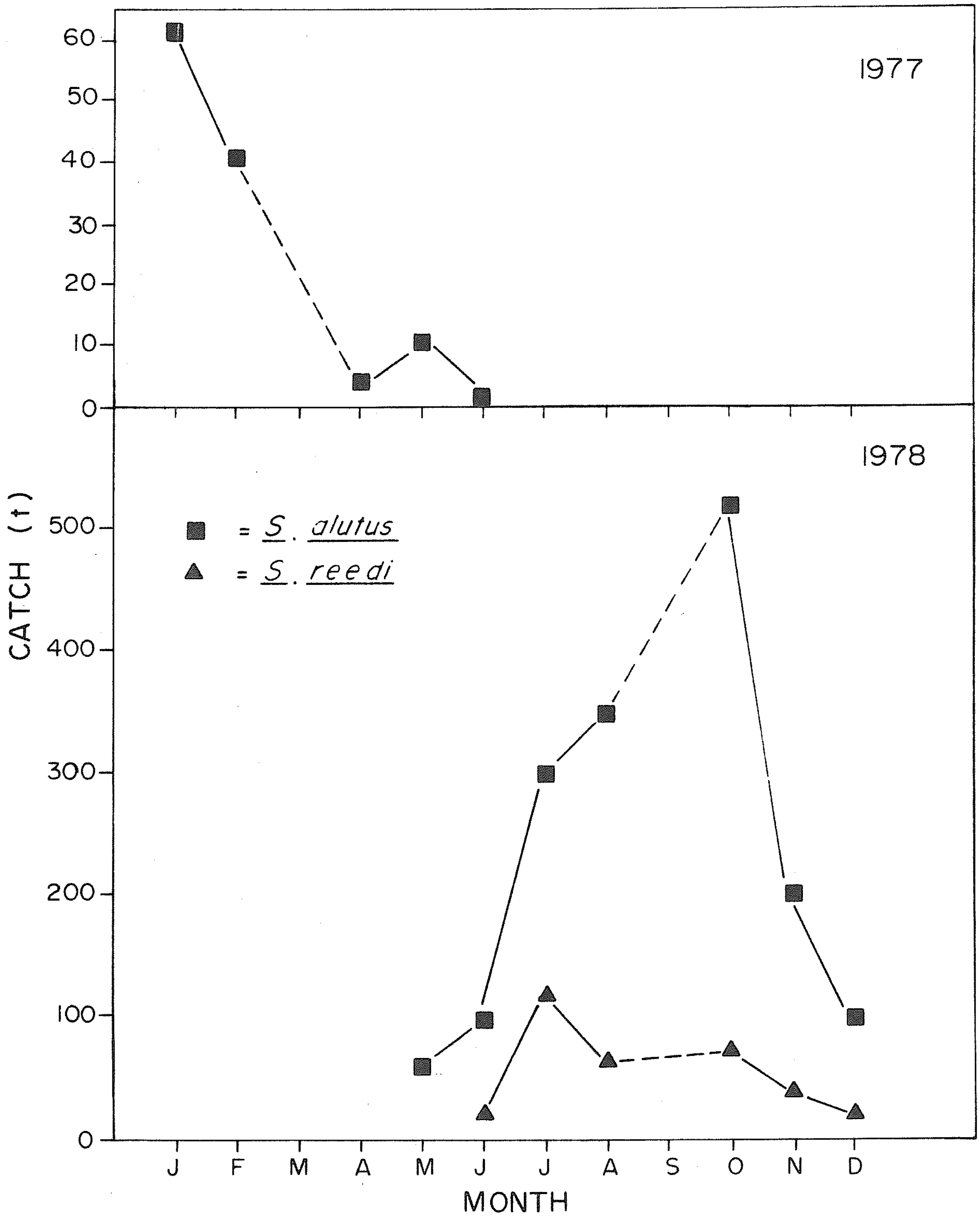


Fig. 10a. Seasonal trends in catch, 1977-1978, Study Area III.

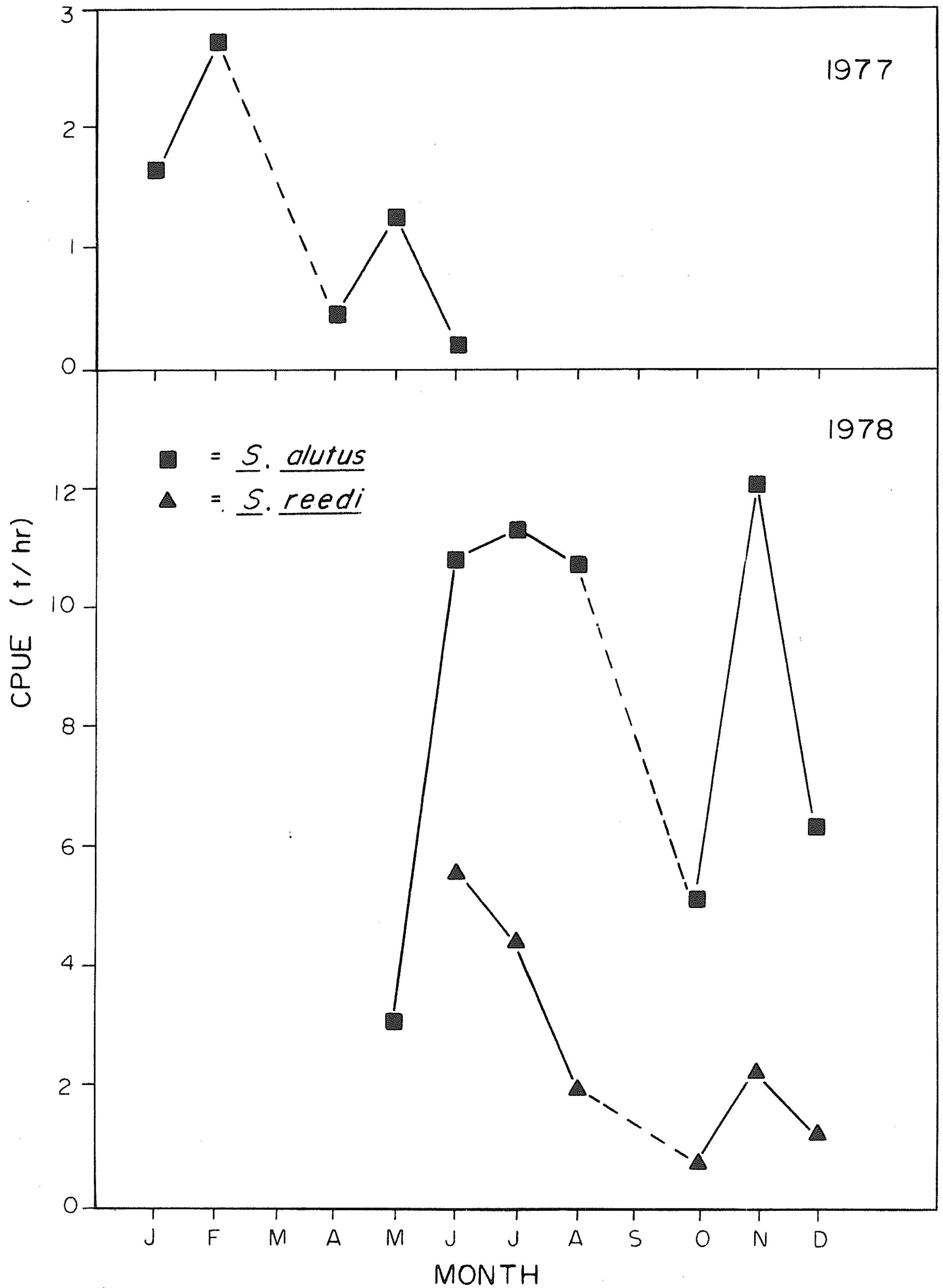


Fig. 10b. Seasonal trends in CPUE, 1977-1978, Study Area III.

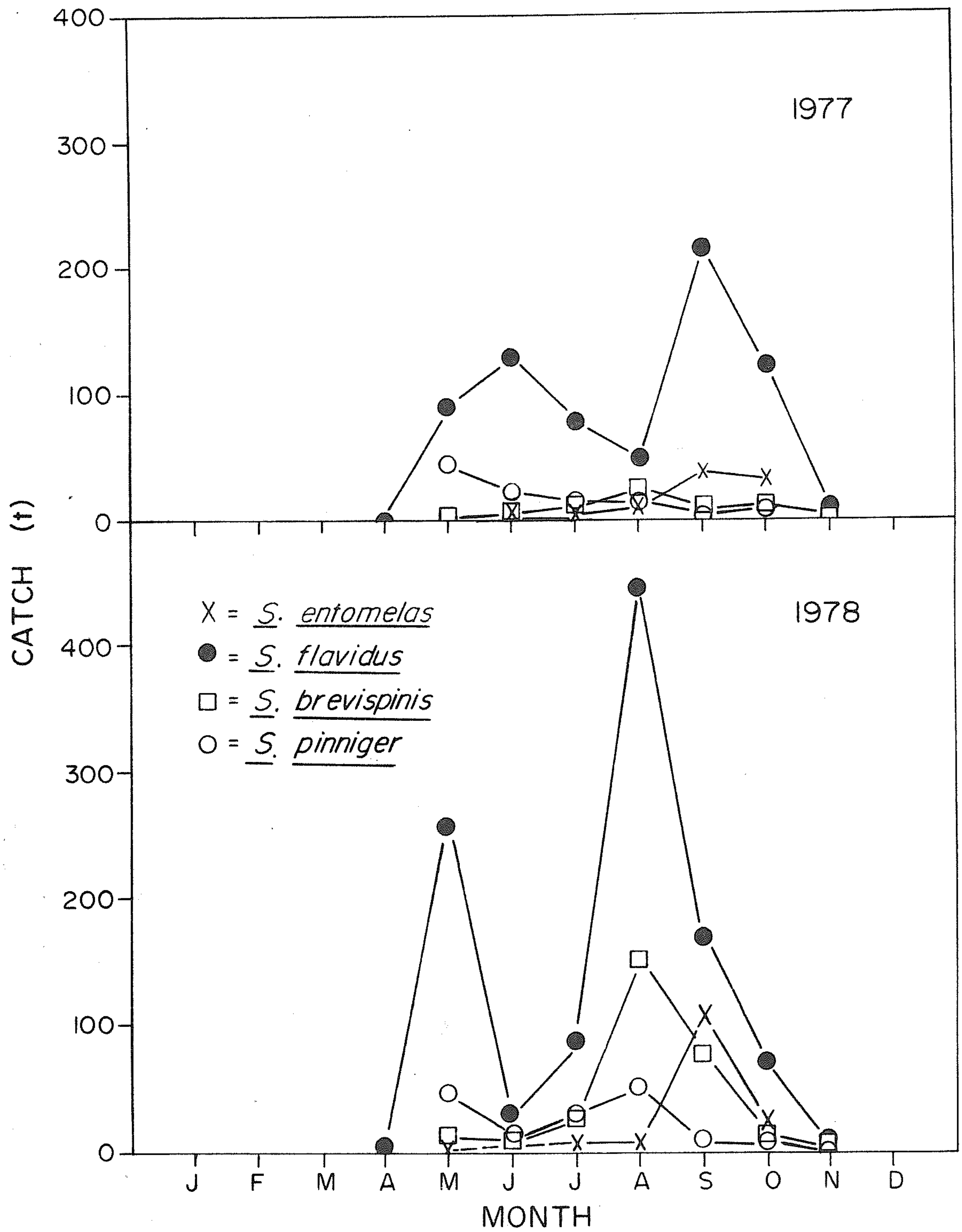


Fig. 11a. Seasonal trends in catch, 1977-1978, Study Areas IV and V.

