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SPECIES SIMILARITY OF OTTER TRAWL CATCHES OFF THE NORTHEAST COAST OF THE UNITED STATES

by

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INTRODUCTION

Off the northeast coast of the USA, species specific catch quota regulation has been the primary method of fishery management, both under the auspices of the International Council for Northwest Atlantic Fisheries and Regional Fisheries Management Councils. But otter trawls are not species specific, rather the species composition of the catch is a function of where and when the trawl is deployed as well as characteristic of the gear itself.

An optimal set of species specific catch quotas can be determined by linear programming based on the historic species composition (Brown et al 1979). An alternative approach is to define fishery management units such that catches with a specific type of fishing gear have a relatively unique and homogenous species composition. Total catch (all species combined) and/or fishing effort could then be regulated with reasonable expectation of the species composition of the resulting catch. Other forms of fisheries management (e.g. mesh regulation, closed areas or seasons) are also compatible with management units defined based on species composition.

Fishery units may be defined as ecological communities (Gabriel and Tyler 1980; Tyler et al. 1981). However, knowledge of the influences of fishing patterns and technologies on particular groups is important since the size and species composition of landings may be dramatically different than the natural system due to gear selectivity and culling practices.

In this study we develop a paradigm for fishery unit definition by examining aspects of the presence and persistence of multi-species groups, defined in space and time, that are exploited by otter trawlers. The approach is empirical in that we define groups based on patterns of species of composition from historical catch, effort, and biological sampling data available from the study area during 1964-1980. In other documents long-term variability in nominal catch, effort and species composition is analyzed (Lange et. al. 1981), and the species composition of landings is compared with data from research surveys to estimate discards (Mayo et. al. 1981).

Data Sources and Methodologies

A potential criterion for the delineation of operational units within the northeast region otter trawl fishery is the presence of relatively unique species composition of landings from one or more geographic areas, at specific times. If reoccurring species groups can be mapped and are contiguous in space and time they may then be treated as a unit. Accordingly, the feasibility of establishing fishery units based on similarity of species composition in commercial landings was evaluated using available data from otter trawl vessels operating off the Northeast Coast of the United States during 1964-1980.

A modern series of catch and effort data have been collected by National Marine Fisheries Service (NMFS) port agents in the Northeast Region from individual vessel trips since 1964. Each trip record includes

date, catch in weight by species, statistical area (Figure 1) and depth zone fished, days fished and other data not considered in this study. Trip records are available for most trips landing in New England ports. They are also available for some trips landing in mid Atlantic ports, but these data are either only available for recent years (i.e. New Jersey since 1978) or are not readily available for computer processing. Therefore, only trips landing in New England were considered. The analysis of statistical areas off the middle Atlantic coast is based on trips from that area, but landing in New England ports. Thus, the proportion of total landings represented by trip records is smaller and more sporadic in time and space in the middle Atlantic area than in New England.

Species composition data for our analyses were generated by summing landings from individual vessel trips falling into various space/time categories. Spatial designations were by statistical area (Figure 1), and depth zone (Table 1). Correlations of otter trawl catches with depth are well known (Gabriel and Tyler 1980, Bortone et. al. 1979). Many of the species of interest inhabiting the region display seasonal migratory patterns in response to cyclic changes in environmental parameters. Thus, it was appropriate to examine the species composition in each statistical area/depth zone more frequently than on an annual basis. Typically, the date landed is recorded by trip, thus virtually any relevant time scale could be integrated into the analysis. Initially, data were grouped by month, thus potentially resulting in 12 sets of species compositions for each area/depth category.

The percent species composition of landings derived from each statistical area, depth zone, and calendar month was calculated using aggregated data for the period 1977-1979. These particular data were considered in the analysis because, presumably, the most recent available information reflects current fishing practices and includes data on species that are presently abundant and important, but that may have been historically scarce (e.g. haddock during the early 1970's). Depth zones 8 and 9 (Table 2) were not included since accurate capture locations were not available. Lange et al. (1981) discuss long-term variability in species composition, effort, and C/E for area/depth/month groupings identified as relatively homogeneous with respect to species composition in our static (1977-1979) analysis. Additionally, they present an accounting of catches in depth zones 8 and 9 that were not considered here.

A total of 3,612 possible area/depth/month combinations (43 areas · 12 months · 7 depths) yielded 576 cells actually containing catch information. Most of the combinations lacking catch data were in the Middle Atlantic region, where sampling coverage and commercial otter trawler landing in New England are least. Additionally, several of the areas were characterized by depth ranges beyond those normally associated with otter trawling (i.e., 543, 542, 541, etc.; Figure 1).

Because of the enormous quantity of data to be synthesized, initial groupings of area/depth/month cases exhibiting similar species compositions were assigned using a clustering algorithm and computer program given in Dixon (1977). The task of the computer was to describe the relationship

between area/depth/month cases based strictly on the relative proportions of species in the landings. The quantity of landings was not an objective criterion for grouping at this stage.

A total of 67 different species was recorded from at least one of the area/ dpeth month cases during 1977-1979. However, many of the species occurred rarely and contributed little to the total landed weight. The computer program used in the clustering process (BMDP2M) did not have the capacity to analyze all species (67) and cases (576) simultaneously. Thus, the number of species considered was reduced to 27, based on rankings of landed weight and frequency of occurrence (Table 2). The percent of the total landings in weight contributed by each of the 27 species was coded as a distinct variable. Thus, a vector of 27 percentages described each case. These percentages generally did not sum to 100% for each case since a portion of the landings were contributed by species not included in the analysis. However, in most cases, over 95% of landed weight was accounted for.

