Structure and Dynamics of Northeastern Pacific Demersal Fish Assemblages

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Regions of similar species composition and groups of demersal fish species with similar distribution patterns from Cape Flattery, Washington to Point Hueneme from 50-250 fm (93-460 m) were defined based on results of an agglomerative cluster analysis of National Marine Fisheries Service Rockfish Survey data taken during the summer of 1977. Three major site groups appeared: 1) an upper slope region extended from Juan de Fuca Canyon to Point Hueneme at depths of 100-250 fm (183-467 m); 2) a northern mid-shelf break region extended from Cape Flattery to Cape Blanco at depths of 55-187 fm (100-340 m); 3) a southern mid-shelf break region began inshore at Cape Flattery and extended to the shelf break from Cape Blanco to Point Hueneme at depths of 50-146 fm (91-267 m). These major site groups were subdivided into subregions, often along depth contours. Eight species groups appeared: a deepwater group (in site region 1 and parts of site region 2), including some ubiquitous species; a shallow water group, concentrated in the south (site region 3) and a shallow water group,

concentrated in the north (site region 2) included the most abundant species. Five other groups included rarer species with more localized distributions.

Diversity trends and relationships between composition of species groups and environmental factors were investigated using AIDN analysis of information and diversity and principal component, canonical correlation and factor analyses. Diversity decreased with depth, and was highest at the northern and southern ranges of the sample areas. Local low diversity values within latitudes were usually due to dominance by splitnose rockfish (*Sebastes diploproa*) in the south or Pacific hake (*Merluccius productus*) inshore between 38°N and 46°N. Diversity was relatively low in some assemblage regions between Cape Blanco and Cape Mendocino, an area of strong upwelling and narrow shelf. The effect on species group composition of a 50 fm (92 m) change in depth within a particular degree of latitude appears larger than the effect of a 1° change in latitude in many regions. Multivariate analyses extracted and clarified local patterns of latitudinal change in species groups from cluster analysis, which appeared most strongly related to latitude itself and onshore Ekman transport.

Several hypotheses relating assemblage structure to oceanographic features are presented. Assemblage characteristics may change with depth in response to changing forms of available food and distance from inshore upwelling fronts; and with latitude in response to environmental uncertainty. Replicate surveys and analyses are desirable to measure the repeatability of assemblage structure, and eventually assess the natural range of variability in composition and spatial and temporal extent of species groups. A model is hypothesized to consider the relative influences of environmental variability and density dependence (among and within functional groups) on structure and dynamics of demersal fish assemblages of the California Current.

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STRUCTURE AND DYNAMICS OF NORTHEASTERN PACIFIC DEMERSAL FISH ASSEMBLAGES

INTRODUCTION

The objectives of this study are 1) to define regions of similar species composition along the northeastern Pacific continental shelf and upper slope based on data collected during the 1977 National Marine Fisheries Service rockfish survey cruises, 2) to define groups of species with similar distribution patterns and 3) to relate these results to problems of multispecies management.

From a biological perspective, the goals of single species fishery management have traditionally been to maintain a population at a level that produces maximum fishery yields or to rebuild the abundance of a depleted stock. In practice, single species management recommendations have been based on cohort analysis, Beverton-Holt or Ricker yield per recruit models. In the past thirty years, however, Pacific coastal trawl fisheries have diversified to catch a mix of species including rockfishes (genus *Sebastes*), sablefish (*Anoplopoma fimbria*), Pacific hake (*Merluccius productus*) and flatfishes (family Pleuronectidae, family Bothidae). Traditional single species biological management perspectives become inadequate when fishermen target on a multispecies mix, by-catch of non-target species becomes significant, species interact through predation and competition to affect fishery productivity, or extensive data requirements for single species management cannot be met (Anon., 1978). In a multispecies fishery, some proposed management goals would include maintenance of the existing species composition of the fishery, maximizing the total yield from a mix of species or minimizing the variability in yield (Tyler et al, in press; Paloheimo and Regier, in press). In practice, multispecies management recommendations may be based on detailed ecosystem models (e.g., Laevastu, et al. in press; Andersen and Ursin, 1977), holistic measurements of total yield (e.g., Ryder et al. 1974) or adaptive management (Tyler et al. in press). Multispecies fisheries require new perspectives in fishery research and management.

Although assemblage analysis has been proposed in several symposia as an important step in investigating multispecies fisheries systems (Hobson and Lenarz, 1977; Anon., 1978; Mercer, in press), few analyses of Pacific demersal species associations have been undertaken. Investigations of species associations off Oregon have usually emphasized smaller non-commercial species (Day and Pearcy, 1968; Pearcy, 1976) or limited geographic regions (Tyler and Stephenson, in prep.). Species associations off Washington and California have not been extensively described. Although spatial boundaries and species compositions of assemblages may fluctuate through time, this study may provide an initial estimation to serve as a basis for comparisons and more refined definitions in the future.

METHODS AND MATERIALS

Species abundance data were collected as part of a National Marine Fisheries Service rockfish survey from Point Hueneme, California (34° 00' N) to Cape Flattery, Washington (48° 26' N) during July 4 to September 27, 1977. Sampling locations were based on a stratified random grid scheme (Gunderson and Sample, 1980). Thirteen "geographical strata" were delineated from Cape Flattery to Point Hueneme. High density sampling (tracklines perpendicular to depth contours every five nautical miles) was undertaken in regions of known high rockfish densities; otherwise, stations were sampled in each of four depth strata: 50-99 fm, 100-149 fm, 150-199 fm, and 200-260 fm (91-181 m, 182-273 m, 274-364 m and 365-476 m). Where linear distance along the trackline within a stratum was less than 5 n. mi., one station was made; 5-9 n. mi., two stations were made; 10-14 n. mi., three stations were made, etc. Precise location of each station within each depth stratum was chosen at random along the trackline, but no two stations were to be closer than 2 n. mi. when more than one station was made per stratum.

Samples were taken by a Nor'Eastern otter trawl with roller gear and a cod end lined with 1-1/4" mesh net. Tows were made at about 3 knots for one half hour. Catch was identified to species, sorted, and weighed; and a subsample counted. A total of 664 successful hauls were made between Cape Flattery and Point Hueneme.

Statistical analyses were based on biomass data rather than numerical abundances, because fishery managers are generally concerned with yield in terms of biomass rather than numbers, and because some numerical abundances based on extrapolations from catch subsamples were not included in the data set. Because species lists in the analyses were usually extensive (between 60-85 species) and included smaller species, log transformations were applied before cluster analyses to make small, low-biomass species more visible in the analysis.

Site clumping

Haul data were initially regrouped into site clumps composed of hauls at three adjacent sites within a prescribed depth range. Pooling data into clumps reduces the number of required calculations by about 50% and reduces skewness of species frequency distributions (Tyler and Stephenson, in prep.) by up to 50% in some cases. Reduction of skewness is helpful for the calculation of meaningful similarity indices during assemblage analyses such as clustering. Without a central tendency of species distributions, similarity comparisons become more difficult to interpret. There are two disadvantages in pooling data into clumps: 1) Assemblage boundaries across depth contours may be obscured while boundaries along depth contours may be reinforced. 2) Similarity with adjacent overlapping clumps is artificially increased, and observations are no longer independent of each other. Six depth ranges were defined: 50-75 fm, 75-100 fm, 100-125 fm, 125-150 fm, 150-200 fm and 200-25 fm (91-137 m, 137-183 m, 183-229 m, 229-275 m, 275-366 m, and 366-458 m). Site clumps overlapped within each depth range. The third site added to a clump was also the first site for the following clump.

Thus, some hauls appeared in two clumps, while others appeared in only one, and sample independence may be decreased. A cluster analysis based on overlapping site clumps showed nearly the same site and species groups as one based on non-overlapping site clumps in the Gulf of Alaska, however. Where a third haul within the depth range was more than 1/2° latitude away, the clump was either completed by the nearest haul whose depth was less than 20 fm (37 m) from the first two or based on only two sites.

Cluster analysis

Cluster analysis is a classification technique designed to place observations with common attributes into discrete groups. In the first analysis, a series of site groups with similar species compositions was produced. In the second analysis, a series of species groups with similar spatial distribution patterns was produced. An agglomerative clustering procedure was used. A Bray-Curtis dissimilarity coefficient was calculated for each pair of observations. (In the first analysis, an observation consisted of the vector of species abundances at a site clump.)

$$D_{jk} = \frac{\sum_{n=1}^{i} |X_{nj} - X_{nk}|}{\sum_{n=1}^{i} (X_{nj} + X_{nk})} \qquad \text{(Boesch, 1977)}$$

where D_{jk} = dissimilarity between sites j and k

i = number of species

X_{nj} = biomass of n^{th} species at site j

X_{nk} = biomass of n^{th} species at site k

The index takes on values from zero to one. A zero value indicates identical species composition between two sites. Because the denominator is based on the sum of all species abundances (biomass) at both sites, the index is influenced by dominant species. That is, an outstanding species abundance or difference can influence the index value much more easily than a relatively rarely caught species. This influence can be applied in a fisheries context because fishermen and fishery managers are most often concerned about abundant species. Observations were then clustered by a group average fusion strategy (Boesch, 1977; Clifford and Stephenson, 1975). In this process, each pair of observations with most similar species compositions (as reflected by the dissimilarity index) was fused into a group. Another site could be added to a group if the average dissimilarity between all pairs of observations in the new expanded group was lower than averages of any other possible site-group (or group-group) combinations. Groups could be fused with other groups as long as the average dissimilarity between all pairs of constituent sites in the new larger group was lower than any other possible site-group or group-group combinations. Since the Bray-Curtis index is sensitive to abundant species, biomass data for each site clump first was proportionalized (p_i) and log $_{10}$ (p_i+1) transformed. The eighty-five most abundant fish species that contributed at least 10 lbs each to the total biomass in the survey area were included. A dendrogram was produced for each analysis showing at what dissimilarity level sites and groups were fused. Site groups were mapped as drawing boundaries drawn around sites that belonged to clumps found in a dendrogram site cluster. A site group boundary was considered justifiable if sites within the cluster group were contiguous on a map. Site group boundaries were made to follow depth contours between component sites. If a single site was placed in two site cluster groups (when two overlapping site clumps were assigned to different dendrogram site clusters), the boundary was placed close to or through the site, or was only extended in the direction of the site if the site was relatively isolated.

Cluster analysis has several advantages as an exploratory and descriptive technique over other classification methods. The groups formed are hierarchical. For example, large groups of sites with relatively heterogeneous species composition can be decomposed into constituent small groups of sites, each with relatively homogeneous species composition. Thus, several levels of resolution are included at once in the analysis. These levels can be supported by the contiguous mapping criterion mentioned above. Sites grouped statistically were usually geographically contiguous within each hierarchical level.

Results can be easily displayed, inspected and interpreted in a dendrogram. Flexibility in interpretation is possible. No single dissimilarity level may be appropriate for determining formation of every group. If species composition in one region is characteristically more variable from site to site than elsewhere due to a more heterogeneous habitat for example, site groups in that region may form at a higher dissimilarity level in the dendrogram. There is no requirement of multivariate normally distributed data, although skewness will influence the Bray-Curtis index as mentioned above. The analysis produces distinct group boundaries because each observation (site clump or species) can belong to only one group.

There are several disadvantages to agglomerative clustering techniques. Computerized agglomerative clustering is more expensive and time consuming than divisive clustering, especially if the goal is to form a few large groups. The technique is sensitive to sampling intensity: a local area that is sampled intensively will usually form a cluster group. Areas of less intensive sampling will have shorter species lists and may form a different site cluster group. Consequently, a boundary between the two areas may be created even though the species composition was same over both areas. Finally, any environmental factors that may have been the basis for a survey design (e.g. a stratified grid based on depth and latitude strata) are disregarded.

Principal Component Analysis

Principal component analysis (PCA) was undertaken to complement the cluster analysis. PCA has as its objectives: (1) to determine patterns and degree of interrelationships between species and (2) to partition all the variance in species composition among linear combinations of species (species groups). For example, all of the variation in species composition of a series of sites may be explained in terms of, say, the eighty species present. However, if five of the species co-occur in the same ratio over all the sites, we could define a single new variable that is a linear combination of those five species, and explain the same amount of variance with this new variable as we had previously explained with five. We would then have the opportunity of eliminating four of the species from the analysis, because they would have redundant distribution patterns, or we could investigate a common pattern of response by the five species to environmental factors (e.g. increasing depth). In PCA, the overall pattern of individual species variances and co-variances is re-constructed in terms of linear combinations of species, while in cluster analysis (yielding species groups) the overall pattern is eliminated as species and species groups are sequentially fused. As an ordination technique, PCA is more sensitive to species groups which are distributed along a gradient, while cluster analysis is more sensitive to species groups with discrete distributions. In PCA, a species may potentially belong to several species groups (as a linear combination); while in cluster analysis, a species' membership is restricted to only one cluster. Thus, in PCA, each species group accounts for a proportion of the overall variance, and each species group generated contributes sequentially less to the overall variance. In cluster analysis, however, there is no way of assessing how much variance is accounted for by each species group.

Principal component analysis was undertaken with the Oregon State University Statistical Interactive Programming system (SIPS) package. Catch data from three adjacent sample sites were grouped into site clumps as described earlier. For this analysis, however, site clumps were independent, i.e. non-overlapping. Weight data within each observation (site clump) were proportionalized. Sixty species (the maximum allowed by SIPS) were entered as variables. Variances and covariances in species abundances were then calculated based on the proportionalized data. The proportionalized data were then standardized by species, and variance and covariances in standardized species abundances were then calculated. When variances and covariances are calculated from standardized data, the results are identical to correlations calculated from unstandardized data. Thus, two analyses were performed, one on unstandardized data (the variance-covariance matrix) and one on standardized data (the correlation matrix). The variance-covariance matrix reflects the relative magnitudes of abundance (proportions) of two species compared while the correlation matrix may allow a more equitable comparison of distributions of large-bodied (high biomass/individual) vs. small-bodied species.

At the outset of the analysis, each observation can be represented as a point in a sixty dimensional species space. In the process of PCA, the sixty axes will be rearranged so that each new axis will incur the maximum amount of spread among points (variance) (subject to constraints of axis orthogonality). Each new axis can be expressed as coordinates of the old single species axes, and the squared distances from points to each new axis is minimized. The process is imperfectly analogous to fitting a straight line through a swarm of points between x and y axes: the x and y axes represent abundances of species x and y respectively, the fitted line represents the new axis which is a linear combination of x and y, and the fitted new axis minimizes the residual squared distances from each point to the new axis. A second axis, orthogonal to the first, could be added in the direction of next largest variance in points. As a result, we can still reconstruct the original arrangement of points using these two new axes. However, the first new axis may minimize the squared distances from points to axis better than either of the original x or y axes. In that case, we may wish to consider the new axis as a linear combination of species or a species group that does a more efficient job of expressing the relationships between points (observations) than two single axes. Each new axis is called a principal component. The variances associated with each of the new axes (analogous to squared distances from points to axis) are mathematically equal to the eigenvalues or latent roots of the original variance-covariance matrix. The principal components are mathematically equal to the associated eigenvectors: An eigenvector of the variance-covariance matrix expresses the new axis and an affiliated eigenvalue expresses the variance associated with the new axis.

All the variance in the distribution of points can be explained with the original sixty axes, or the new rearranged sixty axes. However, it may take relatively few of the new axes (say, ten) to explain a relatively large proportion of the total variance (say, 90%). The other fifty new axes would explain the remaining ten percent. Most of the relationships between points have thus been captured with only ten axes, where sixty were required before. The proportion of total variance associated with each new axis can be calculated for the j^{th} axis or principal component as:

$$\frac{\lambda_j}{\sum_{i=1}^{S} \lambda_i}$$ for the analysis performed on the variance-covariance matrix (unstandardized data)

or,

$$\frac{\lambda_j}{S}$$ for the analysis performed on the correlation matrix (standardized data)

where λ_j = the eigenvalue associated with the j^{th} principal component

S = the number of species

The denominators represent the traces of the respective matrices. When a proportion fell below 1/S, the new axis explained less variance than one of the original S axes, and therefore was not valuable in simplifying relationships. The importance of each species in defining each new axis was assessed by correlating each species with each principal component.

Like cluster analysis, principal component analysis cannot directly associate environmental factors with species abundance patterns. The investigator must be aware of the important environment gradients along which species combinations orient themselves. However, some species combinations may respond to unidentified factors which may reflect: a) the effects of unobserved environmental influences, b) a non-linear species response to a linear environmental gradient, c) outlying species combinations, or d) spatial distortion that is an artifact of the analysis (Gauch et al., 1977). Additional short-comings of ordination techniques are described by Beals (1973).

As an alternative, multivariate multiple regression and analysis of variance techniques would elucidate environmental factors which influence species abundances, but do not define the species groups (if any) that respond as a unit to an environmental factor.

A series of descriptive statistics were generated for sites within boundaries of each cluster analysis group, including frequency of occurrence of species at sites in the region, proportion contributed by species to total biomass caught in a region, mean catch per tow and standard deviation by species, maximum and minimum non-zero catch of species in a region, and average catch per haul of all species in the area and diversity indices. Data values were adjusted to represent catch per 1.5 mi fished. No adjustments in any analyses were made for different catchabilities.

Three diversity indices were calculated.

$$\text{Simpson's index of diversity} = 1 - \sum_{i=1}^{S} p_i^2$$

where S = number of species

P_i = proportion of sample comprised of i^{th} species

The index ranges from a minimum of 0 (the entire sample consists of only one species) to 1-1/S (the entire sample is composed of equal abundances of each of the S species and diversity goes to 1 as S becomes very large). The index represents the probability that two individuals drawn at random from the sample would belong to different species. Because it is based on proportionalized data, the index is not responsive to density (absolute abundance). As more species are added, diversity increases. As species dominance increases, diversity decreases.

McIntosh's index of diversity $= N - \left(\sum_{i=1}^{S} n_i^2 \right)^{\frac{1}{2}}$

where S = number of species

n_i = number or weight of species i in sample

$N = \sum_{i=1}^{S} n_i$

The index ranges from a minimum of 0 (the entire sample consists of only one species) to a maximum of N - (N/ S) for a given number of species. Diversity increases as density (N) and species number increase, and diversity decreases as dominance increases.

Shannon-Weaver index of diversity = $\sum_{i=1}^{S} p_i \ln p_i$

where S = number of species

P_i = proportion of sample comprised of i^{th} species

The index ranges from a minimum of 0 (the entire sample consists of only 1 species) or $-(S-1) \left(\frac{1}{N} \log \frac{1}{N}\right) + \frac{N-S+1}{N} \log \frac{N-S+1}{N}$ for a given N and S to a maximum of log S for a given S. Diversity increases as species number increases and dominance decreases. The index is not directly sensitive to density, because it is based on proportionalized data.

Analyses of variance and diversity

The Analysis of Information and Diversity over N sites (AIDN) program was used 1) to investigate the importance of latitude, and depth within latitude on species composition in shelf subregions, 2) to describe the relative significance of shelf subregion divisions, latitude within region and depth within latitude in explaining species composition over the survey region, and 3) to describe trends in diversity over depth and latitude. Carney (1977) describes the similarity and diversity indices and the factorial multivariate analysis of variance calculated by AIDN, which was developed by Dr. W. S. Overton of the Oregon State University Statistics Department.

The shelf subregion divisions were based on results of cluster analysis. Seventeen data subsets were defined from combinations of site cluster groups. Data were input by haul as raw weights per 1.5 n. mi. fished. Eighty-two fish species were included over the entire shelf region.

Each haul was assigned to a level of latitude and a level of depth. Fifteen latitude levels, one for each degree of latitude in the survey region, were defined. Five depth levels, one for each fifty fathoms of depth in the survey region were also defined (40-99 fm: level 1, 100-149 fm: level 2,..., over 250 fm: level 5).

To investigate the importance of latitude and depth within latitude on species composition in shelf subregions, AIDN analysis of variance was performed for each of the seventeen subregions, with latitude and depth as factors. Because the same depth strata reocurred over different latitudes, the depth and depth-latitude interaction terms were combined as a depth within latitude effect in a hierarchical nested factorial analysis.

Since the principal objective of the analysis was to assess the relative importance of two environmental factors associated with species composition, the mean square terms and F ratios served as descriptive statistics rather than a means for statistical hypothesis testing. Either the mean square terms or the F ratios may be used to compare relative contributions of latitudinal effects versus depth effects on species abundances. (In the case of the F ratio, the appropriate number of degrees of freedom for statistical testing in the case of multivariate proportionalized response surfaces is presently being developed, but for a conservative test is probably less than (S-1) /3 times the degrees of freedom in the univariate factorial analysis displayed as results, where S is the number of species included in each analysis [Overton, pers. comm.])

The relationship between subregions based on cluster groups and sites within subregions is reflected by values of the similarity index SIMI, computed for each pair of subregions. The index varies between 0 and 1, analogous to a correlation coefficient:

$$\text{SIMI} = \frac{\sum_{j=1}^{S} p_{mj}\, p_{nj}}{\sqrt{\sum_{j=1}^{S} p_{mj}}\ \sqrt{\sum_{j=1}^{S} p_{nj}}}$$

where S = number of species

p_{nj} = proportion of observation n composed of species j

p_{mj} = proportion of observation m composed of species j.

Canonical Correlation

Canonical correlation and factor analysis were used to investigate potential relationships between species composition and local oceanographic effects. The objective of canonical correlation analysis is to find separate but common patterns in species compositions and environmental attributes. In canonical correlation, a linear combination of species composition (similar to PCA) and a linear combination of environmental factors are found, whose canonical variates (the linear combinations evaluated at each location) have the highest correlation possible. This allows a combination of species to be associated with a combination of environmental factors. For example, a group of northern, deep-dwelling species may be related through a linear combination of species, because they would occur together at sites; and depth and latitude in a separate matrix of site environmental attributes would be related through a linear combination, because sites containing those species in this case would have similar environmental conditions. Sites containing that species combination would receive highest scores and deep sites at high latitudes would also receive highest scores. The combinations of species and environmental factors would be adjusted so that the correlation between scores (canonical variates) was a maximum. In geometric terms, any site in a data set with m species and n environmental factors can be represented as a point in m-dimensional species space or n-dimensional environmental space. If certain species combinations are closely affiliated with particular environmental combinations, sites will be approximately the same positions in both spaces relative to new axes (linear combinations) in each space (if standardized). As a result, particular combinations of species compositions can be related to particular combinations of environmental factors, rather than to a single factor at a time. Just as PCA may suggest co-occurring species that may potentially interact, canonical correlation may suggest co-occurring species and co-occurring environmental factors that may potentially interact.

Canonical correlation analysis was undertaken with a Statistical Package for Social Sciences (SPSS) program CANCORR (Nie, et al., 1975). Eighty-one species were entered as one variable set and seventeen environmental factors (described with results) were entered as the second variable set. Data were input without proportionalization, transformation or site clumping.

Factor Analysis

The objective of factor analysis is to generate a combination of common factor variates which reproduce the variance-covariance pattern in a set of observations including both species composition and environmental attributes. Each individual observation can then be expressed as a linear combination of common-factor variates, plus a specific-factor variate (analogous to an error term). The relative importance of each common-factor variate in the generation of an observation is reflected by the size of the coefficient (called a loading) for that factor. The variance of attribute i (e.g., species i) can be found as the sum of squared loadings on the i^{th} term of each common factor, plus the variance of the specific-factor variate for the attribute over all observations. The covariance of attributes i and j can be found as the sum of products of loadings on the i^{th} and j^{th} terms of each common factor, over all common factors. Thus, the variance-covariance structure of a data set is broken into two components: the portion that can be explained by the common factors _via_ loadings and the portion that is specific for each observation. The major emphasis of the analysis is generation of factor loading values.

Environmental attributes and species composition may be associated through the generation of common factors. The common factors represent new linear combinations of potentially interrelated species compositions and environmental characteristics. Thus, factor analysis may be useful in developing a few hypothetical underlying common environmental-species combinations in terms of which all observations can be defined.

Factor analysis was undertaken with SPSS program FACTOR (Nie _et al._ 1975). Seventeen environmental characteristics and eighty one species were entered as variables. No proportionalization, transformations or site clumping was performed. Varimax and oblique rotations were undertaken after initial analyses to clarify factor interpretation.

RESULTS

Cape Flattery to Point Hueneme

Cluster Analysis

Three major site groups appeared in a cluster analysis at a dissimilarity level of 0.59 (Fig. 1). Sites in group 1 were located in a continuous strip along the deepest regions surveyed: sites extended from Juan de Fuca Canyon to Point Hueneme and ranged from 100 to 225 fm (183-467 m), with an average depth of 188 fm (344 m) (Fig. 2, 3, 4). Sites in group 2 were north of Cape Blanco and inshore of group 1 (mean depth of 97 fm or 177 m). Site group 3 first appeared near Cape Falcon inshore of groups 1 and 2 and extended south past Cape Blanco to Point Hueneme.

Each major site cluster could be subdivided into three subregions, although the dissimilarity level for subdivision was not the same for each major region. Sites found in the third subregion (1c, 2c, 3c) in each large cluster group were not always closely linked to each other, but were more similar to members of that major group than any other first order group. Subregions which contained cohesive clusters of adjacent sites were also divided into local areas, e.g., 2ai, 2aii, 2aiii of subregion 2a. These local clusters were usually formed at dissimilarity levels between .35 and .45, depending on the dissimilarity level of the subregion. A series of linear discriminant functions (Dixon and Brown, eds. 1979) developed to discriminate between the

Fig. 1. Schematic dendogram of site clusters, Cape Flattery to Point Hueneme

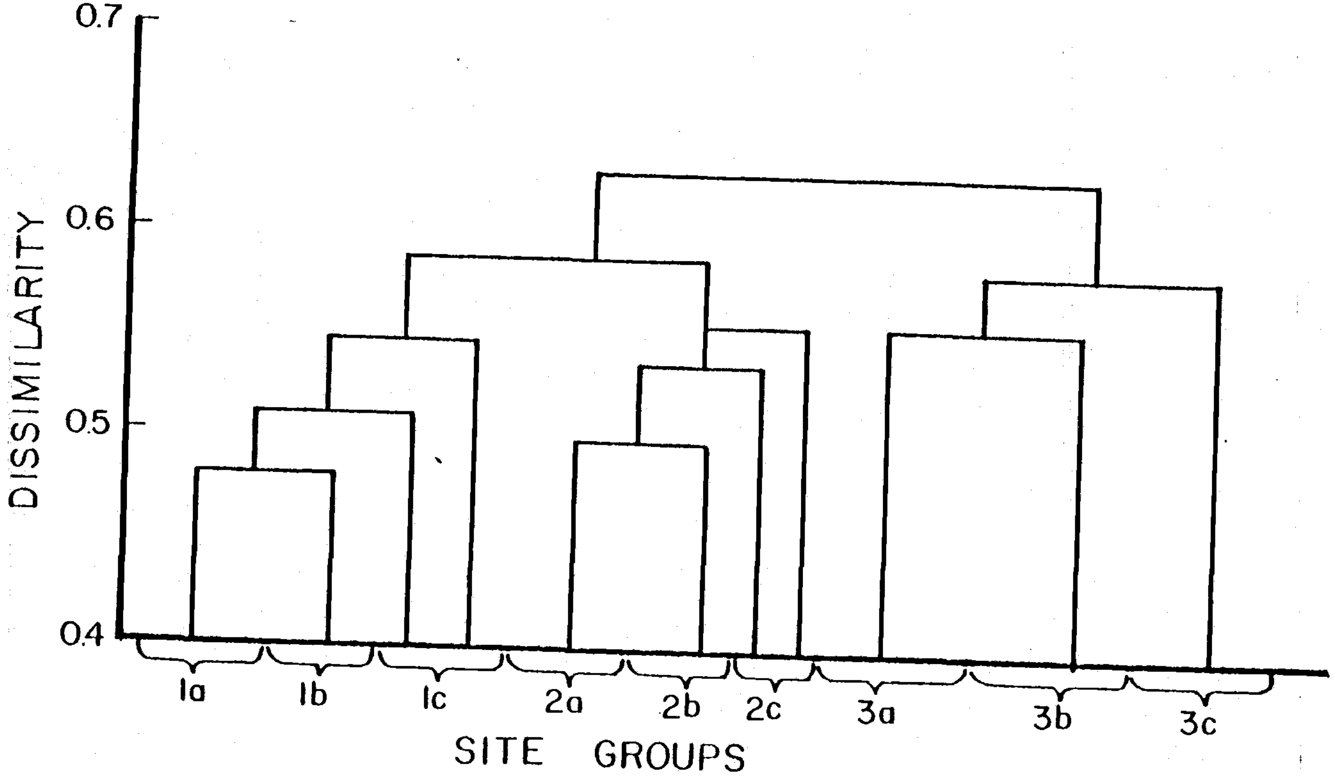
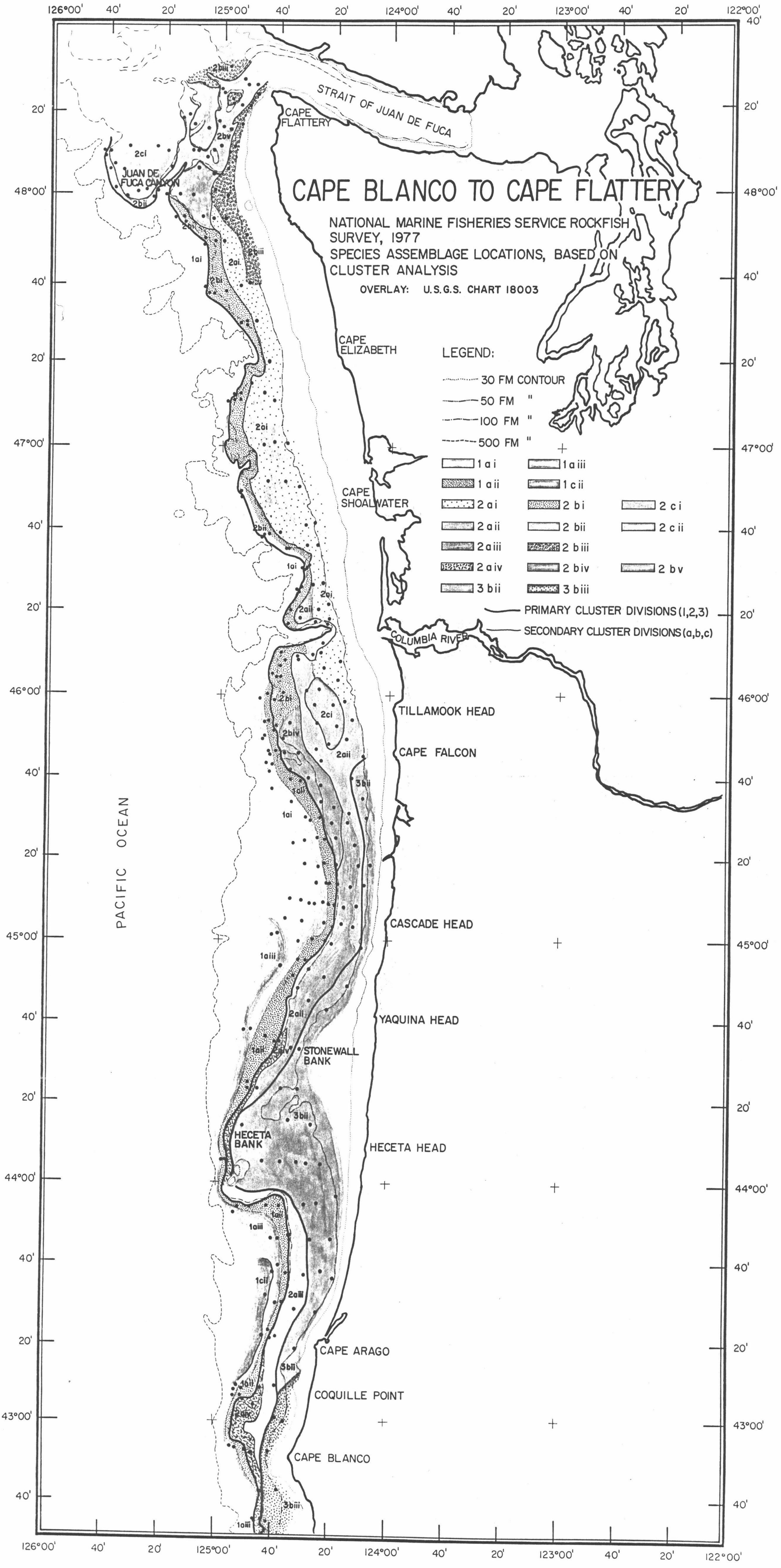


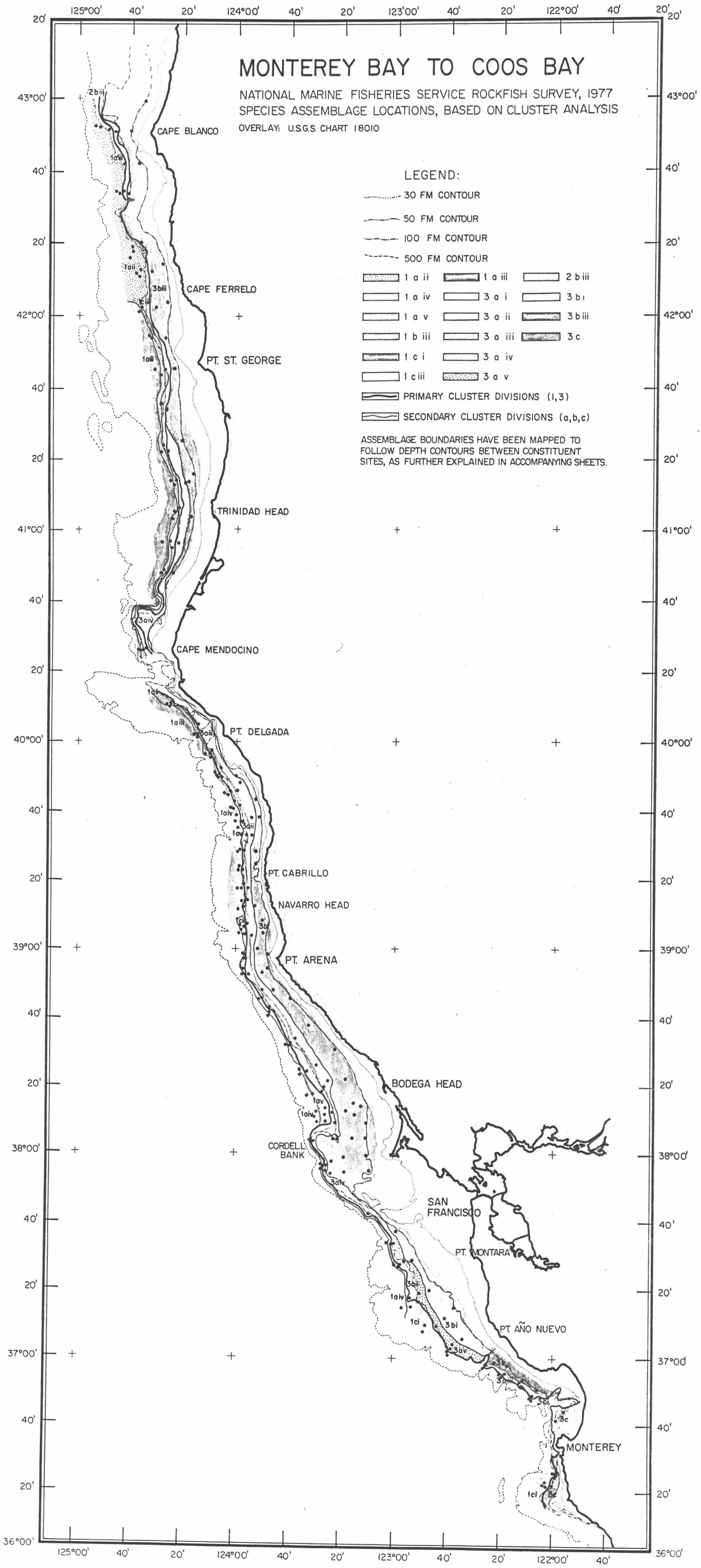
Fig. 1

Fig. 2. Assemblage site regions, Cape Blanco to Cape Flattery.



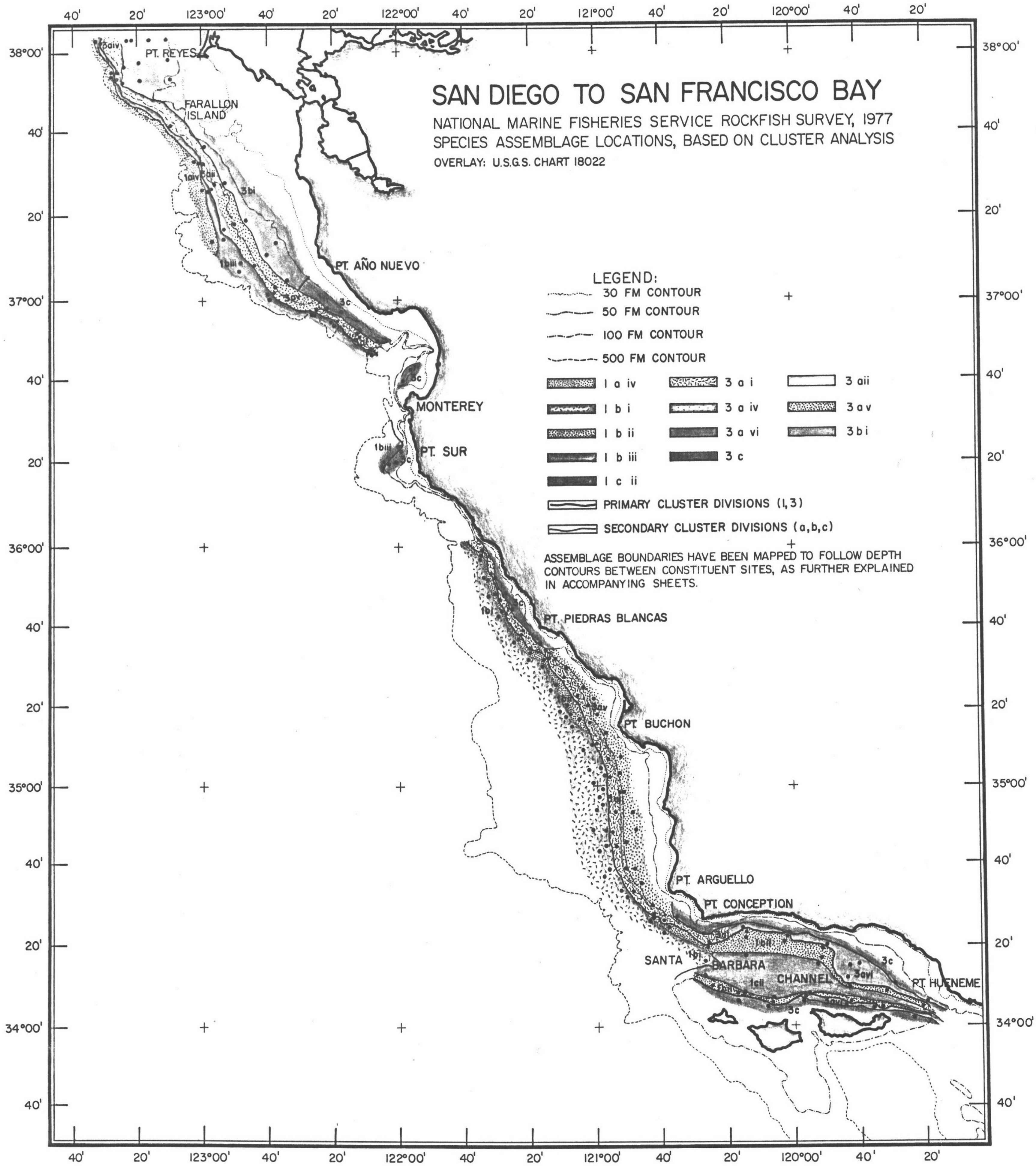
CAPE BLANCO TO CAPE FLATTERY
NATIONAL MARINE FISHERIES SERVICE ROCKFISH SURVEY, 1977
SPECIES ASSEMBLAGE LOCATIONS, BASED ON CLUSTER ANALYSIS
OVERLAY: U.S.G.S. CHART 18003
LEGEND:
30 FM CONTOUR
50 FM "
100 FM "
500 FM "
1 a i
1 a iii
1 a ii
1 c ii
2 a i
2 b i
2 c i
2 a ii
2 b ii
2 c ii
2 a iii
2 b iii
2 a iv
2 b iv
2 b v
3 b ii
3 b iii
PRIMARY CLUSTER DIVISIONS (1,2,3)
SECONDARY CLUSTER DIVISIONS (a,b,c)
STRAIT OF JUAN DE FUCA
CAPE FLATTERY
JUAN DE FUCA CANYON
CAPE ELIZABETH
CAPE SHOALWATER
COLUMBIA RIVER
TILLAMOOK HEAD
CAPE FALCON
CASCADE HEAD
YAQUINA HEAD
STONEWALL BANK
HECETA BANK
HECETA HEAD
CAPE ARAGO
COQUILLE POINT
CAPE BLANCO
PACIFIC OCEAN
126°00'
125°00'
124°00'
123°00'
122°00'
48°00'
47°00'
46°00'
45°00'
44°00'
43°00'

Fig. 3 Assemblage site regions, Monterey Bay to Coos Bay.



MONTEREY BAY TO COOS BAY
NATIONAL MARINE FISHERIES SERVICE ROCKFISH SURVEY, 1977
SPECIES ASSEMBLAGE LOCATIONS, BASED ON CLUSTER ANALYSIS
OVERLAY: U.S.G.S. CHART 18010
LEGEND:
30 FM CONTOUR
50 FM CONTOUR
100 FM CONTOUR
500 FM CONTOUR
1 a ii
1 a iii
2 b iii
1 a iv
3 a i
3 b i
1 a v
3 a ii
3 b iii
1 b iii
3 a iii
3 c
1 c i
3 a iv
1 c iii
3 a v
PRIMARY CLUSTER DIVISIONS (1,3)
SECONDARY CLUSTER DIVISIONS (a,b,c)
ASSEMBLAGE BOUNDARIES HAVE BEEN MAPPED TO FOLLOW DEPTH CONTOURS BETWEEN CONSTITUENT SITES, AS FURTHER EXPLAINED IN ACCOMPANYING SHEETS.
CAPE BLANCO
CAPE FERRELO
PT. ST. GEORGE
TRINIDAD HEAD
CAPE MENDOCINO
PT. DELGADA
PT. CABRILLO
NAVARRO HEAD
PT. ARENA
BODEGA HEAD
CORDELL BANK
SAN FRANCISCO
PT. MONTARA
PT. AÑO NUEVO
MONTEREY
125°00'
124°00'
123°00'
122°00'
43°00'
42°00'
41°00'
40°00'
39°00'
38°00'
37°00'
36°00'

Fig. 4. Assemblage site regions, San Diego to San Francisco Bay.


SAN DIEGO TO SAN FRANCISCO BAY
NATIONAL MARINE FISHERIES SERVICE ROCKFISH SURVEY, 1977
SPECIES ASSEMBLAGE LOCATIONS, BASED ON CLUSTER ANALYSIS
OVERLAY: U.S.G.S. CHART 18022
LEGEND:
30 FM CONTOUR
50 FM CONTOUR
100 FM CONTOUR
500 FM CONTOUR
I a iv
I b i
I b ii
I b iii
I c ii
3 a i
3 a iv
3 a vi
3 c
3 aii
3 a v
3 b i
PRIMARY CLUSTER DIVISIONS (1,3)
SECONDARY CLUSTER DIVISIONS (a,b,c)
ASSEMBLAGE BOUNDARIES HAVE BEEN MAPPED TO FOLLOW DEPTH CONTOURS BETWEEN CONSTITUENT SITES, AS FURTHER EXPLAINED IN ACCOMPANYING SHEETS.
PT. REYES
FARALLON ISLAND
PT. AÑO NUEVO
MONTEREY
PT. SUR
PT. PIEDRAS BLANCAS
PT. BUCHON
PT. ARGUELLO
PT. CONCEPTION
SANTA BARBARA CHANNEL
PT. HUENEME
38°00'
37°00'
36°00'
35°00'
34°00'
123°00'
122°00'
121°00'
120°00'

thirty-two local regions classified 89.0% of the site clump observations in the correct site group. Subregion boundaries (a, b, c) often followed depth contours; local boundaries (i, ii, iii) were more likely to reflect other north-south divisions within depth ranges.

Eight species groups appeared at various similarity levels from an analysis of species clusters (Fig. 5, Table 1). Although the first five species in group A contributed large proportions of the biomass at shelf break and upper slope sites, they were common over the entire latitudinal range of the survey. The second seven species however, were most abundant in the northern section of deeper sites.

Species of group B consisted of ten species that were common at midshelf sites. The ranges of all ten species extend to the northern limits of the survey, but the group was proportionally more abundant in southern regions (site group 3).

Species in group C were most common in shallow sites; and although they were occasionally found in the southern regions of the survey, were slightly more frequent in the north (e.g. site group 2a). Group D contained many species that were common in the eastern half of the Gulf of Alaska, and were rarely caught south of Cape Mendocino. This group was more narrowly distributed than group C, although it was also common in northern shelf regions.

Species group E consisted of four rarely caught species generally found north of San Francisco at shallow sites. All the species were silver-bodied, an adaptation suitable for pelagic habitats. These fishes may have been caught if the trawl came off bottom or as the trawl moved up through the water column on recovery.

Fig. 5. Schematic dendogram of species clusters, Cape Flattery to Point Hueneme.

Fig. 5

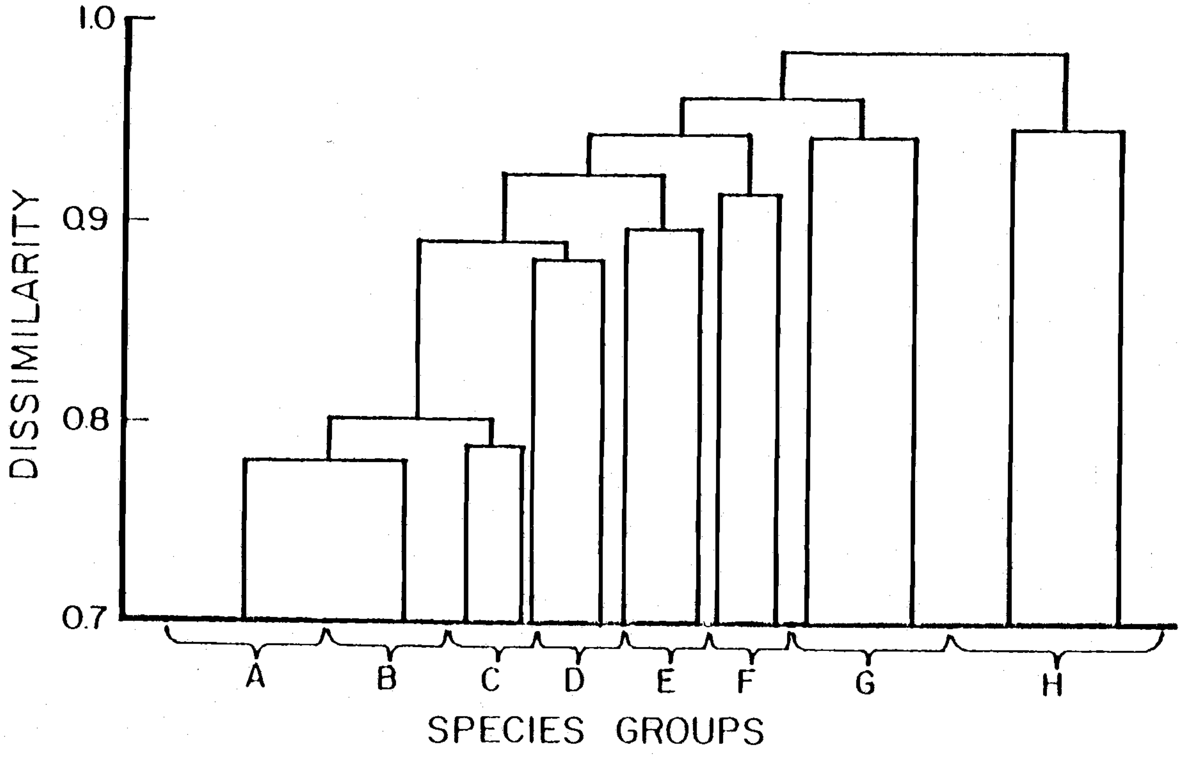


Table 1. Species groups, Cape Flattery to Pt. Hueneme based on the species dendrogram.

A: Deepwater dominant

Sablefish
Dover sole
Pacific whiting
Rex sole
Splitnose rockfish

Darkblotched rockfish*
Shortspine thornyhead
Pacific ocean perch
Arrowtooth flounder
Ratfish
Flag rockfish
Rougheye rockfish

B: Shallow dominant (southern)

English sole
Petrale sole
Pacific sanddab
Lingcod
Spiny dogfish
Stripetail rockfish
Chilipepper
Bocaccio
Shortbelly rockfish
Longnose skate
Widow rockfish

C: Shallow occasional (northern)

Canary rockfish
Greenstripe rockfish
Yellowtail rockfish
Pacific cod
Eulachon
Flathead sole
American shad
Slender sole

*The fishes in this subgroup were more common in northern deepwater areas.

D: Northern occasional (shallow)

Sharpchin rockfish
Silvergray rockfish
Redstripe rockfish
Rosethorn rockfish
Walleye pollock
Pacific halibut
Yelloweye rockfish
Rock sole
Big skate

E: Intermediate rare (shallow)

Chinook salmon
Unid. smelt
Pacific herring
Jack mackerel

F: Deepwater occasional

Blackgill rockfish	Black skate
Aurora rockfish	Brown catshark
Longnose catshark	Roughtail skate
Filetail catshark	Vermilion rockfish
Unid. catshark	Unid. eelpout
Unid. lanternfish	Shortraker rockfish
Bank rockfish	Yellowmouth rockfish

G: Southern shallow (rare)

Copper rockfish	Pacific electric ray
Soupfin shark	Cow rockfish
Loligo opalescens	Speckled rockfish
Pink sea perch	Pacific argentine
Plainfin midshipman	Mola mola
White croaker	Leopard shark
Greenspotted rockfish	

H: Northern-intermediate (rare)

Pygmy rockfish	Whitebait smelt
Quillback rockfish	Pacific tom cod
Coho salmon	

The species in group F included less abundant rockfishes and elasmobranchs that were found occasionally in deep water sites. Most species were not found continuously along the length of the survey region, but several were more common in the south. The species in group G included rarely caught species that occurred in the shallow southern sites, and almost never occurred outside region 3a. The group included several species with distributions which extended southward beyond the boundary of the survey area. Group H included some very rarely caught and loosely grouped species that occurred at midshelf in northern and intermediate latitudes. Species with northern distributions were most abundant north of Cape Blanco; those with southern distributions were most abundant south of Cape Mendocino. An intermediate region may range from Cape Blanco to Cape Mendocino.

Assemblage region 1 consisted of the deepest sites (mean depth 188 fm, 344 m) along the coast. Splitnose rockfish and Dover sole dominated total biomass in this area. Sablefish, Pacific hake, rex sole, and shortspine thornyheads also co-occurred abundantly in more than 79% of the hauls. These five species formed the basis for species group A while darkblotched rockfish, Pacific ocean perch, and arrowtooth flounder also made substantial contributions in terms of frequency and overall biomass.

The deep assemblage region from Cape Flattery to Pt. Hueneme was subdivided into three subareas. Assemblage region 1a extended from Juan de Fuca Canyon to San Francisco (Fig. 2, 3). Region 1b first appeared near Point Arena as an isolated area, but continued unbroken from San Francisco to the Santa Barbara Channel (Fig. 4). Region 1c was a series of separated deep sites between Cape Blanco and Cape Mendocino (local areas 1ci and 1ciii).

Biomass in region 1a (mean depth 185 fm, range 100-225 fm; or 338 m, range 183-411 m) consisted of Dover sole, sablefish, and Pacific hake (12.3, 14.9 and 27.3% of the total biomass caught in the area). When considered on a local scale, this pattern was duplicated in region 1ai (Fig. 2) which occupied a deep narrow strip from Juan de Fuca Canyon to Yaquina Head at an average depth of 210 fm (384 m) (Table 2). The distribution of dominant species in this area was relatively regular: Dover sole, sablefish, Pacific hake, Pacific ocean perch, and shortspine thornyhead appeared in approximately 90% or more of the hauls, and coefficients of variation were less than 125% (Table 3). Members of species group F were often present; members of group D occurred occasionally. The catch rate (294.5 lb/haul) was lower than average for region 1 and subregion 1a (Table 2).

Local region 1aii began south of the Columbia River off Tillamook Head and extended south at a mean depth of 140 fm (256 m) to Cape Blanco (Fig. 2). Total biomass was relatively evenly distributed among Pacific ocean perch, Dover sole, sablefish, darkblotched rockfish, and Pacific hake (18.3 to 9.2% each) (Table 4). Shortspine thornyhead, splitnose rockfish, arrowtooth flounder, and rex sole also occurred frequently; but contributed proportionally less biomass. The average catch per haul, 379.4 lb, was about average for region 1a (Table 2).

Region 1aiii began near Yaquina Head and extended south past Cape Blanco, continued as a narrow strip past Cape Mendocino, and ended near Point Delgado. Species composition in this upper slope region (mean

Table 2. Assemblage region characteristics, Cape Flattery to Point Hueneme.

Assemblage region	Depth (fm) Average Depth	Std. Dev.	Range	Number of Hauls	Average catch (lb/haul)	Number of species present	Diversity indices Simpson	MacIntosh	Shannon-Weaver
1ai	210.4	24.5	155-255	47	294.5	56	.871	8876.69	2.355
1aii	140.4	24.6	104-200	42	379.4	55	.889	10623.96	2.516
1aiii	184.4	31.9	114-248	45	369.7	54	.812	9421.37	2.079
1aiv	212.6	34.5	100-255	28	435.8	40	.771	6363.65	1.855
1av	181.9	17.3	156-215	10	381.3	26	.776	2008.81	1.774
1bi	214.6	26.5	157-252	33	336.0	47	.797	6095.86	1.989
1bii	163.6	22.9	120-205	30	280.9	54	.725	4008.05	1.749
1biii	183.7	28.2	134-241	29	1246.5	46	.714	16800.94	1.812
1ci	226.9	12.0	210-250	13	112.4	31	.739	714.62	1.836
1cii	238.9	7.2	230-250	12	68.9	27	.674	354.47	1.533
1ciii	124.3	7.7	110-139	10	99.4	21	.753	499.43	1.768
2ai	68.1	11.7	51-106	28	1096.2	47	.857	19092.90	2.259
2aii	79.2	11.4	57-101	23	701.3	45	.639	6440.95	1.767
2aiii	89.2	14.5	69-117	16	336.2	42	.895	3636.81	2.631
2aiv	62.6	6.7	51-76	17	740.4	40	.819	7234.58	2.202
2bi	117.8	25.9	86-182	31	1517.2	51	.913	33128.13	2.764
2bii	142.2	38.1	71-175	15	1844.2	41	.695	12386.32	1.896
2biii	110.3	21.1	55-130	9	239.2	38	.875	1391.57	2.583
2biv	98.1	5.7	90-109	7	453.0	33	.878	2063.17	2.554
2bv	143.0	22.2	98-187	17	683.5	33	.880	7590.95	2.416
2ci	85.5	18.4	61-120	17	1388.5	39	.780	12531.00	2.145
2cii	77.7	2.6	74-81	6	473.7	19	.231	349.22	.645
3ai	123.4	12.7	95-140	26	612.5	46	.795	8722.02	2.013
3aii	121.5	11.2	102-146	26	1229.9	44	.845	19379.73	2.165
3aiii	83.5	7.8	71-102	18	1264.1	42	.820	13089.48	2.042
3aiv	92.6	16.7	64-124	15	1130.9	35	.811	9582.02	2.035
3av	78.9	18.6	54-115	28	823.6	49	.741	11333.08	1.965
3avi	90.3	13.2	88-107	10	188.5	36	.898	1283.88	2.637
3bi	59.7	6.5	51-79	33	651.2	48	.598	7868.79	1.574
3bii	62.4	10.9	53-112	30	516.0	48	.545	5033.73	1.607
3biii	62.8	9.9	50-83	18	364.5	34	.577	2292.99	1.580
3c	56.7	5.5	50-72	22	178.4	47	.892	2629.64	2.628

TABLE 3. CATCH STATISTICS FROM ASSEMBLAGE REGION 1AI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
DOVER SOLE	.243	.979	71.464	52.3	2.1	233.9	A
SABLEFISH	.149	.894	43.773	40.2	3.2	158.0	A
PACIFIC WHITING	.133	.936	39.301	45.8	2.1	212.0	A
PAC OCN PERCH	.091	.894	26.690	32.8	.9	148.8	A
SHORTSPINE THORNYHD	.087	.957	25.497	27.4	.4	134.1	A
ROUGHEYE RF	.085	.596	24.954	38.4	3.5	136.5	A
ARROWTOOTH FLOUNDER	.068	.745	20.154	31.7	.3	154.1	A
REX SOLE	.029	.894	8.592	14.2	.1	70.6	A
SPLITNOSE RF	.023	.511	6.690	18.2	.9	107.3	A
SHORTRAKER RF	.018	.106	5.404	18.2	26.3	98.9	F
DARKBLOTCHED RF	.017	.574	5.139	10.0	1.9	59.9	A
FLAG RF	.014	.468	4.073	12.2	.2	66.3	A
LONGNOSE SKATE	.009	.128	2.621	7.8	.6	30.0	B
YELLOWEYE RF	.008	.064	2.272	9.1	24.6	42.2	D
PACIFIC HALIBUT	.006	.021	1.862	12.9	87.5	87.5	D
PETRALE SOLE	.005	.106	1.373	7.2	1.0	48.0	B
AURORA RF	.004	.277	1.052	2.4	.4	12.9	F
BLACK SKATE	.002	.298	.588	1.3	.5	6.6	F
RATFISH	.002	.170	.571	1.8	.9	9.5	A
BIG SKATE	.001	.021	.404	2.8	19.0	19.0	D
VERMILION RF	.001	.064	.320	1.4	2.3	8.1	F
BROWN CATSHARK	.001	.106	.271	.8	1.8	4.0	F
BIGFIN EELPOUT	.001	.213	.206	.6	.1	2.8	F
<u>SEBASTES</u> SP	.001	.021	.196	1.4	9.2	9.2	
MYCTOPHIDAE	.001	.170	.152	.5	.1	3.0	F
YELLOWMOUTH RF	.000	.021	.142	1.0	6.7	6.7	F
ROSETHORN RF	.000	.106	.139	.6	.3	3.8	D
UNID SHRIMP	.000	.043	.087	.6	.1	4.0	
WIDOW RF	.000	.043	.083	.4	1.3	2.6	B
BLACKGILL RF	.000	.021	.080	.6	3.8	3.8	F
PINK SHRIMP	.000	.021	.056	.4	2.6	2.6	
BLACKTAIL SNAILFISH	.000	.106	.053	.2	.2	1.0	
SHARPCHIN RF	.000	.021	.037	.3	1.7	1.7	D
WALLEYE POLLOCK	.000	.021	.037	.3	1.7	1.7	D
ENGLISH SOLE	.000	.021	.032	.2	1.5	1.5	B
EULACHON	.000	.021	.023	.2	1.1	1.1	C
UNID TANNER CRAB	.000	.021	.023	.2	1.1	1.1	
SPINY DOGFISH	.000	.021	.019	.1	.9	.9	B
UNID SNAILFISH	.000	.021	.019	.1	.9	.9	
BLACKMOUTH EELPOUT	.000	.085	.015	.1	.1	.3	
GREENSTRIPE RF	.000	.021	.014	.1	.7	.7	C
PINK SNAILFISH	.000	.021	.013	.1	.6	.6	
UNID VIPERFISH	.000	.043	.011	.1	.1	.4	
SLENDER SOLE	.000	.064	.009	.0	.1	.3	C
ZOARCIDAE	.000	.064	.007	.0	.1	.1	

TABLE 3,CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
OCN PINK SHRIMP	.000	.043	.006	.0	.1	.2	
LONGFIN DRAGONFISH	.000	.043	.005	.0	.1	.1	
PACIFIC VIPERFISH	.000	.021	.004	.0	.2	.2	
UNID HAGFISH	.000	.021	.004	.0	.2	.2	
UNID SCULPIN	.000	.021	.004	.0	.2	.2	
SPOT SHRIMP	.000	.021	.003	.0	.1	.1	
UNID POACHER	.000	.021	.002	.0	.1	.1	
HIGHFIN DRAGONFISH	.000	.021	.002	.0	.1	.1	
STRIPETAIL RF	.000	.021	.002	.0	.1	.1	B
SIDESTRIPE SHRIMP	.000	.021	.002	.0	.1	.1	
UNID HATCHETFISH	.000	.021	.002	.0	.1	.1	

TABLE 4. CATCH STATISTICS FROM ASSEMBLAGE REGION 1AII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PAC OCN PERCH	.183	.905	69.281	130.4	1.0	652.8	A
DOVER SOLE	.171	.952	64.718	77.6	1.1	408.0	A
SABLEFISH	.134	.833	50.972	56.4	2.1	251.2	A
DARKBLOTCHED RF	.102	.857	38.776	68.3	.6	336.4	A
PACIFIC WHITING	.092	.881	34.917	47.0	1.5	215.6	A
SHORTSPINE THORNYHD	.058	.833	22.170	28.9	.1	134.1	A
SPLITNOSE RF	.055	.857	20.840	42.6	.6	199.3	A
ARROWTOOTH FLOUNDER	.054	.762	20.500	22.5	2.0	85.4	A
REX SOLE	.031	.905	11.579	15.9	.1	71.7	A
PINK SHRIMP	.028	.071	10.631	41.4	81.0	188.0	
FLAG RF	.015	.357	5.563	14.1	.1	63.2	A
ENGLISH SOLE	.010	.119	3.848	15.2	2.1	78.1	B
ROUGHEYE RF	.009	.167	3.285	19.9	.1	127.3	A
SHARPCHIN RF	.006	.286	2.266	6.9	.2	32.8	D
WIDOW RF	.006	.238	2.212	6.2	2.7	32.6	B
SHORTRAKER RF	.005	.024	2.056	13.5	86.4	86.4	F
LINGCOD	.005	.071	1.980	10.3	5.9	65.3	B
OCN PINK SHRIMP	.005	.238	1.890	7.9	.1	39.2	
RATFISH	.005	.357	1.766	3.9	.9	15.9	A
PAC ELECTRIC RAY	.003	.024	1.179	7.7	49.5	49.5	G
LONGNOSE SKATE	.003	.095	1.157	4.2	6.3	23.5	B
BOCACCIO	.003	.095	1.114	4.3	3.1	22.5	B
GREENSTRIPE RF	.002	.238	.764	2.5	.6	13.9	C
STRIPETAIL RF	.002	.238	.745	2.7	.1	15.9	B
CANARY RF	.002	.095	.617	2.0	4.3	8.6	C
YELLOWMOUTH RF	.001	.048	.506	2.5	6.6	14.6	F
SPINY DOGFISH	.001	.143	.490	1.6	.2	7.0	B
SILVERGREY RF	.001	.071	.459	1.7	4.6	8.2	D
YELLOWTAIL RF	.001	.119	.448	1.3	2.7	5.0	C
BLACK SKATE	.001	.214	.331	.9	.1	4.3	F
PINK RF	.001	.024	.313	2.1	13.1	13.1	H
PYGMY RF	.001	.024	.298	2.0	12.5	12.5	H
PETRALE SOLE	.001	.024	.280	1.8	11.8	11.8	B
WALLEYE POLLOCK	.001	.024	.255	1.7	10.7	10.7	D
PACIFIC COD	.001	.024	.238	1.6	10.0	10.0	C
ROSETHORN RF	.001	.071	.225	.9	2.1	4.1	D
REDSTRIPE RF	.000	.048	.188	.9	2.9	5.0	D
EULACHON	.000	.167	.115	.6	.1	3.5	C
SLENDER SOLE	.000	.262	.107	.3	.1	2.1	C
BIGFIN EELPOUT	.000	.119	.085	.3	.1	1.6	F
BLACKTAIL SNAILFISH	.000	.071	.076	.3	.5	2.1	
UNID TANNER CRAB	.000	.024	.025	.2	1.1	1.1	
LOPHOLITHODES F	.000	.048	.022	.1	.3	.7	
THREADFIN SCULPIN	.000	.095	.021	.1	.1	.4	
UNID SMELT	.000	.048	.021	.1	.1	.8	F

TABLE 4, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
UNID SNAILFISH	.000	.048	.018	.1	.3	.5	
UNID SCULPIN	.000	.048	.018	.1	.1	.6	
ZOARCIDAE	.000	.024	.012	.1	.5	.5	
SHORTBELLY RF	.000	.024	.009	.1	.4	.4	B
MYCTOPHIDAE	.000	.048	.006	.0	.1	.2	F
UNID VIPERFISH	.000	.024	.004	.0	.2	.2	
WARTY POACHER	.000	.024	.003	.0	.1	.1	
UNID POACHER	.000	.024	.003	.0	.1	.1	
SPOTFIN SCULPIN	.000	.024	.002	.0	.1	.1	
SPOT SHRIMP	.000	.024	.002	.0	.1	.1	

depth of 184 fm or 336 m) was dominated by Dover sole (35.4% of the total biomass), sablefish, and Pacific hake (14.8 and 14.4%, respectively) (Table 5). Splitnose and darkblotched rockfish contributed 9.4 and 8.2% each; rex sole, shortspine thornyhead, Pacific ocean perch, arrowtooth flounder, and flag rockfish each contributed from 4.9 to 1.1% of the total biomass. Members of group F were among the rare species. Single hauls containing members of group B may have occurred near the southern boundary of this region. Diversity was low relative to local regions to its north (Table 2).