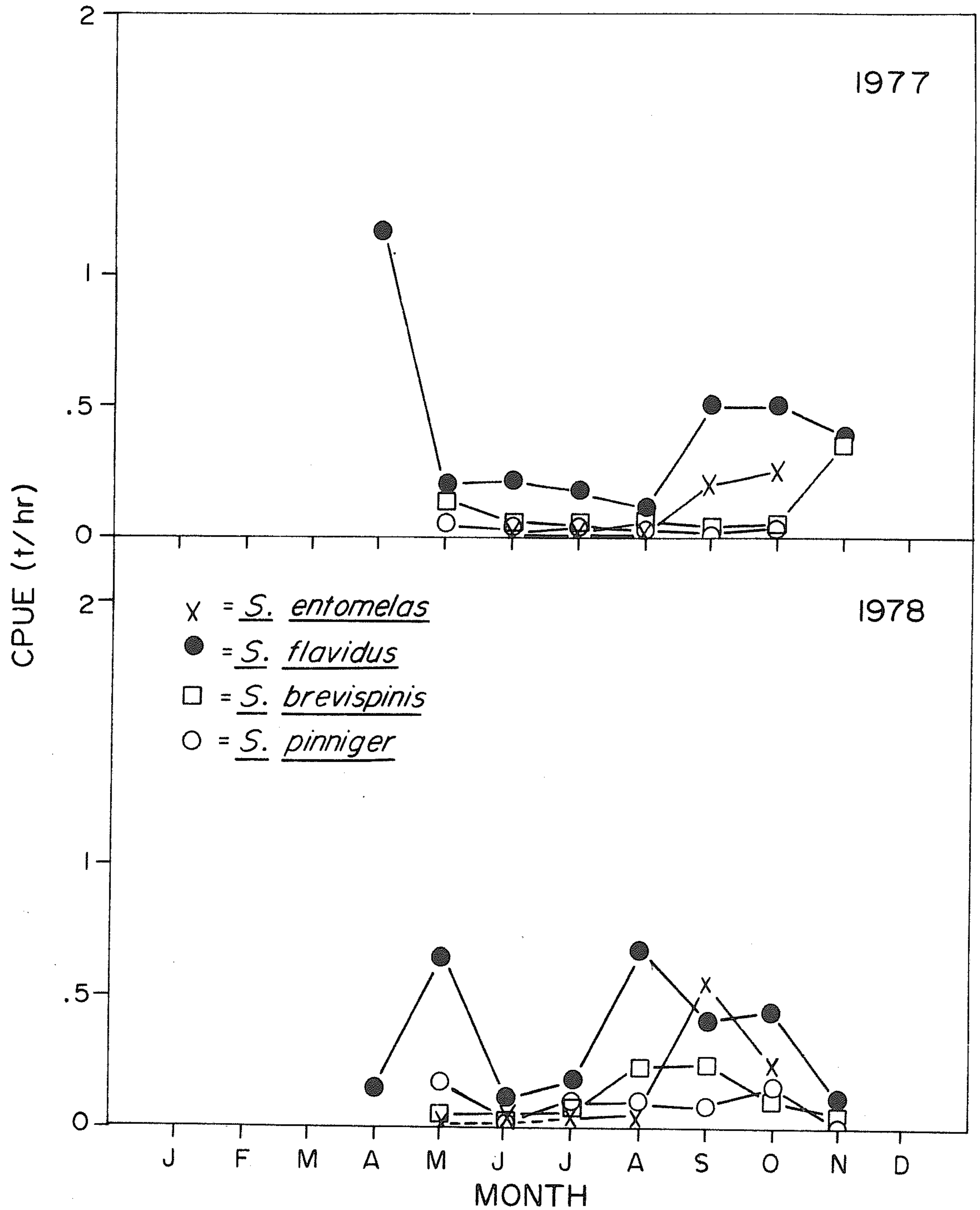


Fig. 11b. Seasonal trends in CPUE, 1977-1978, Study Areas IV and V.

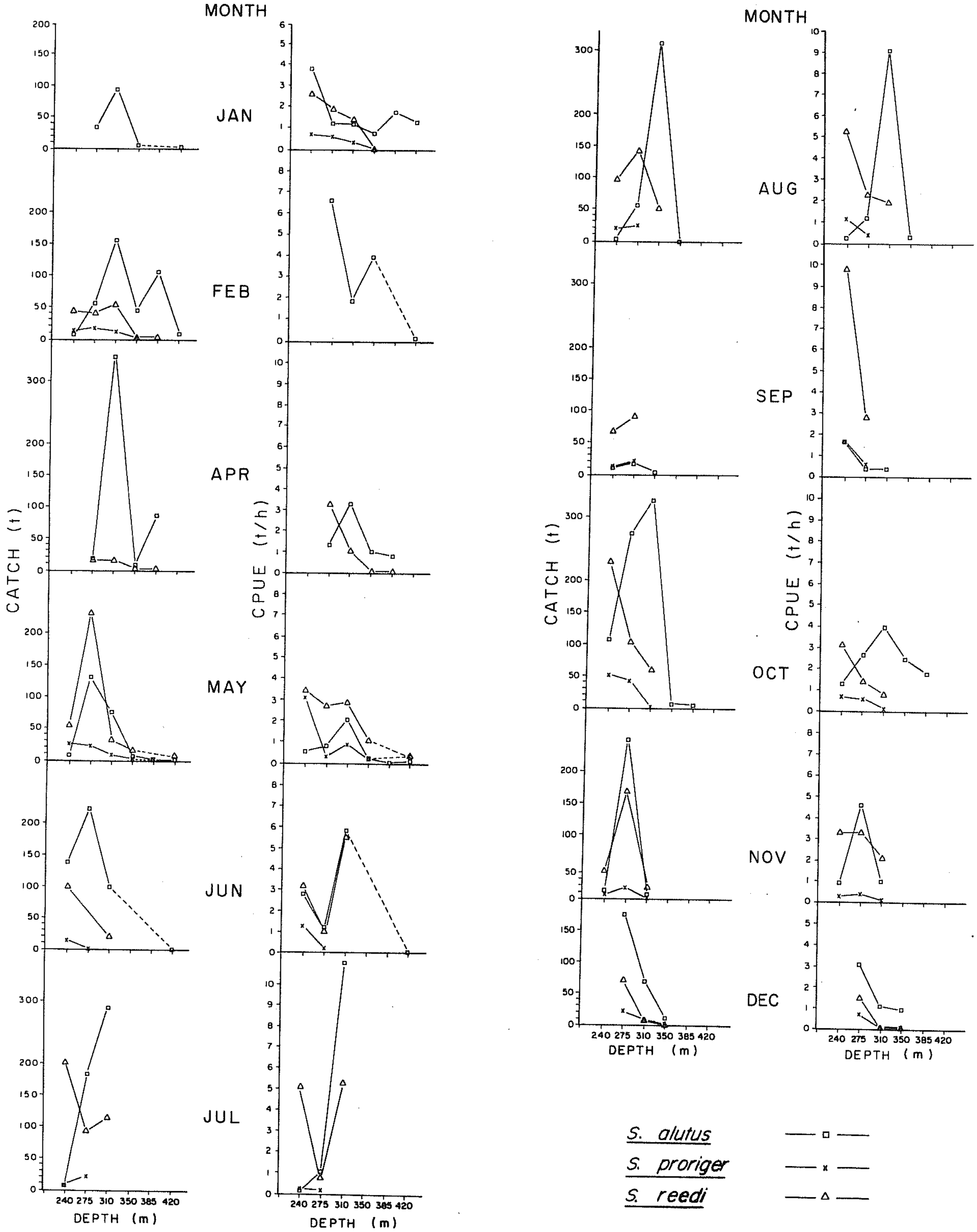


Fig. 12. Seasonal trends in catch and CPUE by depth interval, Major Area 5E.

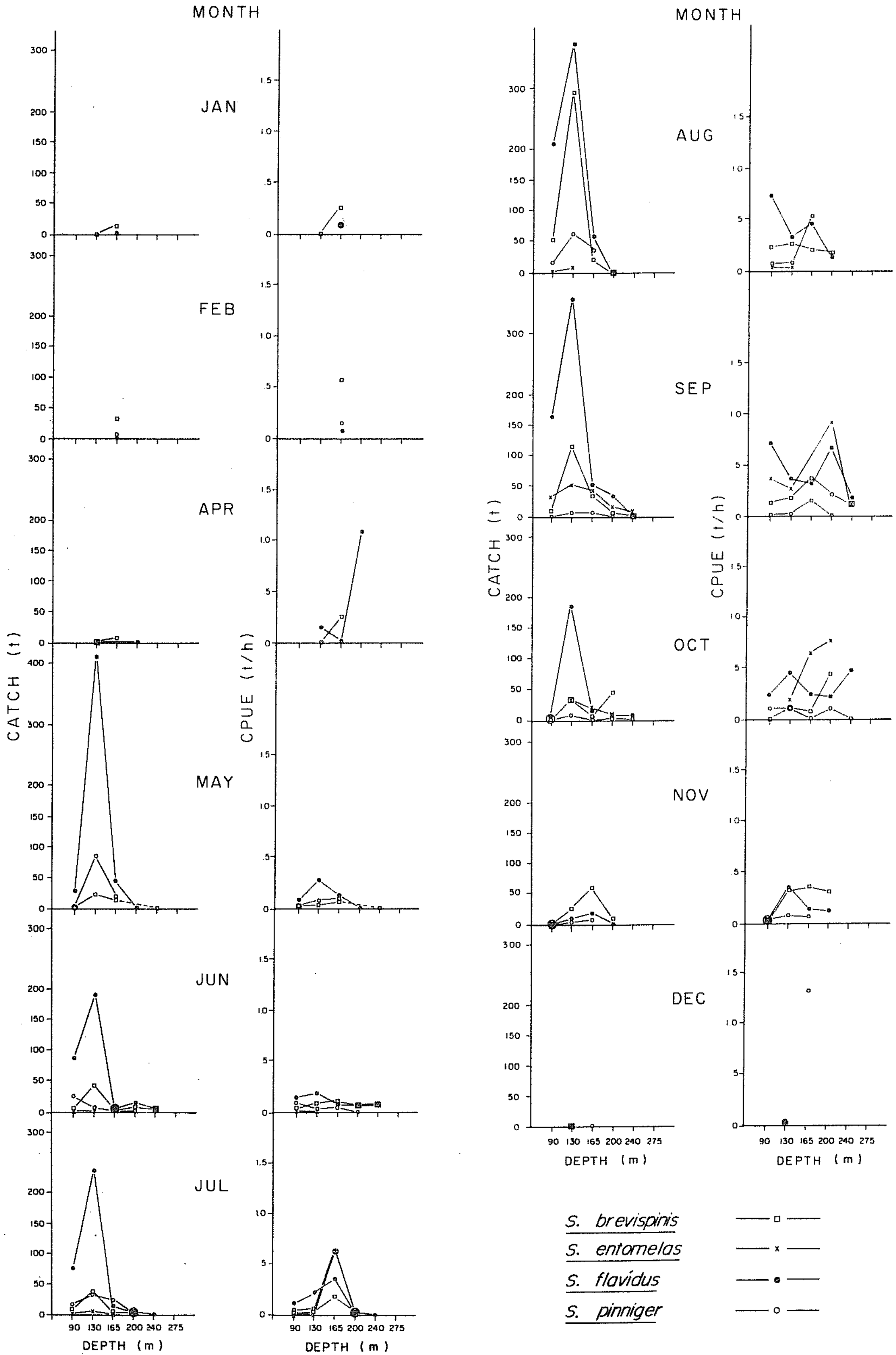


Fig. 13a. Seasonal trends in catch and CPUE by depth interval for shelf rockfish, Major Areas 5A and 5B.