It is unlikely that any two cases have exactly the same percent compositions for all 27 species. In order to group (cluster) cases with *similar* overall species, initially, each case is considered to be in a cluster of its own. At each step of the analysis the two clusters with the shortest distances between them (most similar) are combined (amalgamated) and treated as one cluster. The process of combining clusters could continue until all cases have been combined into one cluster with the degree of homogeneity reduced as the number of clusters is reduced.

A measure of the distance (or degree of dissimilarity) between two cases or clusters j and ℓ is defined as:

$$d_{j\ell} = \sqrt{\sum_{i=1}^{27} (X'_{ij} - X'_{i\ell})^2}$$

where; $d_{j\ell}$ = distance between clusters j and ℓ,

X'_{ij} = standardized percent of total landings contributed by species i in the jth case (i = 1, 2, 3, ...27),

$X'_{i\ell}$ = standardized percent of total landings contributed by species i in the ℓth case (i = 1, 2, 3, ...27).

Input data were first standardized to minimize the influence of variables with large standard deviations on distance measures (Dixon 1977), viz:

$$X'_{in} = \frac{X_{in} - \overline{X}_{i.}}{SD_{i.}}$$

where; X'_{in} = standardized percent of total landings contributed by species i in the nth case (n = 1, 2, 3, ...576),

X_{in} = percent of total landings contributed by species i in the nth case (n = 1, 2, 3, ...576),

$\overline{X}_{i.}$ = Mean percent composition of the ith variable (species) over all cases,

$SD_{i.}$ = standard deviation of the percent composition of the ith variable over all cases.

Results of the step-wise clustering procedure were printed as a dendrogram, illustrating the distances at which clusters are combined (Figure 2).

Cluster analysis experiments utilizing percentage or proportion data often utilize an arcsin transformation (Goodman 1972) hopefully to stabilize within case variances and eliminate functional dependence of variances on mean percentages. Accordingly, we assessed the impact of such a transformation on conclusions from our analysis by conducting a parallel cluster experiment using transformed, non-standardized data:

$$X''_{in} = \arcsin \sqrt{X_{in}/100}$$

where; X''_{in} = transformed percent composition of species i in case n,

X_{in} = percent of species i in commercial landings from case n.

Cluster dendrograms from the two analyses were then compared (Figure 3; Sokal and Rholf 1962).

Following the cluster analysis, we reviewed results and in some cases rearranged or combined clusters. Cluster analysis was considered a preliminary objective method of using a computer to treat a large number of cases with virtually an infinite number of combinations. Since the method is totally objective, it does not consider information which is not easily

quantifiable. Therefore, we considered our judgement as to what "makes sense" as the final basis for defining clusters. In particular, clusters should be continuous in time and space. Continuity was not a criteria considered during the mathematical cluster analysis.

Results and Conclusions

The definition of distinct groups from cluster analysis is dependent on arbitrary assumptions of distances necessary for separation. In the extremes, separation distances may be so large or small that all cases are considered as one group, or each as a distinct cluster. We chose a level of definition sufficient to generate a moderate number of groups (40-50), recognizing that considerable variation in the distance separating clusters was likely. For example, the individual area/depth/month cases that exhibited a high percentage of summer flounder catches separated as a group that was quite distinct (a relatively large distance) from other groups, whereas, several groups with high percentages of redfish were separated by relatively small distances.

In general, dendrograms produced from standardized percentage and arcsin transformed data were quite similar (Figures 2 and 3). Although numerical methods for evaluating the degree of similarity of dendrograms exist (cophenetic correlation coefficient of Sokal and Rohlf 1962), the computation of such a statistic in this case is an imposing task and not necessarily critical (for this problem it would involve assessing the relative amalgamation distances between each pair of cases, resulting in $n(n-1)/2$

or 165,600 elements). Figure 3 illustrates the relationship of 21 of the 576 area/depth/month cases evaluated in the two cluster analyses. These particular cases are ones generating a relatively large proportion of summer flounder (Table 3). Relationships between these cases, inferred from the cluster diagrams, are similar for the two techniques. This example is generally indicative of relationships among cases in the larger data sets. Interestingly, for those cases where summer flounder makes up more than 90% of the catch, the dendrogram employing arcsin transformed data apparently exagerates the distances between cases (i.e. cases 575, 576, etc., Figure 3, Table 3). These data are consistent with observations of Snedecor and Cochran (1967) who noted the arcsin transformation does not produce different results unless percentages being analyzed were either relatively low or high. Comparison of the two dendrograms suggests no meaningful differences in conclusions concerning the relationship of individual cases. Hence, further analyses employed the standardized sums of squares dendrograms exclusively.

The 576 area/depth/month cases were initially separated into 46 groups based on results of the cluster analysis using standardized percentage species composition data (Figure 2; Table 3). The number of cases in each group ranged from one to 41. The average percent species composition for the 46 groups is given in Table 4. Several problems exist, however, if

groups identified from cluster analysis are as logical operating units for assessment purposes. A number of the groups contain individual cases that are non-contiguous in space and/or time. It would be operationally difficult to define fishery units that have widely separated areal components, or that occurred at divergent times (i.e. winter, summer). There are several potential reasons for these discontinuities, including the geographical separation of distinct stocks of particular species (i.e. silver hake in the Gulf of Maine and the Middle Atlantic), and aberrent catches from specific areas/depths/months. The latter case occurred particularly frequently in the Middle Atlantic region where otter trawl landings in New England ports were relatively sporadic.