Area laiv was bounded to the north by Cape Mendocino and continued just south of San Francisco at a mean depth of 212 fm (388 m); Dover sole dominated the catches with sablefish and splitnose rockfish (38.9, 18.6, 17.9%, respectively) (Table 6). Rex sole, Pacific hake, blackgill rockfish, aurora rockfish, shortspine thornyhead, and darkblotched rockfish contributed between 7.7 and 1.0% each. Catch per haul was higher than average (435.8 lb) although diversity was low.

Area lav was found as a pocket off Bodega Head at an average depth of 182 fm (333 m). Hauls from this area were dominated by splitnose rockfish and Pacific hake (31.6 and 30.5% of the total biomass) rather than Dover sole and sablefish, the common dominant species in region la (Table 7). However, most of the hake occurred in a single haul. Most of the darkblotched and shortbelly rockfish occurred in a single haul as well, but accounted for 6.0 and 5.0% of the total biomass. Less common species usually belonged to group F, although members of group B occurred occasionally. Catch rates were slightly higher than the average for area la (381.3 lb/haul) (Table 2).

TABLE 5. CATCH STATISTICS FROM ASSEMBLAGE REGION 1AIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
DOVER SOLE	.354	.889	130.820	188.5	1.1	684.3	A
SABLEFISH	.148	.800	54.717	100.6	.9	604.4	A
PACIFIC WHITING	.144	.933	53.164	86.2	.1	437.6	A
SPLITNOSE RF	.094	.800	34.910	82.9	.2	520.5	A
DARKBLOTCHED RF	.082	.689	30.305	47.5	.6	204.0	A
REX SOLE	.049	.844	18.099	25.5	.2	89.5	A
SHORTSPINE THORNYHD	.030	.778	11.269	18.7	.3	100.8	A
PAC OCN PERCH	.026	.467	9.479	26.6	.5	137.8	A
ARROWTOOTH FLOUNDER	.017	.444	6.419	12.6	.1	50.2	A
FLAG RF	.011	.400	4.200	9.1	.3	43.9	A
BLACK SKATE	.008	.467	2.798	5.3	.5	26.3	F
ROUGHEYE RF	.006	.200	2.124	5.3	1.1	21.9	A
ENGLISH SOLE	.005	.067	1.811	11.8	.4	78.1	B
BOCACCIO	.004	.067	1.518	7.8	6.0	50.0	B
SPINY DOGFISH	.004	.289	1.466	3.1	.5	13.4	B
LONGNOSE SKATE	.003	.133	1.241	4.5	1.8	26.3	B
RATFISH	.003	.311	1.223	2.8	.9	12.9	A
STRIPETAIL RF	.003	.156	.930	5.4	.2	35.7	B
BIGFIN EELPOUT	.002	.356	.878	2.0	.3	9.6	F
UNID CATSHARK	.001	.133	.456	2.0	.2	13.0	F
AURORA RF	.001	.222	.375	.9	.5	4.7	F
GREENSTRIPE RF	.001	.044	.349	2.3	.8	15.0	C
BROWN CATSHARK	.000	.067	.166	.8	.2	3.8	F
LINGCOD	.000	.022	.131	.9	5.9	5.9	B
SHARPCHIN RF	.000	.067	.109	.5	.6	3.3	D
PETRALE SOLE	.000	.044	.094	.4	2.0	2.3	B
BLACKTAIL SNAILFISH	.000	.111	.087	.3	.3	2.1	
WIDOW RF	.000	.022	.077	.5	3.5	3.5	B
UNID SHRIMP	.000	.022	.077	.5	3.5	3.5	
BLACKGILL RF	.000	.022	.072	.5	3.3	3.3	F
ROSETHORN RF	.000	.022	.048	.3	2.1	2.1	D
SLENDER SOLE	.000	.178	.046	.1	.1	.5	C
MYCTOPHIDAE	.000	.289	.037	.1	.1	.2	F
BIG SKATE	.000	.022	.033	.2	1.5	1.5	D
LONGNOSE CATSHARK	.000	.022	.033	.2	1.5	1.5	F
BANK RF	.000	.022	.022	.2	1.0	1.0	F
BLACKMOUTH EELPOUT	.000	.044	.014	.1	.1	.5	
UNID VIPERFISH	.000	.089	.012	.0	.1	.2	
UNID SMELT	.000	.089	.012	.0	.1	.2	F
ZOARCIDAE	.000	.089	.010	.0	.1	.1	
UNID SNAILFISH	.000	.022	.007	.0	.3	.3	
LONGFIN DRAGONFISH	.000	.044	.006	.0	.1	.2	
UNID POACHER	.000	.044	.005	.0	.1	.1	
SEBASTES SP	.000	.022	.004	.0	.2	.2	
ROUGHTAIL SKATE	.000	.022	.004	.0	.2	.2	F

TABLE 5, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
UNID HAGFISH	.000	.022	.003	.0	.1	.1	
SHORTBELLY RF	.000	.022	.003	.0	.1	.1	B
PACIFIC VIPERFISH	.000	.022	.003	.0	.1	.1	
SPOT SHRIMP	.000	.022	.003	.0	.1	.1	
UNID RATTAIL	.000	.022	.002	.0	.1	.1	
UNID HATCHETFISH	.000	.022	.002	.0	.1	.1	
CHINOOK SALMON	.000	.022	.002	.0	.1	.1	F
BLACK EELPOUT	.000	.022	.002	.0	.1	.1	
SIDESTRIPE SHRIMP	.000	.022	.002	.0	.1	.1	

TABLE 6. CATCH STATISTICS FROM ASSEMBLAGE REGION 1AIV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
DOVER SOLE	.389	1.000	169.740	118.7	3.2	484.6	A
SABLEFISH	.186	.821	81.212	145.5	.6	727.5	A
SPLITNOSE RF	.177	.857	77.038	117.3	.5	483.6	A
REX SOLE	.077	1.000	33.618	30.0	.4	119.4	A
PACIFIC WHITING	.060	.929	26.156	28.2	.4	100.1	A
BLACKGILL RF	.031	.286	13.646	33.2	5.4	123.5	F
AURORA RF	.018	.607	7.925	13.0	.2	53.8	F
SHORTSPINE THORNYHD	.016	.821	7.080	7.5	1.1	24.5	A
DARKBLOTCHED RF	.010	.357	4.322	10.5	.1	38.5	A
BOCACCIO	.005	.071	2.340	11.7	4.7	60.8	B
ARROWTOOTH FLOUNDER	.005	.464	2.148	3.3	.6	11.8	A
RATFISH	.004	.536	1.829	2.3	.5	7.0	A
BROWN CATSHARK	.003	.357	1.364	2.7	1.0	10.6	F
BIGFIN EELPOUT	.003	.571	1.234	2.2	.1	8.6	F
BLACK SKATE	.003	.500	1.106	2.3	.1	10.8	F
FLAG RF	.002	.464	1.030	1.6	.3	5.4	A
ROUGHTAIL SKATE	.002	.214	.842	2.7	1.1	13.2	F
ROUGHEYE RF	.002	.071	.668	2.7	6.0	12.7	A
STRIPETAIL RF	.001	.214	.626	2.4	.1	12.3	B
BANK RF	.001	.143	.315	.9	.9	3.0	F
ENGLISH SOLE	.001	.107	.237	.9	.8	4.7	B
PAC OCN PERCH	.000	.107	.208	.6	1.4	2.7	A
ROSETHORN RF	.000	.036	.171	.9	4.8	4.8	D
SPINY DOGFISH	.000	.071	.135	.7	.2	3.6	B
FILETAIL CATSHARK	.000	.071	.125	.5	1.0	2.5	F
UNID CRAB	.000	.036	.085	.5	2.4	2.4	
ZOARCIDAE	.000	.107	.083	.4	.1	2.0	
SLENDER SOLE	.000	.286	.081	.2	.1	.5	C
CHILIPEPPER RF	.000	.107	.079	.3	.2	1.6	B
SHORTBELLY RF	.000	.071	.076	.3	.9	1.3	B
PETRALE SOLE	.000	.036	.067	.4	1.9	1.9	B
UNID CATSHARK	.000	.036	.067	.4	1.9	1.9	F
BLACKMOUTH EELPOUT	.000	.107	.051	.2	.1	1.1	
UNID SNAILFISH	.000	.036	.046	.2	1.3	1.3	
PINK SNAILFISH	.000	.107	.039	.1	.3	.5	
PACIFIC SANDDAB	.000	.071	.023	.1	.3	.4	B
HARLEQUIN RF	.000	.036	.007	.0	.2	.2	
MYCTOPHIDAE	.000	.036	.004	.0	.1	.1	F
UNID SCULPIN	.000	.036	.004	.0	.1	.1	
SPOTTED CUSKEEL	.000	.036	.003	.0	.1	.1	

TABLE 7. CATCH STATISTICS FROM ASSEMBLAGE REGION 1AV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPLITNOSE RF	.316	1.000	120.420	177.9	.1	482.2	A
PACIFIC WHITING	.305	.900	116.346	292.8	1.4	902.0	A
DOVER SOLE	.133	1.000	50.713	70.9	3.2	195.9	A
SABLEFISH	.077	.500	29.438	79.0	2.8	241.1	A
DARKBLOTCHED RF	.060	.400	22.991	57.5	4.2	173.0	A
SHORTBELLY RF	.050	.200	18.972	63.1	.3	189.4	B
REX SOLE	.034	1.000	12.862	18.9	.9	52.0	A
BANK RF	.007	.300	2.570	6.7	2.2	20.5	F
ARROWTOOTH FLOUNDER	.006	.200	2.388	7.3	1.9	22.0	A
RATFISH	.002	.400	.666	1.0	.9	2.7	A
FLAG RF	.002	.300	.588	1.3	.9	4.0	A
SHORTSPINE THORNYHD	.001	.500	.524	.9	.1	2.1	A
AURORA RF	.001	.400	.483	.8	.3	2.0	F
WIDOW RF	.001	.200	.423	1.0	1.4	2.8	B
BLACK SKATE	.001	.200	.410	1.0	1.1	3.0	F
ROUGHTAIL SKATE	.001	.100	.376	1.3	3.8	3.8	F
ENGLISH SOLE	.001	.300	.290	.5	.7	1.1	B
BLACKGILL RF	.001	.200	.254	.6	.7	1.9	F
CHILIPEPPER RF	.001	.100	.220	.7	2.2	2.2	B
SLENDER SOLE	.000	.200	.109	.3	.1	1.0	C
UNID CRAB	.000	.100	.080	.3	.8	.8	
ROSETHORN RF	.000	.100	.050	.2	.5	.5	D
BIGFIN EELPOUT	.000	.100	.040	.1	.4	.4	F
ZOARCIDAE	.000	.200	.038	.1	.1	.3	
MYCTOPHIDAE	.000	.100	.019	.1	.2	.2	F
STRIPETAIL RF	.000	.100	.011	.0	.1	.1	B

Catches in region 1b were strongly dominated by splitnose rockfish and were sometimes larger than those farther north in the same depth zone (Table 2). Dover sole were second most important in terms of overall biomass. Pacific hake, sablefish, rex sole, and darkblotched rockfish all contributed between 3.4 and 7.1% of the total. Rare species often belonged to group F, although group B was represented fairly often. Overall diversity decreased relative to region 1a, due to the dominating effect of the splitnose.

Nearly 50% of the catch in region 1biii consisted of splitnose rockfish (Table 8). The area extended farther north than any other 1b area, first appearing near Point Arena (Fig. 3), then proceeding as a strip from north of San Francisco to Monterey at a mean depth of 184 fm (337 m). Although about 88% of the total biomass was comprised of members of species group A, members of groups B and F occurred in up to 50% of the hauls. The average catch per haul was high (1246.5 lb/haul), and consisted predominantly of splitnose rockfish and Dover sole (Table 2).

Region 1bi extended from south of Point Sur to Point Conception (Fig. 4) along the deepest sites (mean depth 214 fm or 392 m). Domination by splitnose was less pronounced (32.0% of total catch) (Table 9); Dover sole and sablefish comprised 27.0 and 12.3% of the total catch, respectively. Rex sole and Pacific hake contributed 7.7 and 5.2% of the total biomass each. Aurora rockfish, blackgill rockfish, filetail catsharks and other catsharks, members of group F, contributed 3.8 to 1.6% of the total. Members of group G, southern

TABLE 8. CATCH STATISTICS FROM ASSEMBLAGE REGION 1BIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPLITNOSE RF	.486	1.000	606.052	993.4	5.5	4210.5	A
DOVER SOLE	.198	.966	247.404	220.0	11.3	809.3	A
SABLEFISH	.048	.828	59.823	74.7	2.2	291.7	A
DARKBLOTCHED RF	.048	.690	59.769	131.1	.5	640.0	A
PACIFIC WHITING	.042	.828	52.511	168.8	1.4	902.0	A
REX SOLE	.039	.966	48.081	40.3	.3	128.9	A
STRIPETAIL RF	.033	.345	40.749	113.2	.9	533.0	B
BANK RF	.032	.517	39.596	129.9	1.8	676.0	F
CHILIPEPPER RF	.016	.345	20.230	83.7	1.3	444.1	B
SHORTBELLY RF	.014	.207	17.587	55.7	.8	218.3	B
SHORTSPINE THORNYHD	.009	.828	11.653	19.6	.1	69.0	A
BLACKGILL RF	.009	.483	11.382	37.1	.2	195.0	F
RATFISH	.007	.517	9.230	25.1	.9	122.4	A
FLAG RF	.004	.586	5.202	10.8	.2	47.0	A
AURORA RF	.003	.310	3.230	7.4	.3	33.0	F
BOCACCIO	.002	.241	3.025	6.9	.9	26.4	B
SPINY DOGFISH	.001	.103	1.781	6.1	6.4	27.0	B
BIGFIN EELPOUT	.001	.483	1.249	2.1	.1	8.6	F
BLACK SKATE	.001	.414	1.080	2.1	.3	8.8	F
ZOARCIDAE	.001	.172	.962	3.5	.2	17.3	
LINGCOD	.001	.069	.870	3.3	12.0	13.2	B
PETRALE SOLE	.000	.069	.614	2.6	5.2	12.7	B
VERMILION RF	.000	.034	.555	3.0	16.1	16.1	F
ENGLISH SOLE	.000	.207	.514	1.2	.9	4.7	B
LONGNOSE SKATE	.000	.069	.493	1.9	5.8	8.6	B
WIDOW RF	.000	.138	.491	1.9	1.2	9.7	B
ARROWTOOTH FLOUNDER	.000	.103	.469	1.5	2.3	6.0	A
SLENDER SOLE	.000	.414	.394	.9	.1	4.5	C
BROWN CATSHARK	.000	.069	.273	1.2	1.5	6.4	F
CANARY RF	.000	.034	.194	1.1	5.6	5.6	C
SHARPCHIN RF	.000	.034	.155	.9	4.5	4.5	D
ROUGHTAIL SKATE	.000	.034	.148	.8	4.3	4.3	F
FILETAIL CATSHARK	.000	.138	.139	.4	.5	1.5	F
PAC OCN PERCH	.000	.069	.136	.6	1.1	2.9	A
<u>CAREPROCTUS</u> ABBR	.000	.034	.103	.6	3.0	3.0	
ROSETHORN RF	.000	.069	.103	.4	1.2	1.8	D
ROCKSOLE	.000	.034	.069	.4	2.0	2.0	D
LONGNOSE CATSHARK	.000	.034	.052	.3	1.5	1.5	F
PACIFIC SANDDAB	.000	.069	.040	.2	.6	.6	B
UNID SHARK	.000	.034	.032	.2	.9	.9	
GREENSPOT RF	.000	.034	.016	.1	.5	.5	G
THREADFIN SCULPIN	.000	.034	.009	.0	.3	.3	
SPOTTED CUSKEEL	.000	.069	.007	.0	.1	.1	
PYGMY POACHER	.000	.034	.004	.0	.1	.1	
MYCTOPHIDAE	.000	.034	.003	.0	.1	.1	F
UNID SCULPIN	.000	.034	.003	.0	.1	.1	

TABLE 9. CATCH STATISTICS FROM ASSEMBLAGE REGION 1BI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPLITNOSE RF	.320	.939	107.529	134.5	.3	487.5	A
DOVER SOLE	.270	.970	90.849	87.6	1.1	362.7	A
SABLEFISH	.123	.939	41.232	40.8	3.0	142.6	A
REX SOLE	.077	.879	26.016	36.6	.4	134.5	A
PACIFIC WHITING	.052	.970	17.539	25.6	.1	106.5	A
AURORA RF	.038	.879	12.650	18.1	1.1	98.9	F
BLACKGILL RF	.034	.545	11.381	34.5	1.0	195.0	F
FILETAIL CATSHARK	.022	.636	7.269	8.2	1.2	31.0	F
UNID CATSHARK	.016	.212	5.428	17.9	1.1	94.3	F
SHORTSPINE THORNYHD	.012	.788	3.919	5.9	.1	23.5	A
RATFISH	.006	.485	1.936	3.3	.6	13.8	A
LONGNOSE CATSHARK	.005	.485	1.649	2.2	.1	6.6	F
DARKBLOTCHED RF	.004	.273	1.480	3.6	1.1	14.0	A
SPINY DOGFISH	.003	.273	.984	2.7	1.0	14.0	B
PAC ELECTRIC RAY	.003	.061	.953	4.0	11.4	20.0	G
ROUGHEYE RF	.002	.030	.715	4.2	23.6	23.6	A
BROWN CATSHARK	.002	.061	.645	2.9	5.8	15.5	F
ZOARCIDAE	.002	.273	.621	1.7	.2	6.9	
BANK RF	.002	.212	.544	1.2	1.2	4.6	F
BLACK SKATE	.001	.182	.478	1.2	1.2	5.4	F
STRIPETAIL RF	.001	.242	.323	.7	.5	3.2	B
BIGFIN EELPOUT	.001	.333	.292	.8	.1	3.5	F
MYCTOPHIDAE	.001	.606	.270	.5	.1	2.1	F
FLAG RF	.001	.152	.265	.9	.5	4.5	A
MOLA MOLA	.001	.030	.172	1.0	5.7	5.7	G
SHORTRAKER RF	.000	.030	.130	.8	4.3	4.3	F
KING OF SALMON	.000	.030	.105	.6	3.5	3.5	
UNID SHRIMP	.000	.091	.103	.5	.1	2.8	
UNID CRAB	.000	.152	.097	.3	.2	1.2	
SHORTBELLY RF	.000	.091	.091	.5	.1	2.8	B
UNID TANNER CRAB	.000	.030	.085	.5	2.8	2.8	
DEEPSEA SMELT	.000	.152	.045	.2	.1	.9	
GREENSPOT RF	.000	.030	.038	.2	1.3	1.3	G
BLACK EELPOUT	.000	.242	.036	.1	.1	.2	
UNID SKATE	.000	.030	.035	.2	1.2	1.2	
UNID MACKEREL	.000	.030	.032	.2	1.1	1.1	
GREENSTRIPE RF	.000	.030	.030	.2	1.0	1.0	C
CHILIPEPPER RF	.000	.030	.028	.2	.9	.9	B
CANCER PRODUCTUS	.000	.030	.019	.1	.6	.6	
BLACKMOUTH EELPOUT	.000	.121	.018	.1	.1	.2	
LONGNOSE SKATE	.000	.030	.006	.0	.2	.2	B
BLACKTAIL SNAILFISH	.000	.030	.004	.0	.1	.1	
SLENDER SOLE	.000	.030	.003	.0	.1	.1	C
UNID HATCHETFISH	.000	.030	.003	.0	.1	.1	
BOCACCIO	.000	.030	.003	.0	.1	.1	B

TABLE 9, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPOTTED CUSKEEL	.000	.030	.003	.0	.1	.1	
SHORTSP COMBFISH	.000	.030	.003	.0	.1	.1	

species, occurred rarely. Average catches were lower than in region 1biii (336 lb/haul) although diversity was higher (Table 2).

Just inshore of region 1bi and lining the Santa Barbara Channel, splitnose rockfish dominated catches in region 1bii (Fig. 4). Pacific hake, Dover sole and sablefish occurred in 70.0 to 96.7% of the hauls and contributed 22.6, 11.5, and 7.6% of the total biomass, respectively (Table 10). Rare species belonged to groups B, F, and G. Standing stock and diversity in this area was lower than average for region 1b (280.9 lb/haul) (Table 2).

Regions 1ci and 1ciii were located between Cape Ferrelo and Cape Mendocino (Fig. 3). Region 1ci was farthest offshore (average depth 227 fm or 415 m) (Table 2). The catch was strongly dominated by Dover sole (46.3% of the total biomass) (Table 11). Pacific hake and sablefish accounted for 14.5 and 11.2% of the total biomass, respectively. Species group F was the most abundant group after group A. Catches along this strip were very low (112.4 lb/haul).

Region 1ciii extended as a narrow strip from Cape Ferrelo to Cape Mendocino at an average depth of 124 fm (227 m) (Fig. 3). Pacific hake and darkblotched rockfish dominated catches here (38.2 and 30.0% of total biomass, respectively) (Table 12). Pacific ocean perch, Dover sole, stripetail rockfish, splitnose rockfish, lingcod, and sablefish contributed from 9.1 to 1.0% of total biomass each. Catch in this region was extremely low (99.2 lb/haul) (Table 2).

Most sites in cluster 1cii occurred in the Santa Barbara Channel, although a few were grouped off Cape Arago (Fig. 2, 4). Sablefish contributed nearly one-half the total biomass, followed by Dover sole

TABLE 10. CATCH STATISTICS FROM ASSEMBLAGE REGION 1BII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPLITNOSE RF	.450	.900	126.475	158.2	1.6	604.9	A
PACIFIC WHITING	.226	.967	63.552	79.4	.1	322.1	A
DOVER SOLE	.115	.967	32.211	35.3	.4	125.2	A
SABLEFISH	.076	.700	21.242	26.1	2.3	107.0	A
SPINY DOGFISH	.035	.600	9.923	18.8	.2	83.8	B
PAC ELECTRIC RAY	.024	.300	6.767	15.5	6.9	69.0	G
REX SOLE	.017	.733	4.740	7.9	.3	31.0	A
DARKBLOTCHED RF	.007	.133	1.980	7.7	1.1	38.5	A
RATFISH	.006	.600	1.738	2.7	.6	9.2	A
FLAG RF	.005	.200	1.520	3.6	3.3	12.7	A
AURORA RF	.005	.267	1.355	3.7	.4	17.9	F
BANK RF	.005	.333	1.330	3.6	.9	18.4	F
BOCACCIO	.004	.133	1.094	3.4	2.3	12.8	B
BLACKGILL RF	.003	.200	.929	2.9	1.0	15.0	F
LINGCOD	.003	.067	.748	3.1	6.9	15.5	B
FILETAIL CATSHARK	.002	.367	.702	1.8	.2	9.1	F
SHORTSPINE THORNYHD	.002	.433	.604	1.5	.1	7.5	A
GREENSPOT RF	.002	.100	.436	1.7	2.1	8.6	G
COW RF	.001	.033	.375	2.1	11.3	11.3	G
STRIPETAIL RF	.001	.300	.375	.9	.1	3.5	B
LONGNOSE SKATE	.001	.067	.341	1.9	.2	10.0	B
ENGLISH SOLE	.001	.067	.337	1.4	3.2	6.9	B
SLENDER SOLE	.001	.167	.325	1.7	.1	9.2	C
BIGFIN EELPOUT	.001	.367	.303	.7	.1	2.9	F
SHORTRAKER RF	.001	.033	.288	1.6	8.6	8.6	F
UNID CRAB	.001	.200	.159	.4	.1	1.3	
PETRALE SOLE	.001	.033	.153	.9	4.6	4.6	B
BLACK SKATE	.000	.100	.128	.5	.4	2.1	F
MYCTOPHIDAE	.000	.200	.115	.4	.1	2.1	F
LONGNOSE CATSHARK	.000	.200	.115	.3	.1	1.3	F
CHILIPEPPER RF	.000	.033	.083	.5	2.5	2.5	B
PINK RF	.000	.033	.077	.4	2.3	2.3	H
DEEPSEA SMELT	.000	.067	.074	.4	.2	2.0	
PACIFIC SANDDAB	.000	.033	.050	.3	1.5	1.5	B
ZOARCIDAE	.000	.067	.049	.2	.2	1.3	
BIGMOUTH SOLE	.000	.033	.038	.2	1.2	1.2	
CURLFIN SOLE	.000	.033	.038	.2	1.2	1.2	
UNID SHRIMP	.000	.100	.038	.2	.1	.9	
SHORTBELLY RF	.000	.133	.031	.1	.1	.4	B
PLAINFIN MIDSHIP	.000	.067	.012	.1	.1	.3	G
SPOTTED CUSKEEL	.000	.100	.011	.0	.1	.1	
SHARPCHIN RF	.000	.033	.011	.1	.3	.3	D
BLACKTAIL SNAILFISH	.000	.033	.008	.0	.2	.2	
HUNDRED FM CODLING	.000	.033	.008	.0	.2	.2	
THREADFIN SCULPIN	.000	.033	.008	.0	.2	.2	

TABLE 10, continued.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC ARGENTINE	.000	.033	.007	.0	.2	.2	G
BLACKMOUTH EELPOUT	.000	.033	.007	.0	.2	.2	
BROWN CATSHARK	.000	.033	.004	.0	.1	.1	F
HALFBANDED RF	.000	.033	.004	.0	.1	.1	
UNID POACHER	.000	.033	.004	.0	.1	.1	
UNID SHARK	.000	.033	.004	.0	.1	.1	
SPOT SHRIMP	.000	.033	.004	.0	.1	.1	
LONGSPINE COMBFISH	.000	.033	.004	.0	.1	.1	
UNID STOMIATID	.000	.033	.003	.0	.1	.1	

TABLE 11. CATCH STATISTICS FROM ASSEMBLAGE REGION 1CI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
DOVER SOLE	.463	.769	52.093	92.7	1.7	269.1	A
PACIFIC WHITING	.145	.923	16.319	22.5	.1	63.8	A
SABLEFISH	.112	.538	12.568	18.2	3.8	54.6	A
AURORA RF	.068	.846	7.648	5.7	1.7	16.7	F
UNID CATSHARK	.068	.692	7.612	12.0	1.4	43.7	F
BLUE SHARK	.051	.077	5.754	21.6	74.8	74.8	
REX SOLE	.029	.769	3.206	3.9	.4	10.8	A
SPLITNOSE RF	.011	.615	1.274	1.6	.4	4.6	A
ARROWTOOTH FLOUNDER	.011	.154	1.250	3.3	5.8	10.5	A
RATFISH	.008	.231	.941	2.0	3.0	5.8	A
FLAG RF	.006	.077	.673	2.5	8.8	8.6	A
SHORTSPINE THORNYHD	.005	.385	.607	1.3	.2	4.6	A
BLACKGILL RF	.005	.077	.577	2.2	7.5	7.5	F
BROWN CATSHARK	.003	.154	.368	.9	2.1	2.7	F
DARKBLOTCHED RF	.003	.154	.367	1.0	1.3	3.5	A
BIGFIN EELPOUT	.002	.231	.208	.5	.3	1.7	F
BLACK SKATE	.002	.231	.207	.5	.1	1.5	F
BLACKTAIL SNAILFISH	.002	.385	.191	.3	.1	.9	
PETRALE SOLE	.001	.154	.157	.4	.5	1.5	B
MYCTOPHIDAE	.001	.923	.138	.1	.1	.3	F
UNID VIPERFISH	.001	.462	.087	.1	.1	.4	
BLACKMOUTH EELPOUT	.000	.308	.051	.1	.1	.2	
UNID SHRIMP	.000	.308	.045	.1	.1	.2	
PACIFIC SANDDAB	.000	.077	.027	.1	.4	.4	B
OCN PINK SHRIMP	.000	.154	.025	.1	.1	.2	
PALLID EELPOUT	.000	.154	.016	.0	.1	.1	
UNID SMELT	.000	.077	.010	.0	.1	.1	F
FLATFISH LARVAE	.000	.077	.007	.0	.1	.1	
DEEPSEA SOLE	.000	.077	.007	.0	.1	.1	
WHITEBAIT SMELT	.000	.077	.007	.0	.1	.1	
LONGSPINE THORNYHD	.000	.077	.007	.0	.1	.1	

TABLE 12. CATCH STATISTICS FROM ASSEMBLAGE REGION 1CIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.372	.900	36.870	53.2	.7	155.8	A
DARKBLOTCHED RF	.300	.700	29.797	53.0	1.2	144.5	A
PAC OCN PERCH	.091	.500	8.997	21.1	3.8	65.1	A
DOVER SOLE	.077	.700	7.612	14.6	1.1	44.0	A
STRIPETAIL RF	.040	.300	4.003	12.5	.5	37.6	B
SPLITNOSE RF	.037	.500	3.690	7.3	1.1	20.5	A
LINGCOD	.034	.100	3.371	11.2	33.7	33.7	B
SABLEFISH	.010	.200	.982	2.2	4.8	5.0	A
REX SOLE	.008	.400	.782	1.8	.2	5.5	A
WIDOW RF	.008	.200	.772	1.9	2.1	5.6	B
SPINY DOGFISH	.006	.100	.639	2.1	6.4	6.4	B
RATFISH	.006	.100	.611	2.0	6.1	6.1	A
BANK RF	.004	.100	.350	1.2	3.5	3.5	F
GREENSTRIPE RF	.002	.200	.182	.5	.3	1.5	C
FLAG RF	.002	.100	.150	.5	1.5	1.5	A
DUNGENESS CRAB	.001	.100	.132	.4	1.3	1.3	
BLACK SKATE	.001	.100	.130	.4	1.3	1.3	F
SHORTSPINE THORNYHD	.001	.200	.078	.2	.2	.6	A
BIGFIN EELPOUT	.001	.100	.050	.2	.5	.5	F
MYCTOPHIDAE	.000	.300	.034	.1	.1	.1	F
KING OF SALMON	.000	.100	.009	.0	.1	.1	

(31.3%) (Table 13). Rougheye rockfish, Pacific hake, shortspine thornyhead, aurora rockfish, and filetail catsharks contributed from 5.0 to 1.4% of that total each. This region had the lowest diversity and lowest average catch per haul (68.9 lb) of any area in region 1.

Assemblage region 2 contained sites from a wide depth range (51 fm to 187 fm, 93-342 m) from Cape Flattery to Cape Blanco (Fig. 1). Hauls were commonly dominated by Pacific ocean perch (group A), Pacific hake (group A), yellowtail rockfish (group C), spiny dogfish (group B), arrowtooth flounder, and Dover sole (both group A). These species comprised about 62% of the total biomass in the region. Other intermittantly frequent species included lingcod (group A), and canary rockfish (group C). Other members of species groups B, C, and D occurred occasionally.

Area 2a occurred inshore at Cape Flattery, but included some deeper sites near Cape Falcon. South of Cape Falcon, the boundaries moved toward the shelf break outside of Heceta Bank and followed the shelf break south to Coquille Point (Fig. 2). The average site depth was 74 fm (135 m), and ranged from 51-117 fm (93-214 m). Pacific hake and spiny dogfish were most important in terms of total biomass. Members of species group C were common: yellowtail rockfish, canary rockfish, Pacific cod, eulachon, and greenstriped rockfish all occurred in at least 45% of the hauls in the area. Members of group B occurred at lower frequencies.

The northernmost region of areas 2a, section 2aiv, included sites north and inland of Juan de Fuca Canyon at average depth of 68 fm (124 m) (Fig. 2). Mean catch per haul in this region was about average

TABLE 13. CATCH STATISTICS FROM ASSEMBLAGE REGION 1CII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SABLEFISH	.471	.833	32.453	31.2	9.2	98.7	A
DOVER SOLE	.313	.833	21.567	25.6	1.1	86.5	A
ROUGHEYE RF	.050	.167	3.413	9.8	9.0	32.0	A
PACIFIC WHITING	.043	.833	2.979	3.6	1.2	12.0	A
SHORTSPINE THORNYHD	.036	.583	2.487	4.3	.4	12.2	A
AURORA RF	.026	.417	1.826	2.8	2.8	8.4	F
FILETAIL CATSHARK	.014	.333	.973	2.4	.4	8.1	F
REX SOLE	.009	.417	.610	1.3	.1	4.0	A
DEEPSEA SMELT	.006	.417	.404	.7	.1	2.1	
UNID CATSHARK	.006	.250	.388	.9	.5	2.4	F
MYCTOPHIDAE	.005	.500	.368	.5	.2	1.3	F
ARROWTOOTH FLOUNDER	.005	.083	.333	1.2	4.0	4.0	A
SPLITNOSE RF	.004	.333	.280	.4	.6	1.1	A
LONGNOSE CATSHARK	.004	.167	.261	.7	.8	2.3	F
BLACK SKATE	.002	.083	.167	.6	2.0	2.0	F
PROWFISH	.002	.083	.147	.5	1.8	1.8	
DARKBLOTCHED RF	.002	.083	.118	.4	1.4	1.4	A
CALIFORNIA RATTAIL	.001	.083	.035	.1	.4	.4	
PACIFIC VIPERFISH	.000	.167	.019	.0	.1	.1	
LONGFIN DRAGONFISH	.000	.167	.017	.0	.1	.1	
KING OF SALMON	.000	.083	.016	.1	.2	.2	
UNID SMELT	.000	.083	.010	.0	.1	.1	F
LONGSPINE COMBFISH	.000	.083	.010	.0	.1	.1	
UNID VIPERFISH	.000	.083	.010	.0	.1	.1	
SERGESTES SP	.000	.083	.010	.0	.1	.1	
UNID SHRIMP	.000	.083	.009	.0	.1	.1	
BIGFIN EELPOUT	.000	.083	.008	.0	.1	.1	F

for area 2a (Table 2). Spiny dogfish (group B) dominated catches (34.8% of biomass) and occurred in every haul. Other important species included Pacific hake (18.6%, group A), lingcod (10.2%, group B), ratfish (7.6%, group A), walleye pollock (5.6%, group D), yellowtail rockfish (4.8%, group C), and Pacific cod (4.0%, group C) (Table 14). High contributions by spiny dogfish and lingcod were partly due to single large catches. About 15% of the species listed each belonged to groups B, C, and D.

Local area 2ai extended along the same depth range (mean depth 62 fm or 113 m) as 2aiv, starting near Juan de Fuca Canyon and continuing to Tillamook Head (Fig. 2). The catch rate in this area (1096.2 lb/haul) was above average for area 2a. Spiny dogfish (group B) were less frequent in this area than in region 2aiv, but made a large contribution to total biomass in the area through a single large haul (Table 15). Pacific herring (group E) were also less frequent but occurred in a large haul. Yellowtail rockfish and canary rockfish (both group C) were more frequent and abundant than further north, present in 82.1 and 57.1% of the hauls and contributing 19.2 and 10.6% of the total biomass. Pacific hake, Dover sole, arrowtooth flounder, Pacific cod, and sablefish occurred at about the same frequency and mean catch per haul as in 2aiv (if a few single large hauls are de-emphasized).

Area 2aii occurred as a small region near the Columbia River, and extended south and offshore past Cape Falcon (Fig. 2). Mean depth of sites in the area was slightly deeper than 2ai and 2aiv, about 72 fm (132 m) (Table 2). The frequency and proportion of Pacific hake in the catch was higher than in the 2a subregions to the north. Average catch

TABLE 14. CATCH STATISTICS FROM ASSEMBLAGE REGION 2AIV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPINY DOGFISH	.348	1.000	257.663	817.6	3.5	3321.0	B
PACIFIC WHITING	.186	.824	137.428	226.0	1.4	850.0	A
LINGCOD	.102	.294	75.711	277.3	16.1	1115.8	B
RATFISH	.076	.294	56.209	209.2	1.1	839.4	A
WALLEYE POLLOCK	.056	.529	41.114	143.4	1.2	577.2	D
YELLOWTAIL RF	.048	.647	35.809	82.6	2.3	327.0	C
PACIFIC COD	.040	.882	29.733	27.8	1.6	77.0	C
DOVER SOLE	.022	1.000	16.394	40.0	.5	163.0	A
ARROWTOOTH FLOUNDER	.021	.824	15.459	19.4	3.0	62.0	A
PETRALE SOLE	.019	.706	13.854	43.3	.4	175.8	B
SABLEFISH	.017	.471	12.428	30.4	.5	115.0	A
PACIFIC HERRING	.013	.412	9.852	31.5	.9	126.3	E
AMERICAN SHAD	.010	.353	7.160	17.2	1.6	60.2	C
REX SOLE	.008	.882	6.108	14.1	.5	57.0	A
CHINOOK SALMON	.007	.294	4.990	11.5	3.0	43.0	E
BIG SKATE	.006	.059	4.092	17.4	69.6	69.6	D
ENGLISH SOLE	.004	.412	3.082	4.8	1.6	14.0	B
WIDOW RF	.003	.059	2.156	9.2	36.7	36.7	B
REDSTRIPE RF	.002	.059	1.769	7.5	30.1	30.1	D
CANARY RF	.001	.059	1.106	4.7	18.8	18.8	C
DARKBLOTCHED RF	.001	.235	1.058	2.8	.6	9.4	A
YELLOWEYE RF	.001	.059	.995	4.2	16.9	16.9	D
DUNGENESS CRAB	.001	.059	.879	3.7	15.0	15.0	
PACIFIC SANDDAB	.001	.235	.860	1.8	1.9	5.6	B
BOCACCIO	.001	.059	.755	3.2	12.8	12.8	B
EULACHON	.001	.176	.705	2.1	.9	8.1	C
QUILLBACK RF	.001	.059	.553	2.4	9.4	9.4	H
SHORTSPINE THORNYHD	.001	.176	.538	1.4	1.0	4.7	A
GREENSTRIPE RF	.001	.118	.378	1.2	2.1	4.3	C
FLATHEAD SOLE	.000	.118	.353	1.1	2.0	4.0	C
FLAG RF	.000	.059	.235	1.0	4.0	4.0	A
SLENDER SOLE	.000	.294	.204	.5	.1	2.0	C
UNID SHRIMP	.000	.118	.145	.5	.5	2.0	
WHITEBAIT SMELT	.000	.059	.111	.5	1.9	1.9	
OCN PINK SHRIMP	.000	.059	.111	.5	1.9	1.9	
PAC OCN PERCH	.000	.059	.102	.4	1.7	1.7	A
ROSETHORN RF	.000	.118	.099	.3	.8	.9	D
ROCK SOLE	.000	.059	.098	.4	1.7	1.7	D
SURF SMELT	.000	.059	.059	.3	1.0	1.0	
PACIFIC TOMCOD	.000	.118	.057	.2	.5	.5	

TABLE 15. CATCH STATISTICS FROM ASSEMBLAGE REGION 2AI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPINY DOGFISH	.210	.464	230.248	1133.0	1.8	6008.1	B
YELLOWTAIL RF	.192	.821	210.716	601.5	3.8	2344.0	C
PACIFIC WHITING	.180	.750	197.203	392.9	2.4	1721.3	A1
PACIFIC HERRING	.117	.214	128.726	680.8	.1	3539.6	E
CANARY RF	.106	.571	116.240	334.2	3.2	1608.0	C
DOVER SOLE	.038	.929	42.011	63.7	1.0	259.9	A1
ARROWTOOTH FLOUNDER	.038	.857	41.226	50.6	.9	239.7	A
PACIFIC COD	.023	.607	25.328	32.9	6.8	125.0	C
SABLEFISH	.020	.643	22.294	40.7	1.2	184.0	A
LINGCOD	.015	.393	16.194	32.7	6.3	143.4	B
REX SOLE	.009	.893	10.289	9.7	.3	39.8	A
EULACHON	.009	.500	9.538	27.2	.9	115.0	C
PAC OCN PERCH	.008	.179	8.716	39.5	.5	204.9	A
PETRALE SOLE	.005	.679	5.016	8.1	1.2	37.0	B
GREENSTRIPE RF	.004	.357	3.990	10.1	.6	40.8	C
DARKBLOTCHED RF	.004	.607	3.896	7.5	.2	32.3	A
LONGNOSE SKATE	.003	.179	3.627	8.6	8.6	27.2	B
AMERICAN SHAD	.002	.286	2.599	5.8	.5	23.1	C
BIG SKATE	.002	.071	1.886	8.7	8.1	44.8	D
YELLOWEYE RF	.002	.071	1.808	6.9	20.7	29.9	D
FLATHEAD SOLE	.002	.357	1.738	3.3	.3	12.7	C
OCN PINK SHRIMP	.002	.214	1.720	5.2	.1	20.4	
RATFISH	.001	.464	1.461	2.5	.8	9.1	A
SHORTSPINE THORNYHD	.001	.250	1.439	4.4	.6	19.0	A
WIDOW RF	.001	.071	.956	5.0	.9	25.8	B
ENGLISH SOLE	.001	.286	.796	1.9	.9	6.9	B
CHINOOK SALMON	.001	.071	.773	2.9	9.6	12.0	E
ROSETHORN RF	.001	.071	.726	3.2	4.1	16.3	D
BOCACCIO	.001	.036	.583	3.1	16.3	16.3	B
SURF SMELT	.000	.071	.533	2.7	1.0	13.9	
DUNGENESS CRAB	.000	.143	.485	1.4	.6	5.0	
SLENDER SOLE	.000	.500	.468	.7	.2	2.0	C
PINK SHRIMP	.000	.071	.414	2.2	.1	11.5	
PACIFIC SANDDAB	.000	.107	.373	1.8	.2	9.2	B
UNID SHRIMP	.000	.107	.340	1.2	1.8	5.8	
STRIPETAIL RF	.000	.036	.336	1.8	9.4	9.4	B
REDSTRIPE RF	.000	.036	.268	1.4	7.5	7.5	D
UNID SALMON	.000	.036	.250	1.3	7.0	7.0	
SILVERGREY RF	.000	.071	.232	1.0	1.2	5.4	D
WHITEBAIT SMELT	.000	.107	.210	.6	1.9	2.0	
SHARPCHIN RF	.000	.179	.198	.6	.3	2.7	D
PACIFIC TOMCOD	.000	.107	.121	.5	.5	2.3	
SHORTRAKER RF	.000	.036	.082	.4	2.3	2.3	F
BLACK SKATE	.000	.071	.058	.2	.6	1.0	F
SPLITNOSE RF	.000	.036	.034	.2	.9	.9	A

TABLE 15, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
FLAG RF	.000	.036	.014	.1	.4	.4	A
UNID CRAB	.000	.036	.008	.0	.2	.2	

rates were slightly low for region 2a (701.3 lb./haul) and diversity was low due to dominance by Pacific hake (Table 2). Whiting were present in 95.7% of the hauls and contributed 58.4% of the total biomass (Table 16). Canary rockfish were second most abundant in terms of proportion of total biomass caught (9.7%). Dover sole, arrowtooth flounder, eulachon, sablefish, and rex sole each contributed from 6.5 to 2.1% of the total biomass; and occurred in at least 70% of the hauls. Members of species group B such as spiny dogfish, lingcod, petrale sole, longnose skate, and English sole decreased in frequency and proportion of biomass relative to areas 2ai and 2aiv, perhaps because of deeper site distributions.

Area 2aiii continued offshore and south of 2aii from latitude 45° 40'N along the shelf break to Cape Blanco (Fig. 2). Mean depth increased to 89 fm (163 m) (Table 2). Catch rate in this area was low (336.2 lb/haul), although species composition was relatively diverse (Table 2). This area was associated with other 2a regions through the presence of Pacific hake, which occurred in about 69% of the hauls and contributed 21.9% of the total biomass found in the area (Table 17). Moreover, members of group C common to other 2a areas were present, although at lower frequencies and catch rates: yellowtail rockfish, eulachon, greenstripe rockfish, canary rockfish, and Pacific cod all contributed between 9.0 and 1.2% of the total biomass and occurred in 18 to 69% of the hauls. Pygmy rockfish, pink rockfish, and coho salmon (species group H) were observed here. Species group B was represented at low levels.

TABLE 16. CATCH STATISTICS FROM ASSEMBLAGE REGION 2AII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.584	.957	409.318	697.5	10.3	2403.6	A
CANARY RF	.097	.696	68.076	206.7	2.5	917.7	C
DOVER SOLE	.065	.957	45.319	49.9	1.0	168.5	A
ARROWTOOTH FLOUNDER	.060	.957	41.903	36.6	.9	119.1	A
EULACHON	.030	.696	21.097	64.1	.2	267.5	C
SABLEFISH	.028	.696	19.459	29.0	5.5	115.0	A
REX SOLE	.021	.957	14.601	22.2	.3	77.0	A
REDSTRIPE RF	.019	.087	13.427	46.1	129.7	179.1	D
SHARPCHIN RF	.012	.174	8.616	31.7	.6	141.2	D
YELLOWTAIL RF	.009	.348	6.247	13.7	4.4	54.6	C
DARKBLOTCHED RF	.008	.609	5.800	11.0	.2	38.5	A
SHORTSPINE THORNYHD	.008	.522	5.674	12.2	.5	51.2	A
GREENSTRIPE RF	.006	.783	4.290	5.6	.5	19.9	C
PACIFIC COD	.006	.478	3.945	5.6	2.5	17.5	C
FLATHEAD SOLE	.005	.478	3.481	8.0	.5	35.2	C
PAC OCN PERCH	.004	.304	3.144	10.7	.3	48.5	A
BOCACCIO	.004	.217	2.877	6.3	5.1	19.9	B
LINGCOD	.004	.261	2.790	5.6	3.8	17.9	B
DUNGENESS CRAB	.004	.261	2.665	7.8	.5	34.2	
WIDOW RF	.003	.174	2.276	10.3	.9	48.4	B
YELLOWEYE RF	.003	.130	2.131	5.9	11.9	20.5	D
STRIPETAIL RF	.003	.174	2.032	6.8	.3	27.1	B
YELLOWMOUTH RF	.003	.043	1.875	9.2	43.1	43.1	F
RATFISH	.003	.522	1.792	2.7	.9	11.2	A
SPLITNOSE RF	.002	.130	1.252	6.0	.2	28.1	A
SPINY DOGFISH	.002	.304	1.204	2.9	1.1	13.3	B
PETRALE SOLE	.001	.217	.995	2.2	2.3	7.5	B
OCN PINK SHRIMP	.001	.130	.905	3.0	.1	10.7	
AMERICAN SHAD	.001	.217	.769	1.6	2.5	4.4	C
LONGNOSE SKATE	.001	.130	.746	3.1	1.2	14.4	B
SILVERGREY RF	.001	.087	.584	2.0	6.6	6.9	D
ROUGHEYE RF	.001	.087	.515	2.3	1.2	10.7	A
PAC ELECTRIC RAY	.000	.043	.279	1.4	6.4	6.4	GB
SLENDER SOLE	.000	.435	.278	.7	.1	3.5	C
SHORTBELLY RF	.000	.043	.170	.8	3.9	3.9	B
LOPHOLITHODES SP	.000	.087	.152	.5	1.6	1.9	
PACIFIC SANDDAB	.000	.043	.147	.7	3.4	3.4	B
ROSETHORN RF	.000	.130	.136	.4	.3	1.9	D
LONGFIN SCULPIN	.000	.043	.109	.5	2.5	2.5	
BLACK SKATE	.000	.087	.107	.5	.3	2.1	F
ENGLISH SOLE	.000	.043	.093	.5	2.1	2.1	B
FLAG RF	.000	.043	.040	.2	.9	.9	A
SPOTFIN SCULPIN	.000	.043	.010	.0	.2	.2	
WHITEBAIT SMELT	.000	.043	.004	.0	.1	.1	
PINK SHRIMP	.000	.043	.004	.0	.1	.1	

TABLE 17. CATCH STATISTICS FROM ASSEMBLAGE REGION 2AIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.219	.688	73.735	128.9	2.3	432.4	A
SABLEFISH	.132	.750	44.446	65.1	7.0	261.1	A
ARROWTOOTH FLOUNDER	.100	.750	33.550	37.3	.9	116.2	A
DOVER SOLE	.094	.875	31.471	29.6	2.5	87.7	A
YELLOWTAIL RF	.090	.250	30.108	116.7	3.0	453.7	C
PYGMY RF	.066	.063	22.303	92.1	356.9	356.9	H
EULACHON	.062	.688	20.691	54.5	.1	206.3	C
GREENSTRIPE RF	.036	.688	12.089	36.5	.5	143.4	C
SHORTSPINE THORNYHD	.025	.500	8.277	15.6	.3	51.3	A
CANARY RF	.023	.250	7.884	26.0	1.6	100.6	C
LINGCOD	.022	.250	7.496	19.3	10.7	72.5	B
DARKBLOTCHED RF	.021	.563	7.155	14.2	.9	50.0	A
REX SOLE	.016	.875	5.248	6.5	1.0	18.8	A
PACIFIC COD	.012	.188	3.994	10.3	11.5	37.5	C
PAC OCN PERCH	.012	.313	3.979	14.1	.6	55.1	A
RATFISH	.011	.188	3.668	14.3	.5	55.6	A
OCN PINK SHRIMP	.009	.438	3.071	8.9	.1	34.5	
BOCACCIO	.009	.250	2.866	6.1	4.6	20.0	B
ENGLISH SOLE	.006	.125	2.079	7.0	6.4	26.8	B
JACK MACKEREL	.006	.063	2.073	8.6	33.2	33.2	E
LONGNOSE SKATE	.006	.188	1.854	7.0	1.2	27.4	B
SPINY DOGFISH	.004	.375	1.314	1.9	2.1	4.8	B
PETRALE SOLE	.004	.438	1.268	1.8	1.1	4.4	B
STRIPETAIL RF	.003	.313	.951	3.3	.1	12.7	B
SPLITNOSE RF	.003	.188	.841	3.4	.1	13.0	A
UNID SMELT	.002	.125	.736	2.4	2.5	9.2	E
PINK RF	.002	.063	.569	2.4	9.1	9.1	H
REDSTRIPE RF	.001	.125	.488	1.9	.3	7.5	D
COHO SALMON	.001	.063	.368	1.5	5.9	5.9	H
ROUGHEYE RF	.001	.063	.324	1.3	5.2	5.2	A
PACIFIC SANDDAB	.001	.063	.220	.9	3.5	3.5	B
DUNGENESS CRAB	.001	.188	.215	.7	.4	2.5	
SHARPCHIN RF	.001	.188	.203	.6	.3	2.3	D
SHORTBELLY RF	.000	.063	.168	.7	2.7	2.7	B
WIDOW RF	.000	.063	.134	.6	2.1	2.1	B
SLENDER SOLE	.000	.313	.088	.2	.1	.5	C
UNID TANNER CRAB	.000	.063	.072	.3	1.2	1.2	
FLAG RF	.000	.125	.068	.2	.5	.6	A
FLATHEAD SOLE	.000	.063	.039	.2	.6	.6	C
PAC STAGH SCULPIN	.000	.063	.036	.2	.6	.6	
PINK SHRIMP	.000	.063	.031	.1	.5	.5	
WHITEBAIT SMELT	.000	.063	.006	.0	.1	.1	

Assemblage area 2b was found offshore of 2a as a strip along the shelf break (mean depth of 124 fm or 227 m) (Fig. 2). Average catch rates were higher than areas 2a or 1a. Pacific ocean perch, arrowtooth flounder, Dover sole, sablefish, Pacific hake, rex sole, and shortspine thornyhead occurred most frequently (species group A); and together comprised 61% of the total catch. The region had a higher proportion of Pacific ocean perch and arrowtooth flounder than the adjacent deeper assemblage region 1a or area 2a; and members of species groups B, C, and D occurred occasionally.

Assemblage region 2bi was a strip following the shelf break from latitude 47° 55'N to about 45° 50'N at an average depth of 117 fm (214 m) (Fig. 2, Table 2). Species occurring in at least 85% of the hauls in the area were Pacific ocean perch (17.0% of total biomass), arrowtooth flounder (7.4%), sablefish (7.0%), Pacific hake (6.9%), Dover sole (6.2%), shortspine thornyhead (1.6%), rex sole (1.1%), and flag rockfish (0.8%) (Table 18). Yellowtail rockfish (group C), sharpchin rockfish (group D), canary rockfish (group C), bocaccio (group B), splitnose rockfish (group A), and darkblotched rockfish (group A) all contributed between 8.2 and 1.2% of the total biomass and occurred in at least 55% of the hauls. One very large haul of lingcod (6411.3 lb) and one large haul of redstripe rockfish (2340.3 lb) were observed. Average catch per haul was thus fairly large: 1517 lb/haul (Table 2). The species composition was diverse, with about equal representation of groups B, C, and D in the species list (although species in group D were generally least abundant).

TABLE 18. CATCH STATISTICS FROM ASSEMBLAGE REGION 2BI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PAC OCN PERCH	.170	.903	258.481	453.8	1.0	2156.4	A
LINGCOD	.146	.323	221.583	1149.8	5.6	6411.3	B
YELLOWTAIL RF	.082	.548	123.743	432.1	2.6	2340.3	C
ARROWTOOTH FLOUNDER	.074	1.000	113.004	140.3	4.6	719.1	A
SHARPCHIN RF	.072	.645	109.866	312.4	.3	1616.1	D
SABLEFISH	.070	.903	105.999	136.6	3.8	497.0	A
PACIFIC WHITING	.069	1.000	105.410	147.5	.8	510.5	A
DOVER SOLE	.062	1.000	94.616	71.4	1.2	380.7	A
REDSTRIPE RF	.053	.129	80.783	456.6	.5	2501.2	D
CANARY RF	.036	.516	54.982	214.3	6.3	1166.8	C
BOCACCIO	.020	.548	30.052	72.8	4.4	365.7	B
SPLITNOSE RF	.018	.742	26.629	50.4	1.9	258.1	A
SHORTSPINE THORNYHD	.016	.871	23.777	33.3	.4	138.2	A
SILVERGREY RF	.014	.323	20.812	66.4	4.4	264.8	D
DARKBLOTCHED RF	.012	.677	17.879	34.6	1.0	157.6	A
REX SOLE	.011	.968	16.159	14.8	1.0	63.3	A
SPINY DOGFISH	.010	.484	15.395	34.8	1.8	158.7	B
WIDOW RF	.010	.452	15.385	55.5	.9	294.0	B
FLAG RF	.008	.645	11.430	21.6	.5	84.5	A
ROUGHEYE RF	.008	.194	11.383	31.7	1.2	107.0	A
PETRALE SOLE	.007	.387	9.915	26.1	.5	124.1	B
PACIFIC COD	.006	.355	8.597	19.4	1.0	88.8	C
LONGNOSE SKATE	.004	.258	6.006	14.0	1.2	48.1	B
GREENSTRIPE RF	.004	.548	5.661	12.3	.2	60.6	C
YELLOWMOUTH RF	.003	.065	4.224	22.7	6.6	124.3	E
RATFISH	.003	.613	4.181	6.5	.9	28.9	A
PACIFIC HALIBUT	.002	.097	3.273	11.8	11.6	54.5	D
STRIPETAIL RF	.002	.290	2.893	8.1	.4	35.2	B
WALLEYE POLLOCK	.002	.194	2.777	8.8	2.8	40.7	D
PAC ELECTRIC RAY	.001	.129	2.188	9.1	4.7	49.5	G
YELLOWEYE RF	.001	.097	1.905	6.4	13.9	29.1	D
OCN PINK SHRIMP	.001	.097	1.895	7.9	.5	40.0	
BIG SKATE	.001	.032	1.740	9.9	54.0	54.0	D
ROSETHORN RF	.001	.419	1.055	2.5	.3	10.2	D
EULACHON	.000	.129	.667	2.5	.2	10.0	C
BLACK SKATE	.000	.258	.440	.9	.9	3.1	E
FLATHEAD SOLE	.000	.065	.415	1.9	2.5	10.4	C
ENGLISH SOLE	.000	.161	.408	1.3	.5	5.8	B
AMERICAN SHAD	.000	.097	.371	1.8	.8	9.7	C
SHORTRAKER RF	.000	.032	.323	1.8	10.0	10.0	E
SLENDER SOLE	.000	.290	.287	.8	.2	3.8	C
DUSKY RF	.000	.032	.187	1.1	5.8	5.8	
ZOARCIDAE	.000	.065	.185	1.0	.1	5.6	
BROWN CATSHARK	.000	.032	.074	.4	2.3	2.3	E
UNID TANNER CRAB	.000	.032	.035	.2	1.1	1.1	

TABLE 18, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC HERRING	.000	.032	.020	.1	.6	.6	E
THREADFIN SCULPIN	.000	.065	.020	.1	.2	.4	
PINK SNAILFISH	.000	.032	.019	.1	.6	.6	
DUNGENESS CRAB	.000	.032	.014	.1	.4	.4	
UNID SCULPIN	.000	.032	.007	.0	.2	.2	
SPOTFIN SCULPIN	.000	.032	.006	.0	.2	.2	

Assemblage region 2bii was divided into two parts, one near Juan de Fuca Canyon and one near the Columbia River Canyon, at an average depth of 142 fm (260 m) (Fig. 2, Table 2). Catch rates were high: 1844.2 lb/haul (Table 2). Pacific ocean perch and arrowtooth flounder dominated the biomass composition; although in both cases, half of the total catch of the species in the region came from a single haul (Table 19). Seven other members of species group A contributed between 7.6 and 1.8% of the total biomass each and occurred in at least 73% of the hauls. Members of groups B, C, D, and F occurred occasionally. The low diversity arose from dominance by Pacific ocean perch.