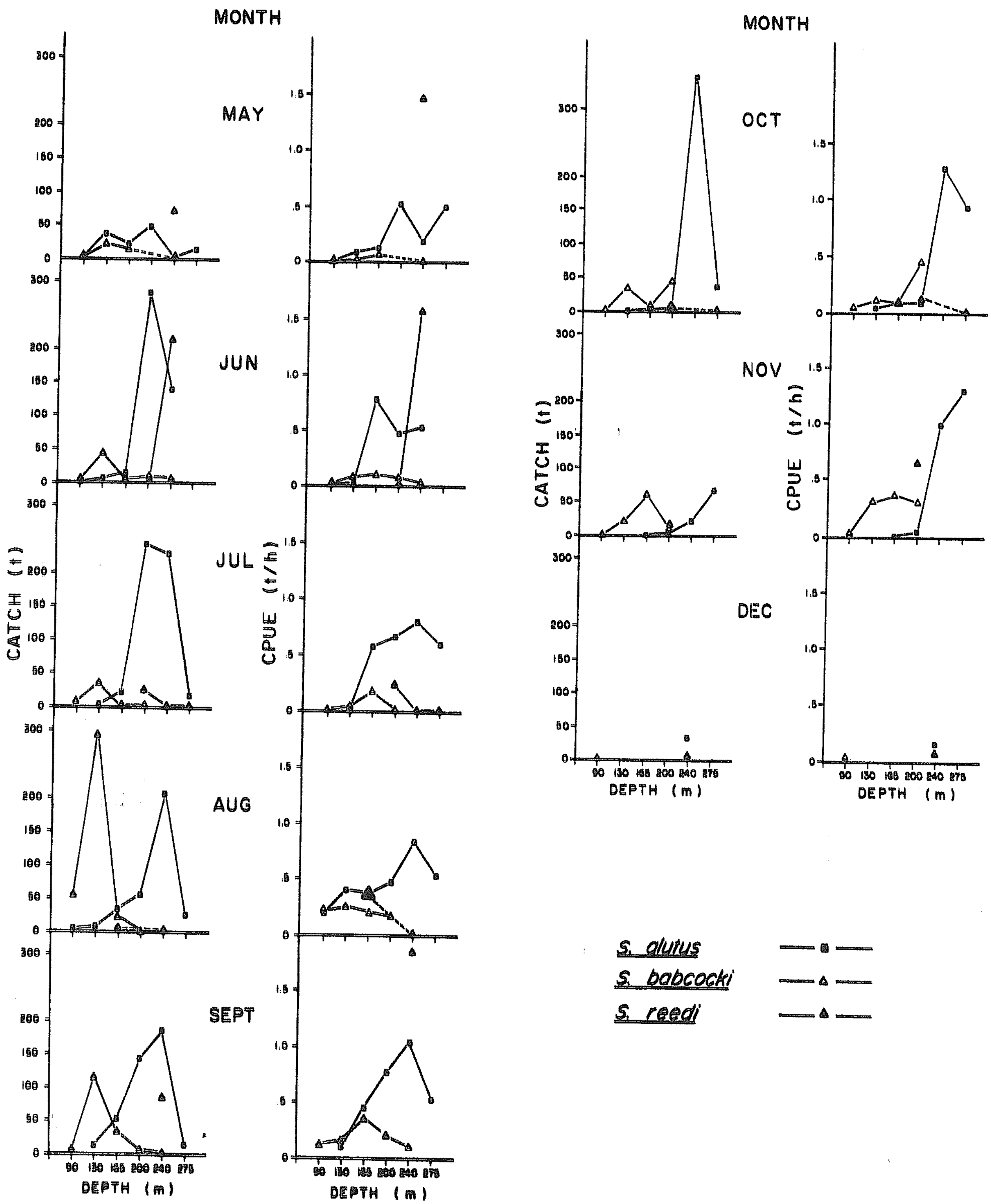


Fig. 13b. Seasonal trends in catch and CPUE by depth interval for slope rockfish, Major Areas 5A and 5B.

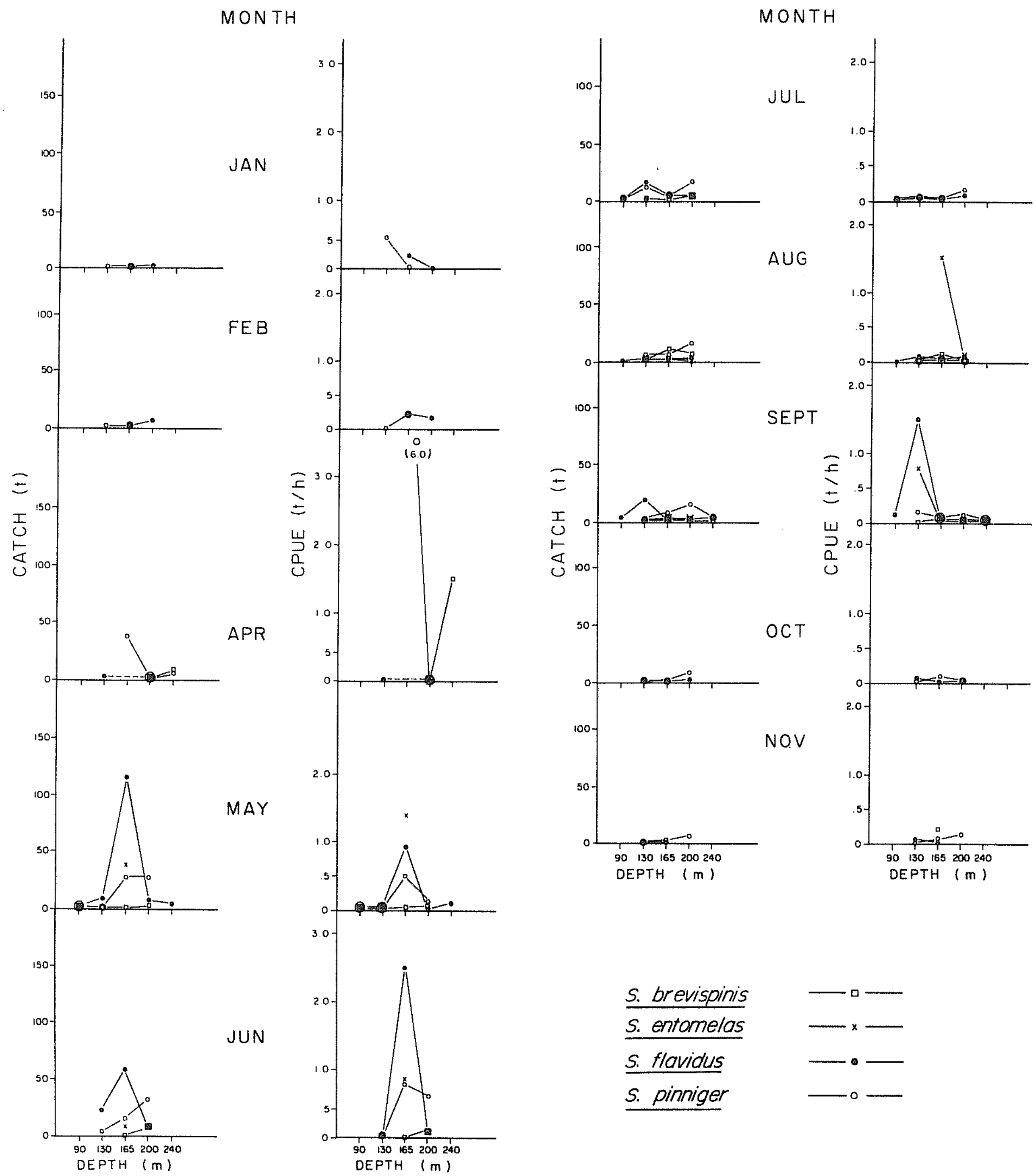
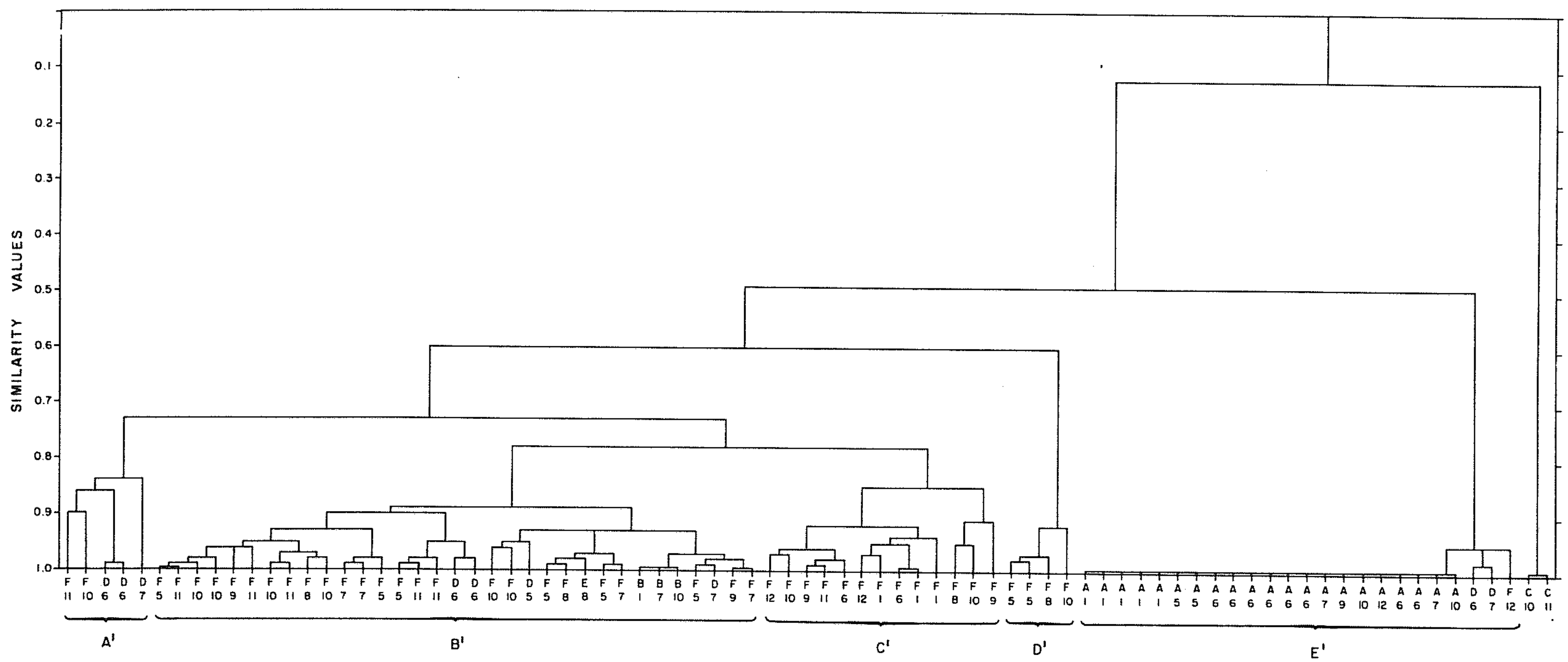


Fig. 14. Seasonal trends in catch and CPUE by depth interval, Major Areas 3C and 3D.