Accordingly, we combined several of the 46 clusters and shifted individual cases among groups with the specific objectives of reducing the total number of fishery units, and eliminating area/time discontinuities that did not reflect significant fishing patterns. A total of 29 fishery units (sub-fisheries) were thus generated and organized into 9 major fishery units (Tables 5-8). Major units generally reflect broad geographic/ecologic zones, while sub-fisheries are defined by the dominance of one or more species or groups (Tables 7,8). Percentages do not sum to 100% since several species were not considered (Table 2). A review of the geographic and temporal definition of the major and sub-fishery units, and significant trnds in species composition follows. Estimates of landings within each major fishery are based on Lange et. al. (1981).

Major Fishery 1: Broadly defined as the deep-water Gulf of Maine unit, major fishery number one includes a high proportion of relatively deep water areas (depth zones 3 and 4) in Statistical Areas 511-524 (Table 6). Redfish is the predominant species, with various groundfish species important at different times, in specific areas/depths. The average annual catch during 1977-1979 was 48 thousand tons.

Sub-fishery 1: In general sub-fishery 1 is characterized by a high proportion of haddock and cod with approximately equal proportions of pollock and redfish. The fishery is located in areas 512-515, and 521-523. Depths variously range from 2-7. In shallower depths (2-4) it is predominately a winter fishery, but is year-round in deeper waters (particularly depth 5).

Sub-fishery 2: The primary species caught during 1977-1979 was silver hake (49.5%) with some cod, haddock, and redfish. Areas are 513-515, 521, and 522. Depths zones range from 1-5; months are generally throughout the year. This fishery primarily occurs on Georges Bank in summer, in Massachusetts Bay during autumn and winter, and deep-water Gulf of Maine areas during spring.

Sub-fishery 3: Sub-fishery 3 is primarily in deep water areas of the northern Gulf of Maine, it is characterized by nearly equal proportions of redfish and haddock, with American plaice, cod, and witch flounder being important components.

Sub-fishery 4: Sub-fishery 4 is primarily a late summer-autumn fishery occurring in statistical areas 513, 515, and 522. Species composition is characterized by nearly equal proportions of haddock, redfish, cod, silver hake, and pollock. Depth zones range from 2-5.

Sub-fishery 5: Sub-fishery 5 is primarily located in the Northwestern Gulf of Maine, it is prosecuted during August-February in depths 2-6. Redfish (41.1%) is the most abundant species, with American plaice, witch flounder, pollock, and cod as important constituents.

Sub-fishery 6: Sub-fishery 6 occurs during January-June in the region from Massachusetts Bay (514) to Georges Bank, in depth zones 3-5. Redfish and cod are the two most important species, with haddock and pollock contributing significant proportions of the landings.

Sub-fishery 7: Sub-fishery 7 is primarily a late winter-spring fishery, occurring in depth zones 3 and 4 and areas 513, 515, and 521. Redfish (51.5%) accounts for most of the landings, with silver hake (24.3%) being most of the remainder.

Sub-fishery 8: Sub-fishery 8 is prosecuted on Georges Bank (521, 522) and central Gulf of Maine (statistical areas 513, 515) during spring and summer and in the northern Gulf of Maine (areas 511, 512) during late autumn. Depths range from 2-4. Redfish (44.6%) is the predominant species with pollock, haddock, and cod contributing approximately equal proportions.

Sub-fishery 10: Sub-fishery 10 occurs primarily in the central Gulf of Maine in depths 3 and 4. Most of the landings are taken during late winter-spring. Landings were almost exclusively redfish (72.8%).

Major Fishery 2: Major fishery 2 includes 1 sub-fishery (11) and is characterized by a proportionally large (66.4%) occurrence of summer flounder.

Statistical areas are in the Middle Atlantic (525-636); depths range from 1-4. However, a distinct seasonality is indicated. Winter and spring catches generally come from deep-waters along the edge of the continental shelf, while summer and autumn catches are generated from nearshore waters. This pattern is generally consistent with the migratory patterns of summer flounder. The average annual landings in 1977-1979 are estimated as 20.5 thousand tons.

Major Fishery 3: Major fishery 3 may be gnerally characterized as the nearshore Gulf of Maine Fishery (Table 5). It is characterized by a large proportion of mixed groundfish and flounders, with relatively little redfish (Table 4). Depths zones 1-2 and statistical areas 511-514 account for most of the landings. Average annual landings for 1977-1979 are estimated as 22.1 thousand tons.

Sub-fishery 12: Sub-fishery 12 occurs in areas 511, 514, 515, and 521. It is characterized by a large proportion of cod (46.4%) with approximately equal amounts of pollock, haddock, yellowtail flounder, and American plaice.

Sub-fishery 13: Sub-fishery 13 is predominately a pollock fishery (41.3%). It occurs exclusively in areas 514 and 515 and generally in depth 2. Landings are taken in area 514 during November, December, and January, and throughout the year in area 515.

Sub-fishery 14: The primary species of sub-fishery 14 is cod (52.4%) with a significant amount of ocean pout (16.5%). Most of the landings are taken from area 515 and depth 1 throughout the year.

Sub-fishery 15: Sub-fishery 15 is characterized by nearly equal proportions of pollock, cod, American plaice, haddock, and redfish, the major reason for grouping is the proportion of northern shrimp (8.2%) which in years previous to 1977 contributed a significantly greater proportion of landings from this sub-fishery. The fishery occurs in areas 513 and 514, depths 2-3, and during February and March.

Sub-fishery 16: Sub-fishery 16 generates primarily cod (37.6%), American plaice, and silver hake, and occurs in areas 512, 513, and 514. Most catches occur in depth zone 1 throughout the year.