Assemblage region 2biv occurred between 46° and 45° 30'N latitude at an average depth of 98 fm (179 m) (Fig. 2). Total catch was low compared to others in region 2b: 452.9 lb/haul (Table 2). Catches were a mixture of arrowtooth flounder, sablefish, Pacific hake and Dover sole (25.3, 16.8, 7.7 and 6.4% of total biomass, respectively) (Table 20). Other species that occurred less frequently included canary rockfish (10.4% of biomass, group C), sharpchin rockfish (6.2%, group D), and stripetail rockfish (2.9%, group B). Other members of Groups A, D, and C occurred as lower proportions of total biomass.

Area 2biii occurred as two narrow strips, one off Heceta Bank and one between Coquille Point and Cape Blanco (Fig. 2). Catch in this shelf break region (110 fm or 201 m) was low, 239.2 lb/haul (Table 2). The area may not extend as far north as Stonewall Bank: classifications of those northern sites in the analysis were ambiguous, and sites may instead be placed in region 2aiii. Catch in the area was dominated by Dover sole and Pacific ocean perch (27.4 and 16.2% of total biomass,

TABLE 19. CATCH STATISTICS FROM ASSEMBLAGE REGION 2BII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PAC OCN PERCH	.527	.933	972.600	2162.6	12.0	8305.0	A
ARROWTOOTH FLOUNDER	.116	1.000	214.029	458.9	8.8	1729.0	A
DOVER SOLE	.076	1.000	141.011	135.9	16.1	450.3	A
SPLITNOSE RF	.062	.733	114.898	287.5	2.3	826.0	A
SABLEFISH	.026	.800	48.287	63.0	3.3	197.9	A
SHORTSPINE THORNYHD	.025	.933	46.517	50.8	2.8	147.8	A
PACIFIC WHITING	.025	.867	45.347	62.0	5.3	210.5	A
DARKBLOTCHED RF	.022	.800	39.775	64.6	1.0	236.0	A
REX SOLE	.018	.933	33.901	43.0	1.9	154.2	A
SHARPCHIN RF	.013	.667	23.722	58.1	1.0	172.9	D
YELLOWMOUTH RF	.013	.133	23.666	94.2	2.5	352.5	E
SHORTRAKER RF	.012	.200	22.254	53.8	63.8	183.7	E
ROUGHEYE RF	.010	.600	18.989	35.2	.1	107.0	A
FLAG RF	.010	.600	18.131	25.4	3.5	65.0	A
SILVERGREY RF	.009	.067	16.417	65.8	246.3	246.3	D
SPINY DOGFISH	.008	.467	14.746	48.2	2.0	182.5	B
YELLOWTAIL RF	.007	.333	13.615	46.8	2.6	176.3	C
PACIFIC COD	.003	.333	5.484	14.2	2.5	52.9	C
RATFISH	.003	.600	4.813	6.5	1.1	17.5	A
WALLEYE POLLOCK	.002	.333	4.207	9.0	1.7	27.6	D
BOCACCIO	.002	.133	3.831	11.8	15.0	42.5	B
CANARY RF	.002	.200	3.521	8.4	7.5	26.7	C
PETRALE SOLE	.002	.333	3.019	6.9	4.6	25.9	B
PACIFIC HALIBUT	.001	.067	1.933	7.8	29.0	29.0	D
WIDOW RF	.001	.333	1.507	3.4	.9	11.1	B
LONGNOSE SKATE	.001	.067	1.467	5.9	22.0	22.0	B
ROSETHORN RF	.001	.467	1.135	1.7	.4	4.1	D
GREENSTRIPE RF	.001	.267	.988	2.3	.7	7.1	C
DUNGENESS CRAB	.000	.067	.800	3.2	12.0	12.0	
ENGLISH SOLE	.000	.200	.733	1.9	1.0	6.7	B
BLACK SKATE	.000	.267	.623	1.6	.8	6.0	E
GIANT WRYMOUTH	.000	.067	.607	2.4	9.1	9.1	
SLENDER SOLE	.000	.467	.468	1.1	.1	4.0	C
AMERICAN SHAD	.000	.133	.415	1.4	1.0	5.2	C
ZOARCIDAE	.000	.067	.333	1.3	5.0	5.0	
BROWN CATSHARK	.000	.067	.153	.6	2.3	2.3	E
FLATHEAD SOLE	.000	.067	.133	.5	2.0	2.0	C
PINK SNAILFISH	.000	.067	.055	.2	.8	.8	
LOPHOLITHODES F	.000	.067	.045	.2	.7	.7	
UNID SCULPIN	.000	.067	.011	.0	.2	.2	
WARTY POACHER	.000	.067	.009	.0	.1	.1	

TABLE 20. CATCH STATISTICS FROM ASSEMBLAGE REGION 2BIV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
ARROWTOOTH FLOUNDER	.253	1.000	114.746	82.8	46.2	251.5	A
SABLEFISH	.168	1.000	75.960	104.9	8.3	279.3	A
CANARY RF	.104	.286	46.997	127.6	14.4	314.6	C
PACIFIC WHITING	.077	1.000	35.041	46.9	2.3	130.0	A
DOVER SOLE	.064	1.000	29.180	16.4	10.6	57.5	A
SHARPCHIN RF	.062	.571	28.083	72.8	2.3	180.8	D
STRIPETAIL RF	.029	.714	13.040	16.6	2.1	40.0	B
NORTHERN ANCHOVY	.028	.143	12.657	36.2	88.6	88.6	
EULACHON	.025	.571	11.277	20.5	2.1	50.0	C
REX SOLE	.024	1.000	10.739	11.2	.6	31.2	A
SPINY DOGFISH	.021	.286	9.419	22.2	10.9	55.0	B
BIG SKATE	.020	.143	8.929	25.5	62.5	62.5	D
DARKBLOTCHED RF	.016	.571	7.263	11.8	.6	29.2	A
SHORTSPINE THORNYHD	.015	.857	6.833	9.8	.5	25.7	A
YELLOWTAIL RF	.012	.286	5.500	10.2	17.1	21.4	C
FLAG RF	.012	.571	5.417	6.4	5.1	15.0	A
BOCACCIO	.011	.143	5.197	14.9	36.4	36.4	B
LINGCOD	.011	.286	5.070	9.4	16.7	18.8	B
PACIFIC COD	.010	.286	4.681	10.4	7.2	25.6	C
REDSTRIPE RF	.009	.143	4.127	11.8	28.9	28.9	D
PAC OCN PERCH	.007	.571	3.346	5.8	.2	12.9	A
GREENSTRIPE RF	.007	.714	3.266	5.4	.8	14.2	C
FLATHEAD SOLE	.004	.429	1.896	3.3	1.1	7.7	C
RATFISH	.003	.429	1.334	1.8	2.7	3.5	A
SILVERGREY RF	.002	.143	.979	2.8	6.9	6.9	D
ROSETHORN RF	.002	.143	.714	2.0	5.0	5.0	D
<u>LOPHOLITHODES</u> SP	.001	.143	.459	1.3	3.2	3.2	
DUNGENESS CRAB	.001	.143	.306	.9	2.1	2.1	
PETRALE SOLE	.000	.143	.214	.6	1.5	1.5	B
SLENDER SOLE	.000	.571	.121	.1	.1	.3	C
SPLITNOSE RF	.000	.143	.090	.3	.6	.6	A
ROUGHEYE RF	.000	.143	.061	.2	.4	.4	A
OCN PINK SHRIMP	.000	.143	.019	.1	.1	.1	

respectively) (Table 21). Members of group B were more common than members of groups C or D. Lingcod, English sole, stripetail rockfish, and widow rockfish (all groups B) occurred in 68 to 33% of the hauls and contributed from 4.7 to 2.3% of the total biomass.

Area 2bv occurred between Cape Flattery and Juan de Fuca Canyon at an average depth of 143 fm (262 m). Average catch per haul (683.5 lb) was low compared to other areas in region 2, but higher than area laii, a site group of comparable average depth further south (Table 2). Arrowtooth flounder (group A), Dover sole (group A), spiny dogfish (group B), and Pacific ocean perch (group A) dominated the catches (19.5, 17.8, 4.2, and 10.7%, respectively) (Table 22). Species groups B, C, and D occurred occasionally, including pollock (2.9% of biomass, group D), sharpchin rockfish (1.2%, group D), and lingcod (1.0% , group B). Pacific cod and flathead sole (both group C) occurred in about 40% of the hauls, but at low catch rates.

Site groups 2ci and 2cii were affiliated with region 2 through the relatively frequent occurrence of species groups C and D and species in groups A and B that were especially abundant in region 2: arrowtooth flounder, Pacific ocean perch, Pacific hake (group A), and spiny dogfish, longnose skate and lingcod (group B).

Site group 2ci, located near Juan de Fuca Canyon at mean depth of 85 fm (155 m) (Fig. 2), was dominated by species from groups B, C, and D: yellowtail rockfish (group C), widow rockfish (group B), redstripe rockfish (group D), spiny dogfish (group B), Pacific cod (group C), and silvergrey rockfish (group D) contributed 42.8, 12.1, 8.9, 7.8, 5.5, and 2.5% of total biomass, respectively (Table 23). Arrowtooth flounder,

TABLE 21. CATCH STATISTICS FROM ASSEMBLAGE REGION 2BIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
DOVER SOLE	.274	.889	65.636	137.4	.4	404.5	A
PAC OCN PERCH	.162	.667	38.763	71.5	2.7	200.0	A
PACIFIC WHITING	.091	.333	21.864	59.4	11.2	170.5	A
REX SOLE	.052	.889	12.553	21.2	.3	59.5	A
LINGCOD	.047	.667	11.211	11.0	6.4	28.5	B
DARKBLOTCHED RF	.044	.667	10.559	17.1	1.8	49.0	A
ENGLISH SOLE	.043	.333	10.192	18.9	13.9	50.0	B
SHARPCHIN RF	.034	.444	8.220	18.7	1.4	54.0	D
FLAG RF	.031	.222	7.480	18.1	17.0	50.3	A
SHORTSPINE THORNYHD	.030	.556	7.089	19.0	.1	54.5	A
STRIPETAIL RF	.029	.444	7.011	16.0	.3	46.0	B
SABLEFISH	.026	.556	6.209	11.0	2.7	32.0	A
WIDOW RF	.023	.444	5.422	12.2	2.0	35.3	B
SPLITNOSE RF	.022	.667	5.311	9.1	.3	25.5	A
SILVERGREY RF	.015	.111	3.702	11.8	33.3	33.3	D
OCN PINK SHRIMP	.015	.222	3.667	11.6	.1	32.9	
YELLOWTAIL RF	.013	.222	3.000	8.4	3.0	24.0	C
BOCACCIO	.009	.111	2.111	6.7	19.0	19.0	B
ARROWTOOTH FLOUNDER	.008	.444	1.976	3.4	1.1	9.5	A
CHINOOK SALMON	.006	.111	1.360	4.3	12.2	12.2	E
RATFISH	.004	.444	.872	1.6	.2	4.3	A
PETRALE SOLE	.003	.222	.801	1.7	3.2	4.0	B
CANARY RF	.003	.111	.731	2.3	6.6	6.6	C
GREENSTRIPE RF	.003	.333	.650	1.3	.5	3.2	C
ROSETHORN RF	.003	.333	.617	1.5	.3	4.3	D
UNID SNAILFISH	.002	.111	.476	1.5	4.3	4.3	
GREENSPOT RF	.001	.111	.357	1.1	3.2	3.2	G
BIGFIN EELPOUT	.001	.111	.278	.9	2.5	2.5	E
UNID SMELT	.001	.111	.227	.7	2.0	2.0	E
ROUGHEYE RF	.001	.111	.209	.7	1.9	1.9	A
EULACHON	.001	.222	.162	.5	.1	1.4	C
SHORTBELLY RF	.000	.111	.119	.4	1.1	1.1	B
SPOT SHRIMP	.000	.111	.119	.4	1.1	1.1	
SPINY DOGFISH	.000	.111	.111	.4	1.0	1.0	B
SLENDER SOLE	.000	.333	.078	.2	.1	.5	C
BLACK SKATE	.000	.111	.036	.1	.3	.3	E
THREADFIN SCULPIN	.000	.111	.023	.1	.2	.2	
WHITEBAIT SMELT	.000	.111	.011	.0	.1	.1	

TABLE 22. CATCH STATISTICS FROM ASSEMBLAGE REGION 2BV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
ARROWTOOTH FLOUNDER	.195	.941	133.072	288.7	3.8	1144.0	A
DOVER SOLE	.178	1.000	121.416	73.6	1.8	259.9	A
SPINY DOGFISH	.142	.706	97.206	186.1	1.9	579.6	B
PAC OCN PERCH	.107	.824	73.273	114.9	1.7	363.0	A
PACIFIC WHITING	.092	1.000	63.190	85.9	2.5	344.5	A
SABLEFISH	.074	.824	50.653	51.5	11.9	150.4	A
REX SOLE	.050	.941	34.438	41.4	.4	138.0	A
FLAG RF	.026	.529	17.631	41.5	1.8	165.9	A
WALLEYE POLLOCK	.020	.765	13.991	17.6	.9	48.3	D
ROUGHEYE RF	.019	.412	12.729	26.1	.9	80.3	A
SHORTSPINE THORNYHD	.018	.882	12.178	9.7	2.2	30.0	A
RATFISH	.013	.588	8.794	12.3	.8	35.0	A
SHARPCHIN RF	.012	.235	8.059	30.7	1.3	123.5	D
LINGCOD	.010	.118	6.936	24.3	21.6	96.3	B
LONGNOSE SKATE	.009	.294	5.859	14.2	1.1	51.8	B
PACIFIC COD	.008	.412	5.235	13.7	1.9	55.0	C
PACIFIC HALIBUT	.007	.118	4.909	16.9	17.0	66.4	D
SILVERGREY RF	.006	.059	4.262	18.1	72.5	72.5	D
FLATHEAD SOLE	.004	.412	2.629	6.8	.5	27.0	C
YELLOWTAIL RF	.003	.176	1.778	6.1	2.5	24.6	C
DARKBLOTCHED RF	.002	.294	1.565	4.0	.6	12.5	A
ENGLISH SOLE	.001	.294	.734	1.5	1.1	5.8	B
BOCACCIO	.001	.059	.629	2.7	10.7	10.7	B
BIG SKATE	.001	.059	.608	2.6	10.3	10.3	D
BLACK SKATE	.001	.294	.523	1.0	.5	3.3	E
SLENDER SOLE	.001	.294	.350	1.0	.3	4.0	C
PETRALE SOLE	.000	.118	.202	.7	.9	2.5	B
AMERICAN SHAD	.000	.059	.176	.8	3.0	3.0	C
SPLITNOSE RF	.000	.176	.151	.4	.4	1.2	A
GREENSTRIPE RF	.000	.059	.118	.5	2.0	2.0	C
ROSETHORN RF	.000	.118	.066	.2	.5	.6	D
EULACHON	.000	.059	.063	.3	1.1	1.1	C
REDSTRIPE RF	.000	.059	.037	.2	.6	.6	D

TABLE 23. CATCH STATISTICS FROM ASSEMBLAGE REGION 2CI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
YELLOWTAIL RF	.428	.471	594.605	1576.9	13.2	4879.5	C
WIDOW RF	.121	.235	167.474	578.9	4.0	2283.8	B
REDSTRIPE RF	.089	.588	123.631	292.9	.5	1074.3	D
SPINY DOGFISH	.078	.882	108.949	203.6	1.1	801.9	B
PACIFIC COD	.055	.647	76.655	210.0	3.5	852.5	C
ARROWTOOTH FLOUNDER	.047	.824	65.039	82.8	1.0	310.0	A
PAC OCN PERCH	.030	.294	41.229	110.6	.1	401.3	A
SILVERGREY RF	.025	.529	34.255	72.6	5.6	280.6	D
SABLEFISH	.020	.529	27.557	49.3	2.5	158.0	A
PACIFIC HERRING	.013	.353	18.616	48.7	7.5	188.0	E
CANARY RF	.012	.471	17.064	33.7	3.8	125.0	C
PACIFIC WHITING	.012	.235	16.674	56.6	10.6	227.7	A
DOVER SOLE	.011	.706	14.615	22.0	1.1	75.9	A
RATFISH	.009	.647	12.040	31.5	.5	128.0	A
SHARPCHIN RF	.008	.529	11.064	29.7	.2	115.0	D
BIG SKATE	.007	.059	10.294	43.8	175.0	175.0	D
LINGCOD	.006	.294	8.863	18.3	11.3	65.0	B
BOCACCIO	.006	.353	8.065	14.7	8.6	45.1	B
LONGNOSE SKATE	.004	.294	5.991	10.3	14.1	28.9	B
REX SOLE	.003	.588	4.810	8.5	.9	31.0	A
GREENSTRIPE RF	.003	.353	4.114	8.4	1.4	28.2	C
PETRALE SOLE	.003	.588	3.977	5.2	1.0	14.0	B
SPLITNOSE RF	.002	.059	3.146	13.4	53.5	53.5	A
ROCK SOLE	.001	.118	1.274	5.0	1.7	20.0	D
YELLOWEYE RF	.001	.118	1.259	3.7	9.4	12.0	D
OCN PINK SHRIMP	.001	.059	1.059	4.5	18.0	18.0	
SHORTSPINE THORNYHD	.001	.118	1.026	4.3	.2	17.3	A
ENGLISH SOLE	.001	.176	1.024	2.7	1.8	9.0	B
ROUGHEYE RF	.001	.059	.735	3.1	12.5	12.5	A
WALLEYE POLLOCK	.001	.176	.699	1.7	2.8	5.8	D
PAC ELECTRIC RAY	.000	.059	.608	2.6	10.3	10.3	G
EULACHON	.000	.059	.529	2.3	9.0	9.0	C
DARKBLOTCHED RF	.000	.118	.309	1.0	1.7	3.5	A
PACIFIC SANDDAB	.000	.059	.294	1.3	5.0	5.0	B
BLACK SKATE	.000	.176	.244	.6	.5	1.9	E
ROSETHORN RF	.000	.235	.238	.6	.5	2.5	D
SLENDER SOLE	.000	.235	.206	.5	.5	1.8	C
FLAG RF	.000	.118	.199	.8	.2	3.2	A
PINK SNAILFISH	.000	.059	.034	.1	.6	.6	

Pacific ocean perch, and sablefish (all groups A) comprised 4.7, 3.0, and 2.0% of the total biomass. Although members of species group A may have occurred frequently, the biomass contributed by this group was relatively small compared to other regions. Catch rate (1385.5 lb/haul) was high (Table 2).

Site group 2cii, located off Tillamook Head at a mean depth of 78 fm (143 m) (Fig. 2), was strongly dominated by Pacific hake, which occurred in every haul (Table 24). Catch rate (473.7 lb/haul), when compared to other regions in area 2, was relatively low. About 88% of the total biomass caught in the area consisted of Pacific hake. Species from groups A and C comprised the rest of the biomass, contributing less than 4% of the total biomass each. Diversity was the lowest of any local area, due to the extreme dominance by hake.

Assemblage region 3 started as an inshore strip near Cape Falcon and extended to the shelf break south of Cape Blanco (Fig. 2, 3). The area continued as a band inshore of region 1 along the length of the sampled area to Point Hueneme. Average catch rates were lower than in region 2, and species diversity was the lowest of the three major regions. Species group B contributed a much higher proportion of biomass in this region, compared to Region 2. Species group A was represented primarily by Pacific hake, and splitnose rockfish; Dover sole and sablefish occasionally made important contributions. Species group C occurred rarely, with the exception of yellowtail rockfish, greenstripe, and occasionally canary rockfish and slender sole.

Area 3 was divided into three subregions. Region 3b was northern-

TABLE 24. CATCH STATISTICS FROM ASSEMBLAGE REGION 2CII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.876	1.000	414.810	581.7	64.7	1431.9	A
DOVER SOLE	.037	.667	17.312	39.9	.9	91.5	A
ARROWTOOTH FLOUNDER	.017	.833	7.838	8.5	.9	17.4	A
SABLEFISH	.016	.500	7.712	13.3	2.8	30.1	A
CANARY RF	.016	.667	7.682	7.1	7.3	15.6	C
REX SOLE	.010	.667	4.818	10.5	.5	24.3	A
FLAG RF	.008	.333	3.883	8.2	4.7	18.6	A
FLATHEAD SOLE	.006	.833	2.628	3.3	.9	7.7	C
SHORTSPINE THORNYHD	.005	.333	2.168	4.9	1.7	11.3	A
EULACHON	.003	.500	1.263	2.8	.5	6.5	C
LONGNOSE SKATE	.003	.167	1.227	3.3	7.4	7.4	B
YELLOWTAIL RF	.001	.167	.563	1.5	3.4	3.4	C
ROUGHEYE RF	.001	.167	.470	1.3	2.8	2.8	A
DUNGENESS CRAB	.001	.167	.383	1.0	2.3	2.3	
OCN PINK SHRIMP	.001	.333	.328	.8	.1	1.9	
RATFISH	.000	.167	.235	.6	1.4	1.4	A
PAC OCN PERCH	.000	.167	.188	.5	1.1	1.1	A
DARKBLOTCHED RF	.000	.167	.083	.2	.5	.5	A
SLENDER SOLE	.000	.333	.063	.1	.2	.2	C

TABLE 25. CATCH STATISTICS FROM ASSEMBLAGE REGION 3BII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.669	.767	345.026	723.2	3.2	2823.5	A
REDSTRIPE RF	.054	.167	27.755	152.6	.1	821.9	D
DOVER SOLE	.043	.833	22.257	22.0	.5	70.0	A
PYGMY RF	.035	.067	18.208	73.9	189.4	356.9	H
YELLOWTAIL RF	.019	.267	10.053	40.1	.8	206.3	C
ENGLISH SOLE	.018	.600	9.324	18.4	.7	71.3	B
SABLEFISH	.017	.467	8.974	24.8	.6	129.5	A
EULACHON	.017	.633	8.758	29.6	.1	157.3	C
LINGCOD	.015	.300	7.923	18.6	1.9	72.8	B
PETRALE SOLE	.012	.600	6.034	11.2	.6	55.6	B
JACK MACKEREL	.011	.033	5.859	32.6	175.8	175.8	E
PACIFIC HERRING	.011	.033	5.617	31.3	168.5	168.5	E
PACIFIC COD	.010	.100	5.013	22.5	6.6	120.0	C
DUNGENESS CRAB	.008	.267	4.278	15.2	.4	59.8	
ARROWTOOTH FLOUNDER	.008	.567	3.959	10.0	.9	53.8	A
PACIFIC SANDDAB	.007	.533	3.853	7.5	.1	33.0	B
REX SOLE	.007	.867	3.412	3.6	.3	13.6	A
OCN PINK SHRIMP	.006	.133	3.125	13.5	.5	71.3	
SPINY DOGFISH	.005	.467	2.744	4.2	1.3	16.5	B
RATFISH	.005	.400	2.737	10.3	.5	55.6	A
GREENSTRIPE RF	.002	.467	1.286	2.7	.1	11.9	C
ROCK SOLE	.002	.167	1.113	4.4	.9	23.5	D
DARKBLOTCHED RF	.002	.200	1.050	4.0	.2	21.0	A
FLATHEAD SOLE	.002	.167	.851	2.4	.5	10.0	C
UNID SANDDAB	.002	.033	.813	4.5	24.4	24.4	H
SHORTSPINE THORNYHD	.002	.167	.792	3.3	.3	17.1	A
SHORTBELLY RF	.002	.067	.777	3.8	2.7	20.6	B
COHO SALMON	.001	.067	.738	3.2	5.9	16.3	H
WHITEBAIT SMELT	.001	.133	.572	2.4	.1	12.5	
AMERICAN SHAD	.001	.233	.552	1.4	.6	5.9	C
CANARY RF	.001	.100	.481	1.5	4.1	5.4	C
SPLITNOSE RF	.001	.067	.467	2.4	1.0	13.0	A
CHINOOK SALMON	.001	.033	.345	1.9	10.4	10.4	E
YELLOWEYE RF	.001	.033	.321	1.8	9.6	9.6	D
BOCACCIO	.001	.067	.277	1.4	.8	7.5	B
SLENDER SOLE	.000	.267	.189	.5	.1	2.2	C
STRIPETAIL RF	.000	.033	.133	.7	4.0	4.0	B
PACIFIC TOMCOD	.000	.133	.079	.2	.3	1.2	
BLACK SKATE	.000	.033	.063	.3	1.9	1.9	F
ROSETHORN RF	.000	.067	.050	.2	.6	.9	D
WIDOW RF	.000	.033	.036	.2	1.1	1.1	B
ROUGHEYE RF	.000	.033	.036	.2	1.1	1.1	A
LONGNOSE SKATE	.000	.067	.033	.1	.5	.5	B
SHARPCHIN RF	.000	.067	.022	.1	.1	.5	D
UNID SMELT	.000	.067	.015	.1	.2	.3	E

TABLE 25, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
UNID LITHODID	.000	.033	.014	.1	.4	.4	
UNID HAGFISH	.000	.033	.011	.1	.3	.3	
PAC OCN PERCH	.000	.033	.003	.0	.1	.1	A

most, extending from Cape Falcon to Point Ano Nuevo at shallow depths (mean 61 fm, range 50-112 fm; or 117 m, range 91-205 m) (Table 2, Fig. 2, 3). Region 3a appeared near Trinidad Head and extended to Point Hueneme at intermediate shelf break depths (mean 100 fm, range 54-147 fm; or 183 m, range 99-267 m) (Fig. 2, 3). Region 3c replaced region 3b as the shallow water site group at Point Ano Nuevo. It extended southward to Point Hueneme, except for a gap between Point Piedras Blancas and Point Arguello. Subregions will be discussed as they appeared from north to south.

Species composition of assemblage area 3b, a shallow site group extending from Cape Falcon to Point Ano Nuevo (Fig. 2, 3) was dominated by Pacific hake, which contributed from 43.2 to 66.9% of the total biomass caught in those areas. Members of species groups E and H, although rare, occurred in this region more often than any other.

Site group 3bii was found in the northernmost of area 3b. It extended from Cape Falcon to near Coquille Point at a mean depth of 62 fm (113 m), and included sites inshore of Heceta Bank (Fig. 2). Average catch per haul (516.0 lb) was relatively low, as was diversity (Table 2). Pacific hake dominated catch in this region (66.9% of biomass in 76.7% of the hauls) (Table 25). Other species that occurred in at least 50% of the hauls included Dover sole (group A), English sole (group B), eulachon (group C), petrale sole (group B), arrowtooth flounder (group A), Pacific sanddab (group B), and rex sole (group A). These species contributed from 4.3% (Dover sole) to 0.7% (rex sole) of the total biomass. Large single hauls of redstripe rockfish (group D), pygmy rockfish (group H), jack mackerel, and Pacific herring (both group

E) were observed. All members of species group E and three members of group H were present.

Site group 3biii began just north of Cape Blanco and continued to Cape Mendocino at a mean depth of 63 fm (115 m) (Fig. 3). Catch per haul was lower than the 3bii area north of Cape Blanco (Table 2). As in the other 36 regions, species composition was dominated by Pacific hake (64.0% of total biomass, in 72% of the hauls) (Table 26). Species that occurred in at least 44% of the hauls included ocean pink shrimp (Pandalus jordani, 3.0% of the total biomass), sablefish (2.4% of total biomass), unidentified smelt (1.8%), arrowtooth flounder (1.4%), chinook salmon (0.7%), and rex sole (0.2%). Yellowtail rockfish (group C), spiny dogfish (group B), lingcod (group B), jack mackerel (group E), and longnose skate (group B) each contributed at least 1.6% of total biomass. Species group E, though rare, was represented in addition to groups A, B, and C.

Area 3bi began south of Cape Mendocino and continued past San Francisco to Point Ano Nuevo at a mean depth of 60 fm (110 m) (Fig. 3, 4). The area between Cordell Bank and Bodega Head may have included sites which could be placed in groups 3aiii or 3aiv, because some overlapping site clumps were affiliated with different clusters. The average catch per haul as well as diversity was highest of the group 3b subregions (651.2 lb/haul) (Table 2). Pacific hake accounted for 60.9% of the total biomass and occurred in 79% of the hauls (Table 27). Inshore and southern species as spiny dogfish, Pacific sanddab, English sole, lingcod, bocaccio, and petrale sole (all group B) were common (in 42 to 88% of the hauls); and collectively contributed 25.0% of the total

TABLE 26. CATCH STATISTICS FROM ASSEMBLAGE REGION 3BIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.640	.722	233.438	685.0	1.4	2828.6	A
YELLOWTAIL RF	.064	.278	23.438	68.7	4.8	254.0	C
SPINY DOGFISH	.064	.278	23.269	98.6	.5	407.0	B
OCN PINK SHRIMP	.030	.556	10.926	20.7	.7	71.3	
LINGCOD	.027	.333	9.964	17.2	10.6	46.2	B
DOVER SOLE	.027	.611	9.837	20.7	.2	78.2	A
JACK MACKEREL	.026	.056	9.422	41.1	169.6	169.6	E
SABLEFISH	.024	.444	8.847	15.6	.4	54.1	A
UNID SMELT	.018	.500	6.392	19.2	.1	78.0	E
LONGNOSE SKATE	.016	.111	5.778	20.0	23.5	80.5	B
PACIFIC HALIBUT	.015	.056	5.558	24.3	100.1	100.1	D
ARROWTOOTH FLOUNDER	.014	.444	5.041	10.9	1.4	44.2	A
STRIPETAIL RF	.009	.222	3.236	12.4	.1	51.2	B
CHINOOK SALMON	.007	.444	2.561	4.0	1.9	12.2	E
PACIFIC HERRING	.004	.167	1.415	4.2	.6	13.9	E
CANARY RF	.003	.167	1.081	2.6	4.6	8.0	C
EULACHON	.002	.167	.837	3.0	.4	12.3	C
REX SOLE	.002	.444	.707	1.4	.1	4.1	A
PETRALE SOLE	.001	.167	.511	1.4	1.3	4.7	B
DUNGENESS CRAB	.001	.111	.390	1.6	.4	6.6	
PACIFIC SANDDAB	.001	.111	.294	1.2	.5	4.8	B
WIDOW RF	.001	.056	.208	.9	3.8	3.8	B
AMERICAN SHAD	.001	.111	.201	.7	.9	2.7	C
DARKBLOTCHED RF	.001	.278	.198	.5	.1	1.3	A
RATFISH	.000	.056	.157	.7	2.8	2.8	A
ENGLISH SOLE	.000	.111	.153	.5	.9	1.9	B
WHITEBAIT SMELT	.000	.167	.148	.6	.1	2.4	
SHORTSPINE THORNYHD	.000	.056	.128	.6	2.3	2.3	A
CHILIPEPPER RF	.000	.056	.111	.5	2.0	2.0	B
NORTHERN ANCHOVY	.000	.056	.104	.5	1.9	1.9	
SLENDER SOLE	.000	.167	.056	.2	.2	.6	C
FLATHEAD SOLE	.000	.056	.042	.2	.8	.8	C
ROUGHEYE RF	.000	.056	.032	.1	.6	.6	A
GREENSTRIPE RF	.000	.056	.014	.1	.3	.3	C

TABLE 27. CATCH STATISTICS FROM ASSEMBLAGE REGION 3BI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
PACIFIC WHITING	.609	.788	396.882	939.2	2.3	5156.9	A
SPINY DOGFISH	.162	.848	105.333	208.6	3.0	959.2	B
SHORTBELLY RF	.028	.152	18.039	97.5	.1	551.4	B
DOVER SOLE	.025	.848	16.555	18.2	.4	63.8	A
PACIFIC HERRING	.024	.273	15.502	48.0	.1	191.1	E
PACIFIC SANDDAB	.022	.879	14.391	23.5	.2	116.2	B
ENGLISH SOLE	.022	.818	14.121	17.1	.2	73.3	B
LINGCOD	.020	.515	13.238	30.7	1.6	155.0	B
BOCACCIO	.018	.424	11.690	25.3	2.0	100.0	B
YELLOWTAIL RF	.013	.152	8.218	28.9	5.6	138.2	C
REX SOLE	.008	.879	5.007	5.0	.1	16.0	A
LONGNOSE SKATE	.007	.212	4.853	14.2	3.5	67.0	B
SABLEFISH	.006	.424	3.848	10.6	1.1	56.9	A
CHILIPEPPER RF	.006	.273	3.835	12.5	.5	51.0	B
PETRALE SOLE	.006	.606	3.675	4.2	.1	13.2	B
ROSETHORN RF	.004	.061	2.461	13.8	3.2	78.0	D
WIDOW RF	.003	.061	1.712	8.7	7.5	49.0	B
PLAINFIN MIDSHIP	.002	.364	1.558	3.6	.1	13.2	G
CANARY RF	.002	.152	1.529	5.2	3.8	27.0	C
EULACHON	.002	.121	1.311	7.2	.1	40.8	C
GREENSTRIPE RF	.002	.242	1.102	2.9	.5	14.0	C
RATFISH	.002	.303	1.074	3.2	.5	16.3	A
CHINOOK SALMON	.001	.061	.922	3.9	10.9	19.6	E
AMERICAN SHAD	.001	.212	.839	2.3	.3	10.0	C
PAC ELECTRIC RAY	.001	.091	.769	3.4	2.3	18.8	G
WHITEBAIT SMELT	.001	.091	.616	3.5	.1	20.0	
ROCK SOLE	.001	.091	.442	2.5	.2	13.9	D
WHITE CROAKER	.000	.061	.269	1.2	2.3	6.6	G
STRIPETAIL RF	.000	.182	.186	.8	.1	4.7	B
PACIFIC TOMCOD	.000	.242	.173	.6	.1	2.8	
ARROWTOOTH FLOUNDER	.000	.121	.169	.5	1.2	1.6	A
PINK SEA PERCH	.000	.242	.143	.3	.1	1.3	G
DARKBLOTCHED RF	.000	.152	.127	.5	.1	2.2	A
NORTHERN ANCHOVY	.000	.091	.105	.4	.6	1.9	
BLACKGILL RF	.000	.030	.105	.6	3.5	3.5	F
PINK RF	.000	.030	.091	.5	3.0	3.0	H
SPLITNOSE RF	.000	.061	.080	.4	.6	2.0	A
UNID SURFPERCH	.000	.091	.076	.4	.1	2.3	
UNID LITHODID	.000	.030	.043	.2	1.4	1.4	
SLENDER SOLE	.000	.152	.034	.1	.1	.5	C
LOPHOLITHODES F	.000	.030	.018	.1	.6	.6	
SHORTSPINE THORNYHD	.000	.061	.009	.0	.1	.2	A
GREENSPOT RF	.000	.030	.008	.0	.3	.3	G
HORNYHEAD TURBOT	.000	.030	.008	.0	.3	.3	
CURLFIN SOLE	.000	.061	.007	.0	.1	.1	

TABLE 27, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
LONGSP THORNYHD	.000	.030	.003	.0	.1	.1	
BUTTER SOLE	.000	.030	.003	.0	.1	.1	
UNID SMELT	.000	.030	.003	.0	.1	.1	E

biomass. Shortbelly rockfish, also in group B, occurred in 15% of the hauls and contributed 2.8% of the total biomass. Although Dover sole, rex sole, sablefish, and ratfish (all group A) occurred in 30 to 80% of the hauls, they collectively contributed only 4.1% of the total biomass. All members of species group E were present. Members of species group G appeared for the first time in shore, representing rare southern shallow species.

Subarea 3a was found along the shelf break (mean depth 100 fm or 183 m) from Trinidad Head to Point Hueneme, offshore of subareas 3b or 3c, (Fig. 2, 3). However, from Point Piedras Blancas to Point Arguello, it extended inshore to interrupt area 3c. Average catch per haul was larger than in areas 3b or 3c. Important species belonged to group B: shortbelly rockfish, chilipepper, stripetail rockfish, bocaccio, and spiny dogfish. Pacific hake, splitnose rockfish and Dover sole, and sablefish were the most abundant members of species group A. Members of group C were rare, with the exception of canary and greenstripe rockfish and slender sole. Species groups F and G were present, although not abundant. Subregions will be described as they occurred from north to south.

Area 3aiv occurred in two sections, one from Trinidad Head to Cape Mendocino and one from Cordell Bank to Point Montara (Fig. 2). The average site depth was 93 fm (170 m). Average catch/haul was slightly higher than average for subregion 3a (Table 2). Bocaccio, chilipepper, Pacific hake, stripetail rockfish, and lingcod (all group B except hake) together accounted for 83.4% of the total catch although 80% of the bocaccio biomass occurred in a single haul (Table 28). Darkblotched and

TABLE 28. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AIV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
BOCACCIO	.335	.533	378.361	1172.2	7.1	4533.8	B
CHILIPEPPER RF	.205	.667	231.861	565.1	2.6	2082.3	B
PACIFIC WHITING	.137	.733	154.633	452.7	1.0	1716.3	A
STRIPETAIL RF	.085	.667	95.560	168.9	.4	556.5	B
LINGCOD	.075	.533	85.129	169.3	12.3	570.1	B
DARKBLOTCHED RF	.039	.267	44.131	152.7	.2	570.8	A
CANARY RF	.036	.333	40.599	100.6	5.4	306.9	C
SABLEFISH	.018	.400	20.368	52.7	7.5	196.4	A
DOVER SOLE	.018	.733	20.091	37.9	.5	125.7	A
SPINY DOGFISH	.013	.333	14.783	37.3	4.6	126.3	B
WIDOW RF	.010	.267	11.551	35.0	2.8	129.1	B
ENGLISH SOLE	.008	.400	8.596	32.6	.2	122.5	B
HUMPY SHRIMP	.004	.133	4.189	13.6	12.8	50.0	
ARROWTOOTH FLOUNDER	.003	.333	3.663	7.4	.6	23.5	A
SHORTBELLY RF	.003	.400	3.213	6.8	.1	17.9	B
REX SOLE	.003	.733	3.033	5.6	.3	16.6	A
GREENSTRIPE RF	.003	.400	3.019	6.7	.5	20.3	C
CHINOOK SALMON	.002	.067	2.159	8.7	32.4	32.4	E
BANK RF	.002	.067	1.780	7.1	26.7	26.7	F
PETRALE SOLE	.001	.200	1.597	4.6	.9	16.6	B
ROSETHORN RF	.001	.067	.633	2.5	9.5	9.5	D
PAC OCN PERCH	.000	.067	.417	1.7	6.3	6.3	A
BLACK SKATE	.000	.133	.357	1.0	2.7	2.7	F
RATFISH	.000	.133	.300	1.0	.9	3.6	A
UNID LITHODID	.000	.067	.157	.6	2.4	2.4	
UNID SANDDAB	.000	.067	.153	.6	2.3	2.3	H
LOPHOLITHODES F	.000	.067	.133	.5	2.0	2.0	
GREENSPOT RF	.000	.067	.105	.4	1.6	1.6	G
PACIFIC SANDDAB	.000	.200	.073	.2	.1	.6	B
SPLITNOSE RF	.000	.067	.071	.3	1.1	1.1	A
SLENDER SOLE	.000	.200	.050	.1	.1	.5	C
SHORTSPINE THORNYHD	.000	.067	.036	.1	.5	.5	A
UNID SURFPERCH	.000	.067	.027	.1	.4	.4	
PLAINFIN MIDSHIP	.000	.133	.020	.1	.1	.2	G
SHARPCHIN RF	.000	.067	.007	.0	.1	.1	D

canary rockfish, sablefish, Dover sole, spiny dogfish, and widow rockfish contributed between 3.9 and 1.0% of the total biomass each; but generally occurred less frequently than members of group B (27-40% of the hauls, except Dover sole).

Area 3aiii first appeared south of Cape Mendocino and continued to Cordell Bank at an average depth of 83 fm (153 m) (Fig. 3). The mean catch per haul, 1264.1 lb, was higher than the average for region 3b. Catch was dominated by spiny dogfish (30.2% of total biomass for the area), chilipepper (19.6%), Pacific hake (18.0%), shortbelly rockfish (10.6%), and stripetail rockfish (5.6%) (all group B except hake) (Table 29). Jack mackerel (group E) mostly occurred as a single large haul (3.9% of total biomass). Dover sole (group A), bocaccio (group B), and sablefish (group A) occurred frequently, but not in large amounts. Of group C species, American shad contributed the most biomass, but greenstripe rockfish and slender sole were most frequent.

The first section of area 3aii began south of Cape Mendocino and extended to just north of Cordell Bank, and the second appeared as a short strip off Point Montara (Fig. 3). It lay offshore of region 3aiii at a mean depth of 121 fm (221 m). Catch rate in this region averaged 1229.9 lb/haul, comparable to surrounding regions 3aiii and 1biii (Table 2). Catches were dominated by chilipepper, shortbelly, and stripetail rockfish (22.1, 21.8, and 19.4% of total biomass, all group B); although most of the shortbelly biomass was observed in a single haul (Table 30). Pacific hake, splitnose rockfish, Dover sole, darkblotched rockfish, and rex sole were most abundant members of species group A. Cow rockfish (group G) contributed 1.5% of total biomass. Other

TABLE 29. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AIII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPINY DOGFISH	.302	.556	382.253	1076.6	1.3	3436.7	B
CHILIPEPPER RF	.196	.889	247.869	545.4	.1	2120.6	B
PACIFIC WHITING	.180	.889	227.220	501.1	1.0	1981.6	A
SHORTBELLY RF	.106	.611	134.359	510.2	.2	2102.0	B
STRIPETAIL RF	.056	.833	71.276	143.1	.1	440.0	B
JACK MACKEREL	.039	.111	48.906	212.9	2.3	878.0	E
DOVER SOLE	.031	1.000	39.471	31.6	1.0	103.8	A
BOCACCIO	.027	.889	33.558	42.4	1.2	143.1	B
AMERICAN SHAD	.015	.333	18.386	49.3	.9	154.7	C
SABLEFISH	.014	.722	18.265	30.4	3.5	119.6	A
YELLOWTAIL RF	.005	.056	6.528	28.5	117.5	117.5	C
LINGCOD	.005	.389	6.127	11.1	3.8	34.5	B
REX SOLE	.005	1.000	5.868	5.8	.2	19.4	A
GREENSTRIPE RF	.004	.667	4.927	7.9	.5	29.3	C
HUMPY SHRIMP	.003	.111	4.264	13.4	26.8	50.0	
CANARY RF	.003	.278	3.419	8.0	2.5	27.6	C
ENGLISH SOLE	.002	.500	2.494	5.1	.2	17.7	B
PETRALE SOLE	.001	.167	1.562	3.9	6.4	12.5	B
DARKBLOTCHED RF	.001	.389	1.479	3.0	.4	9.1	A
ARROWTOOTH FLOUNDER	.001	.222	1.139	2.7	1.9	10.0	A
SOUPFIN SHARK	.001	.056	.894	3.9	16.1	16.1	G
SLENDER SOLE	.001	.722	.789	1.3	.1	4.6	C
WIDOW RF	.001	.167	.735	1.8	3.5	6.3	B
OCN PINK SHRIMP	.001	.056	.694	3.0	12.5	12.5	
PACIFIC SANDDAB	.000	.333	.557	1.3	.2	4.6	B
SPLITNOSE RF	.000	.111	.219	.8	.5	3.5	A
PAC ELECTRIC RAY	.000	.056	.147	.6	2.6	2.6	G
UNID PANDALID	.000	.056	.128	.6	2.3	2.3	
<u>LOPHOLITHODES</u> F	.000	.056	.111	.5	2.0	2.0	
ROSETHORN RF	.000	.056	.104	.5	1.9	1.9	D
UNID CATSHARK	.000	.056	.089	.4	1.6	1.6	F
RATFISH	.000	.111	.052	.2	.1	.8	A
SHORTSPINE THORNYHD	.000	.111	.038	.1	.2	.5	A
FLAG RF	.000	.056	.032	.1	.6	.6	A
BIGFIN EELPOUT	.000	.111	.026	.1	.2	.2	F
LONGNOSE SKATE	.000	.111	.024	.1	.1	.4	B
SPOT SHRIMP	.000	.111	.018	.1	.1	.2	
DECORATOR CRAB	.000	.056	.017	.1	.3	.3	
EULACHON	.000	.111	.014	.0	.1	.1	C
ROUGHTAIL SKATE	.000	.056	.011	.0	.2	.2	F
NORTHERN ANCHOVY	.000	.056	.007	.0	.1	.1	
SHARPCHIN RF	.000	.056	.006	.0	.1	.1	D

TABLE 30. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AII, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
CHILIPEPPER RF	.221	.808	271.665	526.4	1.1	1876.0	B
SHORTBELLY RF	.218	.577	267.974	1237.4	.1	6331.2	B
STRIPETAIL RF	.194	.846	238.529	363.5	.2	1587.9	B
PACIFIC WHITING	.097	.885	119.682	410.0	.7	2080.6	A
SPLITNOSE RF	.069	.577	84.520	317.9	.2	1542.5	A
BOCACCIO	.066	.769	80.603	196.8	1.5	952.4	B
DOVER SOLE	.041	.962	50.708	47.3	1.4	166.0	A
DARKBLOTCHED RF	.026	.885	32.090	65.9	.1	255.6	A
COW RF	.015	.192	18.785	79.2	4.3	396.5	G
REX SOLE	.010	.923	11.986	14.0	.2	51.0	A
BANK RF	.006	.231	7.839	27.6	2.0	128.8	F
SABLEFISH	.005	.577	6.304	10.0	1.1	36.9	A
SOUPFIN SHARK	.004	.038	5.029	26.2	130.8	130.8	G
LINGCOD	.004	.231	4.822	14.2	3.8	64.2	B
SHARPCHIN RF	.004	.038	4.403	22.9	114.5	114.5	D
PAC ELECTRIC RAY	.003	.154	3.447	10.0	8.6	36.4	G
WIDOW RF	.002	.269	2.743	5.7	2.0	23.1	B
ROSETHORN RF	.002	.192	2.645	8.8	.6	33.9	D
SHORTSPINE THORNYHD	.002	.423	2.625	6.1	.2	25.8	A
FLAG RF	.002	.346	2.432	6.5	.2	31.3	A
ARROWTOOTH FLOUNDER	.002	.346	2.198	4.8	.5	21.3	A
ENGLISH SOLE	.001	.385	1.673	5.1	.2	25.2	B
SPINY DOGFISH	.001	.192	1.368	4.8	.1	23.5	B
GREENSTRIPE RF	.001	.385	1.276	3.3	.1	16.3	C
LONGNOSE SKATE	.001	.154	1.120	4.1	.2	18.8	B
ROUGHEYE RF	.001	.038	.655	3.4	17.0	17.0	A
HUMPY SHRIMP	.000	.038	.494	2.6	12.8	12.8	
SLENDER SOLE	.000	.577	.403	.5	.1	2.0	C
RATFISH	.000	.192	.379	.9	.4	3.0	A
CANARY RF	.000	.077	.372	1.5	2.7	7.0	C
BIGFIN EELPT	.000	.192	.248	.8	.2	3.2	F
BLACK SKATE	.000	.231	.209	.6	.1	2.7	F
GREENSPOT RF	.000	.077	.180	.9	.4	4.3	G
SPOT SHRIMP	.000	.077	.165	.6	2.1	2.1	
PACIFIC SANDDAB	.000	.077	.127	.6	.1	3.2	B
PETRALE SOLE	.000	.077	.113	.5	.3	2.6	B
AMERICAN SAHD	.000	.038	.085	.4	2.2	2.2	C
SPOTTED CUSKEEL	.000	.077	.007	.0	.1	.1	
PAC STAGH SCULPIN	.000	.038	.004	.0	.1	.1	
MYCTOPHIDAE	.000	.038	.004	.0	.1	.1	F
PYGMY POACHER	.000	.038	.004	.0	.1	.1	
BLACKMOUTH EELPOUT	.000	.038	.004	.0	.1	.1	
UNID VIPERFISH	.000	.038	.004	.0	.1	.1	
BASKETWVE CUSKEEL	.000	.038	.003	.0	.1	.1	

occasionally occurring species belonged to groups B, C, F or G.

Area 3av consisted of an outer shelf strip from Point Montara (37° 30'N) to Point Ano Nuevo and an inshore strip from Point Piedras Blancas to Point Arguello (Fig. 4). Mean depth of sites in this region was 79 fm (144 m); depths ranged from 54 to 115 fm (99 to 120 m). Diversity and catch rates in this region were lower than other local 3a regions (Table 2). Shortbelly rockfish dominated species composition in this region, comprising 46.7% of total biomass and occurring in 82% of the hauls (Table 31). Stripetail rockfish, Pacific hake, bocaccio, chilipepper, and Dover sole occurred frequently and contributed between 13.7 and 2.7% of the total biomass each. A large haul of jack mackerel (1330.0 lb) was observed at a site which bounded region 3av and 3bi. Group C was represented by greenstripe rockfish, canary rockfish, slender sole, and yellowtail rockfish at low biomass levels (less than 0.3% of total biomass).

Area 3ai began south of Point Ano Nuevo and extended south to Point Conception at a mean depth of 123 fm (225 m). Although area 3ai had the same depth distribution as 3aii that occurred farther north, species composition was dominated by splitnose (34.0% of total catch) (Table 32), rather than chilipepper rockfish. Average catch per haul (612.5 lb) and diversity were both lower than area 3aii (Table 2). Stripetail rockfish, Dover sole, Pacific hake, and chilipepper rockfish contributed 25.8, 9.2, 8.0, and 5.9% of the total biomass sampled in the area. Sablefish, spiny dogfish, bocaccio, and rex sole occurred in at least 73% of the hauls and contributed between 4.8 and 1.4% of the total biomass each. Members of species groups C and F occurred occasionally.

TABLE 31. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AV, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SHORTBELLY RF	.467	.821	384.875	1223.6	.1	6146.1	B
STRIPETAIL RF	.137	.750	113.051	220.6	.2	706.1	B
PACIFIC WHITING	.109	.750	89.468	205.4	.1	1034.0	A
BOCACCIO	.060	.643	49.054	146.3	.1	695.6	B
JACK MACKEREL	.058	.036	47.607	256.5	1333.0	1333.0	E
CHILIPEPPER RF	.030	.714	24.612	59.5	.2	257.0	B
DOVER SOLE	.027	.821	22.022	36.4	.6	155.3	A
SPINY DOGFISH	.020	.500	16.464	45.3	3.8	235.2	B
OCN PINK SHRIMP	.012	.143	10.289	31.8	.6	128.8	
REX SOLE	.011	.714	9.253	20.3	.2	102.7	A
PACIFIC SANDDAB	.011	.536	9.124	16.5	.3	53.8	B
WIDOW RF	.008	.286	6.311	28.8	1.0	150.4	B
SPLITNOSE RF	.007	.286	5.765	23.2	.2	120.0	A
LONGNOSE SKATE	.006	.179	4.664	15.7	1.3	64.4	B
PAC ELECTRIC RAY	.005	.357	4.272	10.1	.6	36.4	G
PETRALE SOLE	.004	.500	3.424	8.8	.2	43.7	B
LINGCOD	.004	.250	3.374	8.5	2.0	34.5	B
WHITE CROAKER	.004	.107	2.912	12.8	1.9	65.6	G
SABLEFISH	.003	.429	2.441	4.4	.2	15.0	A
GREENSTRIPE RF	.003	.393	2.148	4.2	.6	13.2	C
GREENSPOT RF	.003	.250	2.097	9.3	.3	47.9	G
RATFISH	.002	.286	1.902	3.8	1.2	13.2	A
CANARY RF	.002	.214	1.600	4.2	1.9	16.9	C
COW RF	.002	.143	1.427	4.8	1.9	20.2	G
SLENDER SOLE	.002	.429	1.293	3.0	.1	13.2	C
ENGLISH SOLE	.001	.500	1.214	2.0	.2	8.1	B
SPECKLED RF	.001	.071	.851	4.5	.3	23.5	G
DARKBLOTCHED RF	.000	.107	.233	1.0	.6	5.4	A
BANK RF	.000	.071	.226	.9	1.7	4.6	F
UNID CRAB	.000	.071	.226	1.0	1.2	5.2	
YELLOWTAIL RF	.000	.107	.191	.7	1.0	3.2	C
SHORTSPINE THORNYHD	.000	.107	.165	.8	.2	4.0	A
ZOARCIDAE	.000	.179	.149	.4	.3	1.3	
ROSETHORN RF	.000	.036	.123	.7	3.5	3.5	D
VERMILION RF	.000	.036	.123	.7	3.5	3.5	F
PINK SEA PERCH	.000	.250	.117	.3	.1	1.7	G
PLAINFIN MIDSHIP	.000	.107	.073	.2	.4	1.2	G
OLIVE RF	.000	.036	.067	.4	1.9	1.9	
SPOTTED CUSKEEL	.000	.143	.059	.2	.1	1.3	
SPOT SHRIMP	.000	.107	.058	.2	.4	.7	
PACIFIC ARGENTINE	.000	.071	.045	.2	.1	1.2	G
PACIFIC POMPANO	.000	.071	.045	.2	.1	1.2	
SHARPCHIN RF	.000	.036	.041	.2	1.2	1.2	D
FLAG RF	.000	.036	.034	.2	.9	.9	A
UNID CATSHARK	.000	.036	.021	.1	.6	.6	F

TABLE 31, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
RAGFISH	.000	.036	.021	.1	.6	.6	
BIGFIN EELPOUT	.000	.036	.014	.1	.4	.4	F
BUTTERFISH	.000	.071	.008	.0	.1	.1	
BLACKTAIL SNAILFISH	.000	.036	.004	.0	.1	.1	

TABLE 32. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SPLITNOSE RF	.340	1.000	208.286	433.7	.3	1542.5	A
STRIPETAIL RF	.258	.962	157.753	237.7	.5	776.9	B
DOVER SOLE	.092	.923	56.383	57.0	2.0	187.3	A
PACIFIC WHITING	.080	.962	49.161	51.7	.8	205.0	A
CHILIPEPPER RF	.059	.731	35.849	96.9	.5	471.9	B
SABLEFISH	.048	.808	29.568	77.5	.9	335.0	A
SPINY DOGFISH	.031	.731	18.822	29.5	3.8	111.9	B
BOCACCIO	.024	.923	14.887	14.8	1.6	60.0	B
REX SOLE	.014	.846	8.538	13.7	.5	65.3	A
LINGCOD	.008	.500	4.962	8.9	1.5	38.5	B
PAC ELECTRIC RAY	.008	.500	4.855	7.1	1.1	26.3	G
BANK RF	.007	.500	4.548	8.5	.5	32.3	F
RATFISH	.005	.538	2.936	4.6	1.9	19.7	A
WIDOW RF	.004	.346	2.450	5.3	1.9	23.1	B
SHORTSPINE THORNYHD	.004	.462	2.180	6.9	.2	34.5	A
FLAG RF	.003	.115	2.034	6.8	8.1	31.3	A
SHORTBELLY RF	.003	.346	1.593	4.3	.5	16.3	B
PETRALE SOLE	.002	.154	1.088	3.9	.5	18.2	B
DARKBLOTCHED RF	.002	.231	1.050	2.8	.5	11.9	A
ENGLISH SOLE	.001	.231	.833	2.7	.4	13.0	B
GREENSPOT RF	.001	.192	.759	2.4	.6	11.5	G
WOLFEEL	.001	.038	.723	3.8	18.8	18.8	
OCN PINK SHRIMP	.001	.269	.433	1.1	.2	4.7	
GREENSTRIPE RF	.001	.192	.404	1.1	.5	4.0	C
SLENDER SOLE	.001	.577	.373	.6	.1	2.5	C
ZOARCIDAE	.001	.346	.321	.7	.1	3.0	
LONGNOSE SKATE	.000	.077	.261	1.0	2.1	4.7	B
CANARY RF	.000	.038	.247	1.3	6.4	6.4	C
PACIFIC SANDDAB	.000	.077	.217	.9	1.3	4.4	B
BLACKGILL RF	.000	.038	.173	.9	4.5	4.5	F
BLACK SKATE	.000	.115	.163	.6	.1	2.3	F
VERMILION RF	.000	.038	.133	.7	3.5	3.5	F
SPOTTED CUSKEEL	.000	.192	.088	.3	.1	1.3	
SPOT SHRIMP	.000	.192	.086	.3	.1	1.5	
UNID CRAB	.000	.077	.077	.3	1.0	1.0	
YELLOWTAIL RF	.000	.038	.072	.4	1.9	1.9	C
THREADFIN SCULPIN	.000	.154	.053	.2	.1	.5	
SHARPCHIN RF	.000	.038	.044	.2	1.2	1.2	D
UNID LITHODID	.000	.038	.038	.2	1.0	1.0	
BIGFIN EELPOUT	.000	.192	.033	.1	.1	.5	F
LONGSP THORNYHD	.000	.038	.029	.2	.8	.8	
RAGFISH	.000	.038	.022	.1	.6	.6	
UNID SHRIMP	.000	.038	.004	.0	.1	.1	
SCABBARDFISH	.000	.038	.004	.0	.1	.1	
MEDUSAFISH	.000	.038	.004	.0	.1	.1	
PACIFIC POMPANO	.000	.038	.003	.0	.1	.1	

Area 3avi was found inside the Santa Barbara Channel at a mean depth of 90 fm (165m) (Fig. 4). Although catch rates were quite low (188.5 lb/haul), diversity was relatively high (Table 2). Species composition was a mixture of bocaccio, Pacific hake, stripetail rockfish, and spiny dogfish. Each species contributed 17.4 to 12.9% of the total biomass (Table 33). Fourteen species, belonging to groups A, B, G, and E accounted for between 8.2 and 1.0% of total catch. Other members of groups A, B, C, G, and F occurred occasionally.

Area 3c began near Point Ano Nuevo and extended to Point Hueneme at a mean depth of 56 fm (102 m) (Fig. 4). Both regions 3avi and 3c were found inside the Santa Barbara Channel, and had low standing stocks (178.2 lb/haul average at 3c) but high diversities for region 3. The similarity level of sites within this group was lower than that among sites in other groups. Catch was dominated by shortbelly rockfish (21.2% of total biomass in the area), spiny dogfish (11.4%) and English sole (6.7%), and a single haul of yellowtail rockfish (17.2%), (Table 34). Greenstripe rockfish, bocaccio, Pacific hake, and sanddab contributed between 5.8 and 5.5% of total biomass each; petrale sole, lingcod, ratfish, chilipepper, and mola mola accounted for 3.8 and 1.0% of total biomass each. Most of the rare species included in the analysis belonged to group G.