A = *S. alutus*
B = *S. reedi*
C = *S. proriger*
D = *S. alutus* / *S. reedi*
E = *S. reedi* / *S. proriger*
F = *S. alutus* / *S. proriger* / *S. reedi*

Fig. 15. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area I, January-December, 182-291 m. Species composition (A-F) and month caught (1-12) are recorded for each vessel trip.

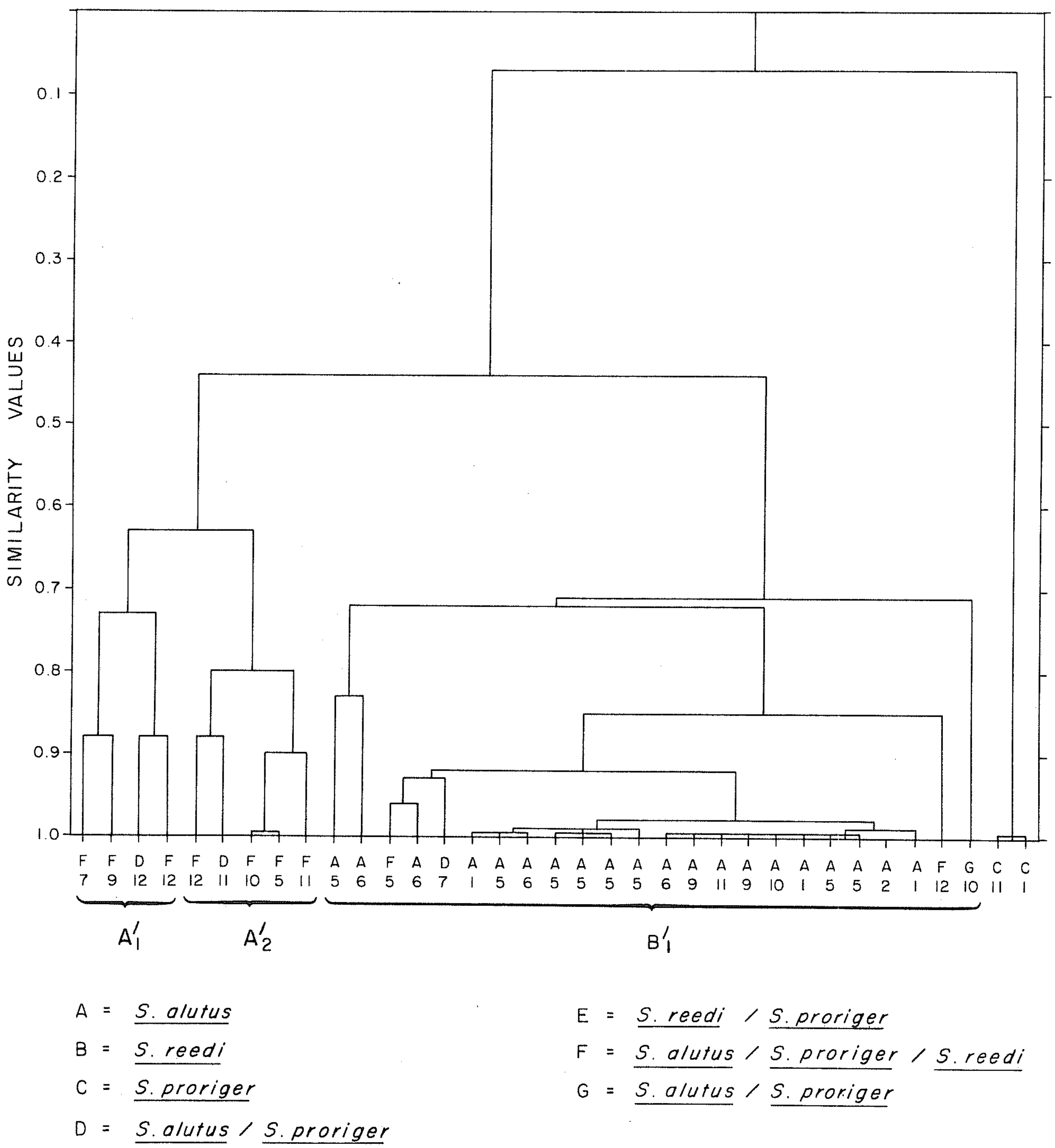
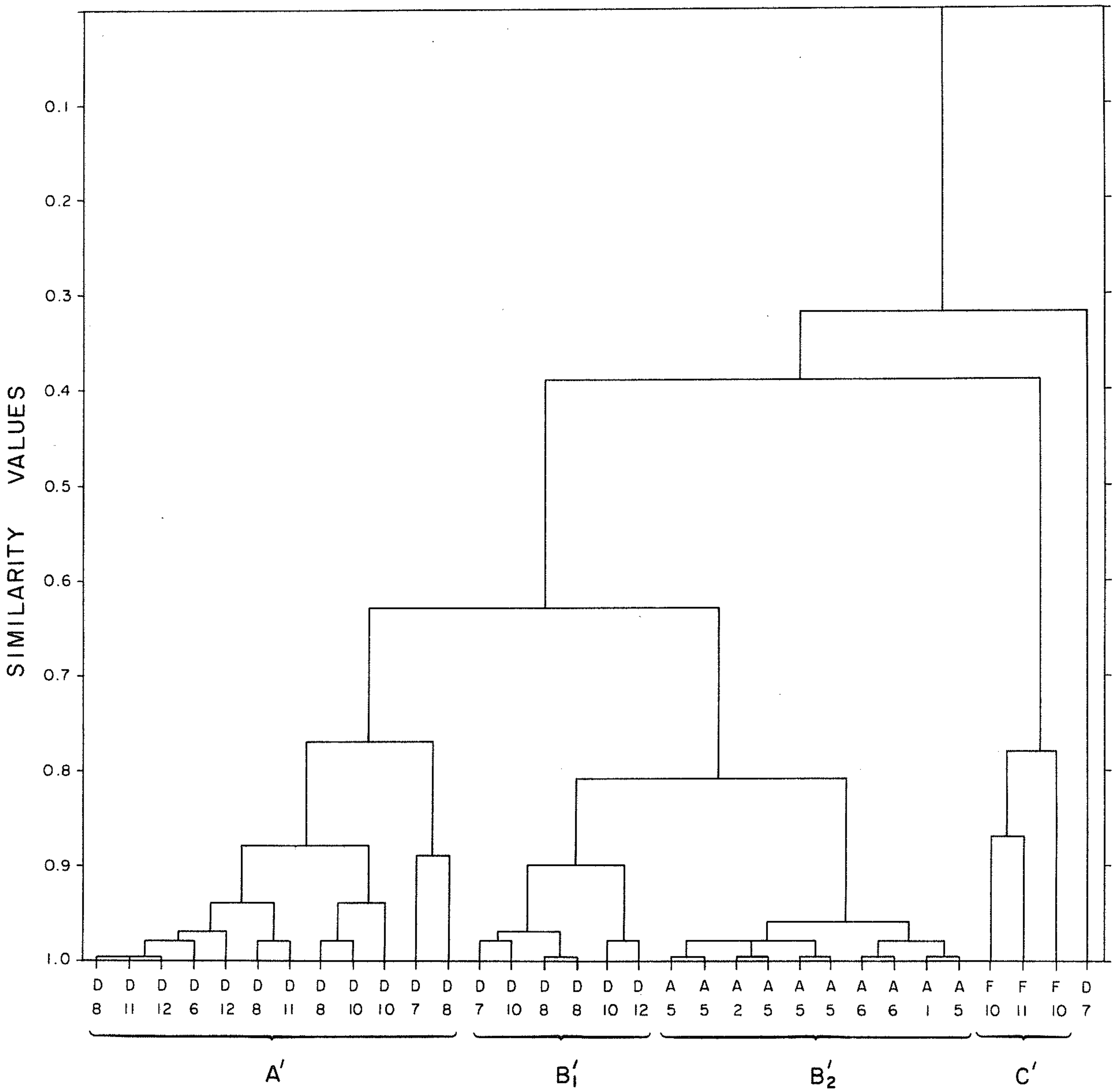


Fig. 16. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area II, January-December, 219-291 m. Species composition (A-G) and month caught (1-12) are recorded for each vessel trip.