Sub-fishery 17: Sub-fishery 17 is characterized by a high proportion of American plaice (38.4%), cod, haddock, and witch flounder. It is primarily a shallow-water northern Gulf of Maine fishery (areas 511, 512, 513), occurring throughout the year.

Sub-fishery 18: Sub-fishery 18 occurs in somewhat deeper waters than fishery 17 (depths 2-4) and generates a high proportion of witch flounder (26.4%), white hake, and redfish.

Major Fishery 4: Major fishery 4 includes 1 sub-fishery (19). Estimated 1977-1979 landings average 6.1 thousand tons annually. This fishery can be characterized as the mixed groundfish fishery occurring on northeast Georges Bank. During 1977-1979 cod (44.9%) and haddock (30.1%) were the predominant species. The fishery occurs primarily in statistical areas 523 and 524 and depths 1-4, throughout the year.

Major Fishery 5: Major fishery 5 has 1 sub-fishery (20) and is considered unique because of the relatively large proportion of *Loligo* squid (34.6%) and scup (25.4%). The fishery is prosecuted during two months (May-June) in Vineyard Sound (area 538, depth 1). During 1977-1979 this fishery averaged 1.9 thousand tons landed annually.

Major Fishery 6: Major fishery 6 includes 1 sub-fishery (21) that produces a large proportion of scup (34.2%), and approximately equal proportions of several other species including butterfish, summer flounder, winter flounder, and the industrial complex. This fishery occurs in various Middle Atlantic statistical areas (Table 5), depths (1 and 2), and months, reflecting the seasonal inshore-offshore migratory pattern of most of these species The fishery accounted for 13.2 thousand tons of average annual landings, 1977-1979.

Major Fishery 7: Major fishery 7 is generally characterized as the mixed species industrial/So. New England small mesh fishery. It is generally prosecuted seasonally in depths 1-4 and in areas 537, 539, 611, 613, and 616. The 1977-1979 average annual landings is estimated as 11.9 thousand tons.

Sub-fishery 22: Sub-fishery 22 is characterized by a large proportion of mixed-species industrial catch (43.1%). Silver hake (20.3%), winter flounder, and yellowtail flounder were significant food-fish components. This fishery is generally prosecuted throughout the Southern New England region in depths 1 and 2.

Sub-fishery 23: Sub-fishery 23 is defined by the large proportion of butterfish (52.2%) in addition to industrial and summer flounder catches. Occurring in relatively deep water (zones 2 and 3) it is retricted to areas 537 and 616.

Sub-fishery 24: Sub-fishery 24 is defined by the predominance of Atlantic herring (46.5%). This is primarily a winter fishery in areas 539 and 611, and a summer fishery in area 514. These areas were grouped because (presumably) fishery effort is being directed at the same (migratory) stock in different areas at those times.

Major Fishery 8: Major fishery 8 can be characterized as the shallow-water Georges Bank-Southern New England fishery primarily generating cod, yellowtail flounder, winter flounder, and haddock. Five sub-fisheries (25-29) are defined based on their varying proportions of these species and seasonality. It was the largest of the nine major fisheries in terms of landings for 1977-1979. Average annual landings are estimated as 44 thousand tons.

Sub-fishery 25: Sub-fishery 25 lands primarily cod (34.1%), yellowtail flounder (27.3%) and winter flounder (12.3%). This fishery occurs primarily during winter and early spring, in depths 1 and 2. Areas are 525, 526, 537, 538, 539, and 613.

Sub-fishery 26: The largest proportion of landings from sub-fishery 26 were yellowtail flounder (57.9%) with approximately equal proportions

of cod (13.4%), and winter flounder (11.3%). Primarily a late summer-autumn fishery it is prosecuted exclusively on Georges Bank (areas 522, 524, 525, 526, in depths 1 and 2).

Sub-fishery 27: Sub-fishery 27 yielded primarily winter flounder (41.1%) with cod (18.2%) and yellowtail flounder (13.6%) being the other significant species. Landings are taken in the Georges Bank-Vineyard Sound-Southern New England shelf area, reflecting primarily a seasonal onshore-offshore movement of winter flounder. Most landings were taken in depth zone 1.

Sub-fishery 28: Sub-fishery 28 and is characterized by a large proportion of cod (48.0%) and lesser percentages of winter flounder (14.2%), haddock (12.3%), and yellowtail flounder (10.9%). The fishery occurs in areas ranging from nearshore Massachusetts (514, 538) through the channel area, on to Georges Bank. The fishery occurs throughout the year in depths 1 and 2.

Sub-fishery 29: Sub-fishery 29 yielded predominately cod (34.9%) and haddock (26.9%) and lesser proportions of yellowtail flounder (12.1%) and winter flounder (10.9%). The fishery is prosecuted exclusively on Georges Bank, seasonally in depths 1-4.

Major Fishery 9: Major fishery 9 includes 1 sub-fishery (9). This fishery occurs in the deep-water areas along the southern edge of Georges Bank. The predominant species in the landings is lobster, with approximately equal proportions of silver hake (20.3%) and redfish (19.3%). The fishery occurs throughout the year in areas 524 and 525, and depths 3-7.

In the process of combining clusters and changing group membership of individual area/depth/month cases to establish the 29 sub-fishery units some cases with relatively dissimilar species compositions were combined in the interest of space/time continuity. Accordingly, it is relevant to assess the degree to which this intuitive process affected within-group variability in species composition. If the logical fishery unit groupings of cases exhibit, on average, substantially more within-group variation than the 46 original clusters, then the utility of using cluster analysis as an intermediate step in the process may be open to question.