Principal Component Analysis, Variance-Covariance Matrix

The first 13 components generated from a variance-covariance matrix of proportionalized clumped data accounted for 91.5% of the overall

TABLE 33. CATCH STATISTICS FROM ASSEMBLAGE REGION 3AVI, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
BOCACCIO	.174	.900	32.784	35.1	3.5	100.6	B
PACIFIC WHITING	.145	.900	27.363	32.1	2.0	79.4	A
STRIPETAIL RF	.139	.800	26.190	80.9	.1	244.4	B
SPINY DOGFISH	.129	.900	24.239	30.8	3.6	100.6	B
PAC ELECTRIC RAY	.082	.500	15.452	30.3	8.5	93.2	G
NORTHERN ANCHOVY	.045	.300	8.479	28.2	.1	84.6	
SABLEFISH	.035	.700	6.591	8.1	3.8	23.0	A
SHORTBELLY RF	.034	.800	6.394	15.9	.1	48.9	B
SPLITNOSE RF	.024	.500	4.616	8.6	2.8	26.5	A
CHILIPEPPER RF	.024	.700	4.514	7.1	.5	20.7	B
OCN PINK SHRIMP	.022	.200	4.140	12.3	4.4	37.0	
RATFISH	.022	.800	4.109	7.6	.9	24.2	A
DOVER SOLE	.020	.700	3.779	4.9	2.0	15.0	A
PETRALE SOLE	.014	.300	2.595	7.6	1.1	23.0	B
ENGLISH SOLE	.013	.600	2.490	4.4	.6	13.2	B
SPECKLED RF	.012	.100	2.354	7.8	23.5	23.5	G
GREENSPOT RF	.012	.300	2.276	4.3	4.0	11.3	G
CHINOOK SALMON	.010	.100	1.974	6.6	19.7	19.7	E
COW RF	.007	.100	1.380	4.6	13.8	13.8	G
UNID CRAB	.007	.500	1.366	2.7	.1	8.1	
PLAINFIN MIDSHIP	.006	.400	1.045	1.8	.2	4.0	G
REX SOLE	.004	.800	.809	.7	.2	2.0	A
SPOT SHRIMP	.004	.400	.737	2.3	.1	6.9	
WIDOW RF	.004	.100	.696	2.3	7.0	7.0	B
PACIFIC ARGENTINE	.003	.500	.560	1.2	.1	3.8	G
YELLOWTAIL RF	.002	.100	.321	1.1	3.2	3.2	C
SLENDER SOLE	.002	.800	.304	.3	.1	1.0	C
PACIFIC SANDDAB	.002	.300	.295	.7	.2	2.1	B
FLAG RF	.001	.200	.273	.6	1.2	1.6	A
BIGFIN EELPOUT	.001	.300	.148	.4	.1	1.2	F
MYCTOPHIDAE	.001	.100	.115	.4	1.2	1.2	F
BLACK SKATE	.000	.100	.088	.3	.9	.9	F
SPOTTED CUSKEEL	.000	.200	.018	.0	.1	.1	
THREADFIN SCULPIN	.000	.100	.012	.0	.1	.1	
HALFBANDED RF	.000	.100	.012	.0	.1	.1	
LONGSP COMBFISH	.000	.100	.009	.0	.1	.1	

TABLE 34. CATCH STATISTICS FROM ASSEMBLAGE REGION 3C, CAPE FLATTERY TO POINT HUENEME.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
SHORTBELLY RF	.212	.545	37.866	108.8	.1	460.0	B
YELLOWTAIL RF	.172	.045	30.641	147.1	674.1	674.1	C
SPINY DOGFISH	.114	.500	20.330	43.0	3.5	144.9	B
ENGLISH SOLE	.067	.682	11.947	27.7	.5	125.2	B
GREENSTRIPE RF	.058	.136	10.412	48.5	1.2	222.6	C
BOCACCIO	.056	.136	9.930	46.2	.2	211.9	B
PACIFIC WHITING	.056	.409	9.916	32.9	.6	150.4	A
PACIFIC SANDDAB	.055	.727	9.811	18.4	.1	65.8	B
PETRALE SOLE	.038	.727	6.842	9.2	.2	32.5	B
LINGCOD	.026	.364	4.634	11.0	1.1	47.6	B
RATFISH	.021	.409	3.761	8.6	1.2	37.4	A
LONGNOSE SKATE	.015	.045	2.626	12.6	57.8	57.8	B
CHILIPEPPER RF	.014	.409	2.560	6.7	.2	28.0	B
MOLA MOLA	.010	.091	1.780	7.3	6.2	33.0	G
JACK MACKEREL	.009	.091	1.685	6.5	7.9	29.1	E
CANARY RF	.009	.227	1.570	4.1	1.9	17.1	C
PLAINFIN MIDSHIP	.009	.364	1.556	4.2	.3	18.7	G
DOVER SOLE	.008	.455	1.401	3.2	.1	12.5	A
SABLEFISH	.008	.182	1.351	3.9	1.9	15.0	A
COPPER RF	.007	.091	1.313	5.2	5.4	23.5	G
SOUPFIN SHARK	.005	.045	.973	4.7	21.4	21.4	G
PAC ELECTRIC RAY	.005	.318	.954	2.2	.5	9.4	G
WHITE CROAKER	.005	.182	.951	3.1	1.5	13.8	G
LEOPARD SHARK	.003	.091	.549	1.9	4.2	7.9	G
STRIPETAIL RF	.003	.409	.446	.8	.2	2.8	B
PINK SEA PERCH	.002	.409	.441	1.0	.1	4.3	G
REX SOLE	.002	.273	.365	.7	.5	2.1	A
CURLFIN SOLE	.001	.182	.228	.7	.3	2.8	
GREENSPOT RF	.001	.091	.195	.7	1.1	3.2	G
PACIFIC ARGENTINE	.001	.091	.154	.7	.2	3.2	G
HORNYHEAD TURBOT	.001	.136	.146	.6	.2	2.5	
PACIFIC HERRING	.001	.045	.131	.6	2.9	2.9	E
SPLITNOSE RF	.001	.136	.123	.4	.4	1.8	A
ROCK SOLE	.001	.045	.097	.5	2.1	2.1	D
SLENDER SOLE	.001	.227	.093	.3	.1	1.3	C
OLIVE RF	.000	.045	.085	.4	1.9	1.9	
BIGMOUTH SOLE	.000	.136	.082	.2	.4	.8	
CAL SCORPIONFS	.000	.045	.080	.4	1.8	1.8	
BLACK SKATE	.000	.045	.052	.3	1.2	1.2	F
HALFBANDED RF	.000	.182	.046	.1	.1	.5	
CANCER PRODUCTUS	.000	.045	.045	.2	1.0	1.0	
BIGFIN EELPOUT	.000	.091	.036	.1	.4	.4	F
SPOTTED CUSKEEL	.000	.045	.009	.0	.2	.2	
LONGSP COMBFISH	.000	.091	.008	.0	.1	.1	
UNID SHRIMP	.000	.045	.005	.0	.1	.1	

TABLE 34, CONTINUED.

SPECIES	PROP TOTAL REGION CATCH	FREQ OCCUR (% HAULS)	MEAN (LB/ HAUL)	STD DEV	MIN CATCH (LB)	MAX CATCH (LB)	SPECIES GROUP
MEDUSAFISH	.000	.045	.004	.0	.1	.1	
SHARPCHIN RF	.000	.045	.004	.0	.1	.1	D

variance (Table 35). Components generally were most highly correlated with only one, two, or occasionally three species (Table 36). The first component, accounting for 26.3% of the variance, was most highly correlated with hake (r = 0.97). Negative correlations with Dover sole, rex sole, sablefish, splitnose rockfish and other deepwater species reflected the shallow to mid-shelf center of distribution for hake. Lack of other high positive correlations may reflect the tendency of hake to dominate many catches in which they occur, because they are strongly schooling fish.

The second component, accounting for 13.6% of the overall variance, was most highly correlated with splitnose rockfish (r = 0.686) and Dover sole (r = 0.504). Splitnose generally occurred in highest relative abundances south of 40°N, at depths between 150-200 fm (275-366 m). Other species whose abundances correlated positively with this component had centers of distribution between 150-200 fm, or were more common in the south (e.g. bank rockfish, bigfin eelpout). Species with negative correlations were generally limited to shallower water, often in the south.

The third principal component was positively correlated with species usually found at depths greater than 100 fm (183 m). Many species were most common north of 42°N, occurred occasionally north of 40° N and relatively rarely south of 38° N (e.g. arrowtooth flounder, shortspine thornyhead, Pacific ocean perch, rougheye rockfish). Species with negative correlations were often concentrated inshore and to the south. This component accounted for 11.6% of the overall variance.

The fourth component (7.2% of variance) was related to the

Table 35. Eigenvalues, percent associated variance, cumulative variance explained by principal components generated from variance-covariance matrix

Principal component	Eigenvalue	Percent variance	Cumulative percent variance
1	.05415	26.3	26.3
2	.02814	13.6	39.9
3	.02392	11.6	51.5
4	.01483	7.2	58.7
5	.01344	6.5	65.2
6	.01157	5.6	70.8
7	.01109	5.4	76.2
8	.00861	4.2	80.4
9	.00740	3.6	84.0
10	.04658	2.3	86.3

Table 36. Correlation of species abundances with principal components generated from variance-covariance matrix. Values less than ± 0.10 are denoted with an asterisk.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Brown catshark	-.11	.11	*	*	*	*	*	*	*	*
Filetail catshark	-.14	.13	*	*	*	*	.11	.16	*	*
Longnose catshark	-.14	.12	*	*	*	*	.11	.13	*	*
Unid. catshark	*	*	*	*	*	*	*	*	*	*
Spiny dogfish	*	-.37	-.16	-.46	*	-.76	*	*	*	.15
Black skate	-.15	.19	.27	*	*	*	*	*	*	*
Longnose skate	*	-.13	*	*	*	*	*	*	*	*
Electric ray	*	*	-.19	*	*	*	*	*	*	*
Ratfish	*	-.13	*	-.18	*	-.37	*	*	*	*
Pacific sanddab	*	-.25	*	-.16	*	-.19	*	*	*	*
Arrowtooth flounder	*	-.14	.34	-.21	-.11	.15	-.29	.16	*	-.23
Flathead sole	.16	*	*	*	*	*	*	*	*	-.14
Slender sole	*	*	*	*	*	*	*	*	*	-.14
Petrale sole	*	-.25	*	-.14	*	-.16	*	*	*	-.17
English sole	*	-.18	*	-.12	*	-.23	*	*	*	*
Dover sole	-.46	.50	.56	.20	.12	-.14	.17	-.32	*	*
Rex sole	-.32	.34	.26	*	*	*	*	-.24	*	-.13

Table 36, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Shortspine thornyhead	-.25	.13	.47	*	*	*	-.21	.13	*	*
Rougheye rockfish	-.13	*	.28	*	*	*	*	.14	*	*
Pacific ocean perch	-.19	-.11	.32	-.19	-.11	.24	-.79	-.13	*	.22
Aurora rockfish	-.11	.16	.10	*	*	*	.13	.14	*	*
Silvergrey rockfish	*	-.13	*	-.11	*	*	*	*	*	-.40
Darkblotched rockfish	-.10	*	*	*	*	.12	-.34	-.12	.10	*
Splitnose rockfish	-.34	.69	-.63	-.11	*	*	*	*	*	*
Greenstripe rockfish	*	-.11	*	*	*	*	*	*	*	-.16
Greenspotted rockfish	*	*	-.16	*	*	*	*	*	*	-.18
Widow rockfish	*	-.18	*	-.13	-.14	.20	.17	*	*	*
Yellowtail rockfish	*	-.30	*	-.41	-.29	.51	.54	-.16	*	.26
Chilipepper	*	-.31	-.29	.65	-.32	*	*	*	-.52	.11
Rosethorn rockfish	*	*	*	*	*	*	*	*	*	*
Shortbelly rockfish	*	-.38	-.27	.15	.84	.19	*	*	*	*
Cow rockfish	*	*	-.19	.11	.19	*	*	*	*	*
Blackgill rockfish	-.19	.22	*	*	*	.14	*	*	*	*
Bocaccio	*	-.26	-.18	.24	*	*	*	*	*	-.36

Table 36, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Shortspine thornyhead	-.25	.13	.47	*	*	*	-.21	.13	*	*
Rougheye rockfish	-.13	*	.28	*	*	*	*	.14	*	*
Pacific ocean perch	-.19	-.11	.32	-.19	-.11	.24	-.79	-.13	*	.22
Aurora rockfish	-.11	.16	.10	*	*	*	.13	.14	*	*
Silvergrey rockfish	*	-.13	*	-.11	*	*	*	*	*	-.40
Darkblotched rockfish	-.10	*	*	*	*	.12	-.34	-.12	.10	*
Splitnose rockfish	-.34	.69	-.63	-.11	*	*	*	*	*	*
Greenstripe rockfish	*	-.11	*	*	*	*	*	*	*	-.16
Greenspotted rockfish	*	*	-.16	*	*	*	*	*	*	-.18
Widow rockfish	*	-.18	*	-.13	-.14	.20	.17	*	*	*
Yellowtail rockfish	*	-.30	*	-.41	-.29	.51	.54	-.16	*	.26
Chilipepper	*	-.31	-.29	.65	-.32	*	*	*	-.52	.11
Rosethorn rockfish	*	*	*	*	*	*	*	*	*	*
Shortbelly rockfish	*	-.38	-.27	.15	.84	.19	*	*	*	*
Cow rockfish	*	*	-.19	.11	.19	*	*	*	*	*
Blackgill rockfish	-.19	.22	*	*	*	.14	*	*	*	*
Bocaccio	*	-.26	-.18	.24	*	*	*	*	*	-.36

Table 36, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Canary rockfish	*	-.19	*	-.18	-.15	.22	.16	*	*	-.60
Redstripe rockfish	*	-.11	*	-.10	*	*	*	*	*	-.30
Yelloweye rockfish	*	*	*	*	*	*	*	-.13	*	-.10
Flag rockfish	*	*	.14	*	*	*	-.19	.10	*	*
Stripetail rockfish	*	-.23	-.28	.57	-.26	*	*	*	.66	.12
Sharpchin rockfish	*	-.14	*	-.13	*	.16	-.31	*	*	-.11
Bank rockfish	-.15	.25	-.28	*	*	*	*	*	*	*
Shortraker rockfish	*	*	.10	*	*	*	-.10	*	*	*

distribution of four shallow water species. Spiny dogfish and yellowtail rockfish were negatively correlated with this component (r = -0.456 and -0.048, respectively); both these species were most common at depths shallower than 100 fm, and spiny dogfish and yellowtail were both relatively common north of 46° N. The two species with the highest positive correlations with the fourth component were chilipepper and stripetail rockfishes (r = 0.646 and 0.569, respectively). Bocaccio also showed a slight positive correlation with this component (r = 0.236). All these species were found at depths between 75-100 fm (137-183 m), and occasionally shallower; but rarely north of 41° N.

The fifth principal component appeared to reflect shortbelly rockfish abundance, which was concentrated south of 39° N and shallower than 100 fm; and contrasted with distribution patterns of yellowtail, chilipepper, and striptail rockfishes as described earlier. This component reflects 6.5% of the overall variance.

Abundances of spiny dogfish and ratfish were most highly correlated with the sixth principal component (r = 0.757, -0.369, respectively). Although these two species were ubiquitous, spiny dogfish were proportionally most abundant in water shallower than 100 fm (183 m). Other species that were negatively correlated with this component were common south of 39° N and shallower than 75 fm (137 m). Yellowtail rockfish, in contrast, were more common in northern shallow water; hence a positive correlation (r = 0.551) with this component, which captured 5.6% of the overall variance.

The seventh principal component reflected mid-depth abundance patterns in the northern portion of the survey area. Pacific ocean perch, an offshore species, was correlated most strongly with this component (r = 0.794); other species with negative correlations include shortspine thornyhead, darkblotched rockfish, sharpchin rockfish, and arrowtooth flounder, all with distributions rarely extending further south than 39° N, and less common deeper than 175 fm (320 m) and shallower than 75 fm (137 m). The shallower but northern distribution of yellowtail flounder is reflected via its positive correlation with this component (r = 0.541), which accounted for 5.4% of the overall variance.

The eighth principal component was correlated most highly with a single species, sablefish (r = 0.735); the ninth principal component was correlated highly with chilipepper (r = -0.517) and stripetail (r = 0.664). These two components reflected 4.2 and 3.6% of total variance, respectively.

The tenth principal component was negatively correlated with silvergrey, bocaccio, canary, and redstripe rockfish (r = -0.398, -0.362, -0.598, and -0.304, respectively). Although silvergrey and redstripe rockfish were found only north of 44° N, usually between 75-125 fm (137-229 m); bocaccio were commonly found south of 44° N, often shallower than 100 fm (183 m), and canary rockfish were found from 50-125 fm (91-229 m) and in larger proportions north of 44° N. Only 2.3% of total variance is accounted for by this component.

Arrowtooth flounder were positively correlated (r = 0.479) with principal component 11, while bocaccio were negatively correlated (r = -0.656). About 1.8% of total variance is included via this component.

The twelfth and thirteenth components, while perhaps eligible for consideration, were not treated in detail. Biological interpretation of component correlations beyond this point appears difficult.

Principal Component Analysis, Correlation Matrix

The first 22 principal components generated from a correlation matrix of proportionalized data accounted for only 53.5% of the overall variance. When species abundances were correlated with principal components, fewer extremely high (above ± 0.60) or low (below ± 0.10) correlations were found, as compared with those generated for the covariance matrix. More correlations were found between ±0.3 and ±0.5. Thus, although the number of species correlating "highly" with a particular component increased, the degree of correlation decreased. Components appeared more closely related to environmental factors or multispecies distribution patterns than to the contributions of only one or two single species. Interpretation of components becomes much more subjective and difficult (Table 37, Table 38).

The first principal component was probably a depth factor. Species that were positively correlated with this component (filetail catshark, longnose catshark, black skate, Dover sole, rex sole, sablefish, bigfin eelpout, shortspine thornyhead, rougheye, aurora, splitnose, blackgill, and flag rockfish) were considered deepwater species. Species with negative correlations (spiny dogfish, longnose skate, ratfish, sanddab, slender, petrale and English sole, plainfin midshipman, pink sea perch, lingcod) were all usually concentrated at depths less than 100 fm (183 m). This component accounted for 8.2% of overall variance.

Table 37. Eigenvalues, percent associated variance, cumulative variance explained by principal components generated from correlation matrix.

Principal component	Eigenvalue	Percent variance	Cumulative percent variance
1	4.826	8.2	8.2
2	3.375	5.7	13.9
3	2.889	4.9	18.8
4	2.434	4.1	22.9
5	2.173	3.7	26.6
6	1.956	3.3	29.9
7	1.769	3.0	32.9
8	1.761	2.9	35.8
9	1.671	2.8	38.6
10	1.609	2.7	41.3

Table 38. Correlation of species abundances with principal components generated from correlation matrix. Values less than ± 0.10 are denoted with an asterisk.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Brown catshark	.19	.16	*	*	*	*	*	*	-.12	.23
Filetail catshark	.33	.46	.10	.42	*	.35	-.17	*	*	-.21
Longnose catshark	.33	.44	*	.43	*	.38	-.17	-.11	.11	-.21
Unid. catshark	.20	.23	*	.30	*	*	*	-.13	*	.67
Spiny dogfish	-.45	.12	*	*	-.26	*	-.28	.11	.21	-.15
Black skate	.40	.24	-.18	*	*	*	*	-.12	*	-.23
Longnose skate	-.31	.17	-.28	*	-.12	.17	.35	*	-.13	*
Electric ray	-.13	.22	.28	-.23	*	.18	-.33	.20	*	-.11
Ratfish	-.23	.21	-.11	*	*	*	-.40	.29	.11	*
Pacific sanddab	-.60	.45	-.33	*	-.19	.15	.28	*	*	*
Arrowtooth flounder	.14	-.44	-.47	*	-.11	.15	-.23	.17	-.17	*
Flathead sole	*	-.26	-.18	.28	*	-.12	-.18	.24	-.35	*
Slender sole	-.39	.34	-.22	-.12	*	*	.11	*	-.11	.15
Petrale sole	-.49	.29	-.33	*	.50	-.13	-.24	-.11	*	*
English sole	-.52	.33	-.30	*	-.22	-.12	-.17	*	*	*
Dover sole	.63	.28	-.24	-.10	*	-.15	*	.13	-.11	-.13
Rex sole	.41	.30	-.21	*	.14	-.29	*	.23	-.18	.31

Table 38, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Shortspine thornyhead	.48	*	-.47	-.30	*	.16	*	-.10	*	-.10
Rougheye rockfish	.27	*	-.36	-.32	*	.12	-.13	-.25	-.15	*
Pacific ocean perch	.18	-.30	-.33	-.27	*	.17	*	*	.30	.12
Aurora rockfish	.40	.45	*	.43	*	.13	*	-.17	*	.50
Silvergrey rockfish	*	-.21	*	.17	.11	.31	*	.19	.38	*
Greenspotted rockfish	-.20	.14	.27	-.22	.21	.27	-.31	.17	-.28	*
Darkblotched rockfish	.18	-.11	*	-.27	*	-.13	.20	*	.24	*
Splitnose rockfish	.27	.26	.33	-.12	.12	-.26	.17	.43	*	*
Greenstripe rockfish	*	-.21	*	*	*	.10	*	*	*	.14
Widow rockfish	-.15	-.10	*	*	.10	.34	.26	*	-.16	*
Yellowtail rockfish	-.18	-.26	*	.36	*	.19	.31	*	-.31	-.24
Chilipepper	-.16	*	.38	-.11	*	*	*	-.32	*	*
Rosethorn rockfish	*	*	*	*	*	*	.16	-.12	*	*
Shortbelly rockfish	-.19	.36	.21	*	.16	*	-.12	-.17	.14	*
Cow rockfish	-.10	*	.33	-.22	.11	.10	-.26	*	*	*
Blackgill rockfish	.34	.39	*	.30	*	.12	*	*	*	-.19
Bocaccio	-.25	*	.48	-.21	.17	.33	-.14	*	-.24	.11

Table 38, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Rock sole	-.21	.18	-.31	.12	.72	-.20	*	-.21	*	*
Sablefish	.53	.15	-.24	*	*	.18	*	-.11	*	-.15
Plainfin midshipman	-.50	.44	-.15	-.21	-.14	.15	*	.11	*	*
Jack mackerel	-.16	*	*	.12	-.11	-.22	-.20	-.21	.17	*
Pacific herring	-.22	*	*	.14	-.21	*	*	*	.12	-.13
Shad	-.14	*	*	.13	-.18	-.21	-.10	-.37	.11	*
Pink sea perch	-.53	.46	-.28	-.16	-.18	.15	.15	*	*	*
Anchovy	*	*	.15	*	*	.24	-.18	*	-.21	.13
Pacific cod	-.17	-.28	-.22	.38	-.13	-.15	-.35	.27	-.13	*
Walleye pollock	*	*	*	*	-.14	-.14	-.14	-.19	.14	-.12
Lingcod	-.30	*	*	.15	*	*	.22	-.16	-.21	-.13
Pacific whiting	-.17	-.17	.18	.10	-.24	-.24	*	-.21	*	*
Unid. smelt	*	*	*	.16	.17	.11	.31	*	-.12	-.22
Eulachon	*	-.22	-.12	.28	*	*	*	.19	-.41	*
Whitebait smelt	-.13	*	*	.14	-.16	-.14	*	*	-.13	*
Unid. eelpout	.17	.21	.12	*	*	*	*	.27	*	*
Bigfin eelpout	.36	.27	*	-.23	*	*	*	.10	-.10	-.26

Table 38, continued.

Principal component	1	2	3	4	5	6	7	8	9	10
Species										
Canary rockfish	-.14	-.32	*	.34	.22	.33	.16	.18	.24	*
Redstripe rockfish	*	-.18	*	.19	.12	.15	*	.15	.28	*
Yelloweye rockfish	*	*	-.30	.17	.75	-.13	*	-.20	*	-.11
Flag rockfish	.25	-.17	-.27	-.21	*	.12	*	*	*	.20
Stripetail rockfish	-.12	*	.40	-.20	.11	*	*	-.13	-.11	.10
Sharpchin rockfish	*	-.26	-.12	*	*	.29	*	.13	.32	.17
Bank rockfish	.10	.10	.23	-.11	.11	-.26	.22	.36	.11	*
Shortraker rockfish	.13	*	-.20	-.22	*	*	-.11	-.20	-.14	*

The second component was most highly correlated with species with extreme northern or southern distributions. Filetail and longnose catshark, sanddab, slender sole, English sole, plainfin midshipman, pink sea perch, aurora, shortbelly, and blackgill rockfish were most highly abundant in the southern part of the survey area and were positively correlated with this component. Arrowtooth flounder, canary rockfish, and secondarily Pacific cod, Pacific ocean perch, silvergrey, yellowtail, and sharpchin rockfish were all negatively correlated with this component and were rare in the south. 5.7% of total variance was associated with this component.

At least three distribution patterns were associated with the third principal component. "High" negative correlations with shortspine thornyhead, rougheye rockfish, yelloweye rockfish and arrowtooth flounder associated this principal component with a northern deepwater species group. Additional negative correlations with sanddab, petrale sole, English sole, rock sole, and secondarily longhose skate and pink sea perch may reflect a shallow water (50-75 fm or 91-137 m) species group south of 38° N. Chilipepper, cow, bocaccio, and stripetail rockfish were positively correlated with this component. These species were common between 75-125 fm, south of 39° N. The positive correlation of splitnose rockfish with this component is puzzling. Although it does occur in this region, its center of abundance appears farther offshore. 4.9% of total variance was associated with this component.

The fourth principal component also reflected at least three species associations: a northern deepwater rockfish "group" (rougheye rockfish and secondarily shortspine thornyhead and Pacific Ocean perch;

negatively correlated), a northern shallow water group (Pacific cod, canary, yellowtail rockfish; positively correlated) and a southern (39° N or less) deepwater species group (filetail catshark, longnose catshark, unidentified catshark, aurora rockfish, and blackgill rockfish; positively correlated). This component accounted for 4.1% of overall variance.

The fifth component was highly correlated with petrale sole, rock sole, and yelloweye rockfish. An artificially high correlation of yelloweye and rock sole abundance resulted when yelloweye were present at 3 of the 8 site clumps in which rock sole were found; further, the maximum yelloweye catch occurred at the same site of maximum rock sole catch for the survey. Petrale sole was a common shallow water (50-75 fm) species. About 3.7% of the total variance was included in this component.

No clear interpretation can be made for the sixth component: silvergrey and canary rockfish have distributions centered in northern shallow water. Widow rockfish and bocaccio had little in common with either of those distributional centers. (A local topographic features such as rock banks for pinnacles may link widow rockfish and canary rockfish via habitat preference, however.) This component expressed 3.3% of the system variance.

The remaining components and correlations were even more difficult to interpret in terms that make biological sense, aside from smallscale regions of similar species composition, perhaps. One exception, the co-occurrence of splitnose and bank rockfish south of 39° N most commonly at depths of 150-200 fm, was reflected in the eighth component.

AIDN Analysis of Variance

The AIDN analysis of variance based on effects of subregion, latitude within subregion, and depth within latitude showed subregion as the most important variable in describing species composition (Table 39). The mean sum of squares associated with subregion was an order of magnitude larger than that associated with effect of latitude within subregion or depth within latitude. Because subregions were based on combined site clusters (seventeen subregions from thirty-two site clusters, Table 40), these results imply that relatively large portions of variation in species composition can be associated with site cluster classifications. If effects of latitude within subregion or depth within latitude were largest, cluster analysis would appear less valuable than arbitrary latitude or depth intervals in explaining species composition.

Trends in the SIMI matrix (Table 41) reproduced trends from cluster analysis. Subregions which were most similar based on the SIMI index of similarity were also closest in cluster analysis. The hierarchial structure of the cluster analysis was reproduced: subregion similarity was highest among deepest subregions (1A1 through 1C2) and shallow subregions were most similar to adjacent subregions in similar depth ranges, e.g., 2A1-2A2, 2B1-2B2-2B3, 3A1-3A2, 3B1-3B2, 3C1-3C2. Of all adjacent subregions, 3C1 and 3C2 were of lowest similarity based on SIMI indices, but included some of the loosest site clusters from the cluster analysis.

Table 39. AIDN analysis of variance, Cape Flattery to Point Hueneme, seventeen subregions.

Source of Variation	Degrees of freedom	Corrected Sum of squares	Mean Square
Subregion	16	35.5801	2.2237
Latitude in subregion	86	27.9378	.3248
Depth in latitude	155	49.8676	.3217

Table 40. Relation between AIDN data subset composition and site cluster groups. Parentheses enclose the latitude ranges and number of hauls in each section of a divided site cluster group.

AIDN Subregion	Cluster Group
1A1	1ai
1A2	1aii
1B1	1aiii
	1aiv (37° 20' - 38° 30') (9)
1B2	1aiv (38° 30' - 39° 50') (10)
	1av
	1ci
1C1	1bi
	1bii (34° 05' - 34° 27') (5)
1C2	1bii (35° 15' - 36° 00') (3)
	1biii
	1cii
2A1	2ai
	2aii (45° 30' - 46° 00') (16)
2A2	2aii (46° 00' - 46° 20') (5)
	2aiii
	2aiv
	2cii
2B1	2bi
	2bii (46° 07'; 46° 26') (2)
2B2	2bii (13)
	2biii
	2biv
	2bv (48° 10', 48° 11') (3)
2B3	2bv (14)
	2ci
3A1	3ai
	3aii (37° 18' - 39° 30') (15)
3A2	3aii (39° 30' - 40° 10') (9)
	3aiii
	3aiv
3B1	3bi
	3bii (43° 18' - 44° 00') (7)
3B2	3bii (44° 00' - 45° 40') (20)
	3biii
3C1	3av
	3avi (34° 06') (1)
3C2	3avi (8)
	3c

Table 41. Between-subregion SIMI similarity index values.

Subregion	1A1	1A2	1B1	1B2	1C1	1C2	2A1	2A2	2B1	2B2	2B3
1A1	1.00										
1A2	.93	1.00									
1B1	.90	.85	1.00								
1B2	.86	.79	.97	1.00							
1C1	.66	.63	.82	.82	1.00						
1C2	.69	.66	.85	.84	.98	1.00					
2A1	.56	.53	.68	.63	.38	.39	1.00				
2A2	.66	.62	.76	.70	.46	.47	.95	1.00			
2B1	.77	.82	.62	.55	.45	.46	.50	.56	1.00		
2B2	.88	.94	.78	.73	.58	.61	.54	.63	.93	1.00	
2B3	.69	.71	.57	.53	.40	.44	.49	.61	.79	.81	1.00
3A1	.44	.42	.58	.59	.62	.66	.40	.44	.32	.43	.29
3A2	.42	.42	.54	.51	.35	.38	.58	.61	.33	.41	.32
3B1	.46	.41	.61	.57	.34	.36	.85	.87	.35	.38	.41
3B2	.56	.50	.70	.66	.40	.41	.94	.93	.43	.47	.40
3C1	.45	.41	.56	.55	.37	.40	.63	.65	.33	.40	.31
3C2	.21	.21	.30	.26	.23	.26	.40	.48	.21	.23	.41

Subregion	3A1	3A2	3B1	3B2	3C1	3C2
3A1	1.00					
3A2	.84	1.00				
3B1	.42	.63	1.00			
3B2	.46	.64	.91	1.00		
3C1	.76	.79	.71	.70	1.00	
3C2	.45	.56	.67	.43	.69	1.00

The mean sum of squares for effects of latitude within subregion and depth within latitude were almost equal. At first, this would seem to indicate that a change of one degree latitude within a subregion would have the same effect of species composition as changing 50 fm (92 m) at any latitude in the subregion. However, many of the subregions were discontinuous in space, as large site cluster groups were subdivided to meet computer processing limits. These latitudinal discontinuities probably inflated latitude effects. For example, some sites in subregion 2A2 were found north of 47° 40' and others were found between 42° 50'-46° 30'. The effect of latitude between 46° 30' and 47° 40' was not included in the analysis, yet may have influenced species composition.

A second AIDN analysis of variance that included only subregions with continuous adjacent sites again associated most variance in species composition with site cluster-based subregions (Table 42). In this case, however, the relative effect of depth within latitude was about three times larger than the relative effect of latitude within subregion on species composition, based on latitude increments of 1° and depth stratification into 50 fm (92 m) intervals at each degree of latitude.

The relative importance of latitude and depth within latitude was reflected by distributions of species groups within subregions. Proportion of catch by species cluster group for each of the eight subregions generally changed more rapidly across depth intervals at a given degree of latitude than across latitude intervals (Tables 43-48). Some deviations from this trend appeared as single hauls within an interval. Subregion effects were reflected by differences in

Table 42. AIDN analysis of variance, eight selected subregions.

Source of Variation	Degrees of freedom	Corrected Sum of squares	Mean Square
Subregion	7	23.6152	3.3736
Latitude in subregion	32	8.6997	.2719
Depth in latitude	67	65.7010	.9806

proportional composition between subregions within the same depth-latitude interval.

The overall trend of relative importance of depth within latitude vs. latitude was not consistent for all subregions, however (Table 49). Latitude effects within some subregions were larger than depth effects at latitude. In some subregions, this was probably due to discontinuity of observations over latitude. Some sites in subregions 1B1, 1C2, 2A2, and 2B2 occurred as patches separated by up to 1° of latitude. In subregions 3B1 and 3B2, several continuous degrees of latitude but only one depth stratum was represented. In subregions 1A2 and 1B2, however, observations were continuous over degrees of latitude and more than one depth stratum was present.

The large latitude effect in region 1A2 was more likely the effect of small sample size within some strata, because the subregion was represented by only one or two sites in each of the three northernmost strata. Relatively large catches of Pacific ocean perch (46° - 2 sites), rougheye rockfish (47° - 1 site) and rex sole with shortraker rockfish (48° - 2 sites) made species composition appear highly dissimilar over these three degrees of latitude. Sites were more similar between 43° - 45° strata, containing ten, five, and twenty-two sites, respectively.

In subregion 1B2, similarities between sites from 39° - 40° N were generally lower than similarities between sites from 40° - 41° or 38° - 39° (Table 50). Sites from 37° - 39° had larger proportions of Dover sole, splitnose, chilipepper, shortbelly, and blackgill rockfish and sablefish (39°) while sites from 40°-41° had larger proportions of

Table 43. Proportionate catch of deepwater dominant species group A, excluding Pacific hake, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parentheses. Latitude (°N) is in leftmost column.

	Depth intervals (50 fm, 91.5 m)				
L °N	>250 fm >7457 m	200-250 fm 366-457 m	150-200 fm 274-366 m	100-150 fm 183-274 m	50-100 fm 92-183 m
48		.956(1A1)(1) .643(1A2)(1)	.705 (1A2)(1) .735(2B3)(5)	.681(2B3)(10)	.210(2B3)(9)
47	.882(1A2)(1)	.881(1A1)(6)	.870(2B1)(3)	.497(2B1)(5) .385(2B3)(1)	.213(2A1)(8) .454(2B1)(3) .121(2B3)(2)
46		.861(1A1)(4)	.937(1A2)(2) .930(2B1)(2)	.740(2A1)(1) .657(2B1)(7)	.251(2A1)(17) .408(2B1)(5)
45		.785(1A1)(21) .859(1A2)(1)	.760(1A1)(6) .832(1A2)(6)	.788(1A2)(15) .185(2A1)(2) .822(2B1)(5)	.232(2A1)(14)
44		.760(1A1)(1)	.702(1A1)(3) .881(1A2)(4)	.855(1A2)(1)	
43			.829(1A2)(1)	.773(1A2)(9)	
42		.632(1B2)(1)			
41		.431(1B2)(4)		.425(1B2)(5)	.875(3A2)(1)
40	.073(1B2)(1)	.446(1B2)(4)		.388(1B2)(4) .464(3A2)(2)	.031(3A2)(3)
39	.236(1B2)(1)	.878(1B2)(10)	.854(1B2)(5)	.352(3A2)(7)	.143(3A2)(13)
38		.764(1B2)(6)	.596(1B2)(4)	.075(3A2)(3)	.088(3A2)(6)
37			.755(1B2)(3)	.023(3A2)(1)	.060(3A2)(3)
36		.439(1C1)(1)			
35		.677(1C1)(14)	.887(1C1)(3)		
34	.613(1C1)(1)	.764(1C1)(10)	.806(1C1)(9)	.425(1C1)(10)	

Table 44. Proportionate catch of Pacific whiting, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parenthesis. Latitude (°N) is in leftmost column

L	Depth intervals (50 fm, 91.5 m)				
	>250 fm	200-250 fm	150-200 fm	100-150 fm	50-100 fm
°N	>7457 m	366-457 m	274-366 m	183-274 m	92-183 m
48		.037(1A1)(1)	.290(1A2)(1)	.051(2B3)(10)	.001(2B3)(9)
		.000(1A2)(1)	.088(2B3)(5)		
47	.000(1A2)(1)	.036(1A1)(6)	.037(2B1)(3)	.099(2B1)(5)	.169(2A1)(8)
				.000(2B3)(1)	.089(2B1)(3)
					.000(2B3)(2)
46		.024(1A1)(4)	.010(1A2)(2)	.002(2A1)(1)	.270(2A1)(17)
			.009(2B1)(2)	.071(2B1)(7)	.221(2B1)(5)
45		.174(1A1)(21)	.232(1A1)(6)	.145(1A2)(15)	.574(2A1)(14)
		.107(1A2)(1)	.116(1A2)(6)	.038(2A1)(2)	
				.041(2B1)(5)	
44		.232(1A1)(1)	.287(1A1)(3)	.000(1A2)(1)	
			.035(1A2)(4)		
43			.050(1A2)(1)	.187(1A2)(9)	
42		.089(1B2)(1)			
41		.207(1B2)(4)		.488(1B2)(5)	.005(3A2)(1)
40	.171(1B2)(1)	.393(1B2)(4)		.407(1B2)(4)	.269(3A2)(3)
				.519(3A2)(2)	
39	.000(1B2)(1)	.030(1B2)(10)	.110(1B2)(5)	.067(3A2)(7)	.276(eA2)(13)
38		.164(1B2)(6)	.294(1B2)(4)	.155(3A2)(3)	.041(3A2)(6)
37			.171(1B2)(3)	.000(3A2)(1)	.139(3A2)(3)
36		.008(1C1)(1)			
35		.047(1C1)(14)	.063(1C1)(3)		
34	.117(1C1)(1)	.056(1C1)(10)	.108(1C1)(9)	.285(1C1)(10)	

Table 45. Proportionate catch of shallow dominant (southern) species group B, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parentheses. Latitude (°N) is in leftmost column.

		Depth intervals (50 fm, 91.5 m)			
L	>250 fm	200-250 fm	150-200 fm	100-150 fm	50-100 fm
°N	>7457 m	366-457 m	274-366 m	183-274 m	92-183 m
48		.000(1A1)(1)	.132(2B3)	.105(2B3)(10)	.292(2B3)(9)
		.000(1A2)(1)	.000(1A2)(1)		
47	.000(1A2)(1)	.001(1A1)(6)	.051(2B1)(3)		.259(2A1)(8)
				.180(2B1)(5)	.273(2B1)(3)
				.063(2B3)(1)	.247(2B3)(2)
46		.057(1A1)(4)	.008(1A2)(2)	.020(2A1)(1)	.047(2A1)(17)
			.008(2B1)(2)	.082(2B1)(7)	.064(2B1)(5)
45		.008(1A1)(21)	.003(1A1)(6)	.012(1A2)(15)	.022(2A1)(14)
		.034(1A2)(1)	.042(1A2)(6)	.050(2A1)(2)	
				.015(2B1)(5)	
44		.000(1A1)(1)	.002(1A1)(3)	.000(1A2)(1)	
			.074(1A2)(4)		
43			.110(1A1)(1)	.017(1A2)(9)	
42		.000(1B2)(1)			
41		.000(1B2)(4)		.081(1B2)(5)	.000(3A2)(1)
40	.000(1B2)(1)	.001(1B2)(4)		.177(1B2)(4)	.594(3A2)(3)
				.006(3A2)(2)	
39	.000(1B2)(1)	.010(1B2)(10)	.001(1B2)(5)	.568(3A2)(7)	.484(3A2)(13)
38		.003(1B2)(6)	.017(1B2)(4)	.755(3A2)(3)	.756(3A2)(6)
37			.030(1B2)(3)	.943(3A2)(1)	.855(3A2)(3)
36		.000(1C1)(1)			
35		.007(1C1)(14)	.011(1C1)(3)		
34	.015(1C1)(1)	.004(1C1)(10)	.002(1C1)(9)	.208(1C1)(10)	

Table 46. Proportionate catch of shallow occasional (northern) species group C, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parentheses. Latitude (°N) is in leftmost column.

	Depth intervals (50 fm, 91.5 m)				
L °N	>250 fm >7457 m	200-250 fm 366-457 m	150-200 fm 274-366 m	100-150 fm 183-274 m	50-100 fm 92-183 m
		.000(1A1)(1)	.004(2B33)(5)	.023(2B3)(10)	.225(2B3)(9)
		.000(1A2)(1)	.000(1A2)(1)		
	.000(1A2)(1)	.000(1A1)(6)	.015(2B1)(3)	.094(2B1)(5)	.301(2A1)(8)
				.123(2B3)(1)	.141(2B1)(3)
					.365(2B3)(2)
		.000(1A1)(4)	.0002(1A2)(2)	.238(2A1)(1)	.357(2A1)(17)
			.003(2B1)(2)	.037(2B1)(7)	.128(2B1)(5)
		.0002(1A1)(21)	.0002(1A1)(6)	.008(1A2)(15)	.167(2A1)(14)
		.000(1A2)(1)	.009(1A2)(6)	.263(2A1)(2)	
				.016(2B1)(5)	
		.000(1A1)(1)	.000(1A1)(3)	.139(1A2)(1)	
			.004(1A2)(4)		
			.001(1A2)(1)	.011(1A2)(9)	
	.000(1B2)(1)				
		.000(1B2)(4)		.002(1B2)(5)	.017(3A2)(1)
	.000(1B2)(1)	.000(1B2)(4)		.000(1B2)(4)	.105(3A2)(3)
				.000(3A2)(2)	
	.000(1B2)(5)	.000(1B2)(10)	.0003(1B2)(5)	.007(3A2)(7)	.038(3A2)(13)
		.0005(1B2)(6)	.001(1B2)(4)	.023(3A2)(3)	.044(3A2)(6)
			.000(1B2)(3)	.031(3A2)(1)	.014(3A2)(3)
		.000(1C1)(1)			
		.000(1C1)(14)	.000(1C1)(3)		
	.000(1C1)(1)	.000(1C1)(10)	.001(1C1)(9)	.001(1C1)(10)	

Table 47. Proportionate catch of norther occasional (shallow) species group D, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parentheses. Latitude (°N) is in leftmost column.

	Depth intervals (50 fm, 91.5 m)				
L °N	>250 fm >7457 m	200-250 fm 366-457 m	150-200 fm 274-366 m	100-150 fm 183-274 m	50-100 fm 92-183 m
48		.002(1A1)(1) .009(1A2)(1)	.040(2B3)(5) .000(1A2)(1)	.130(2B3)(10)	.245(2B3)(9)
47	.000(1A2)(1)	.052(1A1)(6)	.022(2B1)(3)	.065(2B1)(5)	.000(2A1)(8) .037(2B1)(3) .266(2B3)(2)
46		.027(1A1)(4)	.005(1A2)(2) .010(2B1)(2)	.000(2A1)(1) .151(2B1)(7)	.012(2A1)(17) .172(2B1)(5)
45		.007(1A1)(21) .000(1A2)(1)	.001(1A1)(6) .000(1A2)(6)	.032(1A2)(15) .440(2A1)(2) .072(2B1)(5)	.003(2A1)(14)
44		.000(1A1)(1)	.001(1A1)(3) .002(1A2)(4)	.000(1A2)(1)	
43			.004(1A2)(1)	.002(1A2)(9)	
42		.000(1B2)(1)			
41		.000(1B2)(4)		.001(1B2)(5)	.000(3A2)(1)
40	.000(1B2)(1)	.000(1B2)(4)		.000(1B2)(4) .000(3A2)(2)	.000(3A2)(3)
39	.000(1B2)(1)	.000(1B2)(10)	.000(1B2)(10)	.0004(3A2)(7)	.0002(3A2)(13)
38		.001(1B2)(6)	.0002(1B2)(4)	.000(3A2)(3)	.000(3A2)(6)
37			.000(1B2)(3)	.000(3A2)(1)	.001(3A2)(3)
36		.000(1C1)(1)			
35		.000(1C1)(14)	.000(1C1)(3)		
34	.000(1C1)(1)	.000(1C1)(10)	.000(1C1)(9)	.0001(1C1)(10)	

Table 48. Proportionate catch of deepwater occasional species group F, by AIDN subregion, latitude and depth stratum. Subregion and number of hauls in stratum are in parentheses. Latitude (°N) is in leftmost column.

	Depth intervals (50 fm, 91.5 m)				
L °N	>250 fm >7457 m	200-250 fm 366-457 m	150-200 fm 274-366 m	100-150 fm 183-274 m	50-100 fm 92-183 m
48		.000(1A1)(1) .330(1A2)(1)	.000(1A2)(1) .001(2B3)(5)	.001(2B3)(5)	.000(2B3)(10)
47	.118(1A2)(1)	.023(1A1)(6)	.003(2B1)(3)	.0005(2B1)(5) .004(2B3)(1)	.000(2A1)(8) .000(2B1)(3) .000(2B3)(2)
46		.031(1A1)(4)	.040(1A2)(2) .040(2B1)(2)	.000(2A1)(1) .001(2B1)(7)	.001(2A1)(17) .0002(2B1)(5)
45		.019(1A1)(21) .000(1A2)(1)	.000(1A1)(6) .000(1A2)(6)	.008(1A2)(15) .024(2A1)(2) .016(2B1)(5)	.0003(2A1)(14)
44		.000(1A1)(1)	.000(1A1)(3) .002(1A2)(4)	.005(1A2)(1)	
43			.005(1A2)(1)	.001(1A2)(9)	
42		.276(1B2)(1)			
41		.335(1B2)(4)		.003(1B2)(5)	.008(3A2)(1)
40	.748(1B2)(1)	.157(1B2)(4)		.000(1B2)(4) .000(3A2)(2)	.000(3A2)(3)
39	.764(1B2)(1)	.043(12)(10)	.010(1B2)(5)	.0002(3A2)(7)	.0001(3A2)(13)
38		.039(1B2)(6)	.020(1B2)(4)	.000(3A2)(3)	.000(3A2)(6)
37			.043(1B2)(3)	.003(3A2)(1)	.000(3A2)(3)
36		.561(1C1)(1)			
35		.269(1C1)(14)	.039(1C1)(3)		
34	.255(1C1)(1)	.144(1C1)(10)	.041(1C1)(9)	.016(1C1)(10)	

Table 49. AIDN analysis of Variance by Subregion

Subregion	Source of Variation	Degrees of Freedom	Corrected Sum of Squares	Mean Square	F	Number of Species
1A1	Latitude	4	.6367	.1592	1.550	34
	Depth within latitude	5	1.0471	.2094	2.034	
	Residual	32	3.2871	.1027		
	Total	41	4.9709			
1A2	Latitude	5	1.1528	.2306	1.6367	45
	Depth within latitude	18	2.2923	.1268	.8999	
	Residual	18	2.5369	.1409		
	Total	41	5.9720			
1B1	Latitude	8	2.7016	.3377	1.3008	38
	Depth within latitude	27	4.1493	.1537	.5921	
	Residual	12	3.1158	.2596		
	Total	47	9.9667			
1B2	Latitude	5	2.7380	.5476	10.4904	37
	Depth within latitude	18	7.0675	.3926	7.5261	
	Residual	24	1.2530	.0522		
	Total	47	11.0585			
1C1	Latitude	2	.6702	.3351	2.6894	42
	Depth within latitude	9	3.3533	.3726	2.9904	
	Residual	36	4.4844	.1246		
	Total	47	8.5079			
1C2	Latitude	6	3.2721	.5453	2.0263	44
	Depth within latitude	21	1.5606	.0743	.2761	
	Residual	20	5.3828	.2691		
	Total	47	10.2155			
2A1	Latitude	2	1.3742	.6871	3.5254	44
	Depth within latitude	3	2.7919	.9306	4.7747	
	Residual	36	7.0171	.1949		
	Total	41	11.1832			
2A2	Latitude	5	4.6105	.9221	11.8827	46
	Depth within latitude	6	5.3822	.8980	11.5721	
	Residual	29	2.2490	.0776		
	Total	40	12.2477			
2B1	Latitude	2	.3780	.1890	1.5645	42
	Depth within latitude	6	2.1682	.3614	2.9917	
	Resitual	21	2.5378	.1208		
	Total	29	5.0840			

Table 49 (continued)

Subregion	Source of Variation	Degrees of Freedom	Corrected Sum of Squares	Mean Square	F	Number of Species
2B2	Latitude	6	1.5337	.2556	2.1300	45
	Depth within latitude	14	2.6612	.1901	1.5842	
	Residual	9	1.0802	.1200		
	Total	29	5.2751			
2B3	Latitude	1	.2017	.2017	1.4831	39
	Depth within latitude	4	2.6023	.6506	4.7838	
	Residual	21	2.8569	.1360		
	Total	26	5.6609			
3A1	Latitude	5	2.2797	.4559	4.2057	40
	Depth within latitude	6	3.2786	.5464	5.0406	
	Residual	27	2.9265	.1084		
	Total	38	8.4848			
3A2	Latitude	4	1.5481	.3870	1.4873	42
	Depth within latitude	5	3.3009	.6602	2.5373	
	Residual	29	7.5470	.2602		
	Total	38	12.3960			
3B1	Latitude	4	1.3325	.3331	1.9177	41
	Depth within latitude	0	1.3325	.000		
	Residual	32	5.5581	.1737		
	Total	36	8.2231			
3B2	Latitude	5	1.5092	.2515	.7794	45
	Depth within latitude	0	1.5092	.0000		
	Residual	31	10.0049	.3227		
	Total	37	13.0233			
3C1	Latitude	4	1.4686	.3671	1.1306	44
	Depth within latitude	10	3.8063	.3806	1.1721	
	Residual	15	4.8713	.3247		
	Total	29	10.1462			
3C2	Latitude	2	.5303	.2651	1.0224	40
	Depth within latitude	4	1.5740	.3935	1.5175	
	Residual	21	5.4456	.2593		
	Total	27	7.5499			

Table 50. SIMI similarity index values for strata in subregion 1B2. A = 100–150 fm (183–274,), B = 150–200 fm (2174–366 m), C = 200–250 fm (366–457 m), D = >250 fm (>457 m). Number of sites in each stratum are enclosed in parentheses.

	42°-C (1)	41°-A (5)	41°-C (4)	40°-A (4)	40°-C (4)	40°-D (1)	39°-B (5)	39°-C (10)	39°-D (1)	38°-B (4)	38°-C (6)
41° - A	.29										
41° - C	.46	.52									
40° - A	.41	.88	.51								
40° - C	.71	.78	.65	.86							
40° - D	.37	.29	.73	.28	.44						
39° - B	.83	.38	.35	.46	.68	.08					
39° - C	.88	.21	.28	.33	.57	.06	.95				
39° - D	.35	.02	.41	.07	.24	.77	.14	.18			
38° - B	.56	.77	.54	.77	.84	.23	.78	.59	.10		
38° - C	.82	.47	.38	.54	.75	.16	.95	.87	.18	.07	
37° - B	.81	.47	.39	.54	.75	.16	.97	.87	.17	.87	.99

Pacific hake, aurora rockfish, and darkblotched rockfish (Table 44). The 42° stratum contained only one site, whose composition was dominated by Dover sole. The largest depth-related differences in subregion 1B2 were probably due to two deep sites (250 fm or 457 m) at 39° and 40°.

Diversity Patterns

Patterns in diversity may have been confounded by sampling intensity. Number of species present increased with number of hauls in each AIDN subregion depth stratum and latitude stratum (Figs. 6, 7). A weighted mean diversity index was calculated for each AIDN depth and latitude stratum, so that diversity indices from strata containing many hauls were emphasized. A second weighted mean index was calculated that included only strata containing twenty or more hauls. The same overall pattern of diversity with depth emerged from both calculations (Fig. 8). The same overall patterns of diversity with depth emerged from means based on Simpson's diversity index and means based on SDI/SDIMAX (where SDI = Simpson's diversity index, and SDIMAX = the maximum diversity possible given the number of species present) (Fig. 8). These patterns also appeared over latitude strata, but subregions often contained fewer than 10 sites within the same degree of latitude. The weighted mean diversity index by latitude stratum did not appear closely correlated with the number or hauls in the stratum, however (Fig. 9, $r = .365$, $r_{crit} = .514$, $= 0.05$, $df = 13$). Relations between depth, latitude and diversity within cluster regions may be more difficult to interpret, because cluster assemblage regions often extended over

Fig. 6. Number of species observed in depth stratum vs. number of hauls in depth stratum, by AIDN subregion.

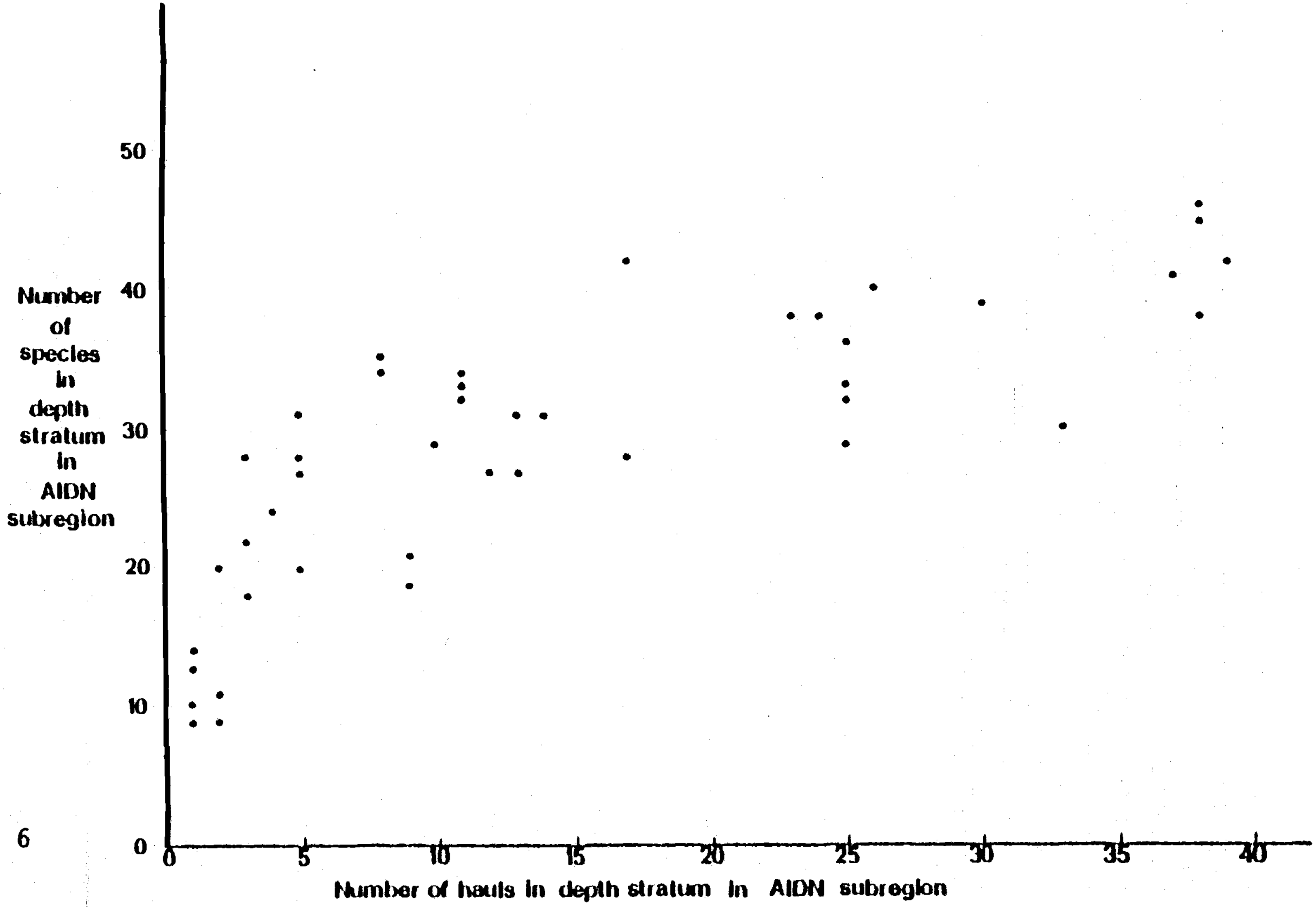

Number of species in depth stratum in AIDN subregion
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40
Number of hauls in depth stratum in AIDN subregion

Fig. 6

Fig. 7. Number of species observed in latitude stratum vs. number of hauls in latitude stratum, by AIDN subregion.

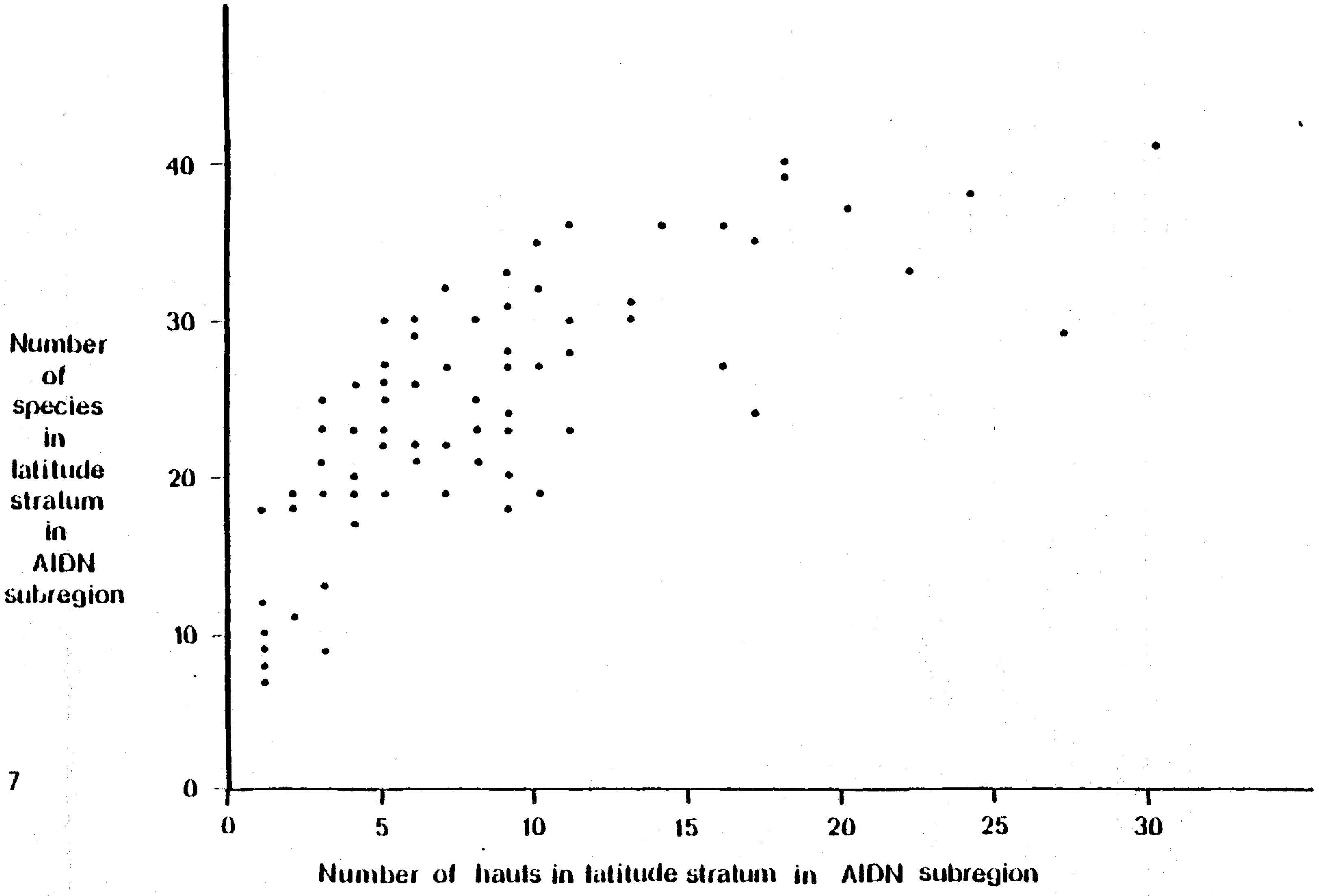

Number of species in latitude stratum in AIDN subregion
0
10
20
30
40
0
5
10
15
20
25
30
Number of hauls in latitude stratum in AIDN subregion

Fig. 7

Fig. 8. Weighted mean Simpson's diversity index and weighted mean SDI/SDIMAX vs. depth stratum, pooled over AIDN subregions (where SDI = Simpson's diversity index and SDIMAX - maximum diversity possible, given the number of species present).