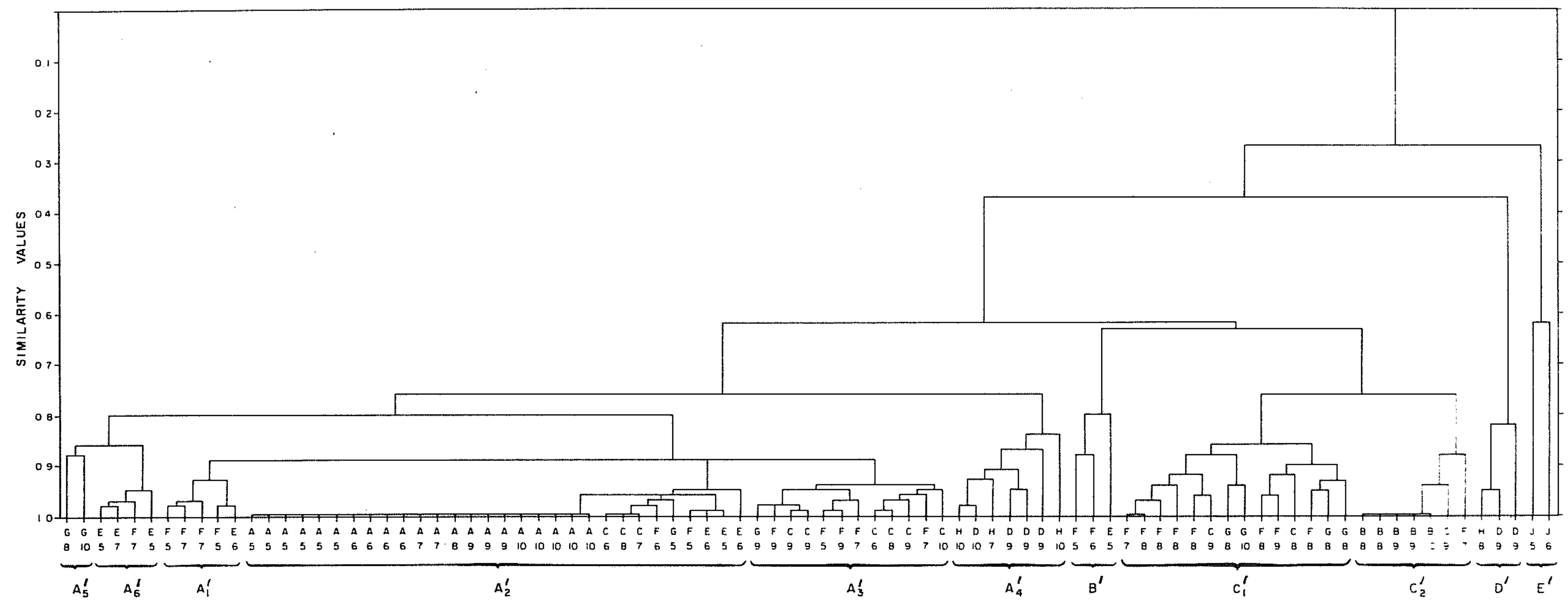


A = *S. alutus*

D = *S. alutus* / *S. reedi*

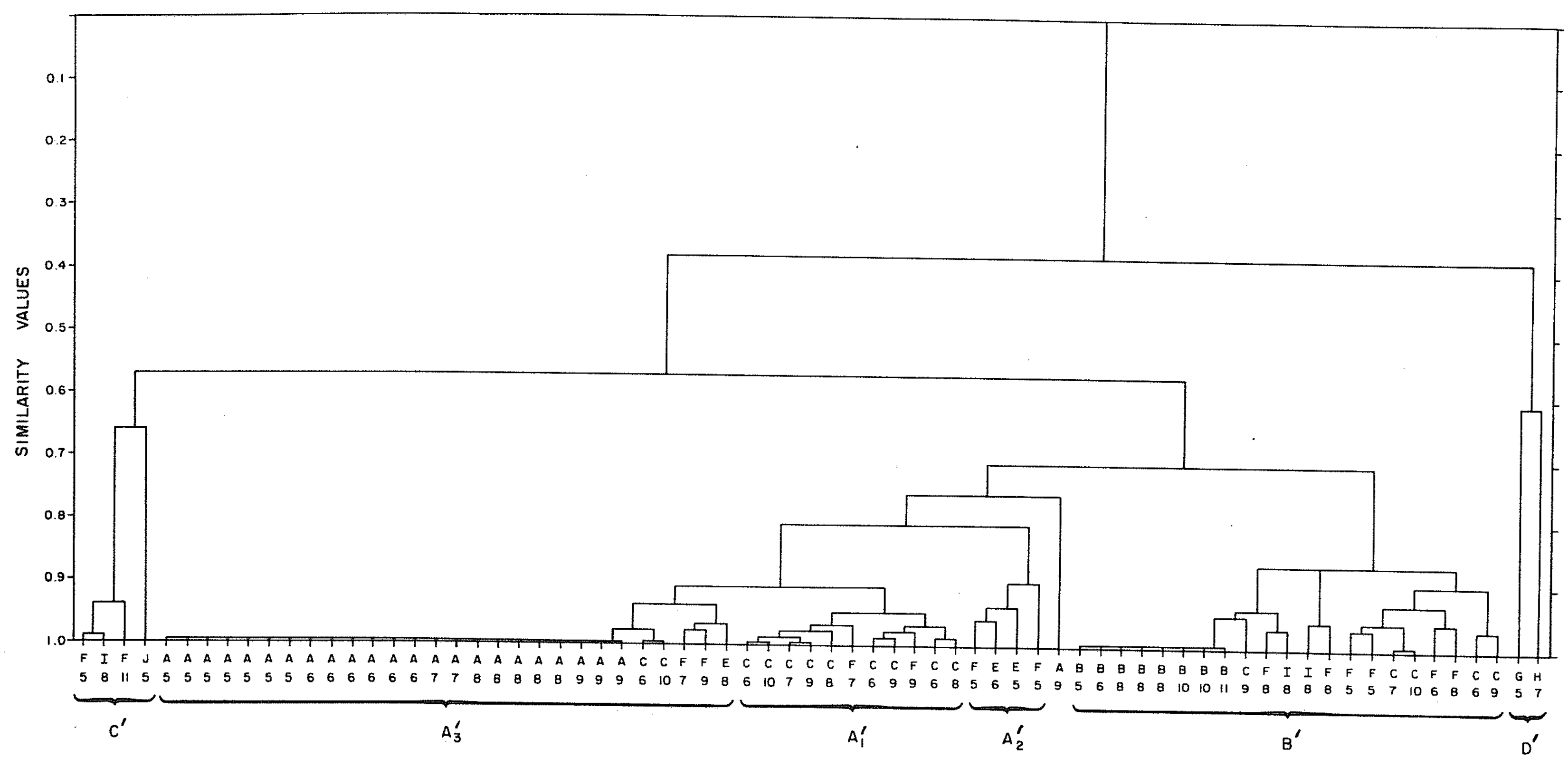
F = *S. alutus* / *S. proriger* / *S. reedi*

Fig. 17. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area III, January-December, 219-291 m. Species composition (A-F) and month caught (1-12) are recorded for each vessel trip.



A = S flavidus
B = S brevispinis
C = S brevispinis / S flavidus
D = S entomelas / S flavidus
E = S flavidus / S pinniger
F = S brevispinis / S flavidus / S pinniger
G = S brevispinis / S entomelas / S flavidus / S pinniger
H = S brevispinis / S entomelas / S flavidus
I = S brevispinis / S pinniger
J = S pinniger

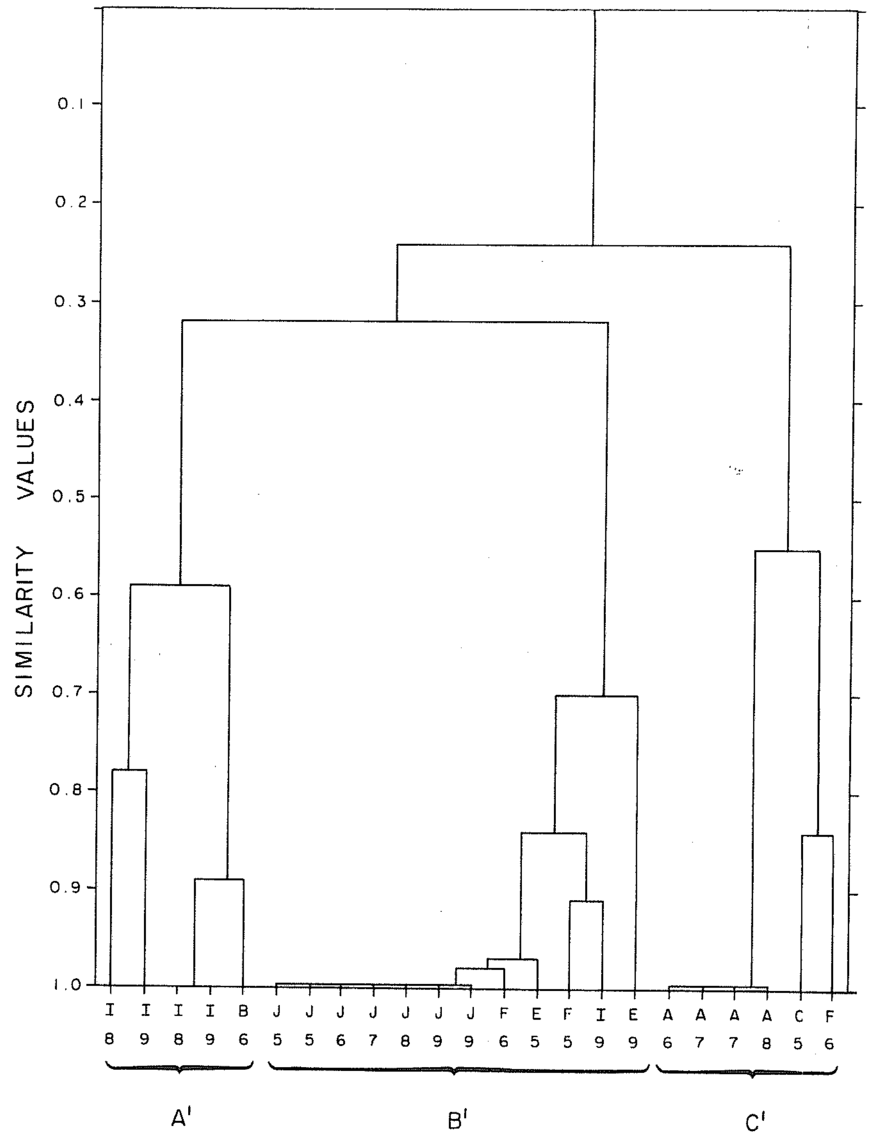
Fig. 18. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area IV, May-October, 72-181 m. Species composition (A-J) and month caught (5-10) are recorded for each vessel trip.



A = S. flavidus
B = S. brevispinis
C = S. brevispinis / S. flavidus
D = S. entomelas / S. flavidus
E = S. flavidus / S. pinniger

F = S. brevispinis / S. flavidus / S. pinniger
G = S. brevispinis / S. entomelas / S. flavidus / S. pinniger
H = S. brevispinis / S. entomelas / S. flavidus
I = S. brevispinis / S. pinniger
J = S. pinniger

Fig. 19. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area V, May–November, 72–181 m. Species composition (A–J) and month caught (5–11) are recorded for each vessel trip.



A = *S. flavidus*

B = *S. brevispinis*

C = *S. brevispinis* / *S. flavidus*

E = *S. flavidus* / *S. pinniger*

F = *S. brevispinis* / *S. flavidus* / *S. pinniger*

I = *S. brevispinis* / *S. pinniger*

J = *S. pinniger*

Fig. 20. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area VI, May-September, 72-181 m. Species composition (A-J) and month caught (5-9) are recorded for each vessel trip.