A measure of the degree of within-group variation in species composition for each of the 46 clusters, and 29 fishery units can be calculated as:

$$\overline{D}_j = \frac{\sum_{k=1}^{n} \sqrt{\sum_{i=1}^{27} (X'_{ik} - \overline{X}'_{i.})^2}}{n}$$

where; $\overline{D}_j$ = average dispersion of individual area/depth/month cases around the mean species composition vector in cluster (or fishery) j,

$\overline{X}'_{i.}$ = average standardized percent composition of species i for all area/depth/month cases comprising cluster (or fishery) j,

X'_{ik} = standardized percent species composition of species i in case k (where k = 1, 2, 3, ...n; n is number of cases in the cluster (or fishery)).

Frequency distributions of $\overline{D}_j$'s for the 46 original clusters and the 29 sub-fishery units are given in Figure 4. The two sets of average distances exhibit distinct modality at the same frequency interval; data for the 46 clusters appear slightly skewed to the left. Two of the 46 clusters were defined by single area/depth/month cases and thus there was no dispersion around the average species composition for these clusters. If these two clusters are not considered, within-group dispersions for the 46 clusters and 29 sub-fisheries are quite similar (Figure 4). Overall average distances change only slightly (3.6484, 3.7916) and are not significantly different when 95% confidence regions are evaluated.

A similar analysis was extended to the nine major fishery groups, average within-group dispersion was 3.7867 (SD = .6283). These data imply the major fishery groups exhibit within-group dispersions similar to those of the sub-fisheries and clusters. However, major fisheries were not weighted by landings. If average dispersions for the nine major fishery groups are weighted by the landings from each, average within-group dispersion increases to 4.1055. This implying that the fishery units with the greatest landings (and containing most of the cases) are characterized by the greatest within-group dispersion.

Sub-fishery units defined in this study were generally consistent with initial groupings identified from numerical clustering techniques. The advantages of the numerical methods for group definition are their ability to organize information in large data sets, such as ours, and to provide

an initial framework for intuitive reclassification based on stock structure, fishing practices, etc. The nine major fishery units exhibited proportionately more within-group heterogeneity in species composition than in the sub-fishery units or the original clusters when relative landings within the units are considered. However, this behavior is to be expected considering the more subjective nature of the major fishery unit classification scheme.

The degree to which fishery units defined in this study represent distinct operational units in the regional otter trawl fishery can only be evaluated using time series data on landings, species composition, fishing effort, and vessel size distribution. Some such analyses are presented in Lange et al. (1981). Evaluation of the extent to which landings data from the fishery units are reflective of the biological fish community requires that landings information be compared with a measure of community structure relatively non-biased by gear selectivity and culling practices inherent in the fishery and non-random fishing practices within each unit. Such and analysis is presented by Mayo et al. (1981).

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Table 1. Arbitrary depth zones to which landings data are assigned.

Depth Zone	Range (fathoms)	Range (meters)
1	0-30	0-55
2	31-60	56-110
3	61-100	111-183
4	101-150	184-274
5	151-200	275-366
6	201-300	367-549
7	>300	>550
8[a]	mixed	
9[a]	unknown	

[a]These categories were not considered in the analyses.

Table 3. Percent species composition (in weight) of landings derived from selected area/depth/month cases during 1977-1979. Cases are those generating a relatively large proportion of summer flounder (Figure 3).

	% LANDINGS BY CASE																				
SPECIES	401	400	560	556	564	568	571	557	559	575	576	595	447	477	572	569	533	441	442	553	399
Goosefish	2.5	.5	.6						.3					1.6			3.4	1.4	1.7		1.5
Butterfish	2.9	.5							.5			.2				.9	.2	.2	.9		2.3
Cod			.2														.2	.5	.3		
Cusk	.7																				
Winter Fl.			.2											3.1			3.9		.1		
Summer Fl.	71.4	97.3	94.2	99.7	100.0	100.0	100.0	99.3	96.7	94.9	95.1	96.3	98.1	92.2	79.7	86.6	84.2	71.7	67.7	63.4	83.1
Witch Fl.	1.6	.2	.1									.1						.2	.1		.8
Yellowtail Fl.		.1	1.1											2.1			5.0	.8	.8		.3
Am. Plaice	11.2																				1.0
Windowpane			.1														.2	.1	.2		1.8
Haddock	.1																				1.8
Red Hake																					
White Hake	1.7								.1				1.9					.1	.2		.3
Sea Herring																					
Mackerel																			.1		
Redfish																		3.2			
Ocean Pout	.9																				
Pollock	1.4		.2					.4										.2			1.6
Scup			.1											1.0			.2		1.3		
B.S. Bass			.1	.3					.2			.2					.9				
Dogfish																					
Silver Hake			.9					.3	.1								1.0	3.2	2.4		
Wolffish																					.3
Industrial																					
N. Shrimp																					
Loligo	.1	.8	.2														.2	.1	1.5		.5
Illex																					
E	94.5	99.4	98.0	100.0	100.0	100.0	100.0	100.0	97.9	94.9	95.1	96.8	100.0	100.0	79.7	87.5	99.4	81.7	77.2	63.4	95.3

Table 4. Average percent composition (weight) of otter trawl landings from area/depth/month cases grouped from cluster analysis.