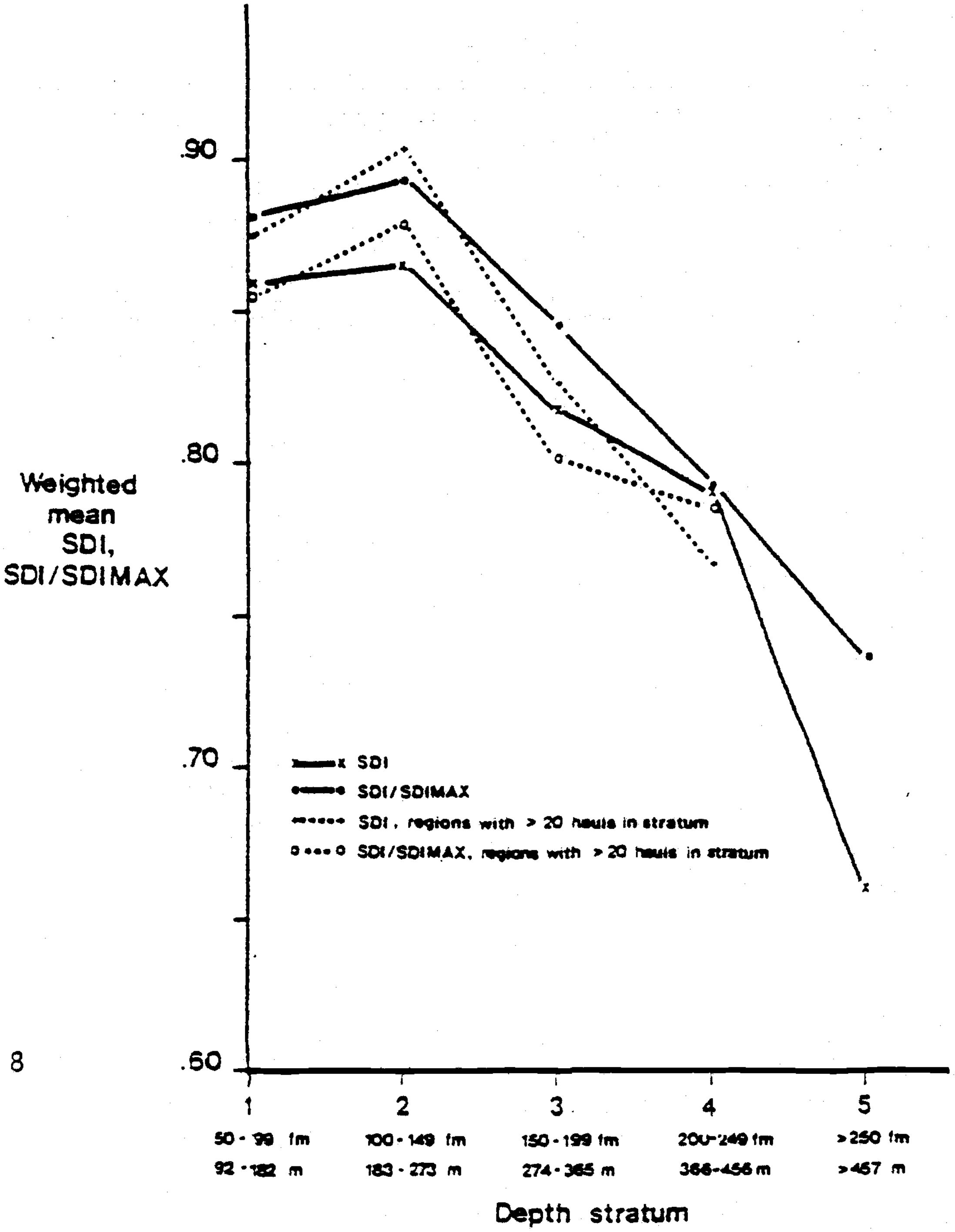

.90
.80
.70
.60
Weighted
mean
SDI,
SDI/SDIMAX
SDI
SDI/SDIMAX
SDI, regions with > 20 hauls in stratum
SDI/SDIMAX, regions with > 20 hauls in stratum
1
2
3
4
5
50 - 99 fm
92 - 182 m
100 - 149 fm
183 - 273 m
150 - 199 fm
274 - 365 m
200-249 fm
366-456 m
>250 fm
>457 m
Depth stratum

Fig. 8

several depth and/or latitude strata.

Diversity tended to decrease with depth (Fig. 8), with the exception of some inshore regions where species composition was dominated by Pacific hake (cluster assemblages 2aii, 2cii, 3bi, 3bii and 3biii; Tables 16, 24, 27, 25, and 26, respectively). Diversity at upper slope strata (150 to >250 fm or 274 - > 457 m) was lower than at outer shelf and shelf break strata (50-150 fm or 92-274 m) (Fig. 8). The first half of the deepwater dominant group (species group A, Table 1) dominated species composition in most deepwater assemblage regions based on cluster analysis as well as in most deepwater subregions (subregions 1A1-1C2) in the AIDN analyses. Dover sole were nearly always most abundant; and, combined with sablefish, contributed from 21-78% of biomass in cluster assemblage regions lai-lciii, and 38-58% of biomass in AIDN subregions 1A1-1C2. Fifty-five to 85% of the biomass in most deepwater cluster assemblage regions (lai-lciii) and 59-80% in deep AIDN subregions (1A1-1C2) could be accounted for by four species: Dover sole, sablefish, Pacific hake, and either splitnose rockfish in the south or Pacific ocean perch in the north.

Diversity appeared to increase somewhat both north and south of the 40°N stratum, with two exceptions (Fig. 10). Diversity tended to increase with latitude from 41° to 48°, with the exception of the 45° stratum. Moving north from 41°, the proportion of Pacific hake generally decreased, except at 45° (Table 44). Dominance by Pacific hake in subregions 2A1 and 2A2 contributed to low diversity at that latitude. North of 41° N, shallow dominant (shallow) species group B (Table 1) declined somewhat in relative abundance, but did not

Fig. 9. Weighted mean Simpson's diversity index for latitude stratum vs. number of hauls in latitude stratum, pooled over AIDN subregions.

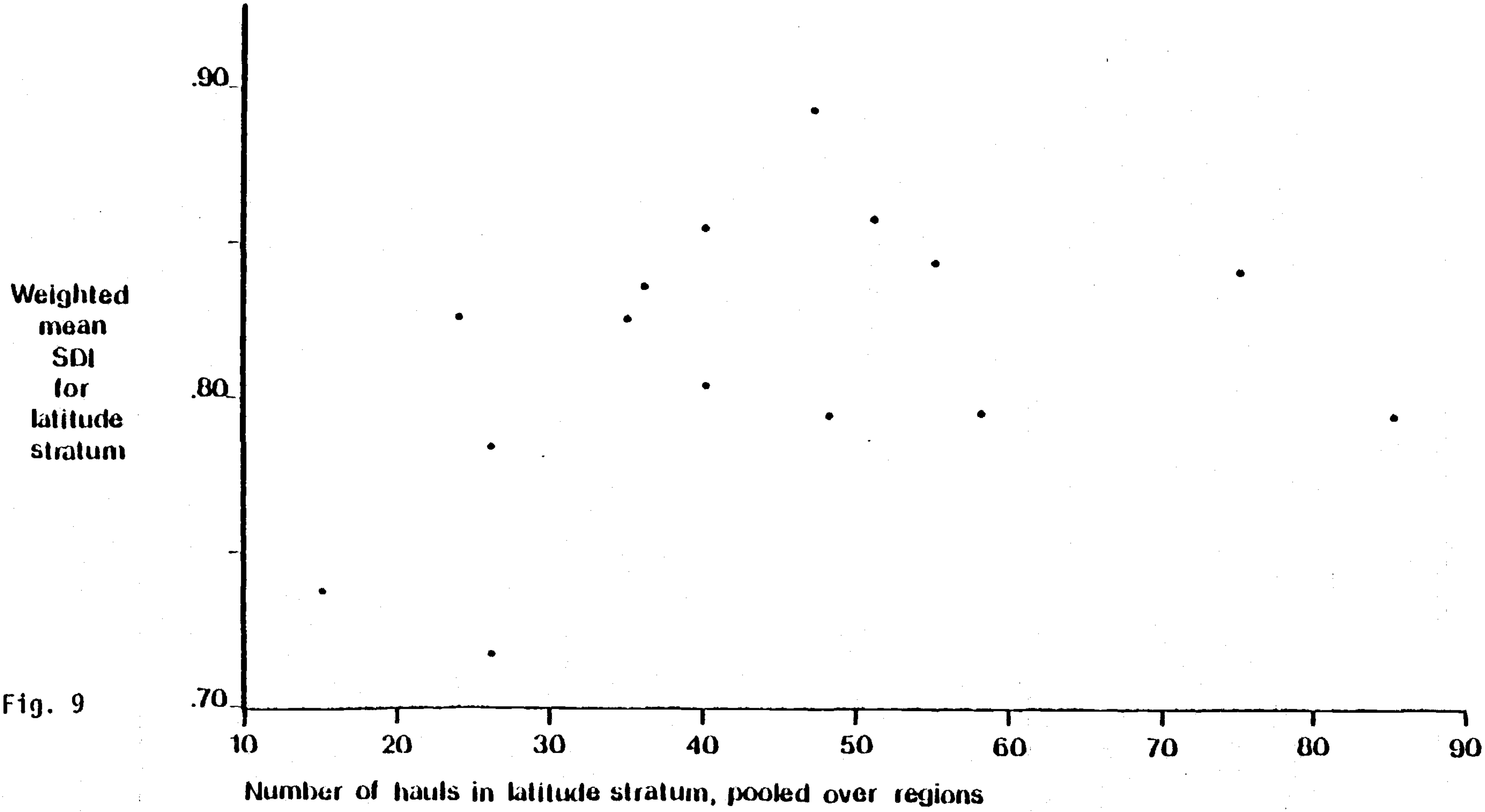

Weighted mean SDI for latitude stratum
.90
.80
.70
10
20
30
40
50
60
70
80
90
Number of hauls in latitude stratum, pooled over regions

Fig. 9

Fig. 10. Weighted mean Simpson's diversity index and weighted mean SDI/SDIMAX vs. latitude stratum, pooled over AIDN subregions (where SDI = Simpson's diversity index and SDIMAX = maximum diversity possible given the number of species present).

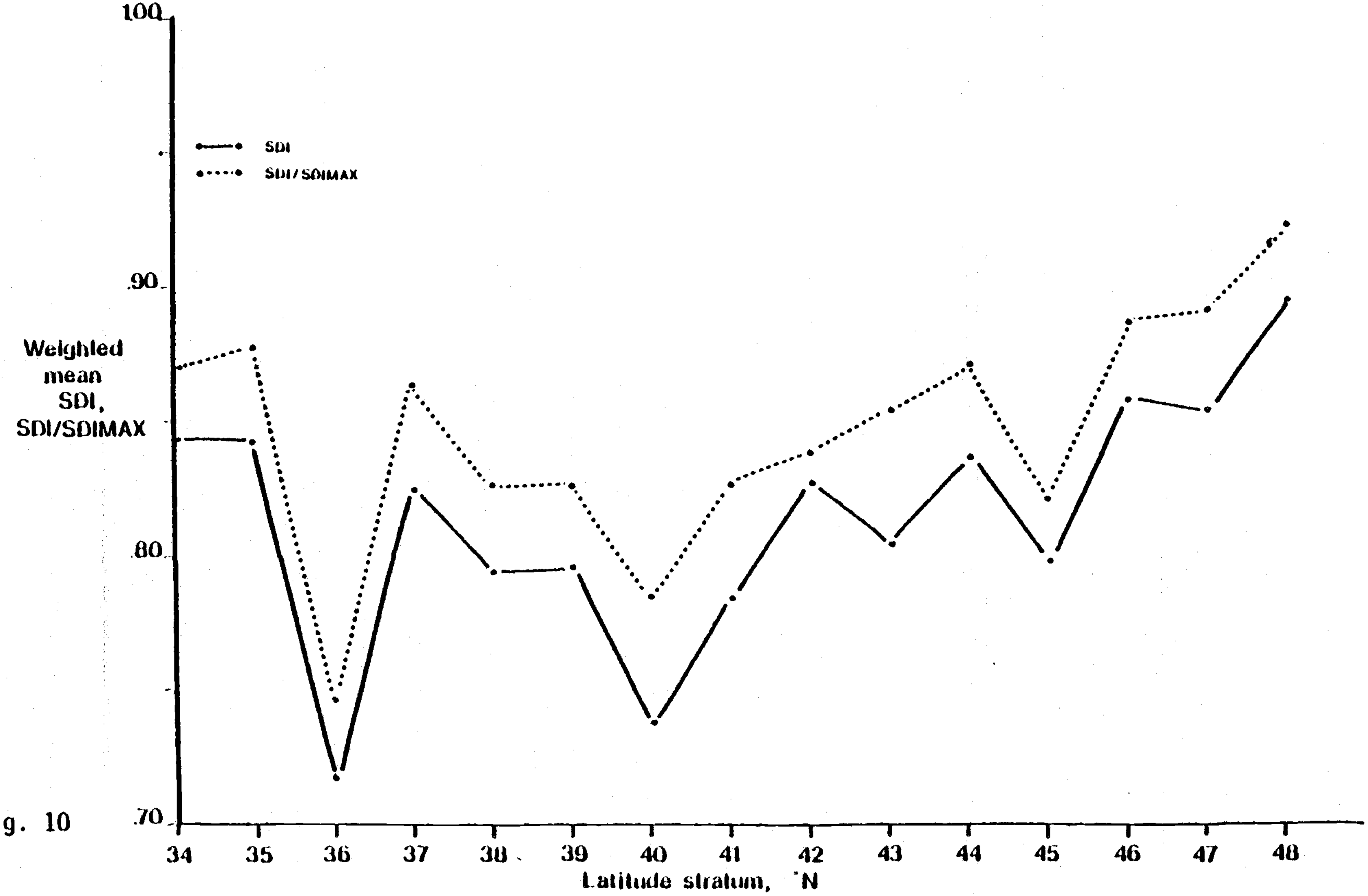

100
.90
.80
.70
SDI
SDI/SDIMAX
Weighted mean SDI, SDI/SDIMAX
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude stratum, °N

Fig. 10

disappear, while shallow occasional (northern) species group C increased (Table 45, 46). Northern occasional (shallow) species group D increased with latitude north of 41° N (Table 47). Farther offshore, deepwater dominant species group A, and its northern component increased north of 41° N; while only the ubiquitous component (Dover sole, sablefish, splitnose rockfish, rex sole) was abundant south of 41° N (Tables 3-12).

Diversity also tended to increase southward from 39° to 34° N with the exception of the 36° stratum. Dominance by splitnose rockfish in subregions 1C2 and 3A1 and blackgill rockfish at one site in subregion 1C1 contributed to low diversity at that latitude. South of 41°, at shallow sites the deepwater dominant species group declined in relative abundance, while shallow (southern) species group B increased (Tables 44, 45). Members of deepwater occasional species group F were present south of 40° N (Table 48). Rare shallow southern species group G was most important at latitudes 34° N and 35° N, in cluster assemblage regions 3c and 3avi (Tables 33, 34).

Environmental Variation

Environmental variables in the canonical correlation and factor analyses included latitude, depth, wind stress curl, onshore Ekman transport, longshore ship drift, onshore wind stress, and longshore wind stress. The last five variables were included as annual means, summer means (April to October), and winter means (November to March, spawning period for many rockfish species) based on long term data tabulated by Nelson (1977, MS). Oceanographic features such as longshore and offshore transport may limit distributions and life history characteristics of some species by affecting egg and larval mortality (Parrish et al., 1981; Boehlert and Kappenman, 1980). Real-time bottom temperature records at survey locations were incomplete and coastwide long-term bottom temperature records were unavailable. However, bottom temperature is correlated with upwelling index, that is in turn related to onshore Ekman transport (Kruse, 1981). Long-term surface temperature means should be included in any further analyses, because rockfish distributions may be limited by temperature-dependent larval survival (Chen, 1971). Long-term surface temperatures may be related to long-term Ekman transport, because surface temperature may be correlated with wind velocity (Fisher, 1970).

Wind stress curl produces divergence that may influence year-class strength in some flatfishes (Kruse, 1981). Wind stress curl generally decreases with distance from shore (Figs. 11-13). Annual wind stress curl is positive coastwide and is highest between 36°N and 40°N, and lowest at 43°N (Fig. 11). In winter, wind stress curl is positive south of 41°N, negative between 41°N and 44°N, and positive north of 44°N (Fig. 12). In summer, wind stress curl is positive coastwide, declining somewhat toward the north (Fig. 13).

Offshore Ekman transport, related to upwelling, may enhance nutrient inputs and surface productivity, or lower surface temperatures and increase offshore advection to the detriment of larval survival. Negative Ekman transport refers to offshore water movement (upwelling), while positive Ekman transport implies eastward, onshore water movement. Ekman transport on an annual and seasonal basis becomes less

Fig. 11. Mean annual wind stress curl by latitude and longitude (°W next to figure points) (from Nelson, 1977).

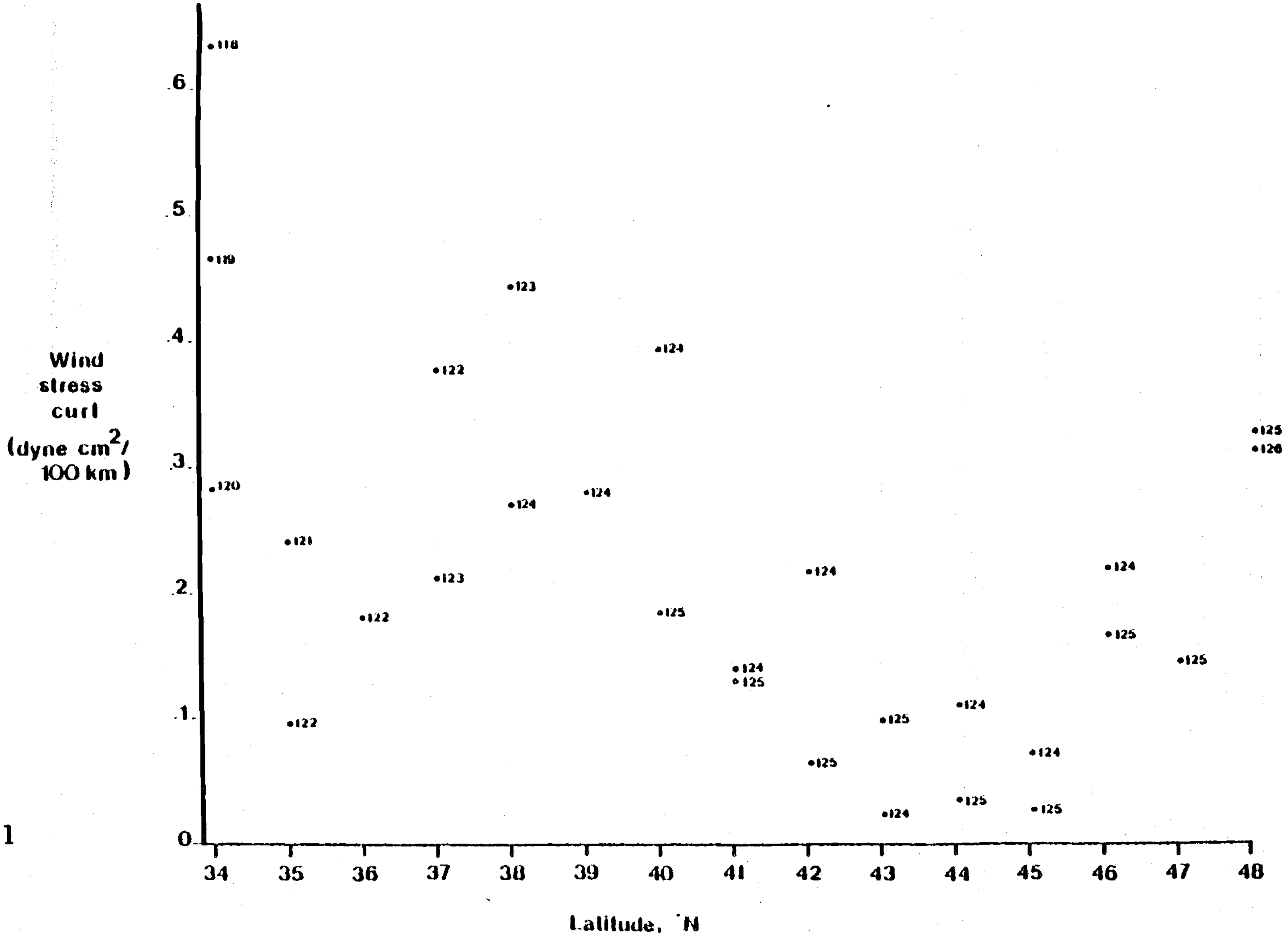

Wind
stress
curl
(dyne cm2/
100 km)
.6
.5
.4
.3
.2
.1
0
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 11

Fig. 12. Mean winter wind stress curl by latitude and longitude (°W next to figure points) (from Nelson, 1977).

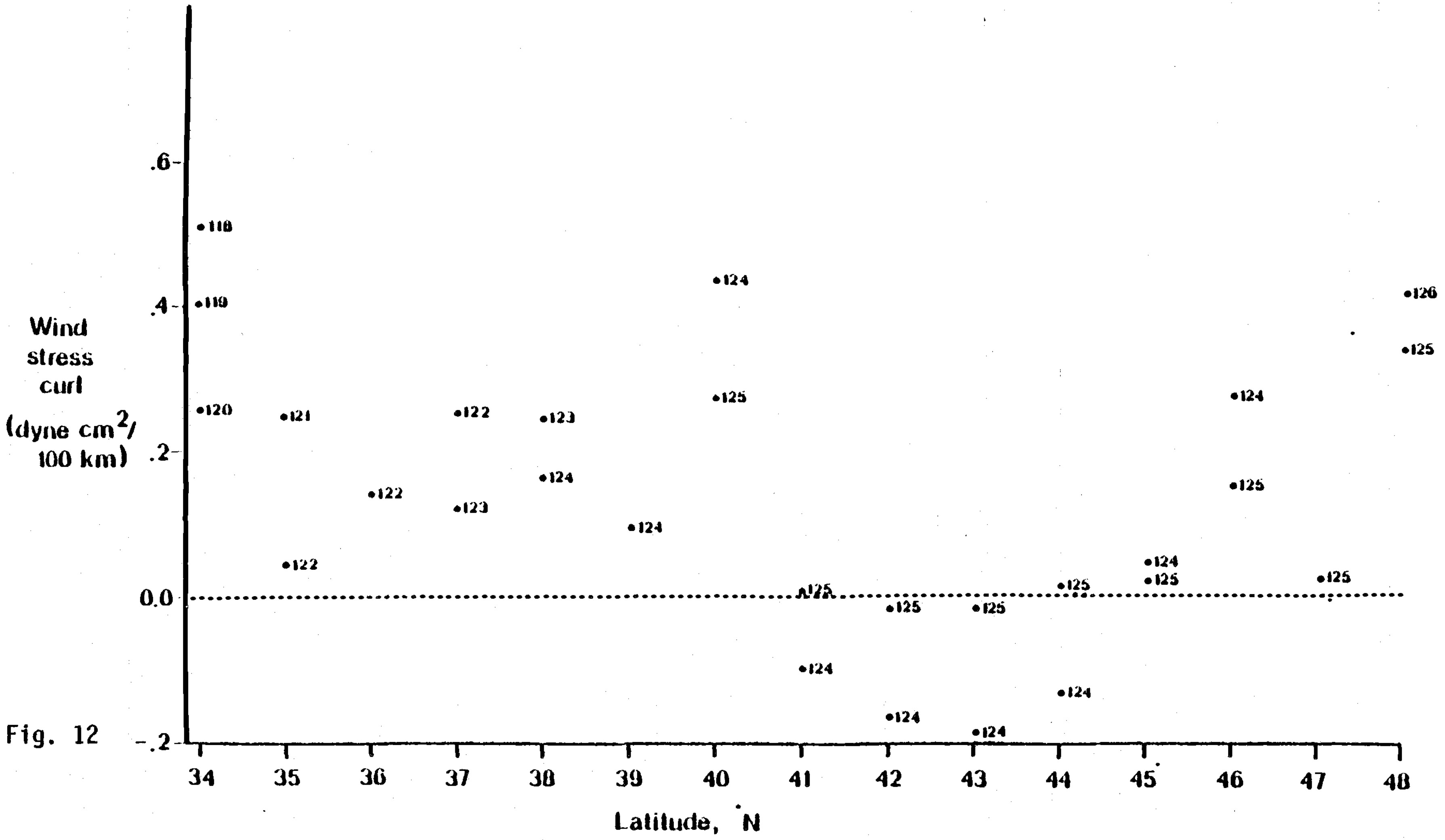

Wind
stress
curl
(dyne cm2/
100 km)
.6
.4
.2
0.0
-.2
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 12

Fig. 13. Mean summer wind stress curl by latitude and longitude (°W, next to figure points) (from Nelson, 1977).

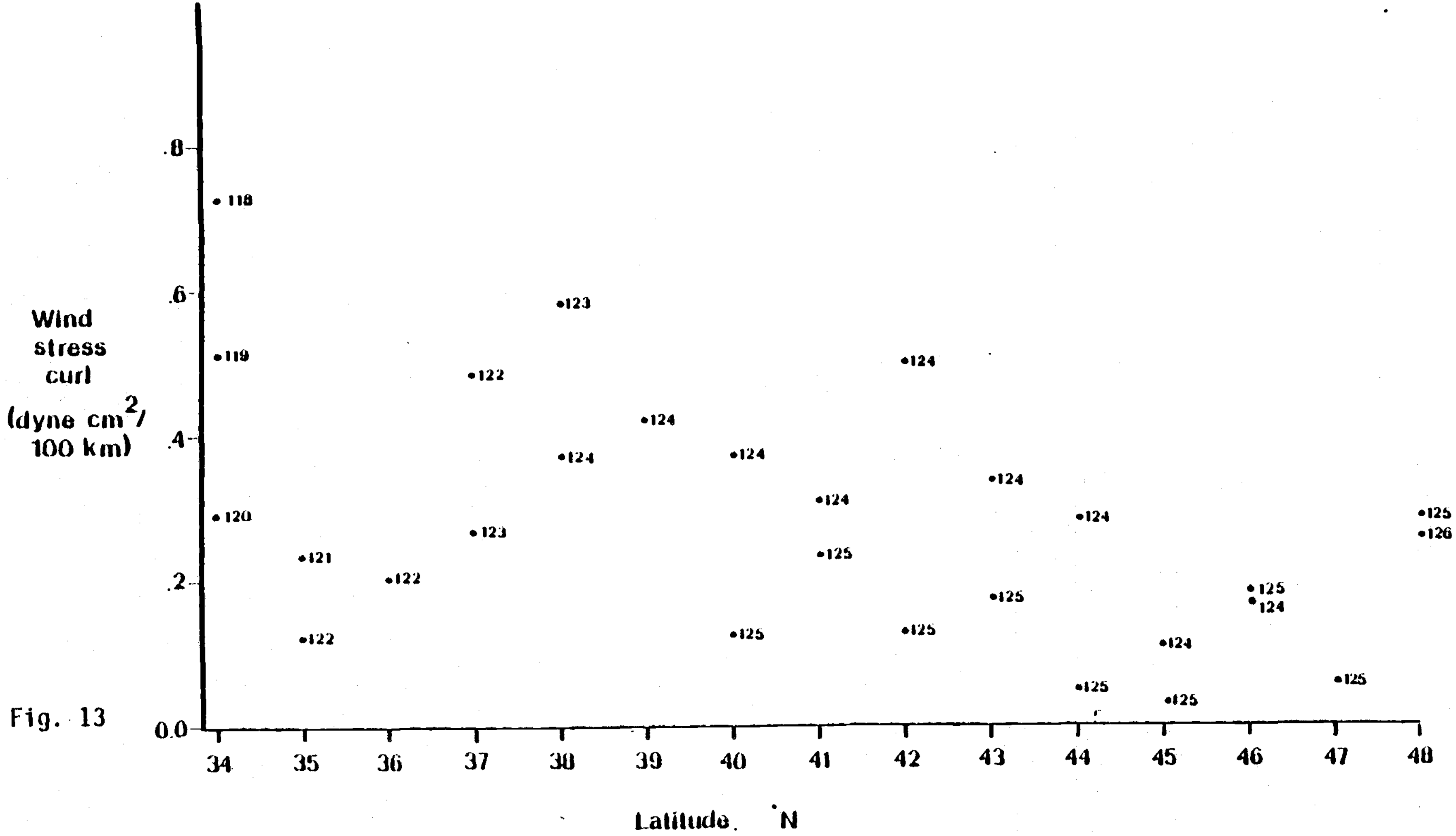
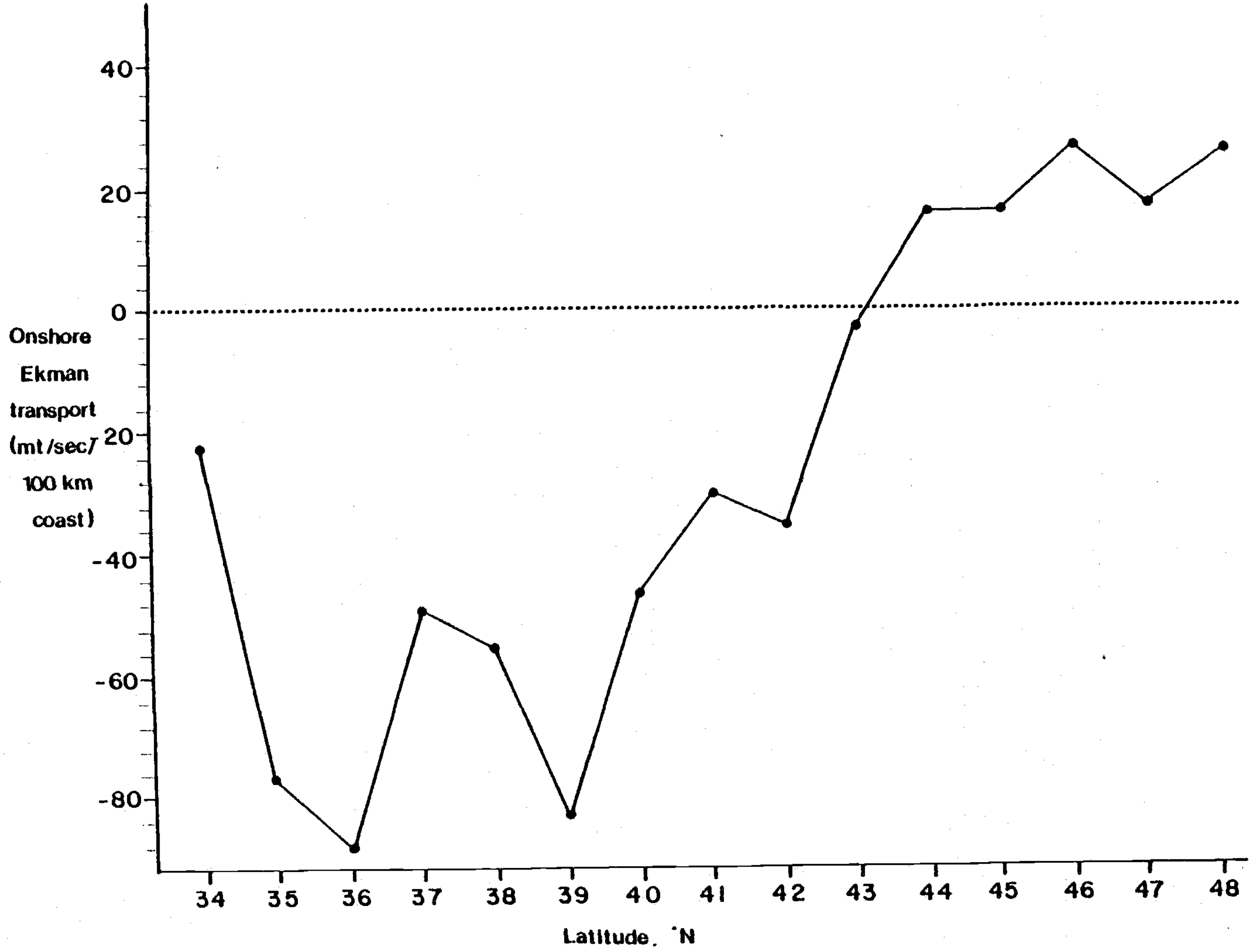

Wind stress curl (dyne cm^2/ 100 km)
.8
.6
.4
.2
0.0
118
119
120
121
122
122
122
123
123
124
124
124
124
124
124
124
124
124
125
125
125
125
125
125
125
125
125
126
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 13

offshore with latitude from 39°N northward (Figs. 14-16). Mean annual transport is offshore south of 43°N and onshore north of 43°N (Fig. 14). In winter, Ekman transport is onshore north of 40°N and offshore south of 40°N (Fig. 15). In summer, Ekman transport is offshore along most of the coast (Fig. 16). The degree of summer offshore transport increases to the south and is strongest at 39°N. Between 38°N and 37°N, summer offshore transport weakens somewhat, and falls off again at 34°N (in both seasons).

Longshore wind stress measurements are used to calculate upwelling indices, and longshore wind stress is highly correlated with Ekman transport estimates (Table 51). The same latitudinal and seasonal patterns in Ekman transport are found in longshore wind stress (Figs. 17-19). Wind stress generally increases with distance from shore. On an annual basis, wind stress is positive (from the south) above 43°N and becomes more negative (from the north) between 43°N and 39°N (Fig. 17). Some decline in northerly wind stress appears between 38°N and 37°N, and again at 34°N. In winter, wind stress becomes more southerly from 40°N to 34°N (Fig. 18). In summer, alongshore wind stress is negative coastwide, becoming more negative from 48°N to 40°N (Fig. 19). Stress is less strong between 38° and 37°N, and again at 34°N. Onshore Ekman transport is directly related to alongshore wind stress:

Fig. 14. Mean annual onshore Ekman transport by latitude (Nelson, MS).


40
20
0
-20
-40
-60
-80
Onshore
Ekman
transport
(mt/sec/
100 km
coast)
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

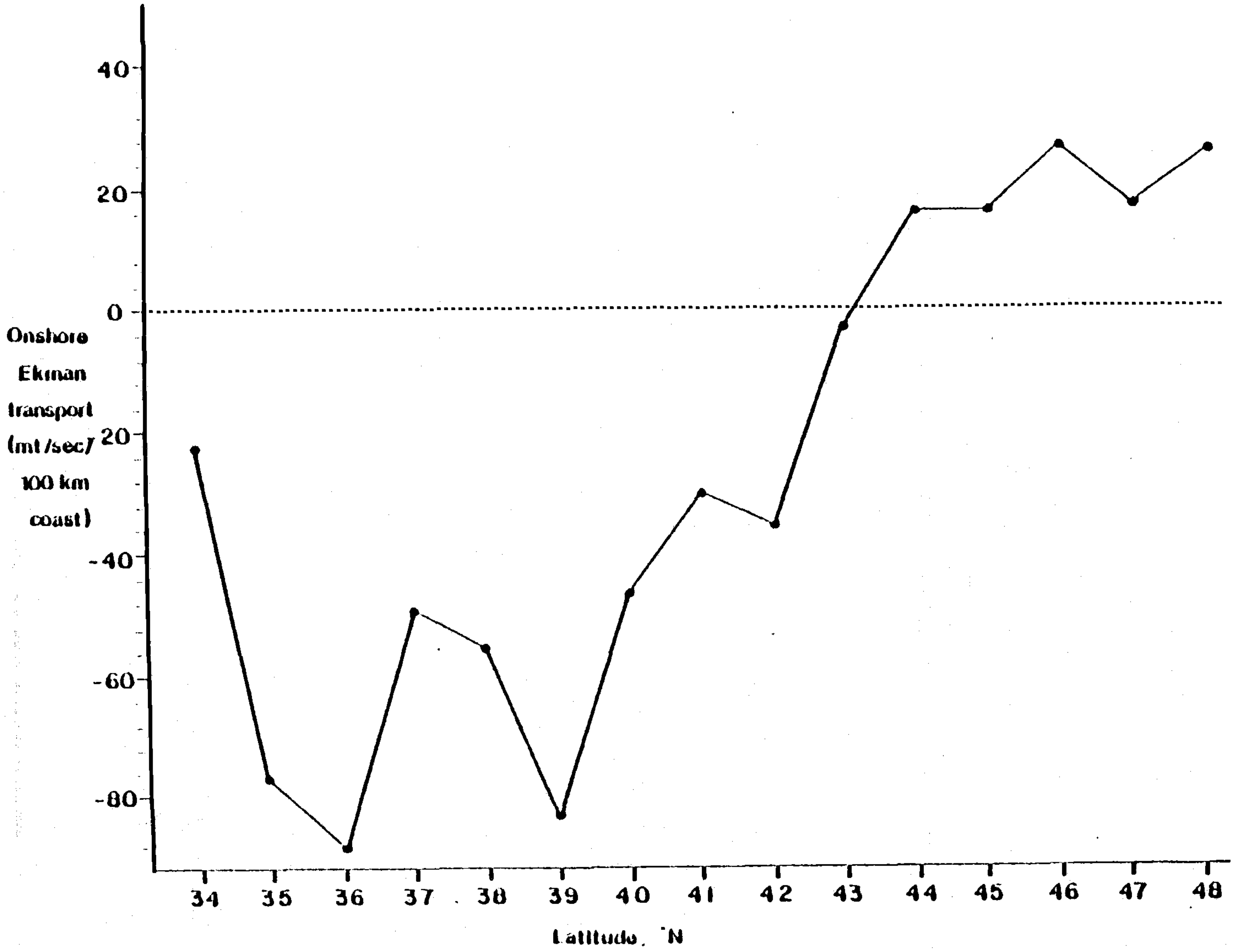

40
20
0
20
-40
-60
-80
Onshore Ekman transport (mt/sec/ 100 km coast)
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 14

Fig. 15. Mean winter onshore Ekman transport by latitude (Nelson, MS).

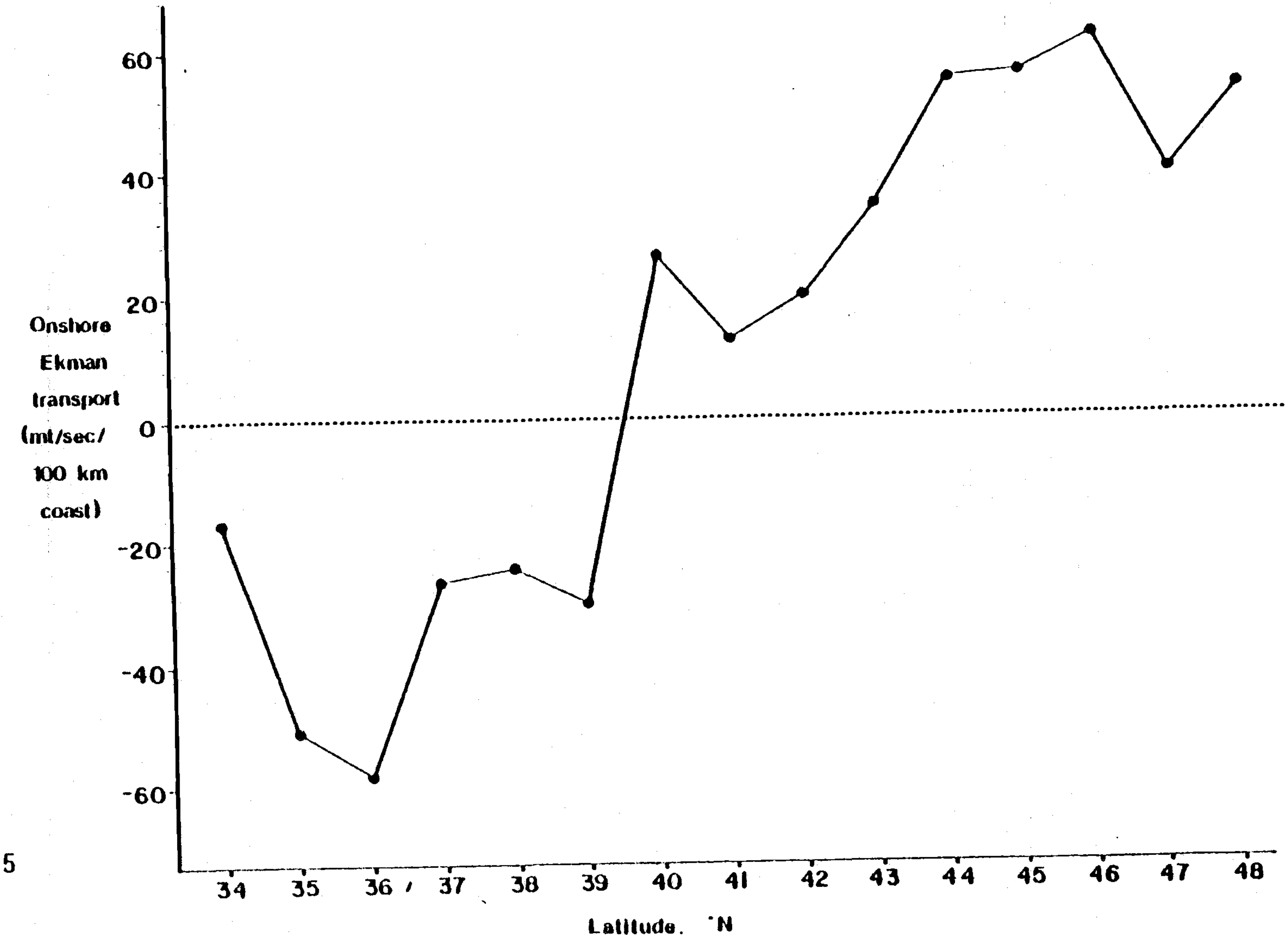

60
40
20
0
-20
-40
-60
Onshore
Ekman
transport
(mt/sec/
100 km
coast)
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 15

Fig. 16. Mean summer onshore Ekman transport by latitude (Nelson, MS).

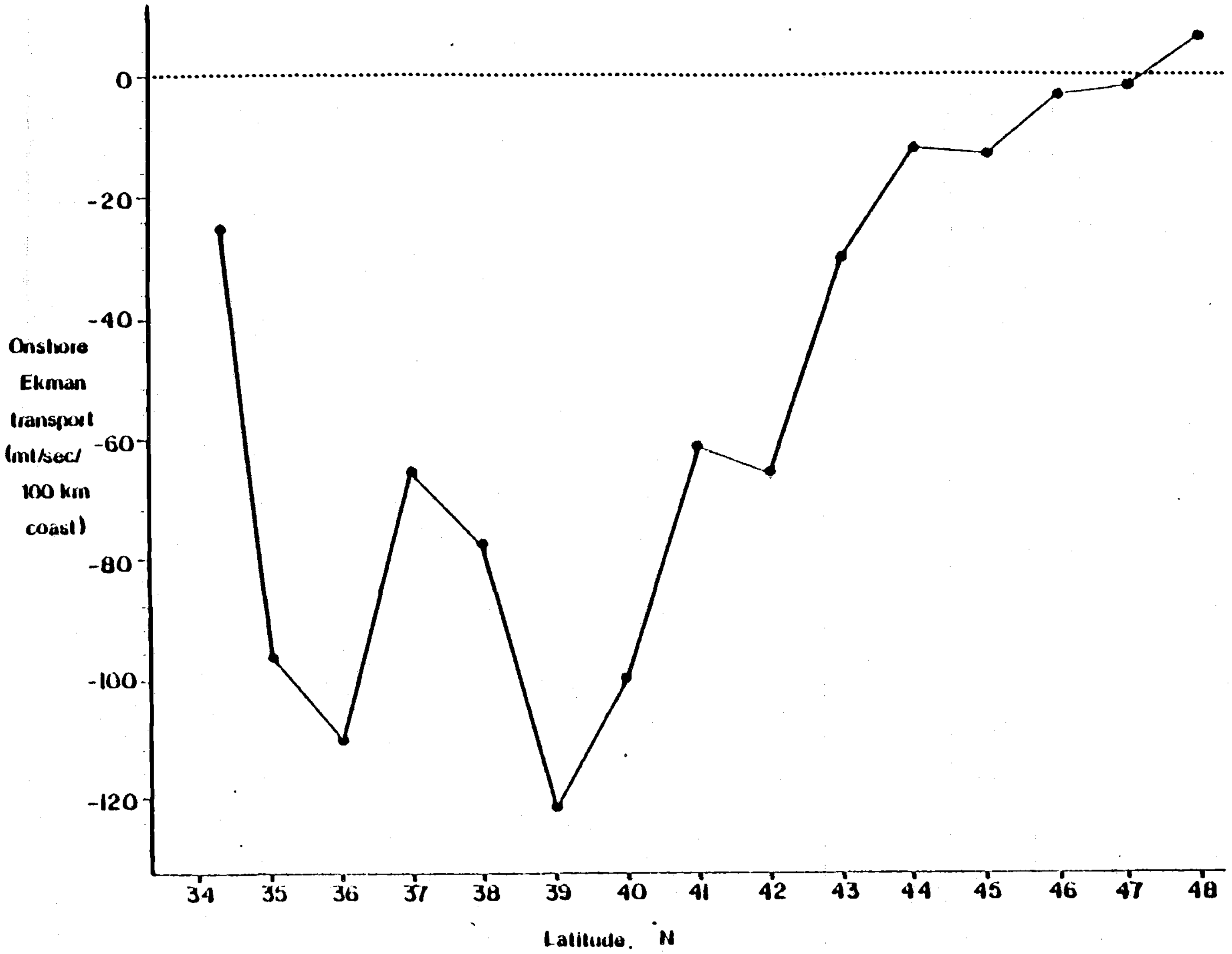

0
-20
-40
-60
-80
-100
-120
Onshore
Ekman
transport
(mt/sec/
100 km
coast)
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, N

Fig. 16

Table 51. Correlation between environmental variables by 1° latitude-longitude squares (except longshore ship drift 2° latitude - 1° longitude squares).

	Latitude	Depth	Wind stress curl annual	Wind stress curl winter	Wind stress curl summer	Ekman transport annual	Ekman transport winter	Ekman transport summer
Latitude	1.000							
Depth	-.107	1.000						
Wind stress curl								
annual	-.449	-.117	1.000					
winter	-.205	-.089	.803	1.000				
summer	-.559	-.085	.888	.483	1.000			
Ekman transport								
annual	.848	-.099	-.322	-.045	-.478	1.000		
winter	.911	-.084	-.390	-.104	-.518	.935	1.000	
summer	.740	-.094	-.255	-.007	-.415	.969	.819	1.000
Longshore ship drift								
annual	.412	-.082	.041	.337	-.277	.549	.385	.617
winter	.722	-.089	-.240	.031	-.474	.775	.619	.823
summer	-.188	-.031	.379	.544	.122	-.025	-.110	.030
Onshore wind stress								
annual	-.891	.123	.496	.287	.544	-.769	-.826	-.675
winter	-.475	.179	-.167	-.274	-.021	-.242	-.414	-.104
summer	-.840	.044	.485	.209	.568	-.767	-.880	-.632
Longshore wind stress								
annual	.883	-.154	-.309	-.044	-.471	.944	.880	.915
winter	.935	-.092	-.455	-.177	-.565	.894	.964	.779
summer	.682	-.180	-.193	.011	-.361	.854	.690	.898

Table 51 (continued)

	Longshore ship drift annual	winter	summer	Onshore wind stress annual	winter	summer	Longshore wind stress annual	winter	summer
Longshore ship drift									
annual	1.000								
winter	.816	1.000							
summer	.698	.156	1.000						
Onshore wind stress									
annual	-.284	-.660	.333	1.000					
winter	-.088	-.211	.096	.550	1.000				
summer	-.232	-.558	.296	.912	.533	1.000			
Longshore wind stress									
annual	.561	.822	-.063	-.839	-.315	-.777	1.000		
winter	.329	.645	-.240	-.896	-.430	-.925	.906	1.000	
summer	.636	.798	.091	-.655	-.126	-.531	.922	.692	1.000

Fig. 17. Mean annual alongshore surface wind stress by latitude and longitude (°W, next to figure points) (from Nelson, 1977).

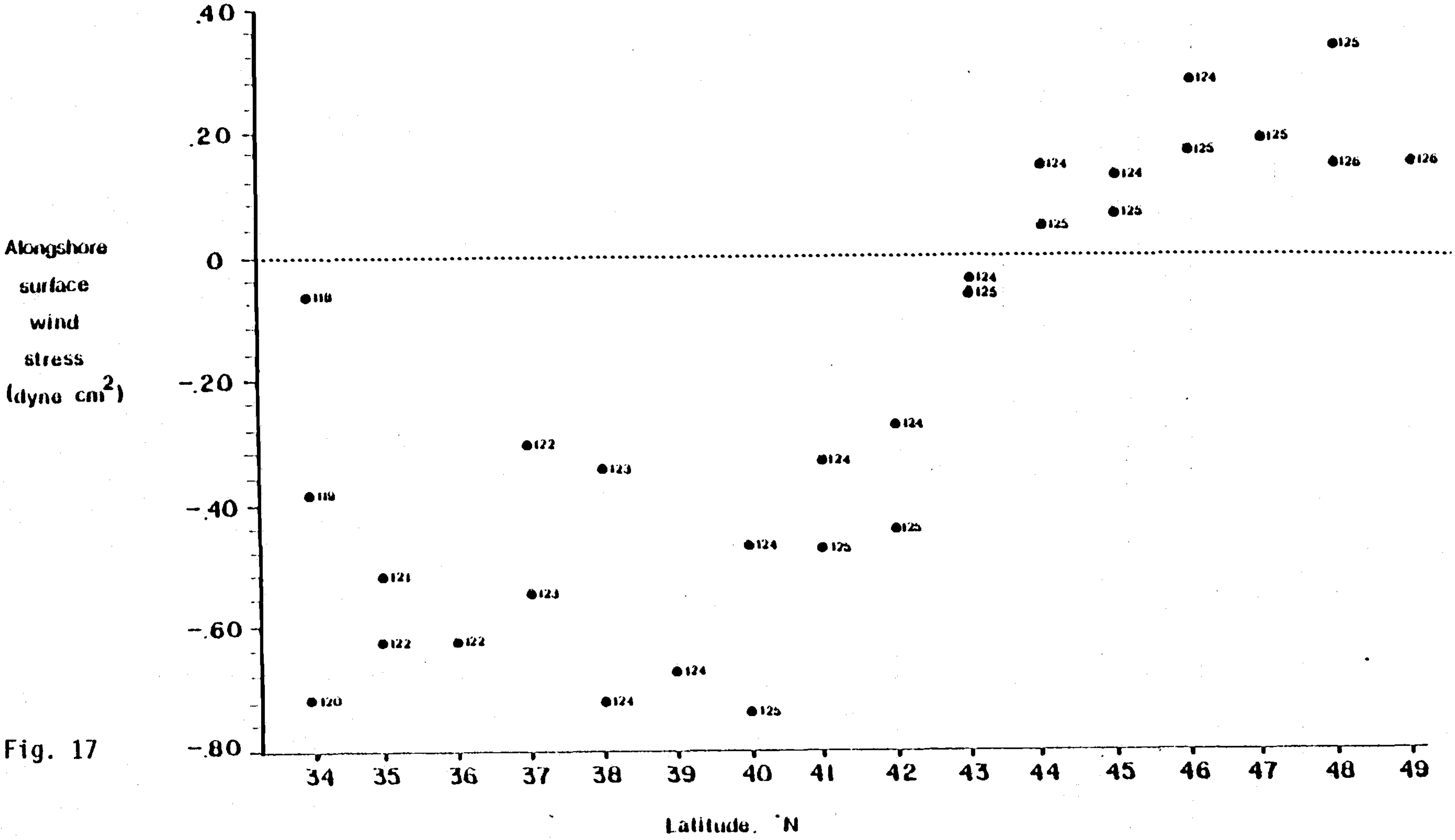

Alongshore surface wind stress (dyne cm²)
.40
.20
0
-.20
-.40
-.60
-.80
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
Latitude, °N

Fig. 17

Fig. 18. Mean winter alongshore surface wind stress by latitude and longitude (°W, next to figure points (from Nelson, 1977).

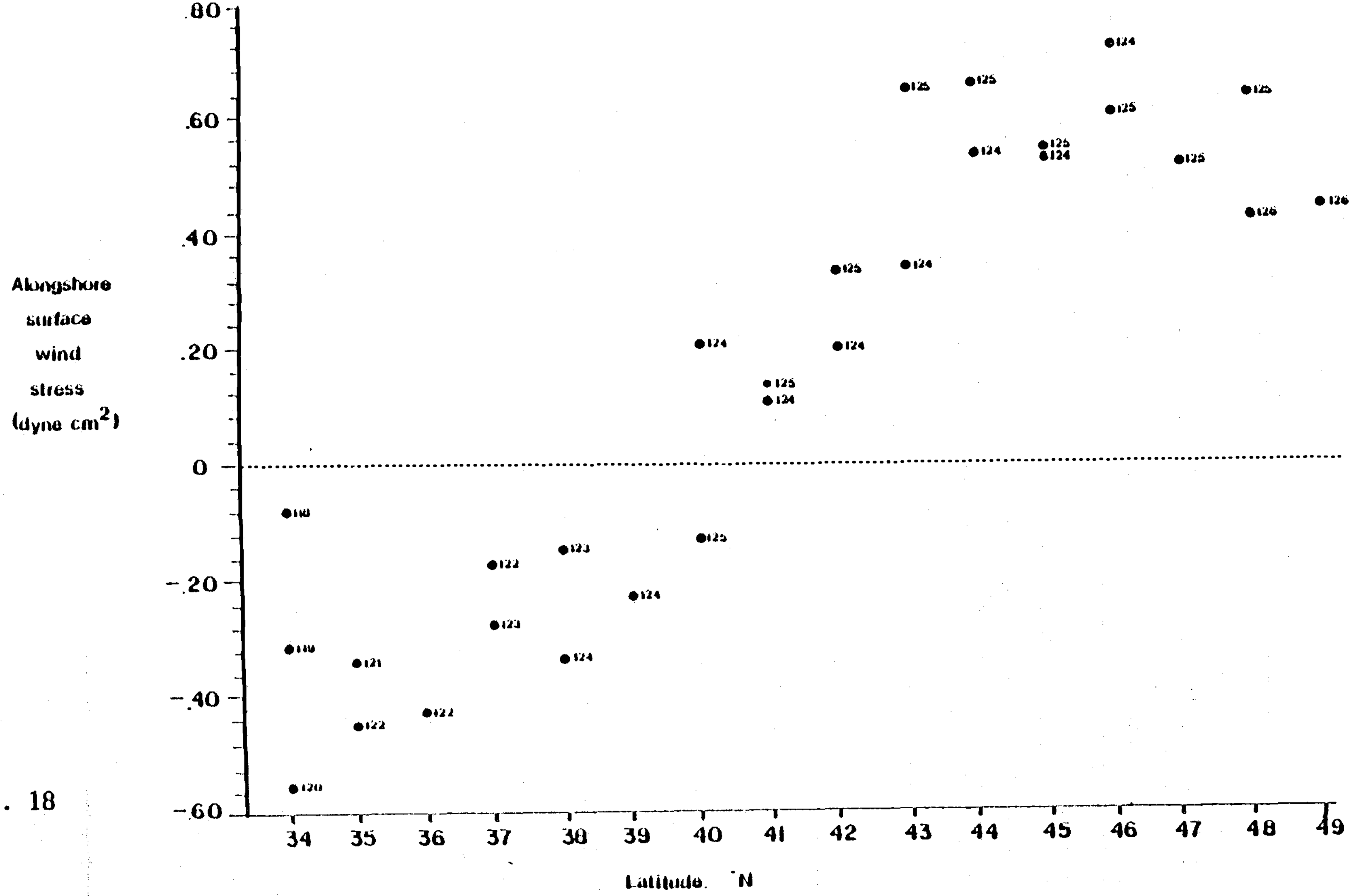
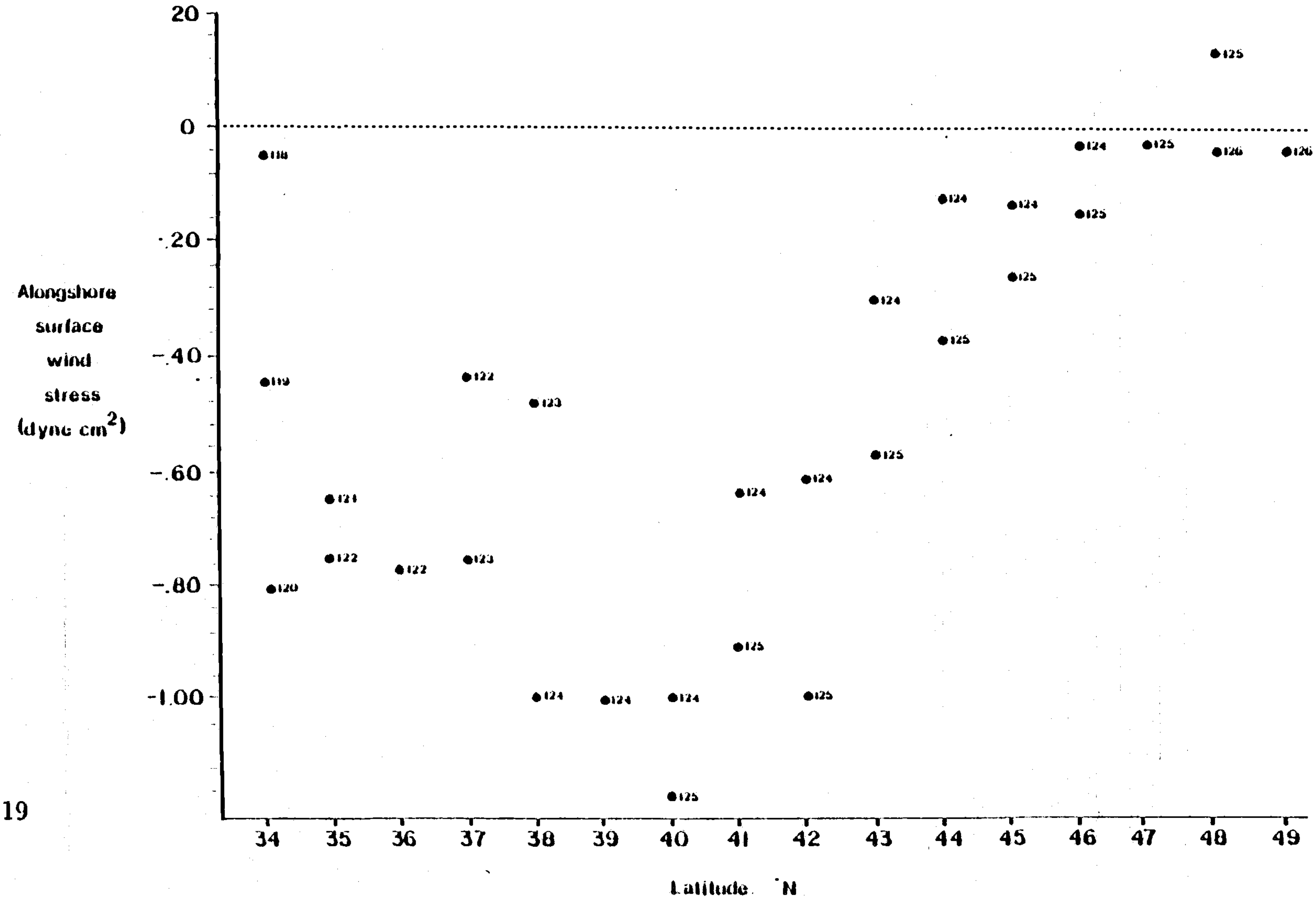

Alongshore surface wind stress (dyne cm^2)
.80
.60
.40
.20
0
-.20
-.40
-.60
34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
Latitude, °N

Fig. 18

Fig. 19. Mean summer alongshore surface wind stress by latitude and longitude (°W, next to figure points) (from Nelson, 1977).



20
0
-.20
-.40
-.60
-.80
-1.00
Alongshore
surface
wind
stress
(dyne cm2)
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
Latitude °N

Fig. 19

$$M_x =_{oo}^{o} \quad Udz = (-\frac{yz}{f})o$$

where M_x = onshore Ekman transport

= water density

U = x-directed velocity

yz = alongshore wind stress

f = Coriolus parameter, increases with latitude.

(McLellan, 1965). Since the sample area covered a wide range in latitude, f would vary and so Ekman transport would be a more appropriate variable. Future models on this scale shuld include Ekman transport rather than alongshore wind stress.

Longshore ship drift data, representing actual current measurements, is slightly correlated with longshore wind stress and Ekman transport means annually and during the winter (r_{crit} = .71 at = 0.05 and df = 6, since longshore ship drift was pooled by Nelson over two degree latitude intervals), but poorly correlated during the summer (Table 51). On an annual basis, southward flow is observed coastwide, but is weakest at 34°N and slightly northward between 47-48°N (Fig. 20). During summer, flow is strongly southward, especially between 41-44°N and again between 37-38°N (Fig. 20). In winter, flow is increasingly northward north of 42°N. Flow is southward between 42°N and 35°N, and most strongly southward between 41° and 37°N (Fig. 20).

Onshore surface wind stress may be a contributing factor to alongshore Ekman transport, and hence indirect north-south advection of surface production, eggs and larvae. Summer onshore wind stress is slightly positively correlated with summer longshore ship drift (Table

Fig. 20. Mean annual, winter and summer alongshore shipdrift data by latitude (from Nelson, MS).