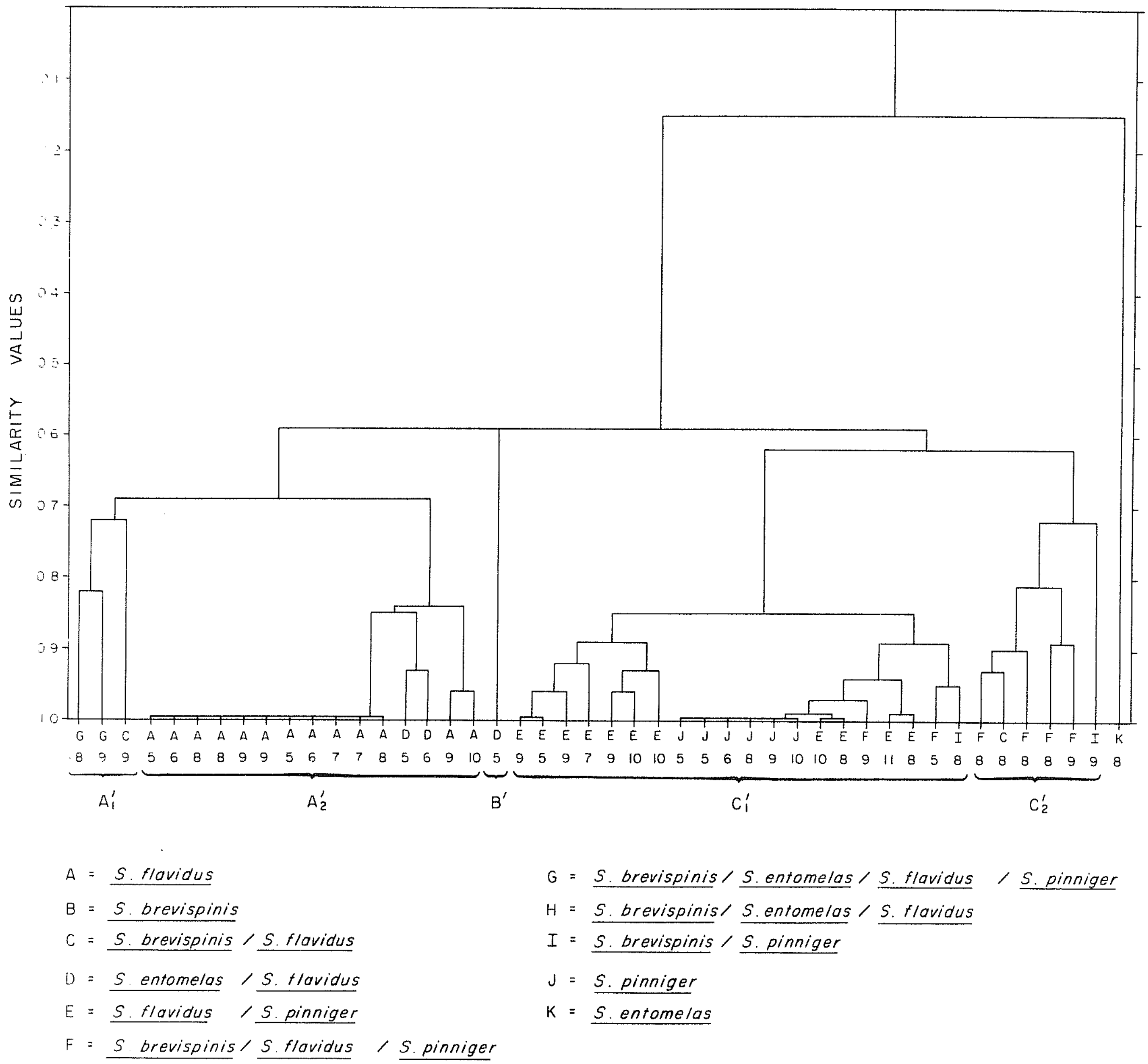


Fig. 21. Cluster analysis of vessel catches based on a relative ratio index (R_{ij}), for Area VII, May-November, 72-181 m. Species composition (A-K) and month caught (5-11) are recorded for each vessel trip.

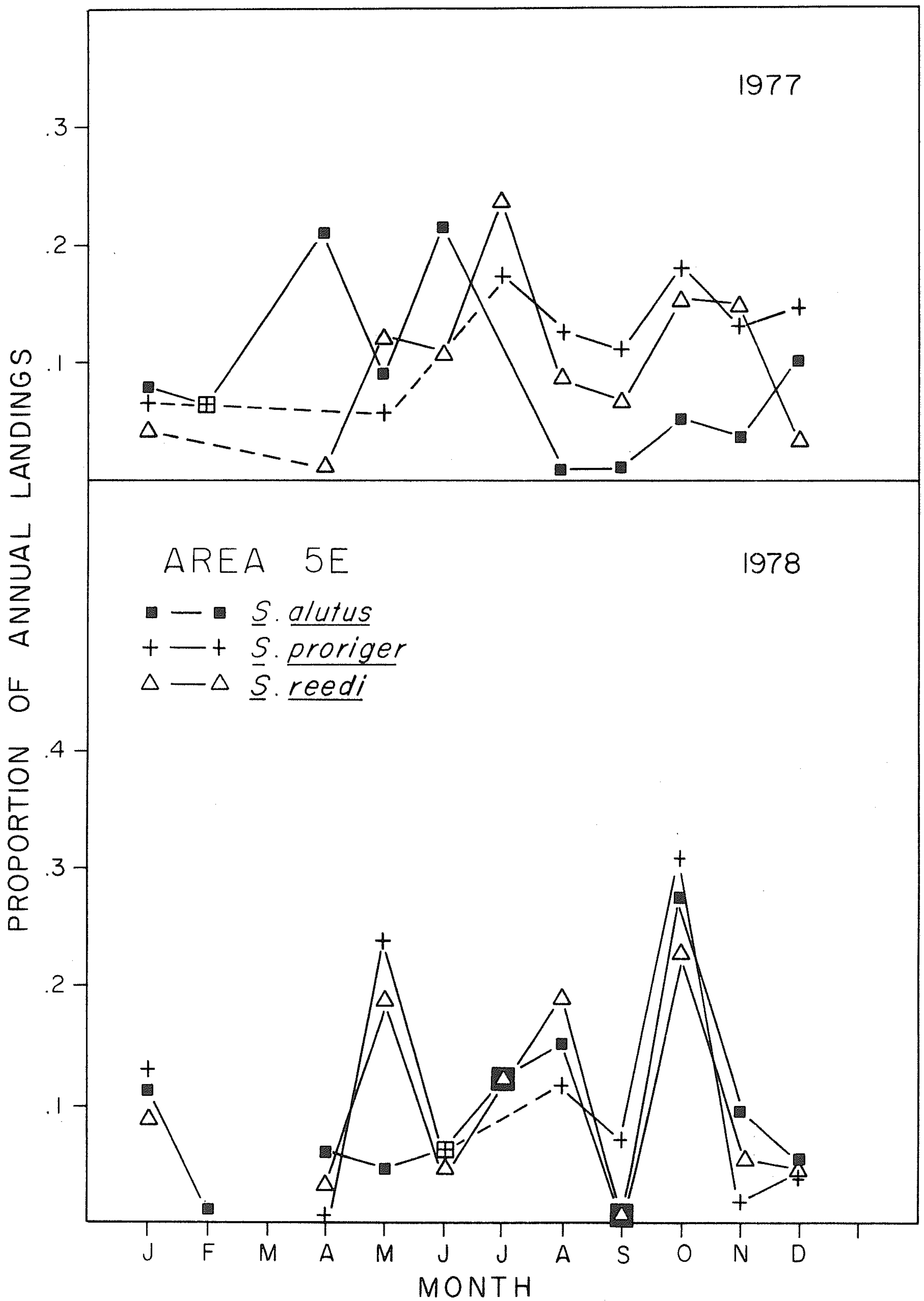


Fig. 22. Monthly proportion of annual landings, 1977-1978, Major Area 5E.

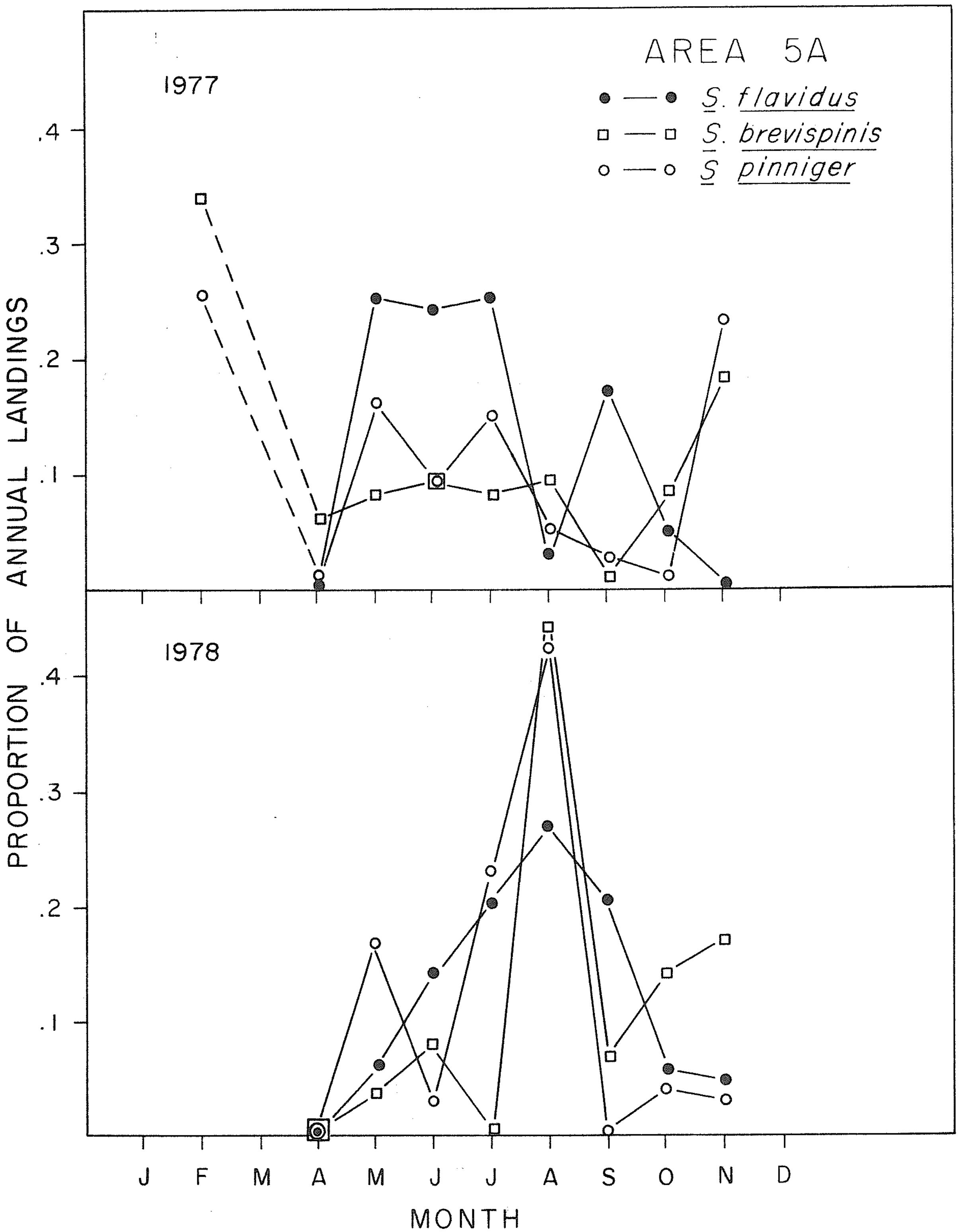


Fig. 23a. Monthly proportion of annual landings, 1977-1978, for Major Area 5A.