PERCENT LANDINGS BY SPECIES

Cluster	Goosefish	Butterfish	Cod	Cusk	Winter Fl.	Summer Fl.	Witch Fl.	Yellowtail Fl.	Am. Plaice	Windowpane	Haddock	Red Hake	White Hake	Sea Herring	Mackerel	Redfish	Ocean Pout	Pollock	Scup	B.S. Bass	Dogfish	Silver Hake	Wolffish	Industrial	N. Shrimp	Loligo	Illex
1	1.5		18.5	.7	2.4		16.2	.3	35.3		7.1	.1	4.7			7.3		2.2				1.7	.5				
2[a]	10.1			1.1			.6						4.2			20.0								.9			
3	.7		13.0	1.7	4.9		4.3	3.1	8.5		24.3	.7	4.5			19.7		10.5				1.4	.5		1.7		
4	.3	4.6	2.3		6.2	7.3	.2	10.9		.8		1.2			.1		.9	.1	2.2	.1		13.0		46.1		.4	
5	.5	1.1	5.0	.3	4.9	.5	.9	3.0	3.5	.1	3.8	.6	1.7	.2	.2	3.5	.3	1.9	.5			59.7	.1	5.3		.3	.2
6	.5		38.2		10.8	2.1	.4	26.5	.6	8.4	5.5					.1	.8	2.0				.1		3.0			
7	.9	9.6	8.9	1.7	9.3	13.6	1.3		5.0	.8	2.6		1.7			2.3		3.5	.3	1.6		2.4	.5			5.3	
8	1.0	.3	15.4		12.2	2.8	.7	53.8	2.9	1.6	4.2		.1				.2	.8	.2			.6	.3	.4			.1
9	.8	.5	8.0		41.7	3.2	.3	15.5	1.9	1.0	4.8	.1	.1		.1	.1	1.0	1.4	1.2	.1		2.6	.1	1.8		.1	
10	.9		36.6	.3	1.8		4.7	4.1	20.4	.1	8.3	3.0	1.2			1.6		3.3				10.0	1.2			.5	.1
11	.4		9.3	2.1	.2	.6	3.0	.2	6.1		11.0	.3	3.2			45.5		17.3					.3	.1			
12	.2		2.7	2.5	.2		2.6		4.2		2.9	.1	3.3			73.8		6.4				.7	.1				
13	.2		3.7	2.3	.2		1.2		2.7		4.7		1.6			75.9		6.8				.2	.1				
14	.4		7.6	2.2			3.2		6.0		7.3	.1	1.6			48.9		5.7				14.7	.1				
15	.2		14.2	.8	.6		1.1	1.1	3.2	.1	7.9	.2	.7			40.0		8.2				.4	.9				
16	.7		7.0	2.5	.2		8.9		19.3		7.0	.3	6.2			36.9		6.6				2.3	.1				
17	.4		13.6	3.2	.1		1.8	.2	4.9		22.1	.5	3.6	.2		31.5		12.1				4.0	.3				.6
18	1.1		31.1		16.7	.1	.4	8.2	.8	.7	2.5	1.4	.4		.5	.4		5.0			3.5	25.6					.1
19	.2		36.4	.8	5.3		1.7	4.3	3.2	.2	35.2		.9			4.2		5.5				.5	.2				
20	.2	.1	37.1	1.1			.3	1.2	2.5		16.8	.2	.6			32.5		6.4				.5	.1				
21	.4		23.4	1.6	.9		2.0	.6	5.4		28.5	.2	2.6			15.7		16.0				1.7	.3	.1			
22	.1		13.3	.6			.7		2.1		55.7		1.3			18.3		7.1					.2				
23	.8		41.4	.1	14.8	.1	.4	13.6	.9	2.3	10.3		.4			.2		14.1				.2	.2				
24	.3		30.0	.6	12.2	.3	.9	6.6	2.4	2.9	26.2		.5			4.4		5.8	.3			.5	.5				
25	.5	.1	31.8	.1	22.5	.2	.5	14.1	1.4	1.1	22.1		.2			.6		2.9				.6	.1	.5			
26	.5		58.3	.2	10.2		.7	8.4	1.4	.8	10.2	.2	.4			.9		5.7				1.0	.3				
27	.6		45.4	.8	.2		3.5	2.8	13.4		21.8	.1	.5			1.4		5.6				.8	.3		.1	.1	
28	.6	2.3	16.4	.9	3.4		1.2	.8	7.6		14.4	.6	1.3			5.0		39.6				2.9	.4				
29	.8	1.8	.1		.8	81.9	.2	2.3	.5	.2	.1		.2		.1	.1		.1	.3	.1		1.3				.4	
30	.7		39.0	.5	2.9		4.6	6.4	7.8	.4	14.0	.4	2.2			2.6	.4	9.0				1.1	3.6		.1		
31	.8		17.5	1.2	.3		3.1	.7	11.0		7.0	2.8	2.5	.1	.1	16.2		7.5			.1	21.7	.5	.1			3.4
32	1.0	10.3	.9		8.1	10.9	.1	6.7	.1	.2		.1			.8				41.0	1.4		2.8		7.2		1.3	
33	2.5	.1	6.1		6.8		.3	35.2	.2	2.3	21.0	.3	.1	2.2		.1	6.8	.1			1.7	11.4					
34	1.1	63.5			.6	5.7	.1	3.3	6.0		.4	.1	.3		.2	.8		.9	1.0	.4		3.1		3.4		1.6	
35	4.1		6.7	1.7	.4		31.4		17.0		6.2		18.9			7.7		4.4			.5		.4			.2	
36	2.0		6.8	1.6		4.7	3.0	2.9	8.1		.7	13.0	.2		3.4	22.1		4.1	2.7	.1		8.6		14.6			
37			14.6		35.8		.1	4.6		12.7	.4			4.3			9.6	1.4						15.3			
38	.4	.3	4.8	.5	.1		.4	.1	1.4		4.2	2.1	1.5	.6		1.3		2.7			4.5	65.5	.1				5.9
39	.4		33.6				.9	1.6	6.3		32.8	1.8	1.8			1.8		8.6				1.3	6.3				2.9
40	.1	.4	.3		9.7	4.9	.1	.1		4.3									28.7	1.3		.8		1.8		36.7	
41	23.9												13.8														
42		38.0	.1		3.4	1.8	29.6		4.3		4.0				13.3				1.3	.1		1.8				2.3	
43	.4		19.3	.8	2.7		3.8	4.5	12.3	.4	1.7	.5	.7	.2		11.9	2.5	16.5				1.1	1.0		8.6		
44	.6	3.1	22.4	17.7		6.3	.8		2.7		7.5		2.5			12.4		14.1					.6				
45	.5		7.2	.1	4.0		.4	10.2	.6	1.2	5.6	.7	10.8	33.6		2.8	1.9	.7			2.1	4.4		11.6			.1
46	1.1		4.0	.5	2.2	2.2	.8	1.1	2.0	.1	1.2	3.4	2.0	.8	7.8	1.1	8.7	1.4	6.1	13.1	7.0	15.2	.1			8.7	1.6