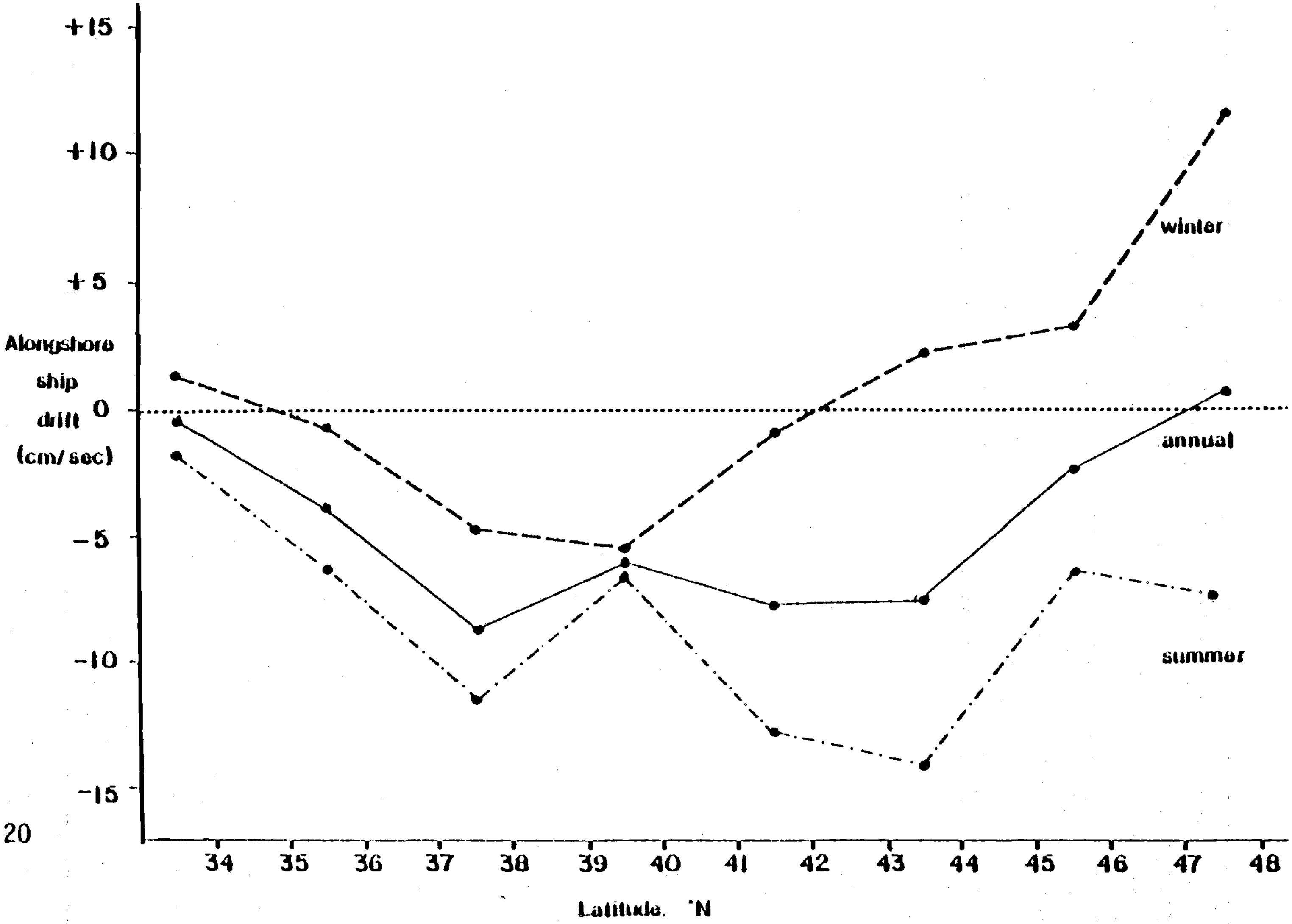

+15
+10
+5
0
−5
−10
−15
Alongshore
ship
drift
(cm/sec)
winter
annual
summer
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Latitude, °N

Fig. 20

51), and may indirectly influence north-south current patterns. Positive onshore surface wind stress would produce southward surface flow. Onshore surface wind stress generally increases with distance from shore. On an annual basis, mean onshore surface wind stress is highest toward the south, decreasing to a lower level north of 40°N (Fig. 21). In winter, onshore stress declines from 34°N to 41°N, increases slightly between 41°N and 45°N and declines further north of 46°N to slightly negative values at 48°N (Fig. 22). In summer, onshore wind stress is high between 34°N and 39°N and drops north of 40°N to relatively low positive values at 43°N (Fig. 23).

Canonical Correlation Analysis

Canonical correlation analysis associated combinations of oceanographic features such as seasonal upwelling and transport patterns with combinations of fish species. The first canonical variable, linear combinations of environmental and species variables, reconstructed the largest amount of variance shared by environmental and species variance-covariance matrices. Depth appeared to be the single dominating environmental influence. Coefficients associated with depth were relatively largest in canonical variables one and two (Table 52), while largest coefficients for other variables appeared in other canonical variables. Coefficients associated with wind stress curl, Ekman transport and longshore ship drift were somewhat larger in the second canonical variable than the first. Species whose coefficients were relatively large with respect to the first canonical variable included filetail, and unidentified catsharks, Dover sole, lanternfish, aurora,

Fig. 21. Mean annual onshore surface wind stress by latitude and longitude (°W, next to figure points) (from Nelson, 1977).

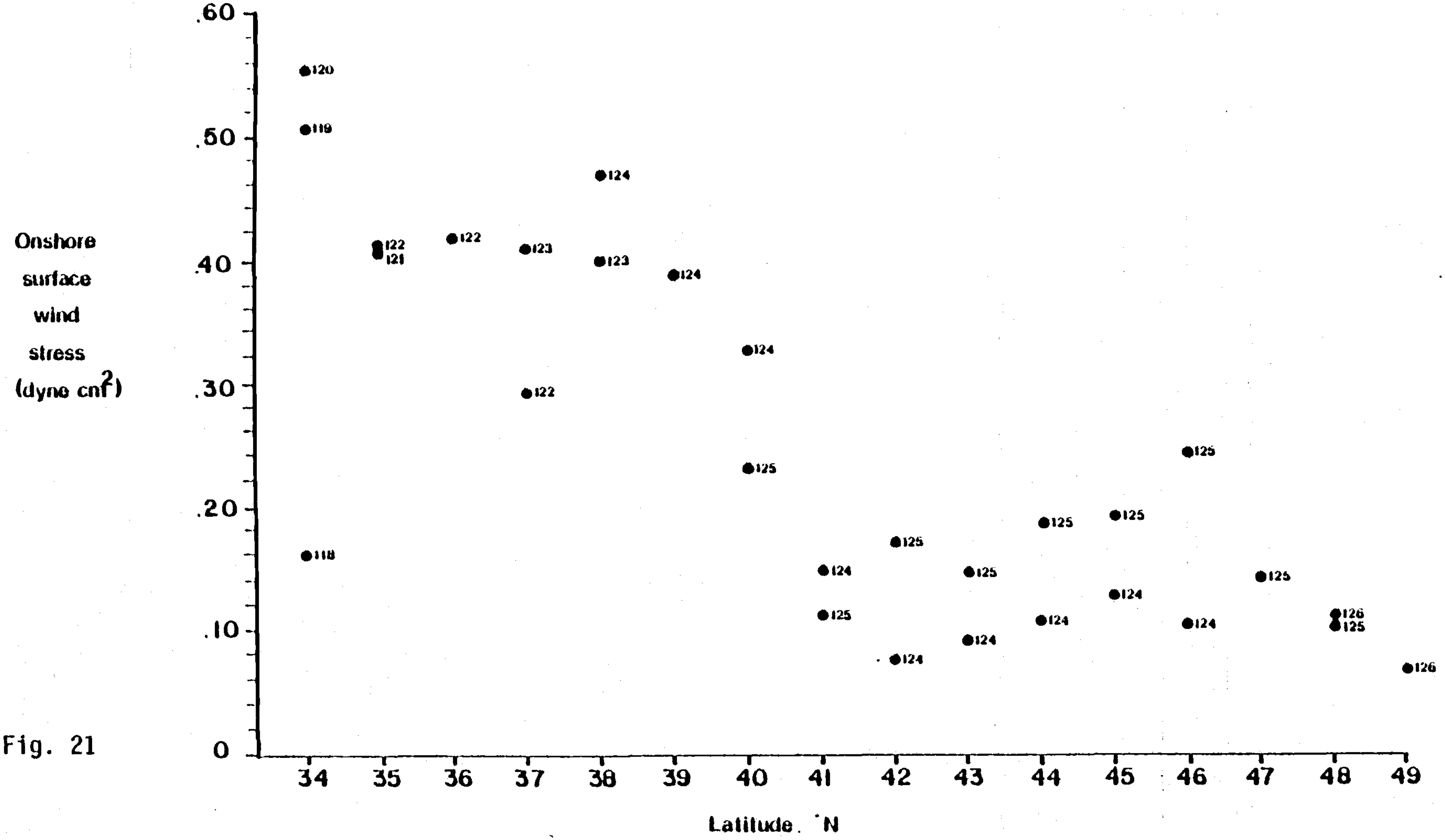

Onshore
surface
wind
stress
(dyne cm^{-2})
.60
.50
.40
.30
.20
.10
0
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
Latitude, °N
120
119
118
122
121
122
123
122
124
123
124
124
125
124
125
125
124
125
124
125
124
125
124
125
124
125
126
125
126

Fig. 21

Fig. 22. Mean winter onshore surface wind stress by latitude and longitude (°W, next to figure points) (from Nelson, 1977).

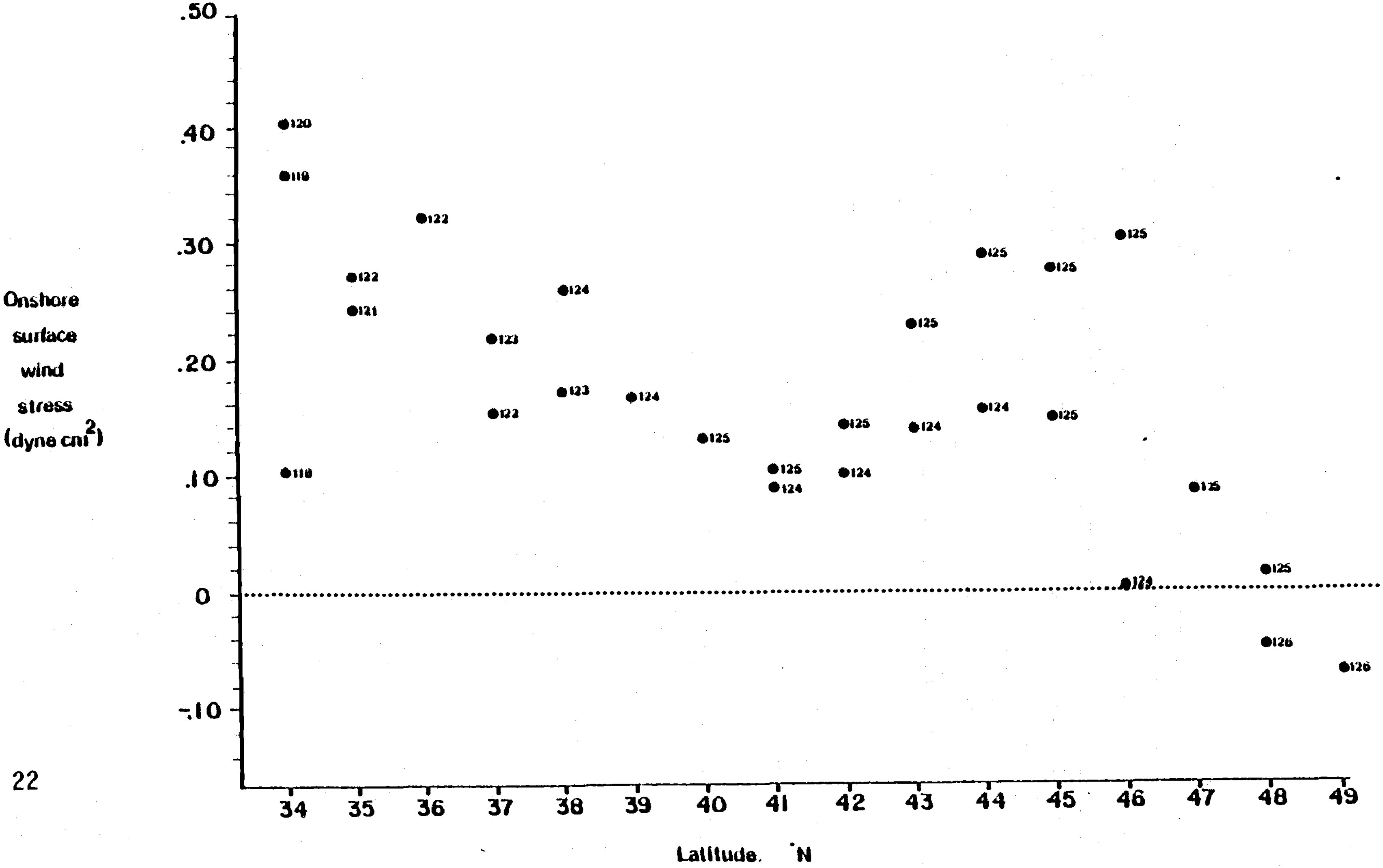

.50
.40
.30
.20
.10
0
-.10
Onshore
surface
wind
stress
(dyne cm^{-2})
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
Latitude, °N

Fig. 22

Fig. 23. Mean summer onshore surface wind stress by latitude and longitude (°W, next to figure points) (from Nelson, 1977).

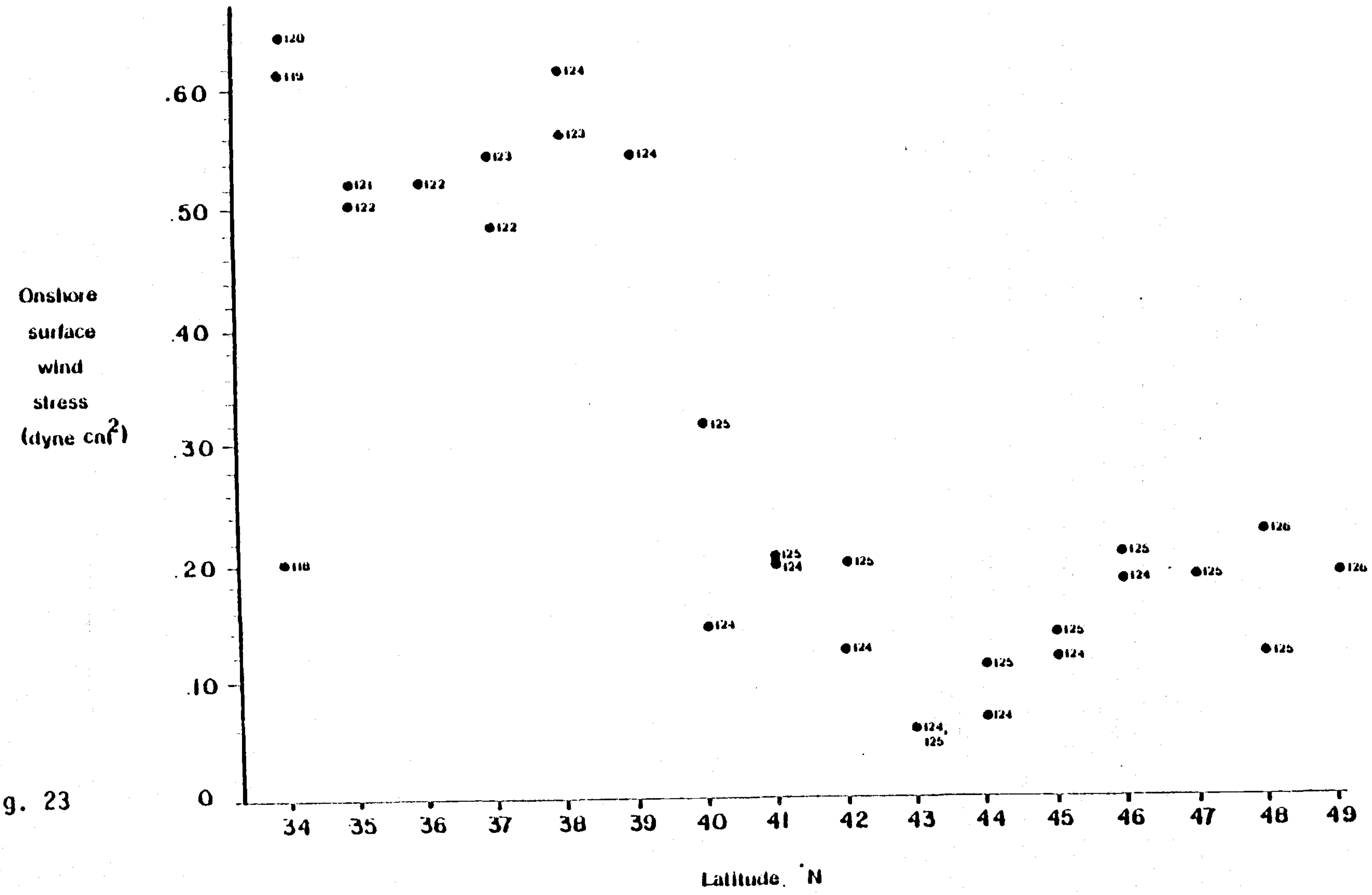

Onshore surface wind stress (dyne cm^{-2})
.60
.50
.40
.30
.20
.10
0
34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
Latitude, °N

Fig. 23

Table 52. Relative importance of environmental and species variables in formation of new canonical variables (CV) from canonical correlation analysis. Numbers represent rank of each environmental or species variables six highest coefficients as contributions to canonical variables.

Variable	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	CV11	CV12	CV13	CV14	CV15	CV16	CV17
Latitude			6	-3	4			-5		2				1			
Depth	1	2		-3	-7	4			5				6				
Wind stress curl																	
annual	(15)	(9)		-3	-2						5		-6	1	-4		
winter	(17)	(11)		4	1						-3	5	6	-2			
summer	(15)	(12)		4	1				5		6			-3	2		
Onshore Ekman transport																	
annual	(16)	(15)	-3						5	6		4	-2				1
winter	(15)	(13)		6									5			2	-1
summer	(17)	(16)	2									-4	3	5	6		
Longshore ship drift																	
annual	(13)	(7)						-2	-3	6		-4	-5	1			
winter	(13)	(7)						2	3	-6		4	5	-1			
summer	(13)	(7)						2	3	-6		4	5	-1			
Onshore wind stress																	
annual								-6	5		-4	-1	2		3		
winter					5		-6	3			2	1			-4		
summer			-4				6	-5				2	-3	-1			
Longshore wind stress																	
annual					2		1		6		5				-3	4	
winter							-3		4		-5	6			2	-1	
summer			4		2		-1			-3	-6				5		

Table 52 (continued)

Variable	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	CV11	CV12	CV13	CV14	CV15	CV16	CV17
Brown catshark						-6		4		-1	-2	-5			-3		
Filetail catshark	5					-2				1	-6				-4	3	
Longnose catshark									-1	-3	4				5	-2	6
Unid catshark	3					-6			-2				4		5		-1
Spiny dogfish		-6		-5			3	-4		-1	2						
Soupfin shark			-6			-3			1	-4	5				2		
Blue shark									6	-4	-3	-1		5	-2		
Leopard shark				1		-6			2	-5	3		-4				
Big skate					-4		2						3	1		5	6
Black skate			-6		4		-5	2		7			-1			-3	
Longnose skate		6	2		3			-5						4		-1	
Roughtail skate			-6	-4					2			3			1	5	
Pacific electric ray			5	1		-4			2		6				-3		
Pacific ratfish	-5	4			1	-3								6	-2		
Unid sanddab		3	-5	4				1			-6		-5	-2			
Pacific sanddab		-1			-6					2		-5	4	-3			
Arrowtooth flounder		5	4		-1	-6		3								2	
Pacific halibut				-4	-2		1	3			5			-6			
Flathead sole					-4			-1				2	-3	5	-6		
Slender sole						-1	-6	-3		-5	-4	-2					
Petrale sole			3		-2	-4	-1	6							5		
English sole			-2						-6		1	4			-3	5	
Dover sole		6	-4	-2		-5							3		-1		
Rex sole							3					2	-5	-1	6	-4	
Rock sole		-4		-3	6		1			-5						-2	
Wolf eel						-2			-1	4			3	6			5
Sablefish					-5	1		-4			6				3		2
Plainfin midshipman								-2		-1	5	-4		-3			-6
Jack mackerel						-6		-5	2		3	4			1		
Pacific herring		6						2		1	-3	4		-5			
American shad			-6							-4	-1	-2		5	-3		
White croaker			-4	5		-3			6				2	-1			

Table 52 (continued)

Variable	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	CV11	CV12	CV13	CV14	CV15	CV16	CV17
Pink sea perch			2			6		3			-4	5		1			
Northern anchovy				6				-2	4			5	-1	3			
Pacific tomcod			-6				-4			-5	-1			2		-3	
Pacific cod			6		3	-5						4	-2	-1			
Pollock			4	-5		-6	1	3		2							
Lingcod	-6				-5	-2	-1							-4	-3		
Pacific hake	-3							-1			-2	4				6	5
Ocean sunfish				1		-2			3		4			6		-5	
Lanternfish	2			3		4			1			5			6		
Unid smelt			-6						-5			-4	-3		2	-1	
Eulachon						6					-2	5	3			1	4
Surf smelt				-5	-2	-3	-1				4	-6					
Pacific ocean perch		5	3		2		-1	-6						-4			
Aurora rockfish	1			-6					5		4			-3	-2		
Silvergrey rockfish				-5		-2		1					-3	-4	-6		
Copper rockfish			3			5	-4	1		6	-2						
Greenspotted rockfish				2	-5			1		6		3		-4			
Darkblotched rockfish		6	-2			5		4				-3		-1			
Splitnose rockfish	5	-2	1	-6		3		4									
Greenstriped rockfish						6					-5		3	-1	-4	-2	
Widow rockfish		6					2	5			4			-3	-1		
Pink rockfish				6				5					3	-1	-4	-2	
Yellowtail rockfish							2			3	-5			4	1		6
Chilipepper			-2	-6		-3			1			-5		4			
Rosethorn rockfish			-4	-5			-6		2			5			1		
Shortbelly rockfish			6			5				2	-3	-4			-1		
Cow rockfish		4		5								-3	-2	-1	-6		
Quillback rockfish	4		-3		-1	2								-6	5		
Blackgill rockfish				-5				-1		6	2	-4		3			
Vermilion rockfish		4			2	-1	-5	-6		3							
Speckled rockfish				5		-3			-2			4		-1		-6	
Bocaccio		-3	2	-6				-1	-5					4			
Canary rockfish					-2			-4				3	-5		1		-6
Redstripe rockfish			3	4	1		-5	-6					2				

Table 52 (continued)

Variable	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	CV11	CV12	CV13	CV14	CV15	CV16	CV17
Yelloweye rockfish		5			-6					-4	2		1		-3		
Flag rockfish		3			5	4	6			2			1				
Stripetail rockfish		-6				-1		4		-5		2	3				
Pygmy rockfish									-5		6	-2		-3		1	4
Sharpchin rockfish						6		-5			4		1	3	-2		
Bank rockfish						-6			5			1	3		4	2	
Shortraker rockfish		5			-2		4		6		3		1				
Yellowmouth rockfish	5	-4	-2				1				6			3			

splitnose, and quillback rockfish with positive coefficients; and ratfish, rock sole, lingcod, and Pacific hake with negative coefficients reflecting relatively shallower distributions. The canonical correlation of 0.76 between the environmental linear combination emphasizing depth and the species linear combination emphasizing Dover sole and Pacific hake (among others) can also be interpreted in terms of affiliated variance. The square of the canonical correlation, 58.5%, reflects the percentage of variance in the first species canonical variable accounted for by the first environmental canonical variable.

In the second canonical variable, depth, was a somewhat smaller contributing factor. However, coefficients for environmental variables related to wind stress curl, onshore Ekman transport, and longshore ship drift were somewhat larger in the second canonical variable than in the first. Species contributing to this variable included spiny dogfish, Pacific sanddab, splitnose rockfish, bocaccio, stripetail rockfish, and yellowmouth rockfish (negative coefficients); and longnose skate, ratfish, unidentified sanddab, arrowtooth flounder, Pacific herring, Pacific ocean perch, darkblotched rockfish, widow, cow, vermilion, yelloweye, flag, and shortraker rockfish (positive coefficients). All species with negative coefficients except splitnose rockfish were negatively correlated with depth, although often at low levels; and were often positively correlated with wind stress curl on an annual or summer basis, negatively correlated with onshore Ekman transport over most seasons, or negatively correlated with longshore ship drift in summer (Table 53). Species with positive coefficients had positive or low (>-.10) negative correlations with depth, and were often positively

Table 53. Correlation between species abundances and environmental factors. Values less than .10 have been replaced by the sign of the correlation. Curl = windstress curl, Ekman = Offshore Ekman transport, Lshdr = longshore ship drift, Owstr = Onshore wind stress, Lwstr = Longshore wind stress, A = annual mean, W = winter mean, S = summer mean.

	Latitude	Depth	Curl A	Curl W	Curl S	Ekman A	Ekman W	Ekman S	Lshdr A
Brown catshark	-	.20	+	+	+	-	-	-.10	-
Filetail catshark	-.24	.26	+	+	-	-.19	-.23	-.14	+
Longnose catshark	-.20	.22	-	+	-	-.19	-.22	-.16	+
Unid catshark	-	.16	-	-	-	-.10	-	-	-
Spiny dogfish	+	-.13	.10	+	+	+	+	+	+
Soupfin shark	-	-	+	+	+	-	-	-	-
Blue shark	-	+	+	+	+	-	+	-	-
Leopard shark	-	-	+	+	+	+	-	+	-
Big skate	.11	-	+	+	-	+	+	+	.10
Black skate	+	.18	-	-	-	-	+	-	-
Longnose skate	+	-	+	+	-	+	+	+	+
Roughtail skate	-	+	+	-	+	-.11	-	-.12	-
Pacific electric ray	-.19	-	.12	.12	.10	-	-.12	-	+
Pacific ratfish	+	-	+	+	+	+	+	+	+
Unid sanddab	-	-	+	+	+	-	-	-	-
Pacific sanddab	-.15	-.24	+	-	.12	-.15	-.17	-.12	-.18
Arrowtooth flounder	.28	-	-	-	-.16	.25	.23	.25	.25
Pacific halibut	.12	+	+	+	-	.10	+	.10	.12
Flathead sole	.17	-.13	-	+	-.10	.17	.17	.16	.13
Slender sole	-	-.14	+	+	+	-	-	-	+
Petrale sole	.10	-.17	+	+	-	+	+	.11	.14
English sole	-	-.22	+	-	.10	-	-	-.10	-.17
Dover sole	+	.29	-	-	-	-	-	-.12	-.10
Rex sole	+	.19	+	+	+	-	-	-	-
Rock sole	+	-	+	+	+	+	+	+	+
Wolf eel	-	-	-	-	-	-	-	-	+
Sablefish	.13	.16	-.11	-	-.12	.11	.11	.10	+
Plainfin midshipman	-.12	-.17	.17	+	.21	-	-.11	-	-.13
Jack mackerel	-	-	-	-	+	-	-	-	-
Pacific herring	+	-	+	+	+	+	+	+	+
American shad	+	-.11	+	+	+	-	+	-	+

Table 53 (continued)

	Latitude	Depth	Curl A	Curl W	Curl S	Ekman A	Ekman W	Ekman S	Lshdr A
White croaker	-	-	+	+	+	-	-	-	-
Pink sea perch	-.12	-.16	.13	+	.16	-	-.11	-	-.11
Northern anchovy	-	-	+	+	+	+	+	+	+
Pacific tomcod	+	-.14	+	+	+	-	+	-	-
Pacific cod	.17	-.11	+	+	-	.14	.12	.15	.16
Pollock	.11	-	+	+	+	+	+	+	.11
Lingcod	+	-	-	-	-	+	+	+	+
Pacific hake	+	-.20	+	-	+	+	+	+	-
Ocean sunfish	-	-	+	+	+	-	-	+	+
Lanternfish	-.13	.26	+	+	+	-	-	+	+
Unid smelt	+	-	-	-	-	+	+	+	-
Eulachon	.11	-.12	-	-	-.10	.11	.12	.10	+
Surf smelt	+	-	-	-	-	+	+	+	+
Whitebait smelt	-	-	-	-	+	-	-	-	-
Coho salmon	+	-	-	-	+	+	+	+	-
Pacific argentine	-.12	-	.15	.12	.14	-	-	+	+
Unid eelpout	-.10	+	-	+	-	-.12	-.14	-.10	-
Bigfin eelpout	-.11	.19	+	+	.12	-.18	-.12	-.22	-.14
Shortspine thornyhead	.28	.18	-.21	-.13	-.25	.27	.28	.24	.15
Rougheye rockfish	.23	.21	-.10	-	-.15	.21	.19	.21	.19
Pacific ocean perch	.15	+	-	+	-	.13	.12	.13	.13
Aurora rockfish	-.20	.39	+	+	+	-.21	-.21	-.19	-
Silvergray rockfish	.15	-	+	+	-	.13	.11	.13	.14
Copper rockfish	-	-	+	+	+	-	-	-	-
Greenspotted rockfish	-.13	-	+	+	+	-	-.10	-	+
Darkblotched rockfish	+	+	-	-	+	-	+	-	-.12
Splitnose rockfish	-.16	.13	.13	+	.18	-.15	-.18	-.13	-.15
Greenstriped rockfish	+	-.15	-	-	-	+	+	+	-
Widow rockfish	+	-	+	+	+	+	+	+	+
Pink rockfish	+	-	-	-	-	+	+	+	-
Yellowtail rockfish	.14	-.12	+	+	-	.11	.10	.12	.13
Chilipepper	-	-	.11	+	.14	-.15	-.11	-.10	-.14
Rosethorn rockfish	+	-	+	-	+	-	-	-	-
Shortbelly rockfish	-	-	+	-	+	-	-	-	-.12

Table 53 (continued)

	Latitude	Depth	Curl A	Curl W	Curl S	Ekman A	Ekman W	Ekman S	Lshdr A
Cow rockfish	-	-	+	+	+	-	-	-	-
Quillback rockfish	+	-	+	+	+	+	+	+	+
Blackgill rockfish	-.12	.21	+	-	+	-.15	-.16	-.14	-
Vermilion rockfish	+	+	-	+	-	-	-	-	+
Speckled rockfish	-	-	+	+	-	-	-	-	+
Bocaccio	-	-	.10	+	.12	-	-	-	-
Canary rockfish	.12	-.13	-	-	-.10	.12	.12	.11	+
Redstripe rockfish	+	-	-	+	-	+	+	+	-
Yelloweye rockfish	.16	-	-	+	-	.15	.14	.14	.14
Flag rockfish	.19	+	-	-	-.12	.15	.15	.13	.12
Stripetail rockfish	-.17	-	.11	+	.13	-.24	-.19	-.25	-.14
Pygmy rockfish	+	-	-	-	-	+	+	+	-
Sharpchin rockfish	.11	-	-	-	-	.11	.12	.10	+
Bank rockfish	-	+	+	-	+	-	-	-	-
Shortraker rockfish	.12	+	-	-	-	.11	.10	.11	.11
Yellowmouth rockfish	+	-	+	+	-	+	+	+	+

Table 53 (continued)

	Lshrdr W	Lshrdr S	Owstr A	Owstr W	Owstr S	Lwstr A	Lwstr W	Lwstr S
Brown catshark	-	+	+	-	+	-	-	-
Filetail catshark	-	.14	.21	.18	.21	-.19	-.24	-.12
Longnose carshark	-	+	.16	.14	.16	-.15	-.19	-.10
Unid catshark	-	-	+	+	+	-.10	-	-.10
Spiny dogfish	+	-	-	-	-	+	+	+
Soupfin shark	-	+	+	+	+	-	-	-
Blue shark	-	+	+	-	-	-	+	-
Leopard shark	+	.10	+	+	+	-	-	+
Big skate	.12	+	-	-	-	.11	+	+
Black skate	-	-	-	-	-	-	+	-
Longnose skate	.11	-	-	-	-	.10	+	.11
Roughtail skate	-.10	+	+	+	.10	-.11	-	-.13
Pacific electric ray	-	.17	.21	.18	.18	-.10	-.16	-
Pacific ratfish	.11	+	-	-	-	+	+	+
Unid sanddab	-	-	+	+	+	-	-	+
Pacific sanddab	-.16	-.11	.12	+	.16	-.14	-.16	-.10
Arrowtooth flounder	.31	+	-.23	-.14	-.19	.28	.24	.26
Pacific halibut	.15	+	-	-	-	.12	+	.10
Flathead sole	.15	+	-.16	-.13	-.12	.19	.17	.18
Slender sole	-	+	+	-	+	-	-	-
Petrale sole	.18	+	-	-	-	.11	+	.12
English sole	-.13	-.12	+	+	+	-	-	-.11
Dover sole	-	-	+	-	+	-	-	-.12
Rex sole	-	-	+	-	+	-	-	-
Rock sole	+	-	-	-	-	+	+	+
Wolf eel	-	+	+	+	+	-	-	-
Sablefish	+	-	-	+	-	.11	.12	.10
Plainfin midshipman	-.12	-	.10	+	.13	-	-.11	-
Jack mackeral	-	-	+	+	+	-	-	-
Pacific herring	+	+	-	-	-	+	+	+
American shad	-	+	-	-.11	-	-	+	-
White croaker	-	+	+	+	+	-	-	-
Pink sea perch	-.10	-	+	+	+	-	-.11	-

Table 53 (continued)

	Lshrdr W	Lshrdr S	Owstr A	Owstr W	Owstr S	Lwstr A	Lwstr W	Lwstr S
Northern anchovy	+	+	+	+	+	+	+	+
Pacific tomcod	-	+	-	-	-	-	+	-
Pacific cod	.21	+	-.14	-.12	-.11	.17	.13	.14
Pollock	.14	+	-	-	-	.10	+	+
Lingcod	+	+	-	-	-	+	+	+
Pacific hake	-	-	-	-	+	+	+	+
Ocean sunfish	-	+	+	+	+	-	-	-
Lanternfish	-	.15	.13	.15	+	-	-.10	-
Unid smelt	+	-.12	-	+	-	+	+	-
Eulachon	+	+	-.10	-	-	.11	.11	.12
Surf smelt	+	+	-	-	-	+	+	+
Whitebait smelt	-	+	+	-	+	-	-	-
Coho salmon	+	-	-	-	-	+	+	+
Pacific argentine	-	.13	+	+	+	-	-	+
Unid eelpont	-	+	+	+	+	-	-.11	-
Bigfin eelpont	-.20	+	.12	-	+	-.19	-.12	-.23
Shortspine thornyhead	.20	+	-.24	-	-.24	.27	.27	.25
Rougheye rockfish	.24	+	-.21	-.10	-.18	.23	.19	.21
Pacific ocean perch	.17	+	-.11	-	-	.12	.10	.14
Aurora rockfish	-.13	+	.17	+	.16	-.20	-.20	-.18
Silvergray rockfish	.18	+	-.10	-	-	.13	.10	.13
Copper rockfish	-	-	+	+	+	-	-	+
Greenspotted rockfish	-	+	.11	+	.11	-	-.10	-
Darkblotched rockfish	-	-.11	-	-	-	-	+	-
Splitnose rockfish	-.15	-	.11	+	.14	-.12	-.17	-
Greenstriped rockfish	-	-	-	-	-	+	+	+
Widow rockfish	.10	+	-	-	-	+	+	+
Pink rockfish	+	-	-	+	-	+	+	+
Yellowtail rockfish	.16	+	-.11	-	-	.14	.11	.12
Chilipepper	-.17	-	.13	-	.11	-.16	-.11	-.18
Rosethorn rockfish	-	-	+	-	+	-	-	-
Shortbelly rockfish	-	-	+	+	.10	-	-	-
Cow rockfish	-	-	+	+	+	-	-	-
Quillback rockfish	-	+	-	-	-	+	+	+

Table 53 (continued)

	Lshrdr W	Lshrdr S	Owstr A	Owstr W	Owstr S	Lwstr A	Lwstr W	Lwstr S
Blackgill rockfish	-.10	-	.14	+	.15	-.14	-.15	-.11
Vermilion rockfish	+	+	+	+	+	-	-	+
Speckled rockfish	-	+	+	+	+	-	-	-
Bocaccio	-	-	+	+	+	-	-	-
Canary rockfish	.10	+	-.10	-	-	.13	.12	.13
Redstripe rockfish	+	+	-	-	-	+	+	+
Yelloweye rockfish	.16	+	-.10	-	-.10	.16	.14	.15
Flag rockfish	.16	-	-.14	-	-.13	.16	.15	.13
Stripetail rockfish	-.20	+	.16	-	.15	-.21	-.18	-.21
Pygmy rockfish	+	-	-	-	-	+	+	+
Sharpchin rockfish	+	+	-	+	-	.10	.10	.10
Bank rockfish	-.10	-	+	+	+	-	-	-
Shortraker rockfish	.13	+	-	-	-	.11	.10	.11
Yellowmouth rockfish	+	-	-	-	-	+	+	+

correlated with onshore Ekman transport or positively correlated with annual or winter longshore ship drift (Table 53). Even though many of these species had restricted depth distributions, those with negative coefficients may have reached maximum abundance between 36°N and 40°N, while those with positive coefficients may increase steadily in abundance north of 40°N. The correlation between scores based on this environmental linear combination and species group linear combination was 0.69.

The third canonical variable most strongly reflected patterns of summer onshore Ekman transport; the correlated variable, summer longshore wind stress; annual Ekman transport; and summer onshore wind stress. Summer (and annual) Ekman transport and summer longshore wind stress reach a local maximum between mimima at 36 and 39°N, increase northward from 39° to 48°N, and increase southward from 36° to 34°N (Fig. 14, Fig. 16). Summer onshore wind stress, negatively correlated, is relatively high between 34° and 39°N, drops between 39° and 43°N and increases from 43° to 48°N. It also increases with distance from shore (Fig. 23). Species with relatively high coefficients with respect to this canonical variable included longnose skate, Pacific electric ray, arrowtooth flounder, petrale sole, pink sea perch, Pacific cod, pollock, Pacific ocean perch, copper rockfish, splitnose rockfish, shortbelly rockfish, bocaccio, and redstripe rockfish (positive coefficients); and soupfin shark, black skate, roughtail skate, unidentified sanddab, English sole, Dover sole, American shad, white croaker, Pacific tom cod, unidentified smelt, darkblotched rockfish, chilipepper, rosethorn, quillback, and yellowmouth rockfish (negative coefficients). Most species with positive coefficients had distributions positively correlated with annual and summer onshore Ekman transport, and negatively correlated with onshore summer wind stress; while species with negative coefficients appeared to be negatively correlated with onshore Ekman transport or positively correlated with summer onshore wind stress in the same region. Species affiliated with this variate through positive coefficients did not all follow the same distribution pattern, but seemed to have followed only portions of the Ekman transport distribution pattern, to 1) increase northward from 39-43°N, 2) reach a maximum between 37-38°N or 3) remain at high levels south of 39°N but decrease to the north (associated with decreasing onshore wind stress). Species with negative coefficients may have been abundant in areas of strong summer offshore Ekman transport but included some rare species with low correlations with any environmental factors (e.g., unidentified sanddab, Pacific tom cod, white croaker, unidentified smelt, rosethorn, quillback, and yellowmouth rockfish). Scores for sites evaluated in terms of the two environmental and species canonical variables had a correlation of 0.59.

The fourth pair of canonical variables included effects of latitude, depth, and wind stress curl in the environmental variate and leopard shark, Pacific electric ray, unidentified sanddab, white croaker, northern anchovy, ocean sunfish, lanternfish, greenspotted, pink, cow, speckled, and redstripe rockfish (positive coefficients); and spiny dogfish, roughtail skate, Pacific halibut, Dover sole, rock sole, pollock, surf smelt, aurora, silvergray, splitnose, chilipepper, rosethorn, blackgill, and bocaccio rockfish (negative coefficient).

Species with positive coefficients were generally most abundant in southern and/or shallow water, while species with negative coefficients were generally most abundant in northern and/or deeper water. The latitudinal annual wind stress curl pattern shows an increase between 34-38°N, a decrease between 38-43°N and a steady increase between 43-48°N (Fig. 17). Species with negative coefficients may have followed one or more segments of this latitudinal pattern of decline and increase. The canonical correlation generated by these two sets of new variables was 0.58.

The fifth canonical variable reflected environmental influences of wind stress curl and summer longshore wind stress, with secondary effects of latitude, onshore wind stress, and depth. Species relatively strongly affiliated with this variate included black skate, longnose skate, ratfish, rock role, Pacific cod, Pacific ocean perch, vermilion redstripe, and flag rockfish (positive coefficient); and big skate, Pacific sanddab, arrowtooth flounder, Pacific halibut, flathead sole, petrale sole, sablefish, lingcod, surf smelt, greenspotted, quillback, canary, and shortraker rockfish (negative coefficient). Most species abundances were positively correlated with longshore surface wind stress, although signs of coefficients were not consistent with signs of correlations between species abundance and wind stress curl. Many species were more abundant to the north. However, species with positive coefficients were generally more abundant in deeper water while those with negative coefficients were often found in shallower water. Correlation between site scores based on environmental and species linear combinations was 0.54. Twenty-nine percent of the variance in the fifth species canonical variable could be affiliated with the fifth environmental canonical variable.

The sixth canonical variable appeared to include effects of depth. However, species with relatively high coefficients for this variate showed no consistent trend in deep vs. shallow distribution. Variance must have been associated with a fairly complex linear combination of environmental factors which could not be easily interpreted. Canonical correlation for this variate was 0.50. Twenty-five percent of the variance in the sixth species canonical variable could be affiliated with the sixth environmental canonical variable. Interpretation beyond this variable was not attempted.

Factor Analysis

Factor analysis emphasized environmental factors which changed primarily with latitude and secondarily with distance offshore. Because correlations between environmental variables were generally higher than between species pairs, factor formation was highly influenced by underlying environmental patterns. Species associations derived from the analysis were sometimes related only to segments of the total latitudinal pattern of an environmental factor, e.g., the increase in Ekman transport north of 39°N or south of 36°N. As a result, some species with no overlap in spatial distribution were grouped together in the analysis. The percentage of total variance related to each factor could not be calculated after oblique rotation, because factor axes were not orthogonal. Correlations between rotated factors ranged between -.20 and .24 (Table 54).

Table 54. Correlation between factors after oblique rotation. Correlations between -.20 and .10 have been omitted.

Factors		Correlation	Factors		Correlation	Factors		Correlation
1	6	.13	3	30	-.17	16	31	-.10
1	7	-.15	3	33	-.14	18	23	-.13
1	9	-.13	4	22	-.14	18	34	-.11
1	12	-.12	4	27	.24	18	37	.16
1	13	-.16	4	30	.11	19	24	.15
1	17	.12	5	15	-.17	19	28	-.12
1	18	.10	5	23	.12	19	34	.14
1	20	-.24	6	21	-.10	20	22	-.10
1	23	-.16	6	31	-.13	20	36	.25
1	24	-.10	7	12	.10	21	26	-.13
1	25	.13	7	13	.10	22	25	.11
1	29	-.14	7	29	.11	22	35	.11
1	31	-.12	7	36	.10	22	37	.11
1	35	.17	9	34	.21	24	28	-.15
1	36	-.10	9	37	-.13	24	34	.13
1	37	.16	10	17	-.12	26	32	.10
2	3	.10	11	18	.11	27	30	.13
2	20	.18	11	23	-.19	28	30	.14
2	24	-.10	12	13	.14	28	33	-.12
2	26	.24	12	20	.18	32	33	-.10
2	32	.14	12	29	.12	32	37	.13
2	33	-.16	12	34	-.14			
3	7	.19	12	37	-.12			
3	22	-.20	13	23	.10			
3	26	.11	14	20	-.13			

Factor structure usually followed one of four patterns: 1) species assemblage group or groups along a portion of a depth-latitude or other environmental gradient, e.g. factor 4, southern shallow rare species; 2) an environmental gradient, e.g. latitude, depth or segments of the Ekman transport pattern, with different species along the range of the gradient, e.g. factor 33, species correlations are ordered by depth; 3) rare or unaffiliated species, e.g. factor 6, unidentified sanddab; 4) environmental characteristics with few species associated e.g. factor 7, winter onshore wind stress.

The first two factors were related to latitude and Ekman effects, and depth, after rotation (Table 55). The first factor was most highly correlated Ekman transport and longshore wind stress, and factor formation was particularly influenced by this combination because these two environmental variables were highly correlated (Table 51). Correlation between the first factor and latitude was slightly lower, relating the general trend of increasing onshore Ekman transport with latitude north of 39°N (Figs. 14-16). Species positively correlated with the first factor were more common north of 39°N; species negatively correlated were more common south of 39°N. The second factor was most highly (negatively) correlated with depth effects, followed by alongshore ship drift, which showed a local decline in southward flow at 39-40°N in summer, but maximum southward flow at 39-40°N in winter (Fig. 20). Species with high negative correlations were more abundant below 150 fm (275 m); black and roughtail skate, Dover and rex sole, sablefish, bigfin eelpout, shortspine thornyhead, darkblotched, splitnose, blackgill, and flag rockfish. These species were common or

Table 55. Correlation between environmental or species variables and factors from factor analysis after oblique rotation. Correlations between -.10 and .10 have been omitted. Species are arranged by cluster group.

VARIABLE	Factor	1	2	9	23	37	20	34	36	12	13	5	11	15	18	25	29	35	6	26	31
Latitude		.76		-.19	-.24	.30	-.32	-.23	-.21	-.26	-.29	-.11	.17	.12	.16	.20	-.29	.29	.12	.11	
Depth			-.23				-.27	.40	-.24	.20	.11	.11	.-.12		-.12	-.12		.19	-.19	-.16	
Wind Stress Curl	A	-.25				-.11	.17									-.20		-.19	-.11		
	W						.14									-.12		-.19			
	S	-.39			.17	-.19	.21		.13	.16	.14					-.21		-.20	-.15	-.14	
Onshore Ekman Transport	A	.93		-.18	-.21	.24	-.30	-.13	-.16	-.22	-.26	-.10	.14		.16	.20	-.21	.25	.15	.16	-.16
	W	.86		-.16	-.20	.20	-.27	-.17	-.22	-.22	-.24		.12		.17	.23	-.22	.25	.13	.14	
	S	.90		-.18	-.21	.25	-.29		-.10	-.21	-.21	-.10	.14		.14	.16	-.18	.23	.16	.15	-.20
Longshore Ship Drift	A	.45	.13	-.17	-.19	.28	-.23			-.18	-.24	-.12	.14		.10		-.18	.18	.14	.21	-.15
	W	.69	.12	-.21	-.26	.39	-.31		-.16	-.23	-.32		.20	.13	.10	.11	-.27	.22	.16	.19	-.18
	S		.14									-.15				-.11				.13	
Onshore Wind Stress	A	-.73		.14	.17	-.24	.29	.14		.23	.26		-.15		-.11	-.18	.25	-.26	-.13		.13
	W	-.23								.22	.17		-.11	-.10			.24	-.10			
	S			.11	.15	-.21	.24		.17	.15	.22		-.12		-.10	-.22	.23	-.20	-.13	-.11	
Longshore Wind Stress	A	.90		-.17	-.23	.28	-.33	-.18		-.27	-.27	-.11	.17	.11	.15	.17	-.24	.27	.13	.13	-.17
	W	.84		-.14	-.20	.24	-.28	-.18	-.19	-.24	-.24	-.10	.14		.15	.23	-.24	.25	.13	.13	
	S	.81		-.18	-.22	.24	-.33	-.17		-.25	-.25		.14		.15	.11	-.15	.28	.12	.10	-.23

Table 55. (continued

Factor	1	2	9	23	37	20	34	36	12	13	5	11	15	18	25	29	35	6	26	31
Sablefish	.12	-.46		-.16	.12	-.25	-.22	.14					.10		.13					
Dover sole		-.75			.13	-.25	-.12	-.16	-.16										-.50	.15
Rex sole		-.50				-.24		-.15	-.41										-.49	.21
Pacific hake							-.12	.18	-.12											
Splitnose rockfish		-.12																	-.71	
(Bigfin eelpout)	-.13	-.64						-.10											-.19	.12
Darkblotched rockfish		-.23					-.10	-.12										-.13	-.46	.21
Shortspined thornyhead	.19	-.30	-.10		.38	-.66	-.14	-.23	-.23										.22	
Pacific ocean perch			-.93		.17		-.16	-.11												
Arrowtooth flounder	.12		-.14		.40	-.33	-.17		-.56	-.24						-.10	.10			
Ratfish											-.97		.17							
Flag rockfish		-.16			.16	-.40	-.18	-.34	-.22										-.15	
Rougheye rockfish	.17				.12	-.64		-.14	-.13											
English sole																				
Petrale sole				-.19		-.18	-.10	-.12		-.11	-.74		.18	.13						
Pacific sanddab	-.11																			.18
Ling cod				-.53								.13								
Spiny dogfish											-.37		.87							
Stripetail rockfish	-.23																	-.19		.50
Chilipepper	-.17																	-.54		.28
Bocaccio																		-.97		
Shortbelly rockfish																.10				.10
Longnose skate				-.46	.25	-.10														
Widow rockfish												.83								
Canary rockfish				-.16								.18		.74						
Greenstripe rockfish				-.13			-.10			-.10				.12						.14
Yellowtail rockfish				-.41								.88		.24						
Pacific cod									-.12	-.87										
Eulachon																	.43			

Table 55. (continued)

Factor	1	2	9	23	37	20	34	36	12	13	5	11	15	18	25	29	35	6	26	31
Flathead sole	.13								-.55								.16			
American shad																-.62				
Slender sole									-.24											.29
Sharpchin rockfish			-.21				-.28							.12						
Silvergray rockfish	.12		-.54	-.19	.16		-.36	.14		-.13				.15						
Redstripe rockfish					.30		-.11							.62						
Rosethorn rockfish							-.11								.16					
Walleye pollock																-.41				
Pacific halibut					.48									.19						
Yelloweye rockfish	.14			-.45			-.12				-.20	.12								
Rock sole																				
Big skate										-.84										
Chinook salmon																				
Unid smelt																				
Pacic herring													.84							
Jack mackerel																-.19				
Blackgill rockfish		-.12																		
Aurora rockfish	-.10						.11													
Longnose catshark																				
Filetail catshark	-.10						.15													
Unid catshark							.11													
Unid lanternfish							.30													
Bank rockfish																			-.41	
Black skate		-.68				-.11														
Brown catshark						-.13														
Roughtail skate	-.11	-.15																		
Vermillion rockfish																				
Unid eelpout						-.15													-.24	
Shortraker rockfish						-.26														
Yellowmouth rockfish			-.89				-.10													

Table 55. (continued)

Factor	1	2	9	23	37	20	34	36	12	13	5	11	15	18	25	29	35	6	26	31
Copper rockfish																				
Soupfin shark																				
Pink sea perch																				
Plainfin midshipman								.14												
White croaker																				
Greenspotted rockfish																				
Pacific electric ray																				
Cow rockfish																			-.14	
Speckled rockfish																				
Pacific argentine																				
Leopard shark																				.17
Pygmy rockfish																				
Quillback rockfish											-.97		.18							
Coho salmon																				
Whitebait smelt																				
Pacific tom cod																				
(Pink rockfish)															.80					
(Northern anchovy)																				
(Unid sanddab)																				
Not included in cluster analysis)																				

Table 55. (continued)

VARIABLE		Factor 32	19	24	4	22	27	3	7	16	10	14	17	28	30	33	8	21
Latitude			-.22	-.20	-.10	.36	-.14	-.13	-.42	.1-			.17					
Depth		-.12	.34	.47	-.24		-.16				-.14	.12		-.38	-.29	.30		
Wind stress curl	A	-.10			.14	-.95	-.13	.35								-.13		
	W					-.72	-.15	.56	-.11							-.22	-.10	.11
	S	-.13			.18	-.85	-.10		.13									
Onshore Ekman Transport	A	.17	-.18	-.23		-.19			-.13				.17			-.10		
	W		-.22	-.24	-.10	.27			-.37				.17	-.12				.11
	S	.23	-.13	-.21		.12		.11					.16	.11		-.11		
Longshore Ship Drift	A	-.15		-.11	-.16			.76			-.10		.15	.18	-.10			
	W	.22		-.11	-.12	.22		.28					.19	.35				
	S		.10		0.12	-.26		.94	.22	-.10				-.12		-.16	-.10	
Onshore Wind Stress	A		.19	.18		-.41	.10	.26	.54	-.10			-.18	-.20				
	W	.15	.19			.14			.86					-.11	-.12			
	S		.18	.17		-.39	.11	.24	.58				-.17					
Longshore Wind Stress	A	.12	-.16	-.22		.20			.20				.19	.17				
	W		-.21	-.22		.34	-.13	-.19	-.42				.18					
	S	.17		-.20		.11		.16					.17	.24	-.12			
Sablefish				.22										-.16		.26		
Dover sole		-.37		.17			-.10					.10				.17		
Rex sole		-.40		.21						-.11						.23		
Pacific hake				-.11							.32							
Splitnose rockfish						-.13						.27						
(Bigfin eelpout)		-.27														.25		

Table 55. (continued)

Factor	32	19	24	4	22	27	3	7	16	10	14	17	28	30	33	8	21
Darkblotched rockfish																	
Shortspined thornyhead					.18										-.13		
Pacific ocean perch																	
Arrowtooth flounder	.19																
Ratfish																	
Flag rockfish	.15																
Rougheye rockfish																	
English sole			.59		.16	-.16							.11	.42			
Petrale sole													.16				
Pacific sanddab			.37		.36	-.12	.12						.15	.23			
Long cod																	
Spiny dogfish																	
Stripetail rockfish								-.13								.12	
Chilipepper																	
Bocaccio								-.13								.24	
Shortbelly rockfish									.75		-.64						
Longnose skate	.18		.31		.43										.10		
Widow rockfish																	
Canary rockfish															-.11		
Greenstripe rockfish			.67														
Yellowtail rockfish																	
Pacific cod																	
Eulachon																	
Flathead sole																	
American shad											-.27						
Slender sole					.14			-.70									
Sharpchin rockfish												-.11					
Silvergray rockfish	.11											-.14					
Redstripe rockfish																	
Rosethorn rockfish																.54	

Table 55. (continued)

Factor	32	19	24	4	22	27	3	7	16	10	14	17	28	30	33	8	21
Walleye pollock																	
Pacific halibut																	
Yelloweye rockfish																	
Rock sole													.11				
Big skate																	
Chinook salmon																	
Unid smelt							-.14							.10			
Pacific herring																	
Jack mackerel												-.87					
Blackgill rockfish			.51														
Aurora rockfish	-.11	.28	.70										-.16				
Longnose catshark		.78	.13														
Filetail catshark		.80	.11														
Unid catshark			.28					.10									
Unid lanternfish		.22					.11	.10					-.19				
Bank rockfish																	.18
Black skate							-.10										
Brown catshark	-.31		.27					-.11			.15		-.10		.12		
Roughtail skate	-.21														.23		
Vermilion rockfish											.75						
Unid eelpout	-.15										.84						
Shortraker rockfish																	
Yellowmouth rockfish																	
Copper rockfish				.18													
Soupfin shark										.86							
Pink sea perch				.85	-.12	.52											
Plainfin midshipman				.77	-.17	.17											
White croaker				.12		.69			-.14								
Greenspotted rockfish						.12			-.78						-.14		
Pacific electric ray					-.10		.18	.22							-.12		

Table 55. (continued)

Factor	32	19	24	4	22	27	3	7	16	10	14	17	28	30	33	8	21
Cow rockfish																	.74
Speckled rockfish																	
Pacific argentine					-.14		.13	.10							-.16		
Leopard shark								.11									
Pygmy rockfish																.99	
Quillback rockfish																	
Coho salmon																.99	
Whitebait smelt													.25				
Pacific tom cod													.41				
(Pink rockfish)																	
(Northern anchoty)									-.12						-.17		
(Unid sanddab)																	
(Not included in cluster analysis)																	

present in the 39-40°N region, but their abundances were usually uncorrelated (-.10 to .10) with longshore ship drift over the entire range of the survey area (Table 53).

Three factors, 9, 23, and 37, included effects of species with northern distributions whose abundance increased with latitude north of 39°N. Species belonged to the northern component of the deepwater dominant cluster group, and the northern occasional cluster group in the case of factors 9 and 37, or shallow northern occasional groups in the case of factor 23 (Table 1). Latitude, Ekman transport, ship drift, and onshore wind stress all increased to the north (Figs. 14-16, 20, 21-23).

Factors 20, 34 and 36 emphasized the importance of species with northern deepwater distributions, including members of the deepwater species cluster group; deepwater occasional species group and sometimes members of the northern occasional species group (which were often absent in 50-75 fm (92-137 m) (shallower sites). All three factors had large correlations with depth, latitude and Ekman transport. Factor 20 emphasized a combination of environmental effects (including wind stress curl) whose northern segments appeared to be correlated with latitude. Factor 34 included effects of some southern deepwater occasional species through correlations with reversed signs. Factor 36 included effects of some species with relatively shallow and/or southern distributions through correlations with reversed signs, e.g., Pacific hake, silvergray rockfish and sablefish may have been slightly more abundant at northern shallow sites and plainfin midshipman were common in southern shallow water, and had correlations of opposite sign to those of species abundant in northern deep water.

Factors 12 and 13 emphasized species with northern distributions but included species found at intermediate to shallow depths [Pacific hake, Pacific cod, flathead sole, slender sole (factor 12); as well as species which ranged into deeper water (Dover and rex sole, shortspined thorneyhead, arrowtooth flounder, flag, and rougheye rockfish (factor 12); arrowtooth flounder (factor 13); petrale sole, greenstripe rockfish, Pacific cod, silvergray rockfish, and big skate (factor 13)]. For both factors, as a combination of latitude, offshore Ekman transport and southward winter ship drift increased, those species abundances increased. However, as depth and onshore wind stress increased, those species abundances probably decreased. Winter onshore wind stress at northern latitudes decreased once at 41°N and again between 46 and 49°N (factor 12) while summer onshore wind stress over all latitudes was lowest at 43°N (Cape Blanco) (factor 13) (Figs. 22-23). Some species related to factor 12 may have increased between 46 and 49°N or at 41°N (although this does not appear to be the case with Pacific Whiting) while those related to factor 13 may have decreased south of 43°N.

Factors 5, 11, 15, 18, 25, 29, and 35 emphasized various species with shallow northern distributions. Signs of correlations of latitude and species abundance with these factors were the same, while signs of correlations of depth and species abundance with factors differed: species abundance would increase with latitude, but decrease with depth. Factors 11, 18, 25, 29 and 35 also included effects of Ekman transport, winter longshore ship drift, onshore wind stress and longshore wind stress. Most species belonged to shallow dominant, shallow occasional (northern) or northern occasional (shallow) species groups from cluster analysis: ratfish, petrale sole, spiny dogfish, and Pacific herring (factor 5); lingcod, widow, greenstripe, and yellowtail rockfish (11); sablefish, ratfish, petrale sole, spiny dogfish, unidentified smelt, canary greenstripe, yellowtail, sharpchin, silvergray, and redstripe rockfish, and Pacific halibut (18); sablefish, rosethorn, and pink rockfish (25); arrowtooth flounder, shortbelly rockfish, American shad, and walleye pollock (29); and arrowtooth flounder, eulachon, and flathead sole (35). Quillback rockfish (factor 5) and jack mackerel (factor 15) were rarely caught and signs of their correlations were opposite to those of other highly correlated species for the same factors.

Factors 6, 26, 31 and 32 included species whose latitudinal distributions appeared to change around 39°N. Factor correlations with latitude were much lower, while correlations with Ekman transport, ship drift, wind stress and/or wind stress curl were about the same as those for factors discussed earlier. Darkblotched, stripetail, chilipepper and bocaccio rockfish were relatively more abundant in the 38-39°N region than farther south (in the case of darkblotched rockfish) or farther north (in the case of the other three species) (factor 6). Factor 26 emphasized deepwater species and was more highly correlated with depth, Ekman transport and ship drift than latitude: species were more common at deep locations in regions of strong offshore Ekman transport (35-39°N) or strong winter southward alongshore ship drift (38-40°N) (Figs. 14-16, 20). Dover and rex sole, splitnose, darkblotched and flag rockfish, shortspined thornyhead, bank rockfish, and bigfin and unidentified eelpout were all correlated with this factor, and were among the most abundant species in cluster assemblage regions 1bi and 1bii [from Point Arena (39°N) to Point Conception (34°20') (Tables 9, 10)] and secondarily in region 1aiii, [from Yaquina Head (43°30') to Point Delgado (41°N) (Table 5)]. Factor 31 was correlated with offshore summer Ekman transport, southward winter alongshore ship drift, Dover and rex sole, bigfin eelpout, darkblotched rockfish, Pacific sanddab, stripetail, chilipepper, shortbelly rockfish, longnose skate, greenstripe rockfish, and slender sole. All these species were present or more abundant south of 40°N, over a variety of depths. Factor 32 was correlated with depth, offshore summer Ekman transport, southward winter ship drift, and annual offshore wind stress; with several species in common with factors 26 and 31 (Dover and rex sole, bigfin eelpout and unidentified eelpout). Species which increased north of 39°N and/or at shallow depths were positively correlated with this factor (arrowtooth flounder, flag and silvergray rockfish, longnose catshark) while other species common in deep water south of 39° were negatively correlated (aurora rockfish, brown catshark, roughtail skate, all members of deepwater occasional species group F).

Factors 19 and 24 emphasized southern deepwater species (sablefish, Dover sole, rex sole, blackgill rockfish, aurora rockfish, longnose catshark, filetail carshark, unidentified catshark, unidentified lanternfish, and brown catshark), all members of deepwater dominant cluster group A or deepwater occasional cluster group F. The correlation of Pacific hake with factor 24 was of opposite sign, and suggested shallower distribution of the species. Distributions may have been related to regions of offshore Ekman transport and onshore windstress, which were also correlated with these factors.