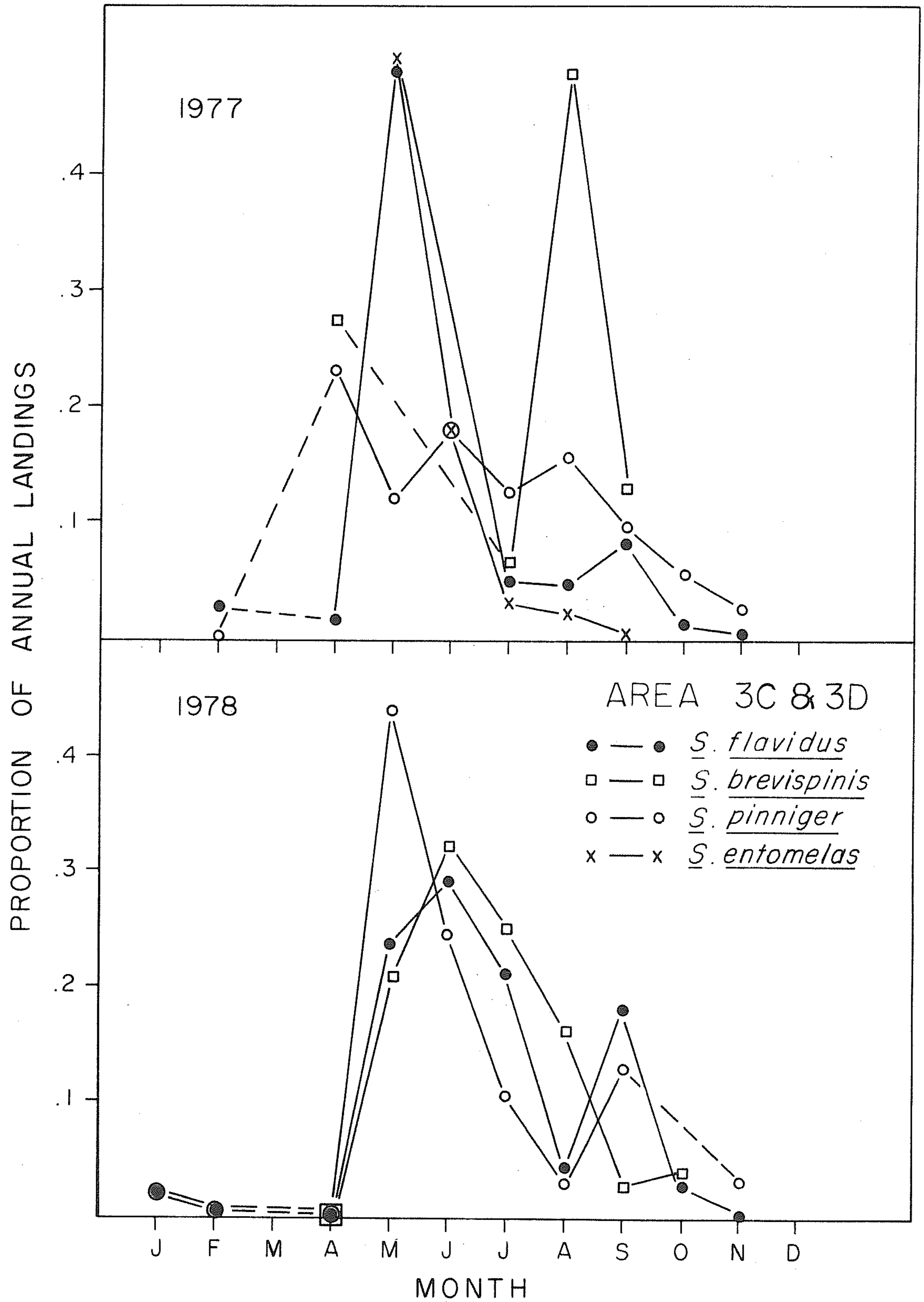


Fig. 24. Monthly proportion of annual landings, 1977-1978, Major Areas 3C and 3D.

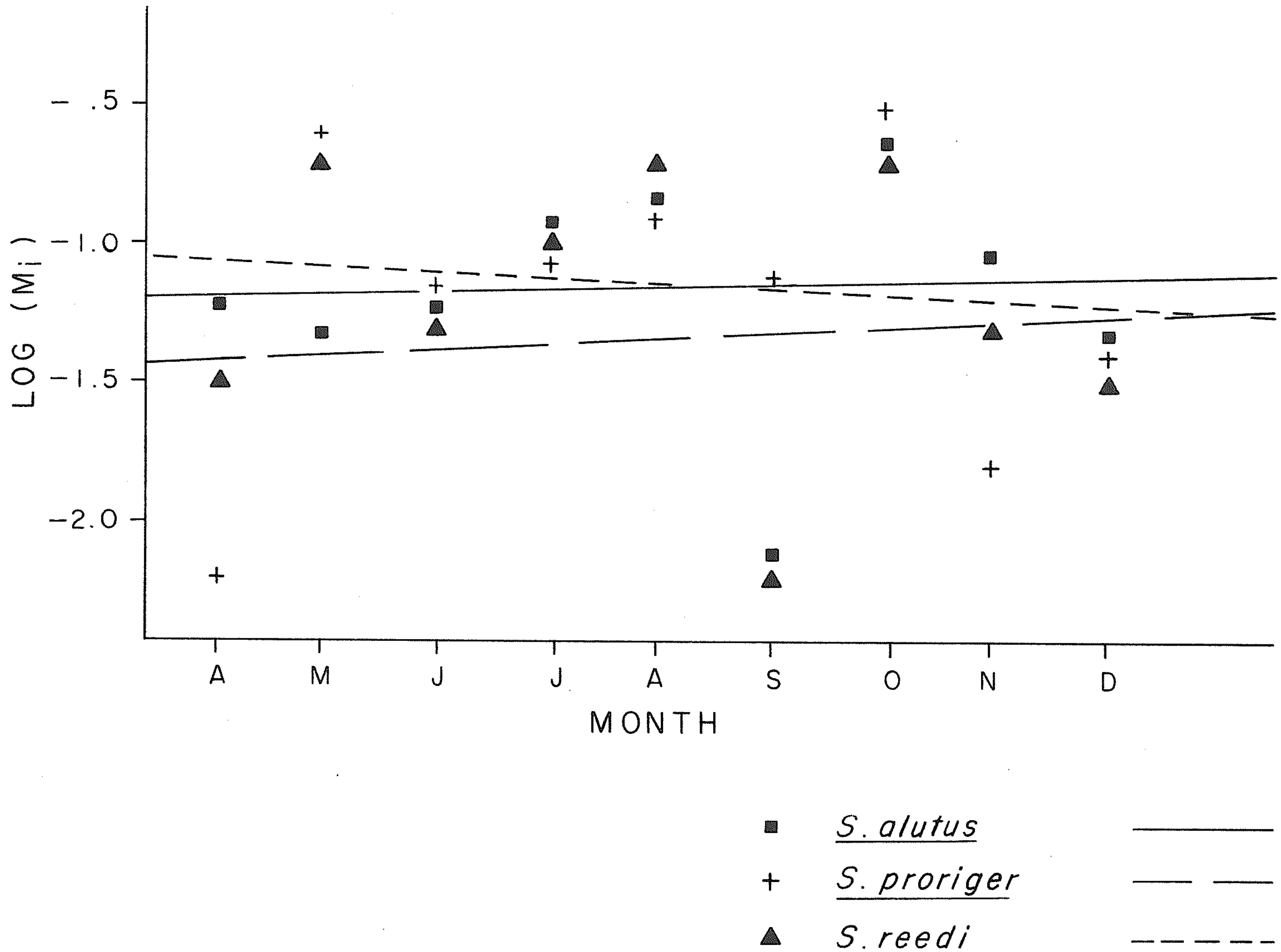


Fig. 25. Analysis of covariance for Study Area I.

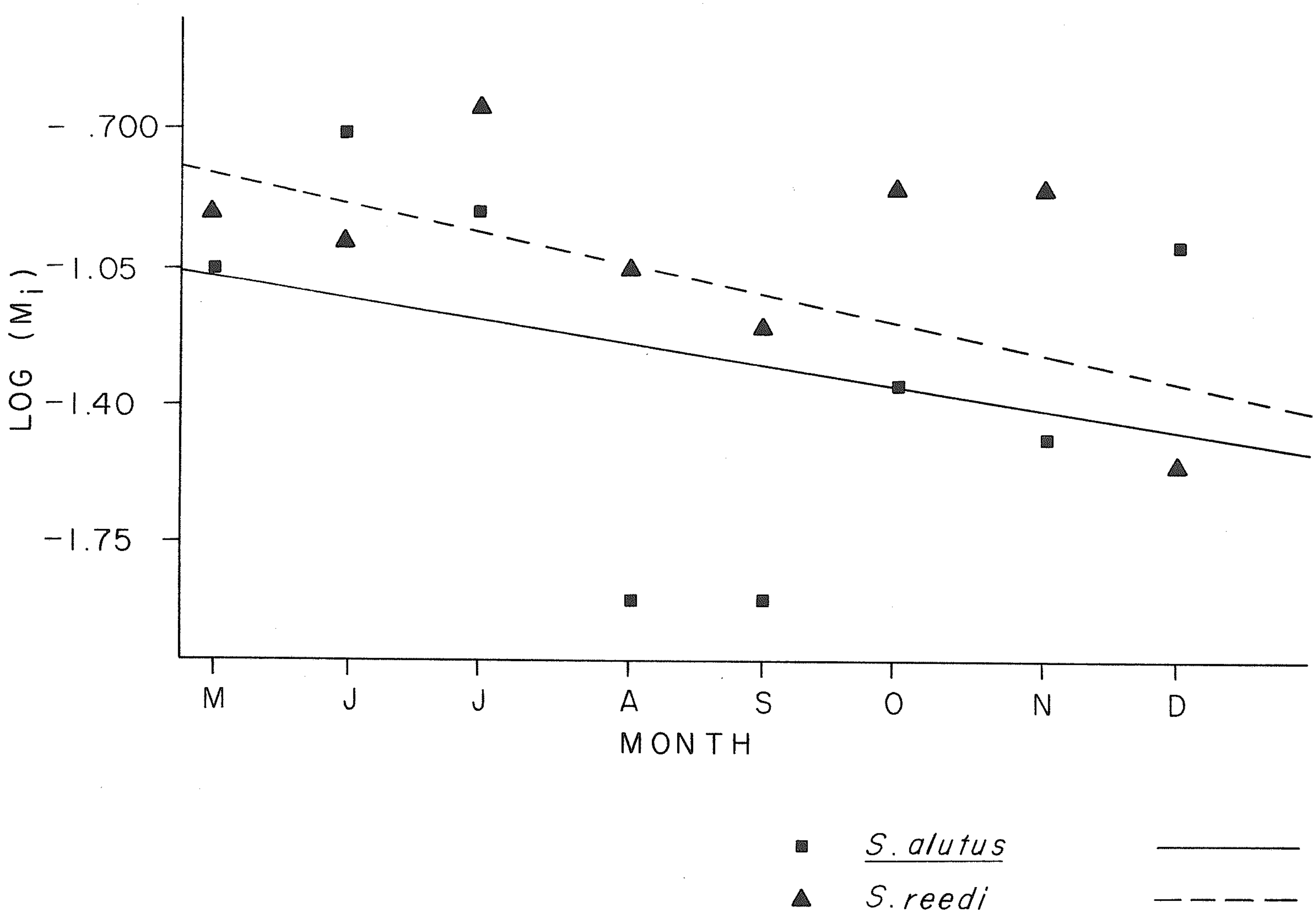


Fig. 26. Analysis of covariance for Study Area III.