Table 5. Classification of 29 sub-fishery units within 9 major with the number of trips on which the classification was based.

Major Fishery Unit	Sub-Fishery Unit	Number of Trips[a] 1977-1979
1	1	1759
	2	1836
	3	363
	4	269
	5	164
	6	145
	7	137
	8	173
	10	1027
2	11	227
3	12	697
	13	396
	14	13
	15	377
	16	1296
	17	313
	18	38
4	19	550
5	20	324
6	21	541
7	22	2337
	23	232
	24	463
8	25	1439
	26	1303
	27	343
	28	3985
	29	790
9	9	31

[a]Otter trawl landings, depths 1-7

Table 6. Distribution of 576 statistical area/depth zone/month cases grouped by major fishery unit. Individual cells are totals over months.

Major Fishery Unit	Depth Zone	Total Cases	STATISTICAL AREA 511	512	513	514	515	521	522	523	524	525	526	537	538	539	611	613	614	615	616	621	622	623	626	627	631	632
1	1	5			1	4																						
	2	13		2	6	2	1		2																			
	3	73	2	11	12	7	12	12	12	5																		
	4	76	1	12	9	10	12	12	12	8																		
	5	6			1		2	1	1		1																	
	6	2			1	1																						
	Σ	175	3	25	30	24	27	25	27	13	1																1	1
2	1	8														1		1	1	1	1	2						
	2	10																2		2	3		1	1				
	3	12										3	4	4							1							
	Σ	30										3	4	4		1		3	1	3	5	2	1	1			1	1
3	1	16		1	10	2	2	1																				
	2	39	5	10	6	9	5	4																				
	3	11	5	1		5																						
	4	4	1		3																							
	5	1						1																				
	6	1						1																				
	Σ	72	11	12	19	16	7	7																				
4	1	7									7																	
	2	9							1		8																	
	3	13									7	6																
	4	7									3	4																
	Σ	36							1		25	10																
5	1	2														2												
6	1	9													2	4	1	1	1			2	1			1	1	
	2	13													2	1	3		1			2						
	3	2																				4	1			1	1	
	Σ	24													4	5	4	1	3									
7	1	33					1								4		10	11	8									
	2	26													10		5	2	8			1						
	3	6													5													
	4	2													2													
	Σ	67					1								21		15	13	16			1						
8	1	84					6		11	12	5	12	12	12	6	5	1		2									
	2	59						1	8	9	4	12	12	12			1											
	3	10											6	4														
	Σ	153					6	1	19	21	9	24	30	28	6	5	2		2									
9	3	3										2	1															
	4	1											1															
	5	3										1	2															
	6	9										5	4															
	7	1										1																
	Σ	17										9	8															
Σ		576	14	37	49	47	35	51	49	47	44	41	32	35	13	21	14	24	1	3	10	3	1	1	1	1	1	1

ble 7. Weighted average percent species composition of otter trawl landings from 9 major fishery units.

	Major Fishery Unit								
pecies	1	2	3	4	5	6	7	8	9[a]
osefish	.4	1.1	.6	.2	.1	.6	.3	.6	7.3
tterfish		4.3			.4	11.3	8.9	.1	.2
d	13.4	.4	34.5	44.9	.3	1.7	4.0	37.3	.2
ak	1.6		.5	.5				.1	1.2
nter Fl.	.9	.3	2.7	6.3	11.9	10.1	6.4	13.9	
mer Fl.		66.4			3.9	10.4	4.0	1.0	
tch Fl.	1.9	.2	3.2	.9		.2	.1	.6	.6
llowtail	1.3	.9	4.4	5.4	.1	6.6	7.0	21.1	
. Plaice	4.7	.3	12.1	2.7		.1	.1	1.6	.1
ndowpane		.3	.3	.3	5.2	.3	1.1	2.9	
addock	13.7	.1	10.5	30.1			.1	12.5	.2
d Hake	.3		1.4			.1	1.3	.1	1.4
hite Hake	2.0	.2	1.1	.5			.1	.2	3.5
. Herring	.1		.1				4.9		
ackerel		.1				.9	.3		
alfish	33.7	1.4	3.9	1.7			.1	.6	19.3
ean Pout			.7				.8	.2	
ollock	10.2	.2	14.4	5.1			.2	4.1	1.3
ap		.4			25.4	34.2	1.5	.1	
.S. Bass		.6			1.1	1.3	.1		
ogfish	.6					.1	.5		
lver Hake	13.7	3.1	5.2	.6	.6	4.4	17.9	.8	20.3
alffish	.2		1.9	.2				.2	
dustrial	.1				1.9	9.0	36.8	.6	.7
. Shrimp	.1		.8						
ollgo		1.9			39.6	1.9	.5		
llex	.3		.2						1.6
	99.2	82.2	98.5	99.4	90.5	93.2	97.0	98.6	57.9

ffshore lobster fishery (otter trawl)