Factors 4, 22, and 27 included species abundant in shallow southern regions: splitnose rockfish, English sole, Pacific sanddab, widow rockfish (shallow dominant cluster group B); greenstripe rockfish, American shad (shallow occasional [northern] group C), copper rockfish, pink sea perch, plainfin midshipman, white croaker, greenspotted rockfish, Pacific electric ray and Pacific argentine (southern shallow [rare] group G). All factors included latitude and winter Ekman transport effects. Factors 4 and 27 included depth and factor 22 included wind stress curl and winter onshore wind stress, which is highest at southernmost latitudes.

Factors 3, 7, and 16 included mid-latitude or southern species and latitude as contributing variables (rex sole, darkblotched rockfish [species group A, deepwater dominant]; English sole, Pacific sanddab, stripetail, chilipepper and bocaccio rockfish [species group B, shallow dominant southern]; slender sole, unidentified smelt [shallow species group C]; unidentified lanternfish, black skate, bank rockfish [deepwater occasional occasional group F]; Pacific electric ray, cow rockfish and speckled rockfish [southern shallow rare group G]). Factors 3 and 7 also emphasized wind stress curl, summer and annual longshore ship drift and onshore windstress effects, all of which increased southward of 39°N.

Other factors related species primarily to depth. Factor 10 related Pacific hake, shortbelly rockfish and soupfin shark abundance through shallow depth and southward ship drift. Factor 14 related increasing sablefish, splitnose rockfish, brown catshark but especially vermillion rockfish and unidentified eelpout abundance (deepwater dominant or deepwater occasional species) and increasing depth. Shortbelly rockfish and American shad were inversely related to depth as well as onshore Ekman transport, northward ship drift and offshore wind stress through factor 17. Species with shallow distributions (English sole, petrale sole, Pacific sanddab, rock sole) were positively correlated with factor 28, while those with negative correlations (sablefish, sharpchin, silvergray, and aurora rockfish, unidentified lanternfish and brown catshark) were more abundant with depth (and southward winter longshore ship drift, in some cases). Factor 30 also included effects of English sole and Pacific sanddab; as well as unidentified smelt, whitebait smelt and Pacific tom cod (groups B and H). The factor emphasized effects of decreasing depth, southward annual longshore drift, winter onshore wind stress and summer northward longshore wind stress. Factor 33 combined effects of increasing depth and increasing abundances of sablefish, Dover sole, rex sole, bigfin eelpout, longnose skate, silvergray rockfish, brown catshark, and roughtail skate. Abundance of canary rockfish, greenspotted rockfish, leopard shark, and northern anchovy decreased with depth. Effects of wind stress curl, Ekman transport, and longshore ship drift were also included; and may also have shared common or inverse distributions with those species.

Factor 8 related coho salmon and pygmy rockfish (two species whose rare occurrences coincided) with low winter wind stress curl and southward summer longshore ship drift. Factor 21 included only effects of summer wind stress among environmental influences; but included effects of stripetail, bocaccio, rosethorn, bank, and cow rockfish. Most species were more abundant in the southern end of the survey region.

DISCUSSION

The fish assemblage is an important concept in multispecies fishery management. We define an assemblage as a group of co-occurring species; and an assemblage region as an area of relatively homogeneous species composition. Although these definitions do not necessarily imply interaction among component species, assemblage groups may include interacting species or species with similar responses to environmental conditions. An assemblage region may represent an area with similar production dynamics within its boundary; for example, spatial and temporal patterns in primary production, common food web structures or similar life history patterns among its occupants. Assemblage analysis could provide geographical boundaries for fishing experiments designed as part of adaptive multispecies management plans (Tyler et al. in press). Assemblage analysis may also be useful to calculate more accurate estimates of incidental catch from log book data. Knowing the assemblage region of a catch, the species composition within the assemblage region, the gear and the catch size, we could estimate by-catch.

Although assemblage analysis has been proposed in several symposia as an important step in investigating multispecies fisheries systems (Hobson and Lenarz, 1977; Anon., 1978; Mercer, ed., in press), few analyses of Pacific demersal species associations have been undertaken. Day and Pearcy (1968) described species associations from the continental slope and shelf off Oregon based on 72 beam trawl hauls made from 20 to 1,000 fm. They identified 67 species in four groups divided by depth; group I, over an interval of 22.9-39.9 fm (42-73 m), dominated numerically by Pacific sanddab; group II, 65.0 - 108.7 fm (119-199 m), dominated numerically by slender sole; group III, 324.6-624.6 fm (594-1143 m), dominated by shortspine thornyhead and longspine thornyhead; and group IV, 755.7-999.4 fm (1383-1829 m); dominated by roughscale rattail. However, few large demersal species were retained by the shrimp net they used and sampling was limited to a 30' range in latitude. Pearcy (1976) described two depth-related assemblages of small flatfishes on the Oregon continental shelf based on 115 beam trawl hauls made seasonally at seven stations for two years. The first group occurred over depths of 40-56 fm (74-102 m), and was dominated numerically by Pacific sanddab. The second group was found between 81-106 fm (148-195 m) and was dominated by slender sole. He observed few significant effects of depth, sediment, season or year on abundances of Pacific sanddab, Dover sole, rex sole, and slender sole; however, ony one replicate was made per sample. Few large species or adult commercial species were caught by the small net.

Tyler and Stephenson (in prep.) described assemblage regions between the Columbia River and Yaquina Bay based on demersal fish survey data collected by the Oregon Department of Fish and Wildlife from 1971 to 1974. Shallow sites (13-60 fm, 24-110 m) were dominated by English sole, spiny dogfish, Pacific sanddab, rex sole, ratfish, and big skate. Deeper regions (40-100 fm, 73-183 m) were dominated by rex sole, aurora rockfish, black skate, longnose skate, arrowtooth flounder, Dover sole, and lingcod. Gabriel and Tyler (1980) compared assemblages based on the 1971-1974 survey data with those based on 1977 National Marine

Fisheries Service rockfish survey data from the Columbia River to Yaquina Bay off Oregon, and found consistent patterns of depth zonation and species dominance between assemblages from each survey. Species associations off Washington and California have not been extensively described.

Water depth appeared to be one major factor that determines assemblage boundaries between Cape Flattery and Point Hueneme. Although small local areas were divided along cross-shelf boundaries, the subregions to which these areas belonged were usually bounded by depth contours. In areas of relatively constant depth (small local areas), changes in species abundance were often minimal. As the depth gradient increased near the shelf break, bands of assemblage regions became narrower.

Several environmental features are strongly related to depth, however; and any combination of them may influence the structure and distribution of assemblages. Bottom temperature and ambient light levels decrease with depth, while pressure increases. Sediment type changes from sand to silt as distance from shore and depth increases. Species composition of benthic invertebrates serving as potential food items may change in response to bottom type. Bottom topography changes from relatively flat shelf to high-relief canyons, rocky shelf break, and upper slope. These depth-related features are probably relatively constant through time (on a scale of decades), and assemblage structure may be restricted by depth-related physiolocial limits, food availability or habitat availability.

Depth may influence assemblage dynamics as well as structure, through food availability. Species that dominated the composition of upper slope assemblages usually belonged to one of three feeding types: 1) Strict benthic feeders such as Dover sole or rex sole consume benthic invertebrates linked to detrital food chains. 2) Mesopelagic feeders (e.g., Pacific ocean perch, darkblotched rockfish, splitnose rockfish) eat euphausiids and shrimps (Brodeur, pers. comm.) which are omnivores or secondary consumers in upwelling food chains. 3) Metabolically plastic generalists, e.g., sablefish, feed on benthic invertebrates, crustaceans or fishes (Hart, 1973). The proportion of pelagic feeders and piscivores may increase moving from upper slope to midshelf. Shelf break assemblages were often dominated by a) fishes feeding on invertebrate omnivores (e.g. *Euphausia pacifica*), such as Pacific ocean perch in the north and chilipepper rockfish in the south; b) by benthic feeders, such as Dover and rex sole; and c) by piscivores, such as arrowtooth flounder (which also feeds on shrimps and euphausiids), and silvergrey rockfish in the north and bocaccio in the south (Hart, 1973). In midshelf regions (50-80 fm, 90-145 m), the proportion of piscivores appeared to increase: Pacific hake (which also feeds on euphausiids), yellowtail rockfish, silvergrey rockfish, spiny dogfish and lingcod (Hart, 1973) dominated most hauls made in northern shallow regions. Among flatfishes, an assemblage including English sole, petrale sole and Pacific sanddab was present in shallow water. However, the English sole has been described as a benthic opportunist and both petrale sole and sanddab feed pelagically on fishes (but occasionally on crustaceans) (Kravitz, *et al*. 1977).

Piscivory among midwater and benthic feeders and consumption of pelagic items by flatfishes may increase as depth decreases because 1) pelagic production is concentrated in shallower regions, and 2) small juvenile fishes are more abundant in shallower regions. Phytoplankton and zooplankton are most abundant within 10 mi (15 km) of shore and circulation and hydrography are most variable within 12 mi (20 km) of shore (Peterson _et al_., 1977). This highly productive zone is the center of concentration for pelagic larvae and juveniles of many species (e.g. Laroche and Richardson, 1979). As well, mid-shelf regions (50-149 fm) generally contain the smaller fish of a _Sebastes_ species as compared with deeper (150-250 fm) strata (Boehlert, 1980). Moving offshore and deeper, a greater proportion of production is transferred downward through vertically migrating euphausiids (e.g. _Euphasia pacifica_), which consume both phytoplankton and copepods (Parsons and Takahashi, 1973), and to detrital production systems. Thus, the form of available food changes with increasing depth and distance offshore.

Mills and Fournier (1979) found the opposite spatial distribution of pelagic and benthic feeders with depth off the Scotian Shelf: demersal fish production declined with distance offshore, while abundance of pelagic feeders was highest over the slope, and declined inshore. However, primary production off Nova Soctia is highest over the slope, where a shelf-slope front enhances nutrient input (Fournier, _et al_., 1977). Assemblage distributions and locations are specific to each shelf ecosystem, and are sensitive to relative spatial distribution of primary and benthic production, as suggested by Mills and Fournier (1979) and supported by this discussion.

Hypothetically, one would expect more stable assemblage dynamics with depth and distance from shore. Detritally based food chains appear proportionally more important with distance from primary production and are generally more stable than pelagic ones: a pool of detrital material is almost always available for oxidation, and serves as a buffer in the face of fluctuating pelagic inputs. Omnivory (in the case of Euphausis pacifica) and hence a feeding strategy based on omnivory, is also a stabilizing mechanism (Parsons and Takahashi, 1973). Mid-shelf, structure may be more resilient and less regular: a potentially higher percentage of piscivory, as consumption of pelagic juvenile fishes, would lead to complex species interactions, feedback mechanisms, and coupling with a potentially fluctuating food source. Life history information provides further evidence for stability with depth: rockfishes in the deep-water assemblages in the north (darkblotched rockfish, Pacific ocean perch, splitnose rockfish, rougheye rockfish, flag rockfish, and shortspine thornyhead) may be generally longer lived but less fecund at average age of maturity (30 years, 45,000 eggs/fish at average age of maturity; 30+ years, 30,000 eggs; 29+ years, 14,000+ eggs; unknown; unknown; unknown; unknown, respectively) compared to species in northern assemblages found inshore (canary rockfish, yellowtail rockfish, greenstripe rockfish, silvergrey rockfish; 26 years, 820,000 eggs/fish at average age of maturity; 23 years, 490,000 eggs; unknown; unknown; unknown;) (Pacific Fishery Management Council, 1979). Thus, it appears that species in deepwater assemblages may follow K-selected life history strategies compared to species found inshore (Adams, 1980b).

Latitude effects appeared to be second to depth in influencing species distributions and assemblage boundaries based on AIDN analysis of variance. Latitudinal patterns in onshore Ekman transport were related to distribution of several species groups, based on canonical correlation and factor analysis. Ekman transport has been correlated with surface temperature (Fisher, 1970), bottom temperature (Kruse, 1981), surface productivity (Small and Menzies, 1981), growth rates of flatfishes (Kreuz, 1978), and cohort strength of flatfishes (Hayman and Tyler, 1980) off Oregon. Wind stress curl, or divergence, has also been correlated with cohort strength of flatfishes off Oregon (Hayman and Tyler, 1980). Several latitudinal effects were not included in multivariate analyses but may influence fish distribution: shelf width and slope depth gradients vary over the survey range and may limit potential available habitat. Mesoscale features such as a potential eddy off San Francisco (Hickey, 1979) may influence local short term productivity and larval retention. Seasonal variability in some of these features may also change with latitude, and species and assemblages may respond to the degree of variability in a feature at a particular latitude as much as the magnitude of the feature.

Wind stress and current patterns may be the most important factors in controlling north-south differences in species assemblage structure and assemblage region standing stocks. Assemblages between Cape Blanco and Cape Mendocino were distinguished by low standing stocks and low diversities: offshore assemblages were strongly dominated by Dover sole, although other members of the deepwater assemblages also occurred; intermediate depth assemblages were strongly dominated by Pacific hake with the rare occurrence of some silver-bodied pelagic species and some southern species. The dominance by Dover sole offshore and Pacific hake at mid-shelf represent two ends of the trophic spectrum proposed earlier: the Dover sole feeds only on benthic invertebrates supported by a detrital production system; while the Pacific hake is closely coupled with the pelagic production system and is frequently found in mid-water. This relatively simple system may be related to several possible effects of wind stress and current. The region between Cape Blanco and Cape Mendocino incurs the largest annual variation in north-south surface wind stress of any area between Cape Flattery and Point Hueneme: northward wind stress is high from January to April and southward wind stress is high from May to September (Hickey, 1979). This may have several possible effects on species diversity and standing stock: 1) Strong northward wind stress in winter and spring may advect larvae north out of the region; onshore Ekman transport may not enhance productivity enough to support larval recruitment in the region during critical periods. Pacific hake would occur as a seasonal migrant and Dover sole would be recruited through deepwater spawning or immigration; 2) Strong southward wind stress during the summer advects surface production south of Cape Mendocino. Production is thus available only for a short time and only to strongly pelagic feeders at the immediate source or to demersal feeders after small amounts which land on the slope cycle through the detrital food chains; 3) Strong southward wind stress enhances surface production to the extent that detrital material accumulates at a high rate, resulting in anoxic conditions along the bottom or "bottom souring" conditions perhaps related to the presence of *Thioploca*-like filaments (Gallardo, 1977).

Low standing stocks of assemblages found at all depths inside the Santa Barbara Channel may possibly be attributable to wind stress patterns as well. The area may lie in the lee of prevailing winds, preventing resuspension of nutrients; or islands bordering the channel may inhibit initiation of upwellling events. Diversity is high in mid-shelf assemblages within the channel relative to other southern mid-shelf site groups, but diversity of slope assemblages within the channel is lower than average for deep site groups. All primary productivity may be captured pelagically, with little input to sediments.

Larval retention areas may influence stock and species distributions (Parrish *et al*., 1981, Iles and Sinclair, 1982) in combination with species reproductive strategies. Parrish *et al*. (1981) reviewed surface circulation and spawning patterns of fishes in the California Current. They suggested that few species between Cape Blanco and Point Conception (the region of maximum upwelling along the coast) produced epipelagic eggs, and that exposure of planktonic phases was reduced either by deepwater spawning (flatfishes, sablefish), ovoviviparity (rockfish), or timing of spawning before onset of maximum upwelling (January to March). Yet these same mechanisms are used by fishes common to the Pacific Northwest region (north of Cape Blanco), where Ekman transport is onshore during the winter, and only weakly offshore during the summer when compared with the Cape Blanco-Point Conception area. Those mechanisms alone do not account for observed differences in assemblage structure and rockfish species composition betwen Cape Blanco (43°N) and San Francisco (38°N).

South of Cape Mendocino, some assemblage characteristics changed: there was a trend toward dominance by smaller sized, earlier maturing, less fecund and shorter lived rockfishes. Splitnose rockfish became more abundant in slope assemblages south of Cape Mendocino and dominated assemblages south of San Francisco (age at maturity 5-12 yrs; fecundity at maturity 14,000+). In shelf break assemblages, chilipepper replaced Pacific ocean perch as euphausiid feeders (Adams, 1980a). However, chilipepper mature earlier (age 6), is more fecund and is shorter lived than the Pacific ocean perch they resemble morphologically (Pacific Fisheries Management Council, 1977, Adams, 1980a). Likewise, bocaccio, a species morphologically and trophically similar to silvergrey rockfish (Adams, 1980a) has a lower age at maturity (4-6) and a higher growth completion rate than silvergrey rockfish (Pacific Fisheries Management Council, 1977) (Data on fecundity are unavailable). Other southern shelf break assemblage species included stripetail rockfish, shortbelly rockfish, and widow rockfish, although widow rockfish was relatively frequent as far north as Cape Flattery while stripetail and shortbelly was not. Ages at maturity and fecundity for stripetail, shortbelly and widow rockfish are 4 years, 15,000 eggs/fish at average age of maturity; 3 years, 6,000; and 4 years, 55,000, respectively. Boehlert and Kappenman (1980) present two hypotheses to explain a cline of decreasing growth rate of splitnose rockfish in the south. The first hypothesis suggests that splitnose rockfish had been heavily exploited in the north in association with Pacific ocean perch. Thus, higher growth rates in the north may be a short-term density response to increased food availability. The second hypothesis suggests that slower growth rates in the south are an evolutionary response at the population level in terms of reproductive strategies. Potential adaptations of reproductive strategies in the face of environmental uncertainty include higher fecundity and iteroparity instead of somatic growth (Murphy, 1968; Charnov and Schaeffer, 1973).

The effects of environmental unpredictability may be reflected in assemblage structure south of Cape Mendocino by rockfish species that reach maturity at a low age and that appear to allot less energy to somatic growth then do species north of Cape Blanco. A model of California mackerel recruitment (Parrish, 1977) incorporating effects of Ekman transport and southward advection predicts poor reproductive success of fishes with epipelagic eggs and larvae between Point Conception and Cape Mendocino. Offshore Ekman transport, although variable from year to year, is generally stronger along the coast south of Cape Mendocino during spawning seasons of splitnose rockfish (Bakun, 1977; Boehlert and Kappenman, 1980).

The choice of an appropriate scale and level of resolution in defining assemblage regions and species groups is tempered by four factors: 1) the scale and resolution of sampling and statistical methods; 2) the scale and resolution appropriate for further research and management efforts; 3) temporal effects on assemblage boundaries and compositions and 4) the natural range of variability in composition and spatial extent of species groups.

The influence of sampling and analytical bias on estimations of assemblage structure and dynamics may be considerable. Roller gear probably leads to underestimation of the importance of flatfishes and other fishes living close to the bottom. Midwater fishes are not available to a seabottom otter trawl but may be trophically coupled with benthic dwellers that feed off the bottom. Different gear types may differentially exploit trophically linked assemblage members; for example, otter trawls, midwater trawls and sablefish pots would be most efficient at catching different members of an assemblage that may share common food sources or prey on each other. Abundances estimated with a biased gear type should be scaled by the relative vulnerability of each species to the gear, if such a factor is available.

High variances in survey sample estimates also hamper precise definition of species composition in an area. Most 90 percent confidence intervals for rockfish species biomass estimates made from the 1977 rockfish survey data were from ±30 to ±150 percent of the actual estimate, and reached as high as ±347 percent (Gunderson and Sample, 1980). Because of the contagious distributions of many demersal fishes, and rockfish in particular, any single haul may not reflect a proposed assemblage composition; but a series of hauls in the region may provide a more precise picture.

Assemblage definition may be distorted by choice of analytical method. In cluster analysis, the choice of dissimilarity index and transformation may influence group formation. Moreover, the choice of the dissimilarity level that defines an assemblage site or species group is subjective. There are no statistical criteria to ensure that groups formed at a specific level of dissimilarity are meaningful, or that assemblage boundaries based on those cluster groups are realistic.

Species groups derived from cluster analysis may be evaluated by comparing groups generated through other multivariate analyses, and by comparing distribution maps species by species. In most cases, species groups were consistent with groups from cluster analysis, although more groups were formed, some with fewer species in a group. Inconsistencies indicated potential alternative or mis-classifications, which could be evaluated by comparing species distribution maps. Factor analysis was the most valuable additional analysis for evaluating species group composition. Cohesive localized species groups from cluster analysis consistently reappeared in factor analysis. Factor analysis can also link species groups with co-occurring environmental features. However, factor formation imposes environmental effects on species group formation: environmental and species characteristics are considered simultaneously in factor formation. In some cases, linkages between environmental effects and species groups may be artificial. A multivariate analysis such as the AIDN program was the most valuable approach to evaluate relative importance of environmental effects on species composition within assemblage boundaries and coastwide. In all analyses, results were used to describe potential patterns rather than to statistically test hypotheses.

Assemblage boundaries can be evaluated ecologically by mapping sites that belong to the proposed assemblage group. If the sites in the group are contiguous, the boundaries may be justifiable: characteristic species combinations should re-occur over sites in the area, and we would infer a continuous distribution of the species combinations over adjacent sites. However, discontinuity in assemblage boundaries may arise if the environmental structure is patchy (e.g. rock outcrops) and species groups respond to that structure. Thus, detailed knowledge of environmental structure is also valuable in determining meaningful assemblage boundaries.

Definition of assemblage regions and site groups should be appropriate for further research and management efforts. Any study of species-group production or interactions within an assemblage region may be severely confounded by environmental variability if an assemblage region is so large that environmental influences on fish production or species co-occurrences are not homogeneous over the entire region. If an assemblage region is so small that boundary placement becomes critical or time-consuming or that neighboring assemblages reflect only small scale local variations when no replication of regions is intended, a study becomes needlessly expensive and produces redundant results between regions. Similarly, species groups that are too large may include species that have only weak interactions among groups members, or none at all; while those groups that are too small may omit the species that ultimately may dominate assemblage dynamics (e.g. keystone predator).

Temporal as well as spatial scales are important in defining assemblage structure. The results of this analysis may be applicable to summer fisheries. However, species distribution patterns are known to change with age of fish and season (Alverson et al., 1964). It is possible that the species distributions and interactions that exist during the summer may not significantly control the dynamics of the summer assemblage. Thus, exploitation and production patterns in other areas and seasons may affect summer assemblages if species distributions and compositions are not constant through the year; or assemblages are reformed seasonally. In some cases, species in an assemblage may be divided into a regular (year-round) component and seasonal components. The seasonal components may crucially influence species interactions among members of the regular component, e.g. by serving as predator or competitors, and may be considered as separate external factors whose affects on the regular assemblage structure vary through time (Tyler *et al*., in press).

One of the most interesting questions associated with investigation of assemblage structure and species groups is the identification of the natural range of variability of species composition in an area over long time-scales. We hypothesize that there may be some enduring underlying patterns in species abundance even though our observations are imperfect. We may term the underlying enduring pattern of species present as persistence. This does not imply that the species composition is constant or stable from year to year, but that there is a range of potential relative abundances, and within that range the basic structure of the assemblage and its characteristic associated interactions remain intact. For example, lake trout (*Salvelinus namaycush*) and its prey, a suite of seven chub species (*Leucichthys* spp.) constituted a deepwater assemblage in the Great Lakes in the 1940's. The original assemblage persisted before fishery overexploitation and lamprey predation became severe, even though the relative abundances of the seven chub species were not necessarily explicit or constant (Smith, 1968).

Analyses of this survey provide no insights into the persistence of assemblage boundaries or species groups. However, persistence is probably a key criterion for boundary and species group definition, especially when the management goal is assemblage maintenance. Holling (1979) suggests that a prime management goal in the face of uncertainty is to maintain future options and to avoid irreversible actions. The degree of natural variability in a system may rule out certain management goals: when important ecological variables are stable over time (for example, species composition), resource use can be specialized and the fishery can be managed with a goal of optimum economic yield. Alternatively, if a system shows frequency cycles and occasional irregularities, resource use must be more flexible, a goal of maximum sustained yield for an assemblage may not be realistic, and a more reactive approach must be taken (Paloheimo and Regier, in press). Replicate surveys and analyses are desirable to measure the repeatability of apparent community structures, and perhaps eventually to assess the natural range of variability in composition and spatial extent of species groups. Some work in this area has already begun (Gabriel and Tyler, 1981).

At present, we can only speculate on environmental and biological mechanisms that structure fish assemblages. Attempting to describe dynamic features of species groups based on a single survey is analogous to inferring a movie plot from a single photograph: surveys were designed to describe abundance patterns, not elucidate underlying biological relationships, in which temporal elements are often crucial. Simulation models and adaptive management experiments may be valuable tools for investigating these mechanisms in the future (Tyler et al., in press) but at the moment, we can only propose hypotheses.

A Conceptual Model of Productivity of Fish Assemblages in the California Current System

A conceptual model of groundfish production can be proposed that incorporates environmental inputs and trophic structures that are unique to the western continental shelf and upper slope of the United States. The model structure has been designed to be generalizable for any shelf fish assemblage between 48°N and 34°N latitude along the Pacific coast. It is applied locally by specifying regional seasonal upwelling patterns, offshore advection patterns, and regional fish assemblage structure in terms of trophic and reproductive functional groups, seasonal predatory groups, and fishery patterns. The assemblage is defined here as a group of co-occurring species which do not necessarily interact biologically but which are often the object of a common multi-species fishery (e.g., an otter trawl fishery).

This model has been conceived as an heuristic exercise rather than a predictive tool, since many of the functional relationships required for simulation are presently poorly quantified (if at all). No attempt will be made to computerize. Instead, the model emphasizes structural relationships within California Current fish assemblages. Although the body of literature related to this region is large and diverse, emphasis has historically been placed on several species of fishes with little concern for species interactions or oceanographic influences (e.g., Alverson et al. 1964) or on single species-environment interactions (e.g., Parrish, 1977). Although a summary of this literature would be rewarding, a large scale overview is achieved more easily through a general rather than exhaustive treatment. In the face of relatively few synthetic research efforts in this region to date, perspectives must often be founded on hypothetical mechanisms and interactions and subjective evaluations. I anticipate that many of the proposals in this paper may ultimately prove to be unfounded, but hope that they will encourage further investigation of emergent properties of demersal fish production systems (Tyler et al., in press).

The goal of this model's construction would be to examine the relative importance of variations in species abundance due to external environmental factors and variation due to density dependent relationships within and among species that could account for groundfish abundance and production patterns. To ecologists, environmental factors are central to ecosystem and community structure (e.g., Southwood, 1977). A modelling approach would allow qualitative comparisons with fish production systems in other upwelling regions. An understanding of emergent properties of fish communities and production systems is central in developing management plans for both single and multispecies fisheries. A modelling approach can provide direction for future investigations: what data appear crucial and which gaps in knowledge are the largest?

The model will be structured to summarize some alternative mechanisms which may give rise to observed assemblage structure. Some specific model mechanisms include: 1) effects of upwelling variability on recruitment, survival and growth in functional groups in assembages, 2) effects of competition and predation by some functional groups in assemblages and 3) effects of various fishing strategies on recruitment, survival, and growth in functional groups. These effects, alone and in combinations, can be proposed as alternative hypotheses to describe abundance and production patterns in western continental shelf fish assemblages. In this model, yield from a functional group is the target of interest.

Role of functional groups in models

For the purpose of this model, I define a functional group as a group of species with similar production characteristics (e.g., growth, reproduction and survival) based on a common trophic base. Production characteristics are specific for a group rather than for each component species. From this larger scale perspective, a single species is no longer the product of interest; and species composition within a functional group is irrelevant, because in different regions, species "function" may be carried out by different species. Biomass within a functional group is considered "equivalent", regardless of the species composition. For example, a model based on functional groups might include all piscivorous rockfishes with similar rates of productivity as one component, while traditional fishery models may have included each species separately. Species within a functional group can substitute one for another. If we wish to study shifts of species composition among rockfish piscivores, at a high level of species-specific resolution, we cannot combine all rockfish piscivores with similar production characteristics into one functional group. Instead, we must use linked single species models. If, however, we wish to study large scale shifts in abundance or importance of environmental variability for rockfish piscivores vs. benthic invertebrate feeders, we may combine several rockfish piscivore species into a functional group to compare with a functional group of benthic invertebrate feeders. A species may belong to more than one functional group over its lifetime, as its survival rates, growth rates, and food sources change with body size.

The use of functional groups in large scale multispecies and ecosystem models simplifies assemblage structure into a form that is more easily modelled but still ecologically meangingful. Large scale interactions (e.g., between demersal and pelagic fishes) are more easily studied by simplifying the number of the components and emphasizing the behavior between components. For many species, the only data that exist may be very coarse scaled, and fine scale single species data may not be required. There may be little loss of realism with this approach when species are functionally similar, e.g., some members of the genus *Sebastes* that share dietary and reproductive similarities.

This agglomeration presents some disadvantages. This approach is inadequate when species a) are strongly affilitated with several trophic groups or radically switch food sources in response to food abundance, or b) have similar feeding habits but different life history and reproductive characteristics. In many cases, biomass from one functional group may recombine into other groups at various stages in life history. For example, several functional groups of adult feeding types may contribute to a common functional group of, say, pelagic larvae, that undergo similar patterns of growth and survival. However, larvae must leave that group to recruit back into separate original adult spawning groups. The approach may not always be suitable as a management method, because, in reality, species composition within a functional group may be critical in a fishery. For example, not all species in the group may be equally marketable; or over long periods of time, fisheries could eliminate sightly less productive species in the group. Finally, the approach is unnecessary in the case of simple systems where most of the biomass occurs as only a few species, each with well-defined trophic roles and reproductive dynamics; or where effects of species interactions are overwhelmed by effects of physical factors.

Functional Groups in Northeastern Pacific Groundfish Assemblages

The groundfish production system along the western continental shelf of the United States may be treated in terms of functional groups. The system is speciose: more than thirty-five species of rockfish (Sebastes) and thirteen species of pleuronectids were recorded during 1977 National Marine Fisheries Rockfish Survey. Many of these species co-occur in an area and are vulnerable to an otter trawl fishery. Reproductive dynamics (Pacific Fisheries Management Council, 1979) and feeding habits (Hart, 1973; Brodeur, pers. comm.; Philips, 1964) for some co-occuring species are sufficiently well-known to place some species into functional groups. Although any models which result from these definitions would be too coarse and generalized for management purposes, they may serve as springboards for hypothesis generation and synthesis.

Functional groups along continental shelves are in general organized around two major bases of food production, pelagic primary production and benthic detritally based production (Fig. 24). In upwelling systems, this pelagic-benthic difference is accentuated by different dynamic oceanographic conditions. The functional group may be affected by the oceanographic conditions directly, e.g., advection of pelagic larvae; or indirectly, via the structure and dynamics of the affiliated food web. The differences in temporal and spatial scales of production between pelagic and benthic seem to be large. Dynamics of primary production in the Oregon upwelling region appear to be highly variable, controlled by a series of short term wind events at a resolution time of three to ten days (Small and Menzies, 1981). The omnivores and secondary consumers affiliated with the pelagic production system, e.g., mesopelagic shrimps and euphausiids, may dampen oscillations in production patterns, since they are generally more longer-lived than other pelagic invertebrates, feed on a diverse array of pelagic invertebrates, and comprise a large proportion of standing biomass (Hebard, 1966; Laurs, 1967). Dynamics of benthic production in any region, including the Oregon continental shelf, are poorly understood; but may be expected to be less variable than primary production (at

Fig. 24. Schematic diagram of continental shelf trophic structure, Oregon coast. Large dashed line encloses groups exploited by demersal fishery.

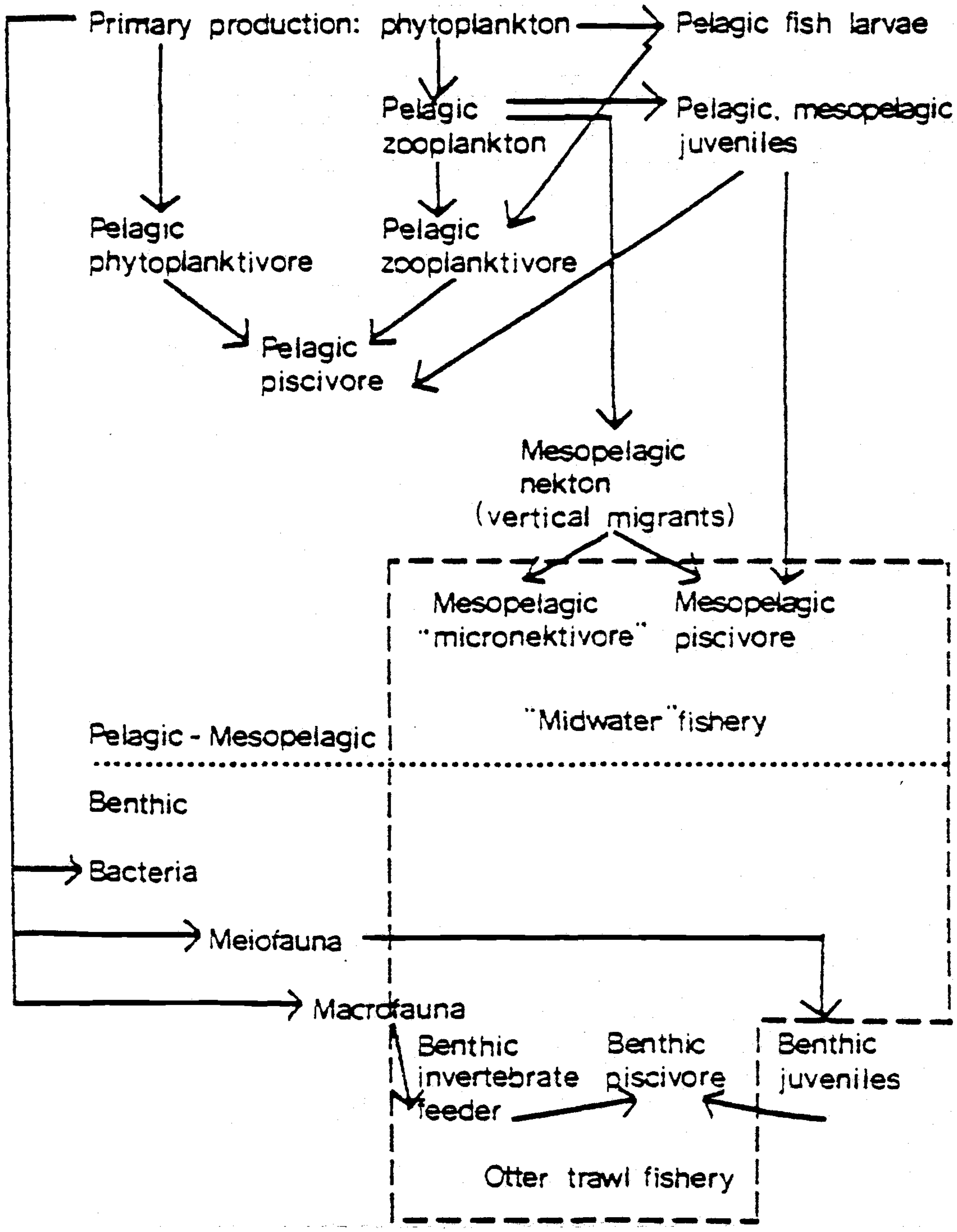

Primary production: phytoplankton
Pelagic fish larvae
Pelagic zooplankton
Pelagic, mesopelagic juveniles
Pelagic phytoplanktivore
Pelagic zooplanktivore
Pelagic piscivore
Mesopelagic nekton (vertical migrants)
Mesopelagic "micronektivore"
Mesopelagic piscivore
"Midwater" fishery
Pelagic - Mesopelagic
Benthic
Bacteria
Meiofauna
Macrofauna
Benthic invertebrate feeder
Benthic piscivore
Benthic juveniles
Otter trawl fishery

Fig. 24

least on scales of three to ten days). Substrate is much more stable than in the pelagic environment. Although sediment and invertebrate distributions may be patchy in space, benthic patches of non-motile invertebrates are not subject to advection and are more permanently located than pelagic patches. Nutrients are available from a solid medium, less subject to turbulence and advection (except for resuspension at the sediment surface) than are nutrients found in the upper water column. Standing crops of phytoplankton important for larval survival may double within a day (e.g., Walsh *et al.* 1978); but members of the benthic component most important to fish production, macrobenthos, have lifespans that can reach up to three years [e.g., the polychaete *Pectinaria californiensis* (Nichols, 1975)]. Bacteria and meiobenthos have relatively short life histories, and hence the potential to oscillate more widely over short periods of time. However, these components have not received wide attention over short time spans. For benthic invertebrate standing stocks, no seasonal variation in biomass was observed in a single year survey by Bertrand (1971) although his samples were small. No estimates of benthic production rates for the Oregon shelf are available.

Most demersal fishes along the western continental shelf are associated with four primary food sources that in turn provide the basis for four basic functional groups (Fig. 24). A functional group of mesopelagic micronectivores would feed primarily on vertically migrating crustaceans such as euphausiids. Mesopelagic piscivores would feed on myctophids, mesopelagic juvenile fishes and other small midwater nekton such as squids. Mesopelagic feeders would include vertically migrating fishes. Benthic invertebrate feeders would consume benthic epifauna and infauna. Benthic piscivores would eat benthic juvenile and adult fishes occurring along the bottom. Other functional groups may be made by combining the four basic food sources: for example, fishes may consume a mixture of mesopelagic zooplankton and fishes; non-migrating fishes may consume a mixture of "mesopelagic" zooplankton at the bottom of its vertical range as well as other benthos.

Additional important functional groups include pre-recruit stages such as eggs, larvae and juveniles, that may be pelagic or demersal. These stages are probably more susceptible to physical environmental factors and predation than adult forms.

For fishery management purposes, resident functional groups which occur in an assemblage may be linked together as assemblage production units (Tyler et al., in press) based on common production bases, Seasonal species may be incorporated into the dynamics of assemblage production as driving variables. Two assemblage production units are shown in the otter trawl fishery example in Fig. 24: a mesopelagic production unit and a benthic production unit. If additional major functional groups are found that link the two bases, for example, an abundant piscivore that feeds on both mesopelagic and benthic fishes, the entire assemblage would be considered a single production unit, since production of all the fishes included would be infuenced by a common predator.

Assemblage species compositions based on cluster analysis of rockfish survey data can be simplified into a series of functional groups (Table 56). Exceptions include some rockfish species whose

Table 56. Example of functional groups represented in assemblage region 1ai defined from cluster analysis.

Functional Group	Benthic Invertebrate Feeder	Benthic Piscivore-Crustacean Feeder	Benthic Omnivore	Mesopelagic Crustacean Feeder	Mesopelagic Piscivore-Crustacean Feeder
Component species	Dover sole Rex sole	Arrowtooth flounder (Pacific halibut)	Sablefish	Pacific ocean perch Splitnose rockfish Darkblotched rockfish Aurora rockfish Rougheye rockfish ? Shortraker rockfish ?	Pacific hake (seasonal)

feeding habits are still poorly defined, although many are probably mesopelagic feeders. The example of functional groups shown in Table 56 is based on species composition in assemblage region 1ai from cluster analysis (Table 3). It includes a group of benthic invertebrate feeders with similar reproductive patterns, pleuronectids (Dover and rex sole). Benthic piscivores are represented by arrowtooth flounder, which also feed on crustaceans (Hart, 1971). Four rockfishes are believed to feed mostly on mesopelagic micronekton such as euphausiids and vertically migrating shrimps: Pacific ocean perch, splitnose rockfish, darkblotched rockfish, and aurora rockfish (Hart, 1973; Adams, 1980a). Pacific hake (a seasonal species) feeds off bottom on mesopelagic zooplankton and fishes, while sablefish appears to be omnivores (Hart, 1973). Rougheye and shortraker rockfish are tentatively placed in the mesopelagic zooplanktivore group, although their feeding habits are not well-described.

Demersal fish production in an upper slope assemblage off Oregon: a speculative model

In concordance with the goals and objectives outlined in the introduction, this model example is designed to consider fish production of a single demersal assemblage from a hypothetical aspect. The compartment model (Fig. 25) differs from the overview of general continental shelf trophic structure (Fig. 24) by emphasizing and elaborating components closely related to demersal fish assemblages and simplifying the remainder where possible. State variables reflect the

Fig. 25. Schematic diagram of components contributing to demersal fish assemblage structure and dynamics, outer continental shelf-slope, northern California Current. Addition to copy: Benthic detrical pool (BDET) is to be labelled (19); functions G_5 (PPL to R), G_{25b} (MPF to RJUV), G_{101} (BINV3 to M) and G_{106} (PADU to SFY/BDET) may be added to this figure.

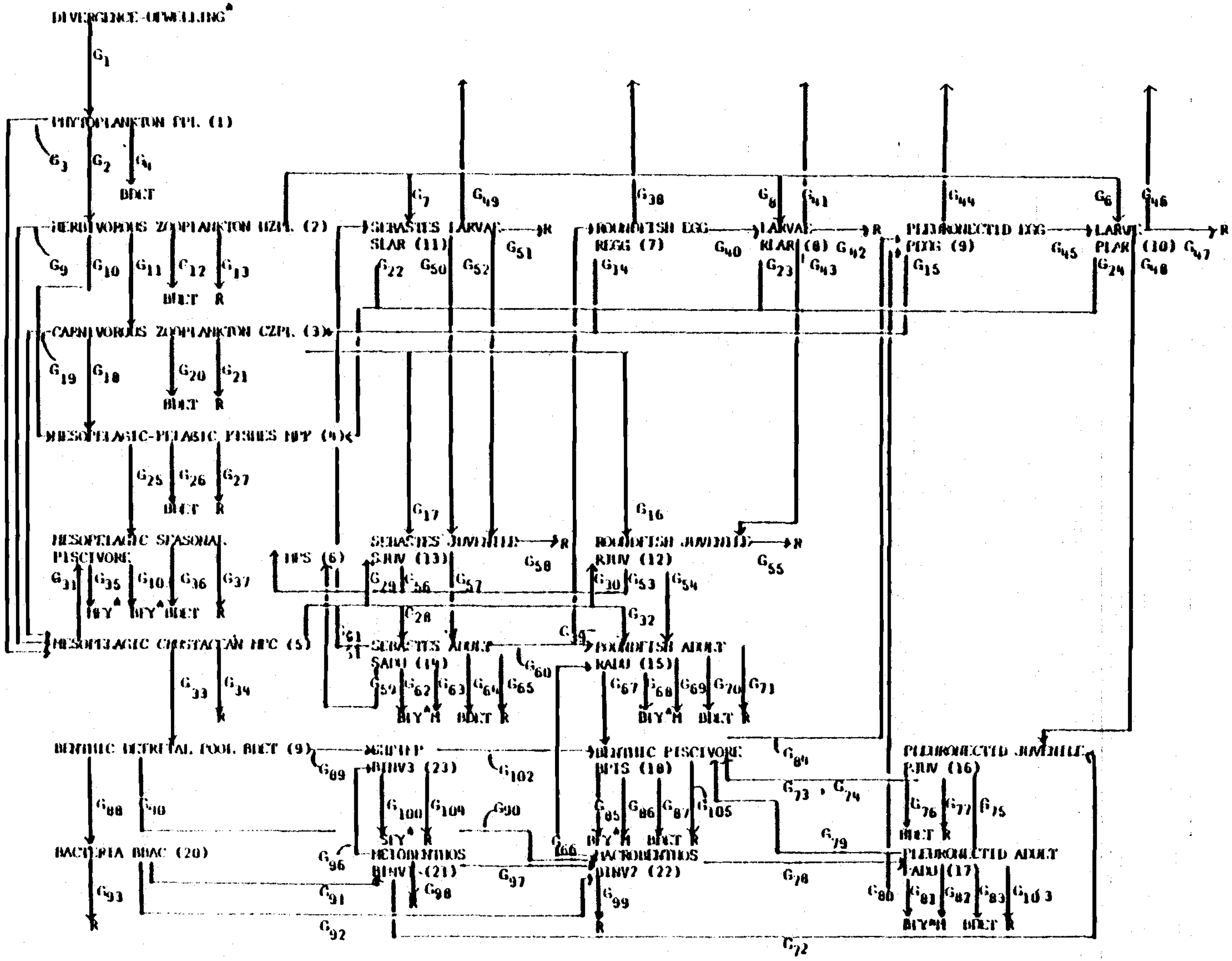

DIVERGENCE-UPWELLING*
PHYTOPLANKTON PPL (1)
HERBIVOROUS ZOOPLANKTON HZPL (2)
CARNIVOROUS ZOOPLANKTON CZPL (3)
MESOPELAGIC-PELAGIC FISHES MPP (4)
MESOPELAGIC SEASONAL PISCIVORE
MPS (6)
MESOPELAGIC CRUSTACEAN MPC (5)
SEBASTES LARVAE SLAR (11)
ROUNDFISH EGG REGG (7)
LARVAE RLAR (8)
PLEURONECTID EGG PEGG (9)
LARVAE PLAR (10)
SEBASTES JUVENILE SJUV (13)
ROUNDFISH JUVENILE RJUV (12)
SEBASTES ADULT SADU (14)
ROUNDFISH ADULT RADU (15)
BENTHIC DETRITAL POOL BDET (9)
MEIOFAUNA BINV3 (23)
BENTHIC PISCIVORE BPTS (18)
PLEURONECTID JUVENILE PJUV (16)
BACTERIA BBAC (20)
MEIOBENTHOS BINV1 (21)
MACROBENTHOS BINV2 (22)
PLEURONECTID ADULT PADU (17)

Fig. 25

condition of functional groups of fishes and their food sources within the system at a particular time (Table 57). Biomass is transferred between state variables through process of predation, recruitment, reproduction, or fishery effort and may be influenced by intercomponent and intra-component competition. These transfers (as kcal/m^2/year or event scale) ultimately influence functional group production, and are denoted with a line in figure 25. Driving variables, biotic and physical environmental inputs which are sensed by the system but are determined outside of it may affect some transfer rates; and include oceanographic features that influence primary production and larval survival (upwelling and divergence), seasonal species whose dynamics may be controlled by proceses outside the model region (the mesopelagic piscivore-micronektivore, Pacific hake), and various fisheries (midwater and benthic trawl fisheries). The information output by the model would include fishery yields and component standing stocks on an event or annual basis. The time resolution within components would vary from the "event" scale, the 3-10 day periodicity of upwelling events, to month, to year, depending on the component. Each component will be discussed separately in a following section.

Model format is patterned after the general systems approach of Klir (1969), elucidated by Overton (1975), as the FLEX paradigm. Future values of state variables are generated from present values of state variables, present values of driving or input variables, and particular past values of state and input variables ("memory") by specific rules for update:

Table 57. Driving variables, state variables and output variables included in conceptual model.

Driving Variables

Z subscript	Description
1	Upwelling index
2	Water depth, m. e.g. 250 m
3	Presence of migrating schools of mesopelagic fishes along Oregon coast
4	Midwater fishery effort
5	Benthic fishery effort
6	Shrimp fishery effort

State Variables

X subscript	Description	Acronym
1	Phytoplankton	PPL
2	Herbivorous zooplankton	HZPL
3	Carnivorous zooplankton	CZPL
4	Mesopelagic fishes	MPF
5	Mesopelagic crustacean	MPC
6	Mesopelagic piscivore	MPS
7	Roundfish eggs	REGG
8	Roundfish larvae	RLAR
9	Pleuronectid eggs	PEGG
10	Pleuronectid larvae	PLAR
11	"Sebastes" larvae	SLAR
12	Roundfish juvenile	RJUV
13	"Sebastes" juvenile	SJUV
14	"Sebastes" adult	SADU
15	Roundfish adult	RADU
16	Pleuronectid juvenile	PJUV
17	Pleuronectid adult	PADU

Table 57. (continued)

X subscript	Description	Acronym
18	Benthic piscivore	BPIS
19	Detrital pool	BDET
20	Benthic bacteria	BBAC
21	Meiobenthos	BINV1
22	Macrobenthos	BINV2
23	Shrimp	BINV3

Output Variables

Y subscript	Description	Acronym
1	Midwater fishery yield	MFY
2	Benthic fishery yield	BFY
3	Shrimp fishery yield	SFY

$x(t+1) = x(t) + \quad (t)$

where $x(t)$ is a vector of state variables at time t

(t) is a function of $x(t)$, the vector of input variables of time t ($Z(t)$), and the vector of past values of X and Z which are retained at time t ($M(t)$).

The state, input and memory variables incorporates in the (t) function for update of each state variable are listed in Table 57. In FLEX convention, all state variables are denoted by subscripted X's. In this presentation, state variables will be abbreviated in mnemonic form for easier reference (Table 57). In FLEX processing, all functions are numbered in order of calculation. In this presentation, functions will be numbered approximately in order of component discussion.

A mixed supply-demand function appears frequently throughout the model to represent flow from one state variable to the next, usually via predation (Overton, 1975):

$$G = b_1 X_2 \left(1 - e^{-b_2 X_1/X_2}\right)$$

where G = biomass equivalents flowing from prey (X_1) to predator (X_2)

X_1 = prey biomass

X_2 = predator biomass

b_1, b_2 = scaling parameters

Flow is scaled by the ratio of prey to predator (X_1/X_2). When prey are relatively more abundant than predators, this ratio is high, the power to which e is raised becomes large and negative, the values of e evaluated at that power becomes small (approaching zero), and flow

Fig. 26. Examples of mixed demand function $G = b_1X_2(1-e^{-b_2X_1/X_2})$.

Curve 1: $b_1X_2 = 20$, $b_2 = .7$ Curve 2: $b_1X_2 = 20$, $b_2 = .2$.

Curve 3: $b_1X_2 = 10$, $b_2 = .7$ Curve 4: $b_1X_2 = 10$, $b_2 = .2$.

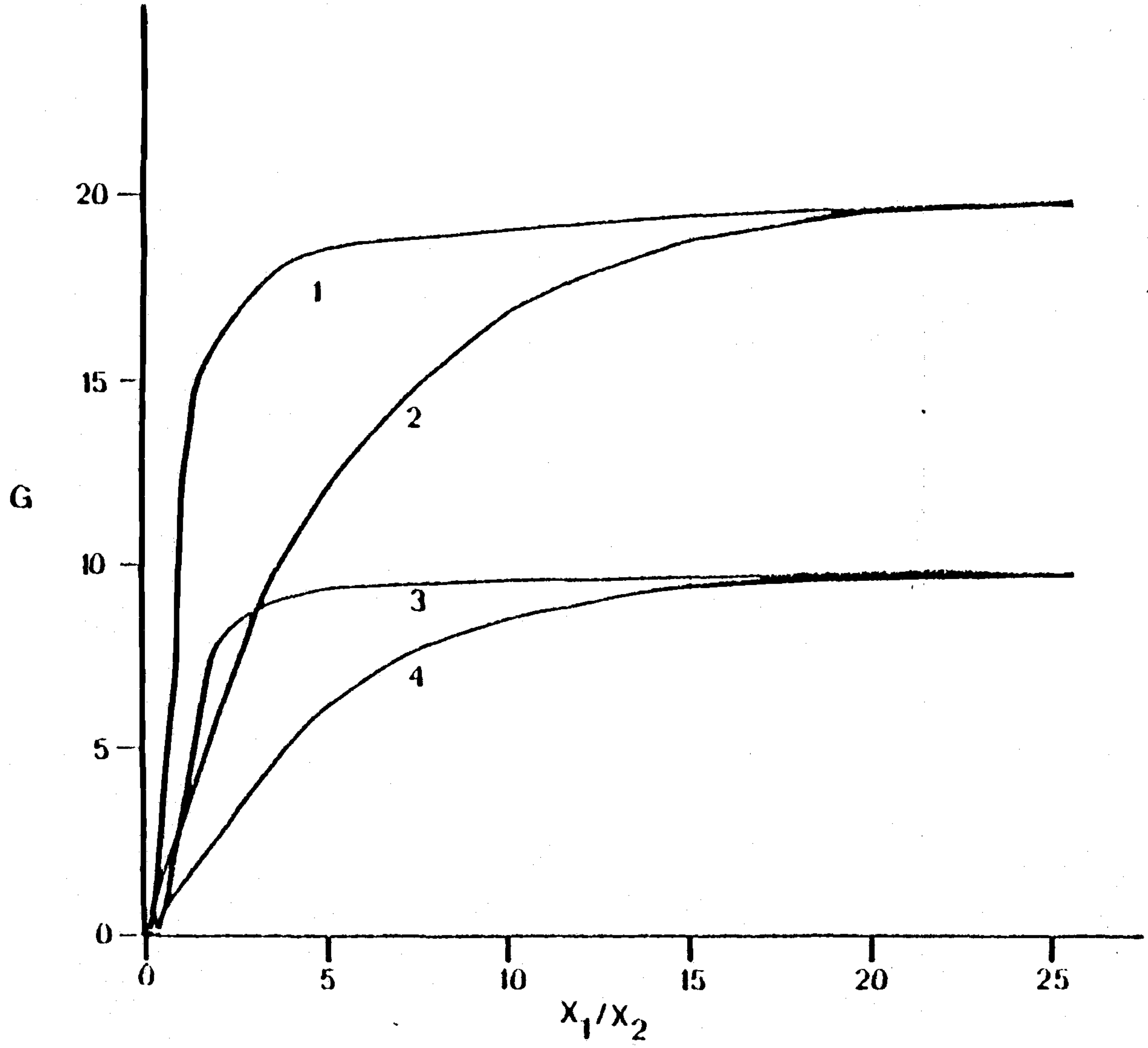


Fig. 26

becomes a function of demand by X_2. When this ratio is low, the power to which e is raised becomes low (approaching zero), the value of e approaches 1, and flow as a function of demand (X_2) is limited by supply (X_1). The scaling parameters change the curve shapes (Fig. 26): b_1 controls the height of the assymptote, and b_2 controls how rapidly the curve approaches the assymptote. The quantity G represents gain by predator X_2 and loss to prey X_1. When a predator feeds non-selectively on a mixture of prey species, the single X_1 prey quantity may be replaced by a sum of potential prey. The loss is then apportioned among prey as a function of each prey's relative abundance.

Changes in phytoplankton standing stock (PPL) are due to gains through primary production, losses due to sinking, predation, and respiration (Table 58). Primary production along the Oregon coast is strongly influenced by the strength and duration of upwelling events, which usually occur as 3 to 10 day episodes within seasons (Small and Menzies, 1981). The effect of upwelling strength is included as the function f(Z1). Production is highest during weak upwelling events. As wind velocity increases, nutrients are added to the system from below, and production is enhanced. At very high levels of velocity, however, primary production is advected offshore (Small and Menzies, 1981); and production over the shelf ultimately decreases. Phytoplankton is cropped first by herbivorous zooplankton and second by mesopelagic micronekton following the supply-demand function.

Flux of carbon to the sediments may be fitted as a function of surface production and depth of the water column overlying the sediment (Suess, 1980); however, this flux must be scaled since the equation is

Table 58. Biomass uptake of phytoplankton (PPL).

F_1 = Biomass uptake of phytoplankton (PPL).

$= G_1 - (G_2 + G_3 + G_4 + G_5)$

Where G_1 = surface primary production as enhanced by upwelling

$= f\ (Z1,\ PPL)$

in the form $f\ (Z1) \cdot PPL$

- •

where Z1 = upwelling index

G_2 = loss of phytoplankton by herbivorous zooplankton predation (HZPL)

$= b_1\ HZPL\ (1-e^{-b_2\ PPL/HZPL})$

G_3 = loss by mesopelagic crustacean predation (MPC)

$= \frac{PPL - G_2}{PRMPC}\ b_3\ MPC\ (1-e^{-b_4\ PRMPC/MPC})$

Where PRMPC = prey available to MPC (see function f_5)

G_4 = loss by sinking to sediments

$= b_5\ PPL$

G_5 = respiration

$= r_1\ PPL$

Table 59. Biomass uptake of herbivorous zooplankton (HZPL)

$F_2 = G_2 - (G_6 + G_7 + G_8 + G_9 + G_{10} + G_{11} + G_{12} + G_{13})$

Where G_2 = consumption of phytoplankton (PPL) (see function f_1)

G_6 = loss due to predation by pleuronectid larvae (PLAR)

$= b_6 \text{ PLAR } (1-e^{-b_7 \text{ HZPL/PLAR}})$

G_7 = loss due to predation by "Sebastes" larvae (SLAR)

$= b_8 \text{ SLAR } (1-e^{-b_9 \text{ HZPL}-G_6/\text{SLAR}})$

G_8 = loss due to predation by roundfish larvae (RLAR)

$= b_{10} \text{ RLAR } (1-e^{-b_{11} (\text{HZPL} - G_6 - G_7)/\text{RLAR}})$

G_9 = loss due to predation by mesopelagic crustaceans (MPC)

$$= \frac{\text{HZPL} - (G_6 + G_7 + G_8)}{\text{PRMPC}} b_3 \text{ MPC } (1-e^{-b_4 \text{ PRMPC/MPC}})$$

where PRMPC = prey available to MPC (see function f_5)

G_{10} = loss due to predation by mesopelagic fishes (MPF)

$$= \frac{\text{HZPL}-(G_6 + G_7 + G_8 + G_9)}{\text{PRMPF}} b_{12} \text{ MPF } (1-e^{-b_{13}\text{PRMPF/MPF}})$$

where PRMPF = prey available to MPF (see function f_4)

G_{11} = loss due to predation by carnivorous zooplankton (CZPL)

$$= \frac{\text{HZPL} - (G_6 + G_7 + G_8 + G_9 + G_{10})}{\text{PRCZPL}} b_{14} \text{ CZPL } (1-e^{-b_{15}\text{PRCZPL/CZPL}})$$

where PRCZPL = prey available to CZPL (see function f_3)

G_{12} = loss due to sinking to sediments

$= b_{18} (\text{HZPL} - (G_6 + G_7 + G_8 + G_9 + G_{10} + G_{11}))$

G_{13} = respiration

$= r_2 \text{ HZPL}$

based on primary production as gm C $m^{-2}yr^{-1}$ and primary production may be repackaged as fecal pellets before reaching the sediment surfaces (Suess, 1980). An additional plankton sink term, to represent predation from other sources such as fishes (e.g., anchovy) may eventually be required to balance flows. This portion of the model could be updated on the "event" basis (3-10 day upwelling scale) if pelagic processes such as larval survival were to be emphasized. Alternatively, monthly or annual updates would be suitable for investigating fishery effects on adult functional groups.

Changes in herbivorous zooplankton standing stocks (HZPL, Table 59) are due to gains through consumption of phytoplankton, losses due to predation by carnivorous zooplankton, fish larvae, juveniles, and pelagic-mesopelagic fishes; and losses due to sinking. Consumption and predation follow supply-demand relations, while the quantity sinking is assumed to be directly proportional to unconsumed standing stocks. Sinking loss is more realistically a function of offshore advection as well. However, this process may also be modelled separately in more detail by a physical transport model. This zooplankton class is intended to serve as small-sized potential prey for fish larvae, mesopelagic fishes, and crustaceans and carnivorous zooplankton; but also may be selected by larger juvenile fishes. Pleuronectid larvae are proposed to out-compete Sebastes larvae, which would in turn out-compete roundfish larvae. This would reflect the advantage of pleuronectid larvae which may remain in the water column longer than the other larvae (Pearcy et al., 1977), and hence attain a larger size. This portion of the model should also be updated on the "event" scale, if larval processes are of special interest.

Carnivorous zooplankton (CZPL, Table 60) are designed to represent larger sized zooplankton such as chaetognaths, salps, mysids or perhaps small euphausiids. Changes in standing stock are due to gains through non-selective consumption of available herbivorous zooplankton, and roundfish and pleuronectid eggs (Hunter, 1981). Eggs that were advected beyond the boundaries of the model are assumed to be unavailable for consumption. Carnivorous zooplankton may also be subject to advection (along with eggs), but this factor has not been included in this description. Losses are due to consumption by roundfish juveniles, "Sebastes" juveniles, and small mesopelagic nekton (fishes and crustaceans), as well as sinking of a proportion of standing stock. There is no evidence for this competitive ranking, however. Time scale for update should be compatible with zooplankton and egg components: if larval processes are emphasized, an "event" scale would be appropriate.