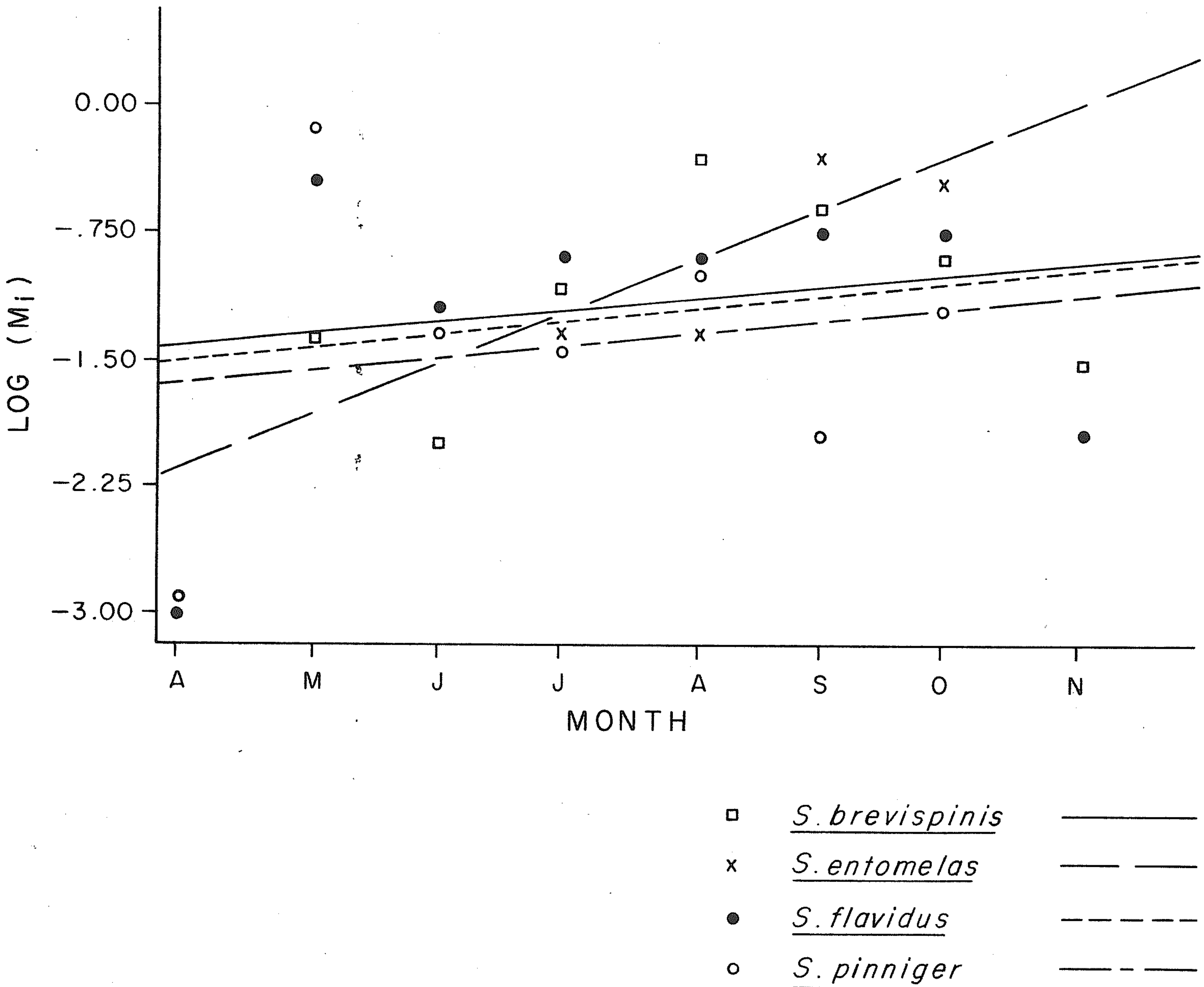


Fig. 27. Analysis of covariance for Study Area IV.

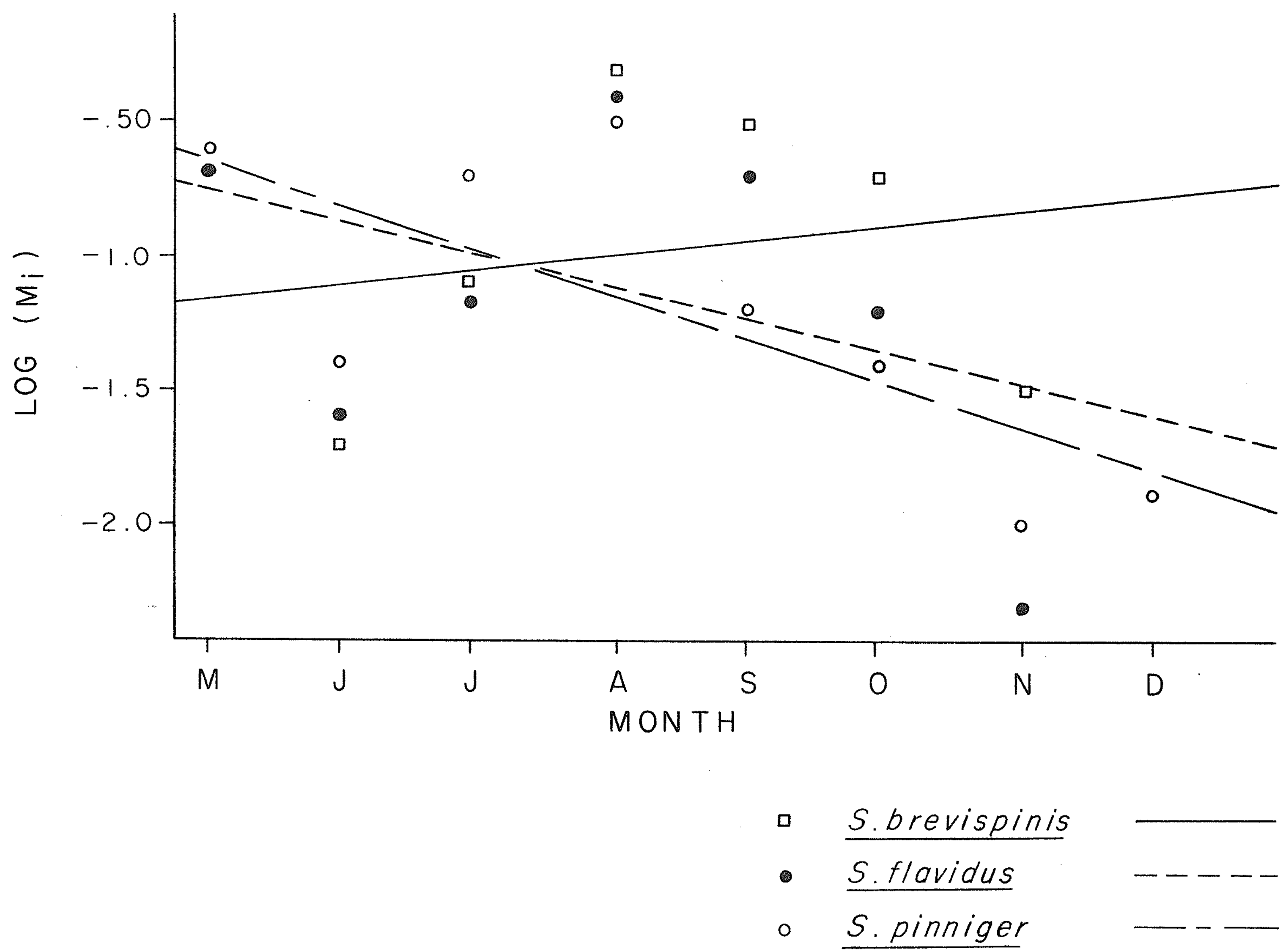


Fig. 28. Analysis of covariance for Study Area V.

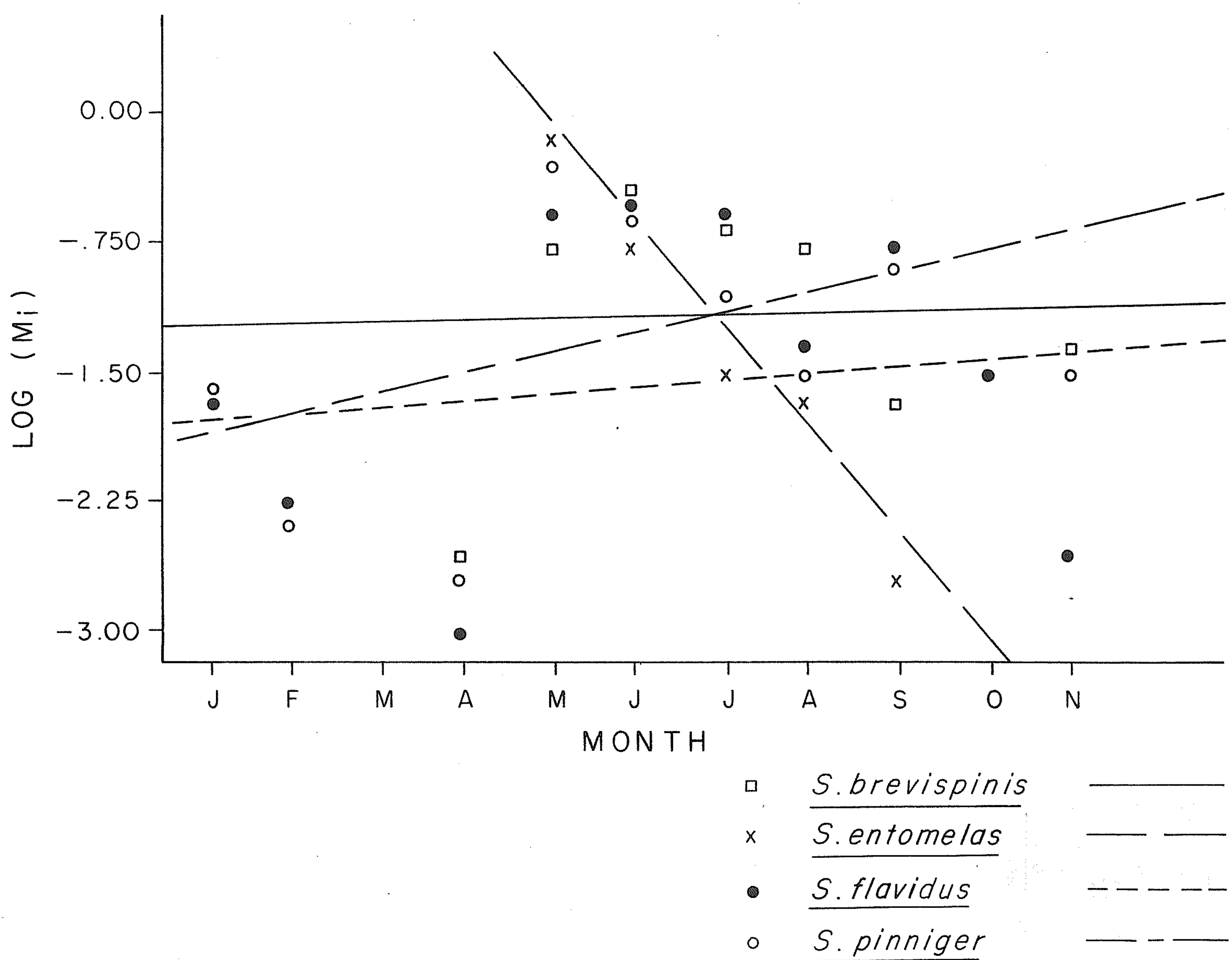


Fig. 29. Analysis of covariance for Study Area VII.

Appendix Table 1. Common names of some rockfishes.

Sebastes alutus	Pacific ocean perch
S. aleutianus	Rougheye rockfish
S. babcocki	Red banded or convict rockfish
S. brevispinis	Silvergray rockfish
S. entomelas	Widow rockfish
S. flavidus	Yellowtail rockfish or greenies
S. paucispinis	Bocaccio or longjaw rockfish
S. pinniger	Canary rockfish
S. proriger	Redstripe rockfish
S. reedi	Yellowmouth rockfish
S. ruberrimus	Yelloweye rockfish or red snapper
S. zacentrus	Sharpchin rockfish