Examples of pelagic-mesopelagic fishes (MPF, Table 61) include myctophids, clupeids, engraulids and some juvenile salmonids. The component is intended to include pelagic feeders that consume relatively small prey items such as herbivorous and carnivorous zooplankton and fish larvae (especially yolk sac stages) (Hunter, 1981), but are in turn subject to predation by larger mesopelagic piscivores and juvenile roundfish (Cailliet, 1981). All potential prey are placed in a pool (PRMPF), and subjected to predation following a demand function. Prey consumption is assumed to be non-selective. Members of this component have also been observed to prey on anchovy eggs (Hunter, 1981), and an

Table 60. Biomass uptake of carnivorous zooplankton (CZPL)

F_3 = Biomass uptake of carnivorous zooplankton (CZPL)

$$= G_{11} + G_{14} + G_{15} - (G_{16} + G_{17} + G_{18} + G_{19} + G_{20} + G_{21})$$

where G_{11} = gain from consumption of herbivorous zooplankton (HZPL)

$$= \frac{HZPL - (G_6+G_7+G_8+G_9+G_{10})}{PRCZPL} b_{14} \, CZPL \, (1-e^{-b_{15} \, PRCZPL/CZPL})$$

where PRCZPL = prey available to CZPL

$$= HZPL - (G_6 + G_7 + G_8 + G_9 + G_{10})$$
$$+ REGG - G_{38}$$
$$+ PEGG - G_{44}$$

REGG, PEGG = available roundfish and pleuronectid eggs after advection (G_{38}, G_{44}), respectively (see functions f_7 and f_9)

G_{14} = gain from consumption of roundfish eggs (REGG)

$$= \frac{REGG - G_{38}}{PRCZPL} b_{14} \, CZPL \, (1-e^{-b_{15} \, PRCZPL/CZPL})$$

G_{15} = gain from consumption of pleuronectid eggs (PEGG)

$$= \frac{PEGG - G_{44}}{PRCZPL} b_{14} \, CZPL \, (1-e^{-b_{15} \, PRCZPL/CZPL})$$

G_{16} = loss due to predation by roundfish juveniles (RJUV)

$$= \frac{CZPL}{PRRJUV} b_{16} \, RJUV \, (1-e^{-b_{17} \, PRRJUV/RJUV})$$

where PRRJUV = prey available to roundfish juveniles (see function f_{12})

Table 60 (continued)

G_{17} = loss due to predation by "Sebastes" juveniles (SJUV)

$$= \frac{CZPL - G_{16}}{PRSJUV} b_{18} \, SJUV \, (1-e^{-b_{19} \, PRSJUV/SJUV})$$

where PRSJUV = prey available to "Sebastes" juveniles (see function f_{13})

G_{18} = loss due to predation by mesopelagic fishes (MPF)

$$= \frac{CZPL - G_{16} - G_{17}}{RPMPC} b_{12} \, MPF \, (1-e^{-b_{13} PRMPF/MPF})$$

where PRMPF = prey available to mesopelagic fishes (see function f_{14})

G_{19} = loss due to predation by mesopelagic crustacean (MPC)

$$= \frac{CZPL - G_{16} - G_{17} - G_{18}}{PRMPC} b_3 \, MPC \, (1-e^{-b_4 \, PRMPC/MPC})$$

G_{20} = loss due to sinking (BDET)
= b_{20} (CZPL - G_{16} - G_{17} - G_{18} - G_{19})

G_{21} = respiration
= r_3 CZPL

Table 61. Biomass uptake of mesopelagic fishes (MPF)

F_4 = Biomass uptake of mesopelagic fishes (MPF)

$= G_{10} + G_{18} + G_{22} + G_{23} = G_{24} - (G_{25} + G_{16} + G_{26} + G_{27})$

where G_{10} = consumption of herbivorous zooplankton (see function f_2)

G_{18} = consumption of carnivorous zooplankton (see function f_3)

G_{22} = consumption of "Sebastes" larvae (SLAR)

$$= \frac{SLAR - G_{49}}{PRMPF} b_{12} \ MPF \ (1-e^{-b_{13} \ PRMPF/MPF})$$

where $SLAR - G_{49}$ = "Sebastes" larvae available to MPF

PRMPF = total prey available to MPF

$= HZPL - (G_6 + G_7 + G_8 + G_9)$

$+ CZPL - (G_{16} - G_{17})$

$+ SLAR - (G_{49})$

$+ RLAR - (G_{41}$

$+ PLAR - (G_{46})$

G_{49}, G_{41}, G_{46} are advective losses of "Sebastes" roundfish and pleuronectid larvae, respectively.

G_{23} = consumption of roundfish larvae (RLAR)

$$= \frac{RLAR - G_{41}}{PRMPF} b_{12} \ MPF(1-e^{-b_{13} PRMPF/MPF})$$

G_{24} = consumption of pleuronectid larvae (PLAR)

$$= \frac{PLAR - G_{46}}{PRMPF} b_{12} \ MPF \ (1-e^{-b_{13} \ PRMPF/MPF})$$

G_{25a} = loss due to predation by mesopelagic seasonal fish (MPS)

$$= \frac{MPF}{PRMPS} b_{21} \ MPS \ (1-e^{-b_{22} \ PRMPS/MPS})$$

where PRMPS = total prey available to MPS (see function f_6)

Table 61 (continued)

G_{25b} = loss due to predation by roundfish juveniles (RJUV)

$$= \frac{MPF - G_{25a}}{PRRJUV} b_{16} RJUV (1-e^{-b_{17} PRRJUV/RJUV})$$

where PRRJUV = total prey available to roundfish juveniles (see function f_{12})

G_{26} = sinking loss

$= b_{23}$ MPF

G_{27} = respiration

$= r_4$ MPF

Table 62. Biomass uptake of mesopelagic crustaceans (MPC)

F_5 = Biomass uptake of mesopelagic crustaceans (MPC)

$$= G_3 + G_9 + G_{19} - (G_{28} + G_{29} + G_{30} + G_{31} + G_{32} + G_{33} + G_{34})$$

G_3 = consumption of phytoplankton (see function f_1)
G_9 = consumption of herbivorous zooplankton (see function f_2)
G_{19} = consumption of carnivorous zooplankton (see function f_3)

where PRMPC = prey availble to mesopelagic crustaceans

$$= PPL - G_2 + HZPL - (G_6 + G_7 + G_8) + CZPL - (G_{16} + G_{17} + G_{18})$$

$$G_3 + G_9 + G_{19} = b_3\ MPC\ (1-e^{-b_4 PRMPC/MPC})$$

G_{28} - loss due to predation by "Sebastes" adults (SADU)

$$= b_{24}\ SADU\ (1-3^{-b_{25} MPC/SADU})$$

G_{29} = loss due to predation by "Sebastes" juveniles (SJUV)

$$= \frac{MPC-G_{28}}{PRSJUV}\ b_{18}\ SJUV(1-e^{-b_{19} PRSJUV/SJUV})$$

where PRSJUV = prey available to "Sebastes" juveniles (see function f_{13})

G_{30} = loss due to predation by roundfish juveniles (RJUV)

$$= \frac{MPC-G_{28}-G_{29}}{PRRJUV}\ b_{16}\ RJUV(1-e^{-b_{17} PRRJUV/RJUV})$$

where PRRJUV = prey available to roundfish juveniles (see function f_{12})

Table 62. (continued)

G_{31} = loss due to predation by mesopelagic seasonal fish (MPS)

$$= \frac{MPC-G_{28}-G_{29}-G_{30}}{PRMPS} b_{21} MPS(1-e^{-b_{22}PRMPS/MPS})$$

where PRMPS = prey availble to mesopelagic seasonal fish (see function f_6)

G_{32} = loss due to predation by roundfish adults (RADU)

$$= \frac{MPC-G_{28}-G_{29}-G_{30}-G_{31}}{PRRADU} b_{26} RADU(1-e^{-b_{27}PRRADU/RADU})$$

Where PRRADU = prey available to roundfish adult (see function f_{15})

G_{33} = sinking loss to sediments

$= b_{28}$ MPC

G_{34} = respiration

$= r_5$ MPC

Table 63. Biomass uptake of mesopelagic seasonal fish (MPS)

F_6 = Biomass uptake of mesopelagic seasonal fish (MPS)

$= G_{200} + G_{25} + G_{31} + G_{53} + G_{56} + G_{59} - (G_{35} + G_{37} + G_{38} + G_{102})$

Where $G_{200} = G_{199}\ Z3$

Where Z3 = seasonal abundance of migrating mesopelagic fishes along Oregon coast

$G_{199} = 0$ if $PRMPS < PRMPS_{crit} = b_{29}$

$= 1$ if $PRMPS \geq PRMPS_{crit} = b_{29}$

PRMPS = total prey available to mesopelagic seasonal fish

= MPF

$+ MPC - (G_{28} + G_{29} + G_{30})$

+ SJUV

+ RJUV

$+ b_{39}$ SADU

G_{25} = consumption of mesopelagic fishes (MPF)

$$= \frac{MPF}{PRMPS} b_{21}\ MPS\ (1-e^{-b_{22} PRMPS/MPS})$$

G_{31} = consumption of mesopelagic crustaceans (MPC)

$$= \frac{MPC - (G_{28}+G_{29}+G_{30})}{PRMPS} b_{21}\ MPS\ (1-e^{-b_{22} PRMPS/MPS})$$

G_{53} = consumption of roundfish juveniles (RJUV)

$$= \frac{RJUV}{PRMPS} b_{21}\ MPS\ (1-e^{-b_{22} PRMPS/MPS})$$

Table 63. (continued)

G_{56} = consumption of "Sebastes" juveniles (SJUV)

$$= \frac{SJUV}{PRMPS} b_{21} \text{ MPS } (1-e^{-b_{22} PRMPS/MPS})$$

G_{59} = consumption of "Sebastes" adults (SADU)

$$= b_{39} \frac{SADU}{PRMPS} b_{21} \text{ MPS } (1-e^{-b_{22} PRMPS/MPS})$$

where b_{39} = proportion of "Sebastes" adults vulnerable to predation

G_{35} = loss to midwater fishery

$$= \frac{b_{30}\ Z4}{b_{30}Z4+b_{31}Z5+b_{32}} \text{ MPS } (1-e^{-(b_{30}Z4+b_{31}Z5+b_{32})})$$

where b_{30} = catchability of mesopelagic seasonals by midwater geat

Z4 = midwater fishery effort

b_{31} = catchability of mesopelagic seasonals by benthic geat

Z5 = benthic fishery effort

b_{32} = natural mortality rate

G_{103} = loss to benthic fishery

$$= \frac{b_{31}\ Z5}{b_{30}Z4+b_{31}Z5+b_{32}} \text{ MPS } (1-e^{-(b_{30}Z4+b_{31}Z5+b_{32})})$$

where variables and parameters are defined in G_{35}

G_{36} = loss to benthic detritus (natural mortality and egestion)

$$= \frac{b_{32}}{b_{30}Z4+b_{31}Z5+b_{32}} \text{ MPS } (1-e^{-(b_{30}Z4+b_{31}Z5+b_{32})}{}^{+b_{69}\text{ MPS}})$$

where variables and parameters are defined in G_{35}

b_{69} - proportionate egestion rate

G_{37} = respiration

= r_6 MPS

alternative structure would be to include eggs among potential prey items for this component. Since these fishes have life cycles extending over years rather than event scales, and reproduce annually, annual updates would be appropriate.

Mesopelgic crustaceans (MPC, Table 62) would include euphausiids as "macrozooplankton" or "micronekton" that serve as potential prey for pelagic juvenile fishes and vertically migrating adults. These omnivorous euphausiids (e.g., Euphausia pacifica, Parsons and Takahashi, 1973) consume phytoplankton or zooplankton. Feeding is non-selective in this model. In turn, they are subject to predation by "Sebastes" adults, "Sebastes" juveniles, roundfish juveniles, mesopelagic seasonal fishes, and roundfish adults, in hypothetical competitive order based on relative dietary specialization of predators (Brodeur, pers. comm.; Hart, 1973). Sinking loss of biomass to sediments as fecal pellets is proportional to standing stock of euphausiids. Either an event scale or annual updates would be appropriate, depending on the context of model experiments, as most euphausiids live for more than a single year (Raymont, 1963).

Mesopelagic seasonal fishes (MPS, Table 63) were included to represent migrating species such as Pacific hake which may not be constantly present throughout the year (or, potentially, seasonally migrating marine mammals with similar feeding habits). Abundance off Oregon is highest from spring to fall (represented by function Z3, seasonal abundance of fish in a region, e.g., Oregon). Fish are assumed to migrate in response to feeding levels (Dark et al., 1980); if prey levels are below a critical level during an update period, predators leave the region. Potential prey include small pelagic and mesopelagic fish, mesopelagic crustaceans, juvenile "Sebastes", and roundfish; and a fraction of the "Sebastes" adult population representing small individuals vulnerable to midwater predation. The "Sebastes" adult fraction has not been reported, but would be consistent with recorded food habits of hake (Hart, 1973). Hake is vulnerable to a midwater fishery and by-catch in a benthic fishery, which will be discussed in a following section. Any natural mortality is input to benthic detritus, as is excretion. The seasonal abundance function should be scaled for desired level of resolution. Monthly updates would resolve seasonal distribution and abundance patterns of fish and prey.

Roundfish egg (REGG, Table 64) and pleuronectid egg (PEGG, Table 66) dynamics are considered similar in this model. Eggs are produced as a function of adult standing stock biomass and condition (discussed in a following section, along with timing of egg production). Egg loss is a function of advection by offshore transport, predation by carnivorous zooplankton (and potentially small mesopelagic fishes, as discussed earlier), and hatching to larval stage. When egg mortality is of special interest, the REGG and PEGG components could be expanded to include egg "age classes", i.e., a separate state variable for eggs 1, 2, ...k event classes old before hatching, each of which would be subject to age-specific ambient advection and predation effects. Eggs would be introduced into the first egg class, subjected to loss processes, and promoted to the next egg class, again subjected to loss, continuing until mean time of hatching is reached. This would be analogous to a typical multiple age-class Leslie-type model, but updated

Table 64. Biomass uptake of roundfish egg standing stock (REGG)

F_7 = Biomass uptake of roundfish egg standing stock (REGG)

$= G_{39} - (G_{38} + G_{14} + G_{40})$

Where G_{39} = eggs produced by adult roundfish standing stock (see function f_{15})

G_{38} = egg loss due to advection

$= f(Z1, REGG)$

in the form $f(Z1) \cdot REGG$

G_{14} = loss due to predation by carnivorous zooplankton (CZPL)

$$= \frac{REGG - G_{38}}{PRCZPL} b_{14}\ CZPL(1-e^{-b_{15}PRCZPL/CZPL})$$

where PRCZPL = prey available to CZPL (see function f_3)

G_{40} = recruitment of eggs to larval stage

$= REGG - G_{38} - G_{14}$

Table 65. Biomass uptake of roundfish larvae standing stock (RLAR)

F_8 = Biomass uptake of roundfish larvae standing stock (RLAR)

$= G_{40} + G_8 - (G_{41} + G_{23} + G_{42a} + G_{42b} + G_{43})$

where G_{40} = recruitment from hatched eggs (see function f_7)

G_8 = consumption of herbivorous zooplankton (see function f_2)

$= b_{10}\ RLAR\ (1-e^{-b_{11}(HZPL - G_6 - G_7)/RLAR})$

G_{41} = loss due to advection
$= f(Z1, RLAR)$
in the form $f(Z1) \cdot RLAR$

G_{23} = loss to predation by mesopelagic fish (MPF) see (function f_4)

$= \frac{RLAR - G_{41}}{PRMPF}\ b_{12}\ MPF\ (1-e^{-b_{13}PRMPF/MPF})$

G_{42a} = loss to starvation
$= G_{201}\ RLAR$

where G_{201} = proportionate loss to starvation as a function of food
$= 1-(b_{34}^{-1}(G_8/RLAR))$ if $G_8/RLAR < b_{34}$
$= 0$ if $G_8/RLAR$ f $G_8/RLAR > b_{34}$
where b_{34} = critical food density required for survival

$G_8/RLAR$: food density per larval biomass
G_{42b} = loss to respiration
$= r_8 PLAR$
G_{43} = recruitment to juvenile phase (RJUV)
$= RLAR + G_8 - (G_{41} + G_{23} + G_{42} + G_{43})$

Table 66. Biomass uptake of pleuronectid egg standing stock (PEGG)

F_9 = Biomass uptake of pleuronectid egg standing stock (PEGG)

$= G_{84} + G_{80} - (G_{44} + G_{15} + G_{45})$

where G_{84} = eggs produced by adult benthic piscivore standing stock (see function f_{18})

G_{80} = eggs produced by adult pleuronectid standing stock (see function f_{17})

G_{44} = egg loss due to advection
$= f(Z1) \cdot PEGG$

G_{15} = loss due to predation by carnivorous zooplankton (CZPL)

$$= \frac{PEGG - G_{44}}{PRCZPL} b_{14} \, CZPL \, (1-e^{-b_{15} PRCZPL/CZPL})$$

where PRCZPL = prey availble to CZPL (see function f_3)

G_{45} = recruitment of eggs to larval stage
$= PEGG - G_{44} - G_{15}$

on the basis of event time scales. However, if adult and fishery dynamics are of primary interest, monthly updates without "egg class" structure would be appropriate.

Roundfish larvae (RLAR, Table 65), pleuronectid larvae (PLAR, Table 67), and "Sebastes" larvae (SLAR, Table 68) are assumed to be subject to common processes of "recruitment" from hatched eggs (or adult spawning effort, in the case of "Sebastes", which eliminates the free egg phase *via* ovoviviparity, bearing live larvae). All consume herbivorous zooplankton, with pleuronectid larvae outcompeting "Sebastes" and roundfish: pleuronectid larvae may remain in the water column for up to one year (Pearcy *et al*., 1977), and a proportion of larvae may be able to exploit a wider variety of prey. Loss due to advection is also included, although potential food items may also be advected offshore with larvae, and pleuronectid larvae may return from long distances from shore (Pearcy *et al*., 1977), in spite of initial offshore advection. Loss due to predation is assumed to be a function of mesopelgic-pelagic fish abundance. Chaetognaths and euphausiids may also inflict mortality on yolk sac larvae, although the extent of mortality is probably small for anchovy larvae and poorly known for other species (Hunter, 1981). Potential cannibalism of "Sebastes" larvae by "Sebastes" juveniles is included, but "Sebastes" juvenile feeding habits are sparsely documented. Losses may also be due to starvation: if prey biomass per unit larval biomass falls below a critical food density, the proportionate loss of larvae through starvation increases. Starvation may indirectly increase rates of predation loss, although this is not included in these model equations. Recruitment to juvenile phases is

Table 67. Biomass uptake of pleuronectid larvae standing ttock (PLAR)

F_{10} = Biomass uptake of pleuronectid larvae standing stock (PLAR)

$= G_{45} + G_6 = (G_{46} + G_{24} + G_{47a} + G_{47b} + G_{48})$

where G_{45} = recruitment from hatched eggs (see function f_8)

G_6 = consumption of herbivorous zooplankton (see function f_2)

$= b_6 \text{ PLAR } (1-e^{-b_7 \text{HZPL/PLAR}})$

G_{46} = loss due to advection

= f(Z1, PLAR)

in the form f(Z1) • PLAR

G_{24} = loss to predation by mesopelagic fish (MPF) (see function f_4)

$$= \frac{\text{PLAR} - G_{46}}{\text{PRMPF}} b_{12} \text{ MPF } (1-e^{-b_{13} \text{ PRMPF/MPF}})$$

G_{47a} = loss to starvation

$= G_{202}$ PLAR

where G_{202} = proportionate loss to starvation as a function of food available.

$= 1 - b_{36}^{-1}(G_6/\text{PLAR}))$ if $G_6/\text{PLAR} < b_{36}$

$= 0$ if $G_6/\text{PLAR} \geq b_{36}$

where b_{36} = critical food density required for survival

G_6/PLAR = existing food density

G_{47b} = loss to respiration

$= r_9$ PLAR

G_{48} = recruitment to juvenile phase (PJUV)

$= \text{PLAR} + G_6 - (G_{46} + G_{24} + G_{47})$

Table 68. Biomass uptake of "Sebastes" larvae standing stock (SLAR)

F_{11} = Biomass uptake of "Sebastes" larvae standing stock (SLAR)

$= G_{61} + G_7 - (G_{49} + G_{22} + G_{50} + G_{51} + G_{52})$

where G_{61} = larvae produced by adult standing stock (see function f_{14})

G_7 = consumption of herbivorous zooplankton (HZPL) (see function f_2)

$$= b_8 \text{ SLAR } (1-e^{-b_9(\text{HZPL}-G_6)/\text{SLAR}})$$

G_{49} = loss due to advection

= f(Z1, SLAR) in the form f(Z1)•SLAR

G_{22}= loss to predation by mesopelagic fish (MPF)

$$= \frac{\text{SLAR} - G_{49}}{\text{PRMPF}} b_{12} \text{ MPF } (1-e^{-b_{13}\text{PRMPF/MPF}})$$

where PRMPF = prey available to MPF (see function f_4)

G_{50a} = loss to starvation

$= G_{203}$ SLAR

where G_{203} = proportionate loss to starvation as a function of food available

$= 1-b_{38}^{-1}(G_7/\text{SLAR}))$ if $G_7/\text{SLAR} < b_{38}$

$= 0$ if $G_7/\text{SLAR} \geq b_{38}$

where b_{38} = critical food density required for survival

G_7/SLAR = existing food density

Table 68. (continued)

G_{50b} = loss to predation by "Sebastes" juveniles (SJUV)

$$= \frac{SLAR - G_{49} - G_{22}}{PRSJUV}\, b_{18}\, SJUV\, (1 - e^{-b_{19} PRSJUV/SJUV})$$

where PRSJUV = prey available to "Sebastes" juvenile (see function f_{13})

G_{51} = loss to respiration

= r_{11} SLAR

G_{52} = recruitment to juvenile phase (SJUV)

= SLAR + G_7 - (G_{49} + G_{22} + G_{50} + G_{51})

the sum of growth (excluding newly added larvae) minus losses for the time increment. As in the case of eggs, larval components could be expanded to contain multiple larval "age classes" to be updated on an event scale. Multiple "age classes" to cover a year-long pelagic larval phase should be included for pleuronectids (Pearcy et al., 1977), while "Sebastes" larvae would remain pelagic for approximately six months (Carlson and Straty, 1981).

Roundfish juveniles (RJUV, Table 69) are considered pelagic consumers of mesopelagic fishes and crustaceans, patterned after sablefish juveniles (Hart, 1973; Cailliet, 1981). Juvenile biomass increases through recruitment from the larval phase and consumption of prey items, but decreases due to predation by mesopelagic seasonal piscivores and recruitment to adult demersal stock. No biomass is input to sediments: sinking due to natural mortality (other than predation, e.g., from parasitism or disease) is assumed to be negligible, and excreted material is assumed to be recycled by pelagic bacteria before sinking.

"Sebastes" juveniles (SJUV, Table 70) increase due to recruitment from larvae and consumption of carnivorous zooplankton and mesopelagic crustaceans (growth), and decrease due to predation by mesopelagic seasonal piscivores and recruitment to adult stocks. Carlson and Straty (1981) reported occurrences of Sebastes young of the year over rocky pinnacles and boulder fields at 90-100 m. off southeastern Alaska. An important alternative structure to this segment of the model would be to replace prey and predator abundance with separate driving variables reflecting local conditions around nursery areas.

Table 69. Biomass uptake of roundfish juvenile standing stock (RJUV)

F_{12} = Biomass update of roundfish juvenile standing stock (RJUV)

$= G_{43} + G_{16} - G_{25} + G_{30} - (G_{53} + G_{54} + G_{55})$

where G_{43} = recruitment from larval phase (RLAR) (see function f_8)

where G_{16} = consumption of carnivorous zooplankton (CZPL) (see function f_3)

$$= \frac{CZPL}{PRRJUV} b_{16} RJUV(1-e^{-b_{17} PRRJUV/RJUV})$$

G_{25b} = consumption of mesopelagic fishes (MPF) (see function f_4)

$$= \frac{MPF-G_{25}}{PRRJUV} b_{16}\ RJUV\ (1-e^{-b_{17} PRRJUV/RJUV})$$

G_{30} = consumption of mesopelagic crustaceans (MPC) (see function f_5)

$$= \frac{MPC - G_{28} - G_{29}}{PRRJUV} b_{16}\ RJUV\ (1-e^{-b_{17} PRRJUV/RJUV})$$

where PRRJUV = prey available to roundfish juveniles

$= CZPL + (MPF - G_{25a}) + (MPC - G_{28} - G_{29})$

$$G_{16} + G_{25b} + G_{30} = b_{16}\ RJUV(1-e^{-b_{17} PRRJUV/RJUV})$$

G_{53} = loss to predation by mesopelagic seasonal fish (MPS) see function f_6)

$$= \frac{RJUV}{PRMPS} b_{21}\ MPS\ (1-e^{-b_{22}\ PRMPS/MPS})$$

where PRMPS = prey available to mesopelagic seasonal fish

G_{54} = recruitment to roundfish adults

$= RJUV + G_{16} + G_{25b} + G_{30} - G_{53} - G_{55}$

G_{55} = respiration

$= r_{12}\ RJUV$

Table 70. Biomass uptake of "Sebastes" juvenile standing stock (SJUV)

F_{13} = Biomass uptake of "Sebastes" juvenile standing stock (SJUV)

$$= G_{52} + G_{17} + G_{29} + G_{50} - (G_{56} + G_{57} + G_{58})$$

where G_{52} = recruitment from larvae (SLAR) (see function f_{11})

G_{17} = consumption of carnivorous zooplankton (CZPL) (see function f_3)

$$= \frac{CZPL - G_{16}}{PRSJUV} b_{18} \, SJUV \, (1-e^{-b_{19} PRSJUV/SJUV})$$

G_{29} = consumption of mesopelagic crustaceans (MPC) (see function f_5)

$$= \frac{MPC-G_{28}}{PRSJUV} b_{18} \, SJUV \, (1-e^{-b_{19} PRSJUV/SJUV})$$

G_{50} = Consumption of "Sebastes" larvae (SLAR) (see function f_{11})

$$= \frac{SLAR-G_{49}-G_{22}}{PRSJUV} b_{18} \, SJUV(1-e^{-b_{19} PRSJUV/SJUV})$$

where PRSJUV = prey availble to SJUV

$= CZPL - G_{16}$

$+ SLAR - G_{49} - G_{22}$

$+ MPC - G_{28}$

$$G_{17}+G_{29}+G_{50} = b_{18} SJUV(1-e^{-b_{19} PRSJUV/SJUV})$$

G_{56} = loss due to predation by mesopelagic seasonal fish (MPS) (see function f_5)

$$= \frac{SJUV}{PRMPS} b_{21} \, MPS(1-e^{-b_{22} PRMPS/MPS})$$

G_{57} = recruitment to "Sebastes" adult (SADU)

$= SJUV + G_{17} + G_{29} + G_{55} - G_{56}$

G_{58} = respiration

$= r_{13}$ SJUV

The functional group of "Sebastes" adults (SADU, Table 71) increases through recruitment and growth _via_ consumption of mesopelagic crustaceans. A fraction of the biomass representing smaller individuals may be vulnerable to predation by piscivores. The actual extent of predation by type of piscivore (mesopelagic or benthic) is unknown, but predation by roundfish (sablefish) has been documented (Cailliet, 1981); and predation by mesopelagic piscivores on feeding schools of small rockfish may be reasonable to assume. Biomass also leaves the compartment as reproductive effort. This flux is modelled as a form of spawning power: reproduction is proportionate to standing stock and fecundity of standing stock, reflected by food consumed per unit biomass of standing stock. In addition, if larval dynamics are to be examined in detail, a year's reproductive effort may be proportionally input to the larval component on an event scale following a function to simulate ranges and peaks of spawning timing. Biomass is also vulnerable to fishing mortality, modelled in the form of the Baranov catch equation. Input to the sediments is through natural mortality other than predation, and egestion.

Roundfish adults (RADU, Table 72) are subject to increase through recruitment, and growth as a generalist predator _via_ consumption of a variety of prey: mesopelagic crustaceans, small _Sebastes_, and macrobenthos (Hart, 1973; Cailliet, 1981). Losses due to predation in the adult phase are assumed to be low based on relative size of prey and potential predators. The adult non-"Sebastes" roundfish is not a strict mesopelagic feeder, but includes benthic invertebrates in its diet, and small individuals may potentially serve as prey to mesopelagic or

Table 71. Biomass uptake of "Sebastes" adult standing stock (SADU)

F_{14} = Biomass uptake of "Sebastes" adult standing stock (SADU)

$$F_{14} = G_{57} + G_{28} - (G_{59} + G_{60} + G_{61} + G_{62} + G_{63} + G_{64} + G_{65})$$

where G_{57} = recruitment from "Sebastes" juveniles (SJUV) (see function f_{13})

G_{28} = consumption of mesopelagic crustaceans (MPC)

$$= b_{24}\ SADU\ (1-e^{-b_{25} MPC/SADU})$$

G_{59} = loss due to predation by mesopelagic seasonal fish (MPS)

$$= \frac{b_{39}\ SADU}{PRMPS}\ b_{21}\ MPS\ (1-e^{-b_{22} PRMPS/MPS})$$

where b_{39} = proportion of adult standing stock vulnerable to predation

PRMPS = total prey available to mesopelagic seasonal fish (see function f_6)

G_{60} = loss due to predation by roundfish adults (RADU)

$$= \frac{b_{39} SADU - G_{59}}{PRRADU}\ b_{26}\ RADU\ (1-e^{-b_{27} PRRADU/RADU})$$

where PRRADU = total prey available to RADU (see function f_{15})

G_{61} = loss due to reproductive effort

$$= b_{40}\ SADU + b_{41}\ \frac{G_{28}}{SADU}$$

G_{62} = loss to benthic fishery

$$= \frac{b_{42}\ Z5}{b_{42} Z5 + b_{43}}\ (SADU - G_{59})\ (1-e^{-(b_{42} Z5 + b_{43})})$$

where b_{42} = catchability coefficient for "Sebastes" adults by benthic gear

Z5 = benthic fishery effort

b_{43} = natural mortality rate (other than predation)

Table 71 (continued)

G_{63} = loss to sediments through natural mortality

$$= \frac{b_{43}}{b_{42}\, Z5 + b_{43}} (SADU - G_{59}) \left(1 - e^{-(b_{42}\, Z5 + b_{43})}\right)$$

G_{64} = loss to sediments through egestion

$= b_{44}$ SADU

G_{65} = respiration

$= r_{14}$ SADU

Table 72. Biomass uptake of roundfish adults (RADU)

F_{15} = Biomass uptake of roundfish adult standing stock (RADU)

$$= G_{54} + G_{32} + G_{60} + G_{66} - (G_{39} + G_{67} + G_{68} + G_{69} + G_{70} + G_{71})$$

where G_{54} = recruitment from juveniles (RJUV) (see function f_{12})

G_{32} = consumption of mesopelagic crustaceans (MPC) (see function f_5)

$$= \frac{MPC - G_{28} - G_{29} - G_{30} G_{31}}{PRRADU} b_{26} \; RADU \; (1 - e^{-b_{27} PRRADU/RADU})$$

G_{60} = consumption of "Sebastes" adults (SADU) (see function f_{14})

$$= \frac{b_{39} \; SADU - G_{59}}{PRRADU} b_{26} RADU \; (1 - 3^{-b_{27} PRRADU/RADU})$$

G_{66} = consumption of macrobenthos (BINV2) (see function f_{22})

$$= \frac{BINV2 - G_{78}}{PRRADU} b_{26} \; RADU \; (1 - e^{-b_{27} PRRADU/RADU})$$

where PRRADU = total prey available to RADU

$$= MPC - G_{28} - G_{29} - G_{30} - G_{31}$$
$$+ b_{39} \; SADU - G_{59}$$
$$+ BINV2 - G_{78}$$

$$G_{32} - G_{65} + G_{66} = b_{26} \; RADU \; (1 - e^{-b_{27} PRRADU/RADU})$$

G_{39} = loss due to reproductive effort

$$= RADU \; (b_{45}) + b_{46} \; \frac{(G_{32} + G_{60} + G_{66})}{RADU}$$

G_{67} = loss to predation by benthic piscivore (BPIS)

$$= \frac{b_{47} \; RADU}{PRBPIS} b_{48} \; BPIS \; (1 - e^{-b_{49} PRBPIS/BPIS})$$

where b_{47} = proportion of RADU vulnerable to predation

PRBPIS = total prey available to BPIS (see function f_{18})

Table 72 (continued).

G_{68} = loss to benthic fishery

$$= \frac{b_{50}\ Z5}{b_{50}Z5+b_{51}} (RADU - G_{67}) (1-e^{-(b_{50}Z5+b_{51})})$$

where b_{50} = catchability coefficient of roundfish adults by benthic gear

$Z5$ = benthic fishery effort

b_{51} = natural mortality rate (other than predation)

G_{69} = loss to sediments through natural mortality (other than predation)

$$= \frac{b_{51}}{b_{50}\ Z5\ +b_{51}} (RADU - G_{67}) (1-e^{-(b_{50}Z5+b_{51})})$$

where b_{50}, b_{51}, $Z5$ are defined in G_{66} abopve

G_{70} = loss to sediments through egestion

$= b_{52}$ RADU

G_{71} = respiration

$= r_{15}$ RADU

benthic piscivores. Only the benthic piscivore is included in the equations and diagram, but effects of the mesopelagic alternative should also be considered. Reproductive effort is again modelled as a form of spawning power, and mortality due to a benthic fishery is modelled in the form of a Baranov catch equation. Input to sediments is through other natural mortality and egestion.

Pleuronectid juveniles (PJUV, Table 73) increase due to recruitment from pleuronectid larvae. Recruitment may be enhanced by onshore transport after settling (Hayman and Tyler, 1980), and the effect of winter transport conditions could be added here to modify the recruitment function (G_{48}). Pleuronectid juveniles grow through the consumption of meiobenthos, and are assumed to suffer losses due to predation by benthic piscivores such as arrowtooth flounder (Hart, 1973). Predation by roundfish is assumed to be relatively low, because most species of fishes serving as prey for sablefish, for example, are schooling species partially associated with midwater habitats e.g., "Sebastes", and juvenile Pacific hake (Cailliet, 1981). Recruitment to adult stocks of flatfishes is divided between the benthic piscivores (e.g., arrowtooth flounder) and the invertebrate-feeding pleuronectids (e.g., Dover sole, rex sole), proportionate to each components' contribution to reproductive effort the previous year. Input to sediments is in the form of egestion and is probably low.

Pleuronectid adults (PADU, Table 74) arise from recruitment from pleuronectid juveniles and consume macrobenthos. A portion of the adult biomass representing small individuals is assumed vulnerable to benthic piscivores. Reproductive effort is again calculated as a function of

Table 73. Biomass uptake of pleuronectid juveniles (PJUV)

F_{16} = Biomass uptake of pleuronectid juveniles (PJUV)

$$= G_{48} + G_{72} - (G_{73} + G_{74} + G_{75} + G_{76} + G_{77})$$

where G_{48} = recruitment from pleuronectid larvae (PLAR) (see function f_{10})

G_{72} = consumption of meiobenthos (BINV1)

$$= b_{53}\ \text{PJUV}\ (1-e^{-b_{54}\text{BINV1/PJUV}})$$

G_{73} = loss to predation by benthic piscivore

$$= \frac{\text{PJUV}}{\text{PRBPIS}}\ b_{48}\ \text{BPIS}(1-e^{-b_{49}\ \text{PRBPIS/BPIS}})$$

where PRBPIS = total prey available to benthic piscivore (see function f_{18})

G_{74} = loss to recruitment to benthic piscivore adults

$$= \frac{M_1}{M_1+M_2}\ (\text{PJUV} - G_{73})$$

where M_1 = number of eggs contributed by benthic piscivore in previous year (G_{84})

M_2 = number of eggs contributed by pleuronectid adults in previous year (G_{83})

G_{75} = loss to recruitment to pleuronectid adults

$$= \frac{M_2}{M_1+M_2}\ (\text{PJUV} - G_{73})$$

where M_1, M_2 are defined in G_{74} above

G_{76} = egestion to sediment

= b_{55} PJUV

G_{77} = respiration

= r_{16} PJUV

Table 74. Biomass uptake of pleuronectid adults (PADU)

F_{17} = Biomass uptake of pleuronectid adults (PADU)

$$= G_{75} + G_{78} - (G_{79} + G_{80} + G_{81} + G_{82} + G_{83} + G_{104})$$

where G_{75} = recruitment from pleuronectid juveniles (PJUV) (see function f_{16})

G_{78} = consumption of macrobenthos (BINV2)

$$= b_{56}\ PADU\ (1-e^{-b_{57} BINV2/PADU})$$

G_{79} = loss to predation by benthic piscivores (BPIS)

$$= \frac{b_{58}\ PADU}{PRBPIS}\ b_{48}\ BPIS\ (1-e^{-b_{49} PRBPIS/BPIS})$$

where PRBPIS = total prey availble to benthic piscivores (see function f_{18})

b_{58} = proportion of adults vulnerable to piscivore predation

G_{80} = loss due to reproductive effort (PEGG)

$$= PADU\ (b_{59}) + \frac{b_{60}\ G_{78}}{PADU}$$

G_{81} = loss due to benthic fishery (BFY)

$$= \frac{b_{61}\ Z5}{b_{61}Z5 + b_{82}Z6 + b_{62}}\ (PADU - G_{79})\ (1-e^{-(b_{61}Z5 + b_{82}Z6 + b_{62})})$$

where b_{61} = catchability coefficient for pleuronectids by benthic gear

Z5 = benthic fishery effort

b_{82} = catchability coefficient for pleuronectids by shrimp fishery

Z6 = shrimp fishery effort

b_{62} = natural mortality (other than predation)

Table 74 (continued)

G_{106} = loss as by catch in shrimp fishery

$$= \frac{b_{82}Z6}{b_{61}Z5+b_{82}Z6+b_{62}} (PADU-G_{79}) (1-e^{-(b_{61}Z5 + b_{82}Z6 + b_{62})})$$

where b_{61}, b_{62}, b_{82}, Z5, Z6, are defined above.

G_{82} = loss due to natural mortality

$$= \frac{b_{62}}{b_{61}Z5+b_{82}Z6+b_{62}} (PADU - G_{79}) (1-e^{-(b_{61}Z5+b_{82}Z6+b_{62})})$$

where b_{61}, b_{62}, Z5 are defined in G_{81} above.

G_{83} = loss to sediments by excretion

= b_{63} PADU

G_{103} = respiration

= r_{17} PADU

biomass and available food. That effort may be apportioned over event scales to simulate ranges and peaks in spawning timing. Two fisheries operate on pleuronectids: a benthic fishery, involving directed effort, and a shrimp fishery, involving by-catch. By-catch in the shrimp fishery, losses due to natural mortality other than predation, and egestion are input to sediments.

Benthic piscivores (BPIS, Table 75) represent the presence of arrowtooth flounder (or Pacific halibut) in outer shelf assemblages. They are recruited from a pool of pleuronectid juveniles, proportional to the reproductive effort contributed to the pleuronectid egg pool by adults in the previous year. Diet of this functional group (based on arrowtooth flounder) includes juvenile and small adult fishes and benthic shrimps (Hart, 1973). Reproductive effort follows the same spawning power adaptation described earlier. These fishes are caught in a benthic fishery. Losses due to natural mortality and egestion are input to sediments.

A pool of benthic detritus (BDET, Table 76) receives input from most components through sinking egested material and/or carcasses arising from either natural mortality (e.g., or disease of adults) or discards as shrimp fishery by-catch. Discards may only be important in regions of intense shrimp fishing, which are most often muddy bottoms; and the entire shrimp fishery-discard interaction may be eliminated from the model if shrimp habitat is not common in the region of interest. Excretory input by fish larvae and pelagic juveniles is assumed to be recycled in the upper water column. The mechanisms of benthic-pelagic coupling are controversial: although organic input to the sediments

Table 75. Biomass uptake of benthic piscivores (BPIS)

F_{18} = Biomass uptake of benthic piscivores (BPIS)

$$= G_{73} + G_{74} + G_{67} + G_{79} + G_{102} - (G_{84} + G_{85} + G_{86} + G_{87} + G_{105})$$

where G_{74} = recruitment from pleuronectid juveniles (PJUV) (see function f_{16})

G_{73} = consumption of pleuronectid juveniles (see function f_{16})

$$= \frac{PJUV}{PRBPIS} b_{48} \text{ BPIS } (1-e^{-b_{49} PRBPIS/BPIS})$$

G_{67} = consumption of roundfish adults (RADU) (see function f_{15})

$$= \frac{b_{47} \text{ RADU}}{PRBIS} b_{48} \text{ BPIS } (1-e^{-b_{49} PRBPIS/BPIS})$$

G_{79}= consumption of pleuronectid adults (PADU) (see function f_{17})

$$= \frac{b_{54} PADU}{PRBPIS} b_{48} \text{ BPIS } (1-e^{-b_{49} PRBPIS/BPIS})$$

G_{102} consumption of shrimps (BINV3) (see function f_{23})

$$= \frac{BINV3-G_{100}-G_{101}-G_{65}}{PRBPIS} b_{48} \text{ BPIS } (1-e^{-b_{49} PRBPIS/BPIS})$$

where PRBPIS = total prey available to BPIS

$$= PRJUV + b_{47} \text{ RADU} + b_{54} \text{ PADU} + BINV3 - G_{100} - G_{101} - G_{65}$$

$$G_{73} + G_{67} + G_{79} + G_{102} = b_{48} \text{ BPIS } (1-e^{-b_{49} PRBPIS/BPIS})$$

G_{84} = loss due to reproductive effort

$$= \text{BPIS } (b_{64}) + b_{65} \frac{(G_{73}+G_{67}+G_{79}+G_{102})}{BPIS}$$

Table 75 (continued)

G_{85} = loss due to benthic fishery

$$= \frac{b_{66}\ Z5}{b_{66}Z5 + b_{67}} \text{ BPIS } (1-e^{-(b_{66}Z5 + b_{67})})$$

where b_{66} = catchability coefficient for benthic piscivores by benthic gear

$Z5$ = effort by benthic fishery

b_{67} = natural mortality

G_{86} = loss due to natural mortality

$$= \frac{b_{67}}{b_{66}Z5 + b_{67}} \text{ BPIS } (1-e^{-(b_{66}Z5 + b_{67})})$$

where b_{66}, Z5 and b_{67} are defined in G_{85} above

G_{87} = loss to sediments by egestion

= b_{68} BPIS

G_{105} = respiration

= r_{18} BPIS

Table 76. Biomass uptake of detrital pool (BDET)

F_{19} = Biomass uptake of detrital pool (BDET)

$$= G_4 + G_{12} + G_{20} + G_{26} + G_{33} + G_{36} + G_{63} + G_{64} + G_{69} + G_{70} + G_{76} + G_{82} + G_{83} + G_{86} + G_{87} + G_{106} - (G_{88} + G_{89} + G_{90})$$

where G_4 = sinking input from phytoplankton (PPL) (see function f_1)

G_{12} = sinking input from herbivorous zooplankton (HZPL) (see function f_2)

G_{20} = sinking input from carnivorous zooplankton (CZPL) (see function f_3)

G_{26} = sinking input from mesopelagic fish (MPF) (see function f_4)

G_{33} = sinking input from mesopelagic crustaceans (MPS) (see function f_5)

G_{36} = sinking input from mesopelagic seasonals (MPS) see function f_6)

G_{63} = carcass input from "Sebastes" adults (SADU) (see function f_{14})

G_{64} = egestion input from "Sebastes" adults

G_{69} = carcass input from roundfish adults (RADU) (see function f_{15})

G_{70} = egestion input from roundfish adults

G_{76} = egestion input from pleuronectid juveniles (PJUV) (see function f_{16})

G_{82} = carcass input from pleuronectid adults (PADU) (see function f_{17})

G_{83} = egestion input from pleuronectid adults

G_{86} = carcass input from benthic piscivores (BPIS) (see function f_{18})

G_{87} = egestion input from benthic piscivores

G_{106} = carcass input from pleuronectid adults (PADU) as discards from shrimp fishery (see function f_{17})

G_{88} = loss due to bacterial activity (BBACT)

$$= b_{70} \text{ BBACT } (1-e^{-b_{71}\text{BDET/BBACT}})$$

Table 76 (continued)

G_{89} = loss due to consumption by scavenging shrimps, crustaceans (BINV3) (see function f_{23})

$$\frac{BDET-G_{88}}{PRBINV3} = b_{72}\ BINV3\ (1-e^{-b_{73}(BDET-G_{88})/BINV3})$$

G_{90} = loss due to consumption by macrobenthos (BINV2)

$$= \frac{BDET - G_{88}-G_{89}}{PRBINV2}\ b_{76}\ BINV2\ (1-e^{-b_{77}PRBINV2/BINV2})$$

appears positively related to surface production, the role of stratification and mixed layer depth in determining downward transport is still undecided (Mills, 1975; Walsh et al., 1978).

Bacteria (BBAC, Table 77) feed on input from the detrital pool, and in turn are consumed by meiobenthos and deposit-feeding macrobenthos. Meiobenthos (BINV1, Table 78) are assumed to feed only on bacteria, and are preyed upon by pleuronectid juveniles (Hogue, 1981), deposit feeding shrimps, and macrobenthos. Meiobenthos links with macrobenthos production may not always be present (McIntyre et al., 1970). The macrobenthos (BINV2, Table 79) may include members with a wide variety of feeding strategies, including direct consumption of unprocessed detritus (scavengers, surface tentaculate feeders), consumption of bacteria (deposit feeders), and consumption of meiobenthos (carnivores) (Jumars and Fauchald, 1977). Macrobenthos in this model are assumed to be equally divided among these feeding types. Macrobenthos serve as prey for pleuronectid adults and roundfish adults. Shrimps (BINV3, Table 80) are assumed to consume detrital material and meiobenthos as deposit feeders and infaunal feeders, and suffer losses due to shrimp fishing effort, natural mortality, and predation by benthic piscivores. The total number of shrimp predators is probably larger, but the role of shrimp in an outer shelf-upper slope region is assumed to be relatively smaller than in mid-shelf areas with larger regions of mud bottom, and therefore their dynamics have not been expanded in this model.

Three fisheries are applied, based on gear differences: midwater trawl (MFY, Table 81), benthic trawl (BFY, Table 81) and shrimp trawl

Table 77. Biomass uptake of bacteria (BBACT)

F_{20} = Biomass uptake of bacteria (BBACT)

$= G_{88} - (G_{91} + G_{92} + G_{93})$

where G_{88} = input from detrital pool

G_{91} = loss due to consumption by meiobenthos (BINV1)

$= b_{74}\ \text{BINV1}\ (1-e^{-b_{75}\text{BBACT}/\text{BINV1}})$

G_{92} = loss due to consumption by deposit feeding macrobenthos (BINV2)

$= \frac{\text{BBACT} - G_{91}}{\text{PRBINV2}}\ b_{76}\ \text{BINV2}\ (1-e^{-b_{77}\text{PRBINV2}/\text{BINV2}})$

G_{93} = respiration

$= r_{20}\ \text{BBACT}$

Table 78. Biomass uptake of meiobenthos (BINV1)

F_{21} = Biomass uptake of meiobenthos (BINV1)

$= G_{91} - (G_{72} + G_{96} + G_{97}) - G_{98}$

where G_{91} = consumption of bacteria (BBACT) (see function f_{20})

G_{72} = loss due to predation by pleuronectid juveniles (PJUV) (see function f_{16})

$$= b_{53}\ \text{PJUV}\ (1-e^{-b_{54}\text{BINV1/PJUV}})$$

G_{96} = loss due to predation by deposit feeding shrimp (BINV3)

$$\frac{\text{BINV1}-G_{72}}{\text{PRBINV3}} = b_{78}\ \text{BINV3}\ (1-e^{-b_{72}(\text{BINV1}-G_{72})/\text{BINV3}})$$

G_{97} = loss due to predation by macrobenthos (BINV2)

$$= \frac{\text{BINV1}-G_{72}-G_{96}}{\text{PRBINV2}}\ G_{76}\ \text{BINV2}\ (1-e^{-b_{77}\text{PRBINV2/BINV2}})$$

where PRBINV2 = total prey available to BINV2

G_{98} = respiration

$= r_{21}$ BINV1

Table 79. Biomass uptake of macrobenthos (BINV2)

F_{22} = Biomass uptake of macrobenthos standing stocks (BINV2)

$= G_{90} + G_{92} + G_{97} - (G_{66} - G_{78} - G_{99})$

where G_{90} = consumption of detritus (BDET) (see function f_{19})

$$= \frac{BDET - G_{88}}{PRBINV2} b_{76} \ BINV2(1-e^{-b_{77}PRBINV2/BINV2})$$

G_{92} = consumption of bacteria (BBACT) (see function f_{20})

$$= \frac{BBACT - G_{91}}{PRBINV2} b_{76} \ BINV2 \ (1-e^{-b_{77}PRBINV2/BINV2})$$

G_{97} = consumption of meiobenthos (BINV1) (see function f_{21})

$$= \frac{BINV1 - G_{72} - G_{96}}{PRBINV2} b_{76} \ BINV2 \ (1-e^{-b_{77}PRNIBV2/BINV2})$$

where PRBINV2 = total prey availble to macrobenthos

$= BDET - G_{88}$

$= BBACT - G_{91}$

$= BINV1 - G_{72} - G_{96}$

$$G_{90} + G_{92} + G_{97} = b_{76} \ BINV2 \ (1-e^{-b_{77}PRBINV2/BINV2})$$

G_{78} = loss to predation by pleuronectid adults (PADU) (see function f_{17})

$$= b_{56} \ PADU \ (1-e^{-b_{57}BINV2/PADU})$$

G_{66} = loss due to predation by roundfish adults (RADU) (see function f_{18})

$$= \frac{BINV2 - G_{78}}{PRRADU} b_{26} \ RADU \ (1-e^{-b_{27}PRRADU/RADU})$$

where PRRADU = total prey availble to RADU

G_{99} = respiration

$= r_{22} \ BINV2$

Table 80. Biomass uptake of shrimp (BINV3)

F_{23} = Biomass uptake of shrimp standing stocks (BINV3)

$$= G_{89} + G_{96} - (G_{100} - G_{101} - G_{102} - G_{103})$$

where G_{89} = consumption of detrital material (BDET) (see function f_{19})

$$= \frac{BDET-G_{88}}{PRBINV3} = b_{72}\ BINV3\ (1-e^{-b_{73}(BDET-G_{88})/BINV3})$$

G_{96} = consumption of meiobenthos (BINV1) (see function f_{21})

$$= \frac{BINVI-G_{72}}{PRBINV3} = b_{72}\ BINV3\ (1-e^{-b_{73}(BINV1-G_{72})/BINV3})$$

where PRB1NV3 = prey available to shrimp

$$= BDET-G_{88}$$
$$+ BINV1-G_{72}$$

G_{100} = loss due to shrimp fishery (SFY)

$$= \frac{b_{80}Z6}{b_{80}Z6 + b_{81}}\ BINV3\ (1-e^{-(b_{80}Z6 + b_{81})})$$

where b_{80} = catchability coefficient for shrimp by shrimp gear

Z6 = shrimp fishery effort

b_{81} = other natural mortality

G_{101} = loss due to natural mortality

$$= \frac{b_{81}}{b_{80}Z6 + b_{81}}\ BINV3\ (1-e^{-(b_{80}Z6 + b_{81})})$$

where b_{80}, b_{81}, Z6 are defined in G_{100}

G_{102} = loss due to predation by benthic piscivore (see function f_{18})

$$= \frac{BINV3 - G_{100}-G_{101}-G_{65}}{PRBPIS}\ b_{48}\ BPIS\ (1-e^{-b_{49}PRBPIS/BPIS})$$

where PRBPIS = prey available to benthic piscivores

Table 80. (continued)

G_{104} = respiration

= r_{23} BINV3

Table 81. Yield to midwater fishery, benthic fishery, shrimp fishery

F_{24} = Yield to midwater fishery (Z4)

$= G_{35}$

where G_{35} = catch of mesopelagic seasonal fishes (MPS) (see function f_6)

F_{25} = Yield to benthic fishery

$= G_{103} + G_{62} = G_{68} + G_{81}$

where G_{103} = catch of mesopelagic seasonal fishes (MPS) (see function f_6)

G_{62} = catch of "Sebastes" adults (SADU) (see function f_{14})

G_{68} = catch of roundfish adults (RADU) (see function f_{15})

G_{81} = catch of pleuronectid adults (PADU) (see function f_{17})

G_{85} = catch of benthic piscivores (BPIS) (see function f_{18})

F_{26} = yield to shrimp fishery

$= G_{100}$

where G_{100} = catch of shrimp (BINV3) (see function f_{23})

(SFY, Table 81). In all these fisheries, effort is considered an external driving variable. The midwater fishery is directed against mesopelagic seasonal fishes such as Pacific hake. A fishery based on schooling fish such as hake may include relatively small by-catches, compared to benthic trawl fisheries. The benthic fishery is directed against "Sebastes" adults, roundfish adults, pleuronectid adults and benthic piscivores. Some variety in gear rigging e.g., application of roller gear for "Sebastes" fishing, may be reflected in catchability coefficient parameters. The shrimp fishery is directed primarily against shrimp, but may include by-catch of other benthic fishes. Equations and diagrams do not include juvenile pleuronectids as vulnerable to the shrimp trawl, but these fish may also be affected by shrimp effort.

One surprising result of this exercise was the poor definition of trophic structure in Pacific outer continental shelf assemblages, based on available literature. Intensity and size relations of predation in general are not well described for outer shelf roundfishes (e.g., Simenstad and Lipovsky, 1977; Lipovsky and Simenstad, 1979), perhaps in part because data on feeding habits of deep-dwelling fishes with swim bladders are difficult to collect. Because Sebastes nursery areas are often untrawlable rocky pinnacles and boulder fields (Carlson and Straty, 1981), feeding habits and co-occurring competitors and predators of young rockfishes are sparsely described. The trophic structure proposed in this model may require major modifications as new information becomes available.

Though feeding selectivity of these fishes is almost unknown, selectivity processes probably will determine the tightness of couplings within and among competing functional groups of an assemblage, and strongly influence assemblage structure and behavior. Feeding selection and specialization patterns may minimize competition among members of an assemblage or functional group by subdividing available resources, especially if the food resource is relatively stable (e.g., benthic invertebrates). Alternatively, a group of generalists, all consuming the most abundant prey, would compete among themselves, but would be capable of responding to fluctuating resource levels by switching prey. The degree of specialization vs. switching within an assemblage will influence the resilience of the assemblage. A more specialized assemblage would be less resilient. At present, we could hypothesize relatively stable assemblage trophic structure, based on the longevity of prey items (longer than a year for euphausiids and some benthic invertebrates; Hebard, 1966; Nichols, 1975); or, alternatively, a somewhat fluctuating resource level if, for example, large seasonal influxes of mesopelagic migrants exploit the same midwater resources as rockfishes. The capability of rockfishes or migrants to switch food sources would lessen this potential seasonal impact. Switch feeding by roundfish omnivores such as sablefish or mixed piscivores such as arrowtooth flounder may intermittently increase competition with more specialized feeders, in response to fluctuating resource levels.

Off the Oregon coast, benthic production is poorly understood (as in most continental shelf systems), but may be complex and incorporate varying lags with respect to surface production events. Annual growth rates vary as much as 19% for Dover and English sole off Oregon, are not well correlated with stock densities or upwelling indices during the year of growth or the year before, but show some relation to upwelling trends when both growth and upwelling indices are averaged over five year periods (Kreuz et al., 1982). The transfer of surface production to benthic production is a function of amount of primary production and depth of mixed layer (Walsh et al., 1978). Production transfer also includes effects of offshore transport of surface production and sinking material, degree of recycling within the pelagic system, and structure of the invertebrate community itself. Structure of the benthic invertebrate community will influence the amount of food available for fish growth, since not all forms of macrobenthos such as large echinoderms are suitable food or consumable by fish (Mills, 1975). If phytoplankton production pulses associated with upwelling could be traced as pulses of detrital input to the benthos and if abundance of benthic fish food organisms closely tracked detrital input, we would expect much closer correlation of fish growth to upwelling. Assemblage standing stocks would fluctuate and trophic structure would become weaker if fish fed opportunistically. The type of relationship of growth and upwelling observed by Kreuz et al., (1982) indicates that there are probably several different routes surface production may follow before being elaborated as benthic fish biomass, and each route may involve a different time lag. This diversity in mechanisms and lags would smooth production initially generated from separate upwelling events.

Several components and processes have been omitted from the present model. Skates and rays are also present in demersal assemblages. They may compete with other invertebrate feeders such as pleuronectids, but they produce a few live young rather than large numbers of eggs (Hart, 1973). Their biomass would be expected to fluctuate less widely than pleuronectids if variability due to larval mortality is eliminated, but would feel the effects of benthic fishing mortality more strongly, because of their lower reproductive potential. The influence of the influx of Dover sole and sablefish migrating into deeper water in the winter (Alverson et al, 1964) may influence available food and predation patterns, and could be incorporated as a driving variable. Other large seasonal pelagic migrants such as salmon or tuna may increase predation on small pelagic and mesopelagic fishes, as would marine mammals and birds. Small benthic fishes such as cottids, agonids and zoarcids may compete with juvenile and young adult groundfishes and serve as alternative piscivore prey, but constitute a relatively small proportion of the total benthic biomass.

The lack of age structure and numbers of individuals in the model is precluded by the functional group structure. The coarse resolution of the model with respect to age and numbers is designed to focus on interactions between functional groups rather than mechanisms such as age or size specific growth and fecundity, whose parameters change with each species. Some realism is lost, since reproductive potential is assumed to be independent of age structure of biomass, as is fishing mortality, once maturity is reached. However, gross features of density-dependent growth, reproduction, and mortality are maintained. The level of resolution is lower than a single species model, but higher than a "generic" ecosystem model. The level is comparable to that proposed by Ursin (unpubl. ms) for investigating multispecies ecosystems and fish stock assessment problems.

SUMMARY

1. The continental shelf and upper slope from Cape Flattery, Washington to Pointe Hueneme, California can be tentatively divided into three large regions, based on similarities in species composition: 1) An outer shelf-upper slope region extending from 49°N to 34°N latitude; 2) A mid- to outer shelf region extending from Cape Flattery south to Cape Blanco, Oregon (43°N) and 3) A mid- to outer shelf region beginning near Cape Falcon (46°N) extending south to Point Hueneme (34°N).

2. The outer shelf-upper slope region is divided into a northern portion, extending to San Francisco (38°N); a southern portion, at Point Arena (39°N) and continuous from San Francisco to the Santa Barbara Channel (38°-34°N); and a deep transition portion, from Cape Blanco to Cape Mendocino (43-40°N).

3. The northern mid- to outer shelf region is divided into a shelf break strip (40°3-'-43°N, mean depth 227 m); a midshelf strip at Cape Flattery, moving to the outer shelf south of Cape Falcon (46°N); and Juan de Fuca Canyon (48°N).

4. The southern mid- to outer shelf region is divided into a shallow northern-transition region, Cape Falcon to Point Ano Nuevo (46-37°N, mean depth 183 m); a shelf break transition southern region, Trinidad Head to Point Hueneme (41-34°N, mean depth 102 m); and a shallow southern region, Point Ano Nuevo to Point Hueneme (37-34°N, mean depth 102 m).

5. Eight species groups generated from cluster analysis can be characterized by centers of distribution based on combinations of depth and latitude: a) deepwater dominant, including a northern component; b) shallow dominant, secondarily in the south; c) shallow occasional, secondarily in the north; d) northern occasional, secondarily in shallow water; e) intermediate (transition) rare species, secondarily in shallow water; f) deepwater occasional species, including northern and southern components; g) southern shallow species and h) northern intermediate species, rare and least affiliated.

6. The major environmental feature determining composition of fish assemblages from Cape Flattery to Point Hueneme appears to be depth. The effect on species composition of moving 50 fm (92 m) in depth within a degree of latitude is usually greater than moving 1° in latitude.

7. Multivariate analyses, relating species composition to environmental variables, extracts and clarifies local patterns of latitudinal chance in species composition. Ekman transport is the most strongly related latitudinal factor. Stronger latitudinal relationships may have been obscured by highly skewed species abundance data, non-linear relationships or inadequate choice of environmental factors. Seasonal variability of a feature may be more important than magnitude of the mean of a feature.

8. Deep (outer shelf-upper slope) regions have more homogeneous species compositions than midshelf regions.

9. Northern (above Cape Blanco, 43°N) regions have more homogeneous species compositions than transition (Cape Blanco to San Francisco) or southern (San Francisco to Point Hueneme) regions.

10. Members of species groups common in deeper water regions may be longer lived and slower growing than members of shallow water species groups. Food sources may be more stable and feeding less opportunistic with distance from upwelling fronts. Shallower species may be more resilient.

11. Members of species groups common in northern regions may be longer lived and slower growing than members of southern species groups. Advective losses of larvae may be more likely in southern regions where ekman transport is offshore year round. A greater proportion of production is likely to be pelagic where Ekman transport is offshore year round. Southern species may be more resilient.

12. Diversity decreases somewhat from mid shelf to upper slope, except for inshore regions dominated by Pacific hake. Dover sole, sablefish, Pacific hake and either splitnose rockfish in the south or Pacific ocean perch in the north together account for 50-80% of biomass in deepest regions. The number of piscivorous, opportunistic and/or mesopelagic species may increase closer to shore if the number of smaller juvenile or pelagic fishes or amount of pelagic and mesopelagic production increases with proximity to upwelling fronts.

13. Diversity is highest at northern and southern extremes of sampling area, where species more common in the Gulf of Alaska (Subarctic) and California Bight (Subtropical) are also present. Local lows are due to dominance by splitnose (and shortbelly) rockfish and in the south and Pacific hake in the north and transitional regions. Diversity is low between Cape Blanco and Cape Mendocino perhaps because all production is pelagic, the shelf is narrow with less variety in

habitat, production is advected offshore into deep water or few larvae are recruited in the region.

14. Replicate surveys and analyses are desirable to measure repeatability of apparent community structure and perhaps eventually to assess the natural range of variability in composition and spatial extent of species groups.

15. A model of this system based on hypothetical trophic structure and functional groups incorporates the relative importance of environmental variability and density dependence (among and within functional groups) on structure and dynamics of California Current demersal fish assemblages. The model is presently too "information-hungry" to be parameterized and computerized for simulations and predictions.

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