Table 8. Weighted average percent species composition of otter trawl landings from 29 sub-fishery units

	SUB-FISHERY UNIT																												
Species	1	2	3	4	5	6	7	8	9[a]	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Goosefish	.5	.5	.8	.5	.8	.3	.3	.3	7.3	.2	1.1	.4	.4	.1	.4	.9	1.1	2.0	.2	.1	.6	.2	.4	.4	.5	.8	.9	.7	.2
Butterfish									.2		4.3									.4	11.3	4.6	52.2		.1	.3	1.1		.1
Cod	24.3	12.2	13.1	16.5	6.5	26.2	4.5	10.1	.2	3.6	.4	46.4	17.9	52.4	18.0	37.6	23.8	7.0	44.9	.3	1.7	3.9	.1	8.5	34.1	13.4	18.2	48.0	34.9
Cusk	1.6	.5	1.4	2.0	3.0	1.4	1.1	2.1	1.2	2.5		.5	.4	.8	.9	.3	.8	3.4	.5									.2	.1
Winter Fl.	.6	2.2	.4	.3	.3	.6	.1	.3		.5	.3	4.8	.9		3.4	1.2	1.6	.9	6.3	11.9	10.1	7.5	1.0	2.3	12.3	11.3	41.1	14.2	10.9
Summer Fl.						.1					66.4	.1								3.9	10.4	3.6	11.6		2.6	1.5	4.3	.1	1.2
Witch Fl.	2.0	1.1	6.9	1.8	8.7	2.0	1.6	3.0	.6	1.4	.2	2.0	.9	1.3	3.4	3.4	8.0	26.4	.9		.2	.1	.2	.3	.6	.6	.3	.8	.5
Yellowtail Fl.	.8	4.0	.6	.7		1.1		.3			.9	7.2	2.0	.5	5.2	3.3	.8		5.4	.1	6.6	7.2	2.8	9.3	27.3	57.9	13.6	10.9	12.1
Am. Plaice	5.8	3.4	13.6	5.1	18.0	4.4	4.1	5.7	.1	3.2	.3	6.8	2.4	3.2	12.0	17.6	38.4	11.1	2.7		.1	.1		.7	.4	.9	.7	1.7	3.1
Windowpane		.1									.3	.7	.1		.4	.1			.3	5.2	.3	1.1	.1	1.4	9.1	1.5	1.9	1.3	4.6
Haddock	27.2	7.6	21.5	20.7	5.5	15.3	4.5	12.1	.2	4.6	.1	11.5	11.9	11.8	11.0	8.3	10.9	8.0	30.1				.2	1.1	6.0	6.7	3.1	12.3	26.9
Red Hake	.2	.6	1.2	.1	.3	.3	.2	.3	1.4	.1		.4	1.7	.1	.4	3.3	.7				.1	1.4	.2	1.5			.3	.2	
White Hake	2.4	1.1	2.3	2.2	5.9	1.2	1.9	3.4	3.5	1.8	.2	.5	.9	2.2	.6	1.0	2.6	17.6	.5			.1		.3		.1	.1	.3	.1
Sea Herring		.6		.1											.2	.3						.3		46.5					
Mackerel											.1		.1								.9	.2	.9				.2		
Redfish	15.9	6.0	26.2	18.9	41.1	31.0	51.5	44.6	19.3	72.8	1.4	1.7	7.7		10.8	1.6	5.3	13.1	1.7				.6	.2	.2			1.0	.7
Ocean Pout												.5		16.5	3.0							.8		2.1	.6			.2	
Pollock	15.5	5.2	5.5	12.0	6.9	13.7	5.1	17.1	1.3	8.7	.2	12.2	41.3	8.1	19.0	4.5	2.3	8.6	5.1			.1		1.0	2.2	1.0	1.0	5.9	4.0
Scup											.4									25.4	34.2	1.7	1.4			.1	1.5		
B.S. Bass											.6									1.1	1.3		.3				.2		
Dogfish		2.8																.4			.1	.1		4.7					
Silver Hake	2.0	49.5	3.0	16.1	.2	.2	24.3		20.3	.4	3.1	.4	9.5	1.8	1.0	12.3	1.7	.1	.6	.6	4.4	20.3	8.1	8.5	.1	.7	3.5	1.1	
Wolffish	.3		.3	.1	.1	1.6	.1	.2		.1		3.4	.4		1.2	1.5	.9	.5	.2							.1		.3	.1
Industrial	.1			.1				.1	.7											1.9	9.0	43.1	14.0	9.4	2.8	.1	3.1	.1	
N. Shrimp			2.5									.1			8.2	.1	.3												
Loligo											1.9			.4						39.6	1.9	.4	2.0				.1		
Illex	.1	.6		1.5	1.1				1.6				.1			.8								.2		.1			
Σ	99.3	98.0	99.3	98.7	98.4	99.4	99.3	99.6	57.9	99.9	82.2	99.6	98.6	99.2	99.1	98.1	99.2	99.1	99.4	90.5	93.2	96.8	90.1	98.4	98.9	97.1	95.2	99.3	99.5

[a]Offshore lobster fishery (otter trawl)

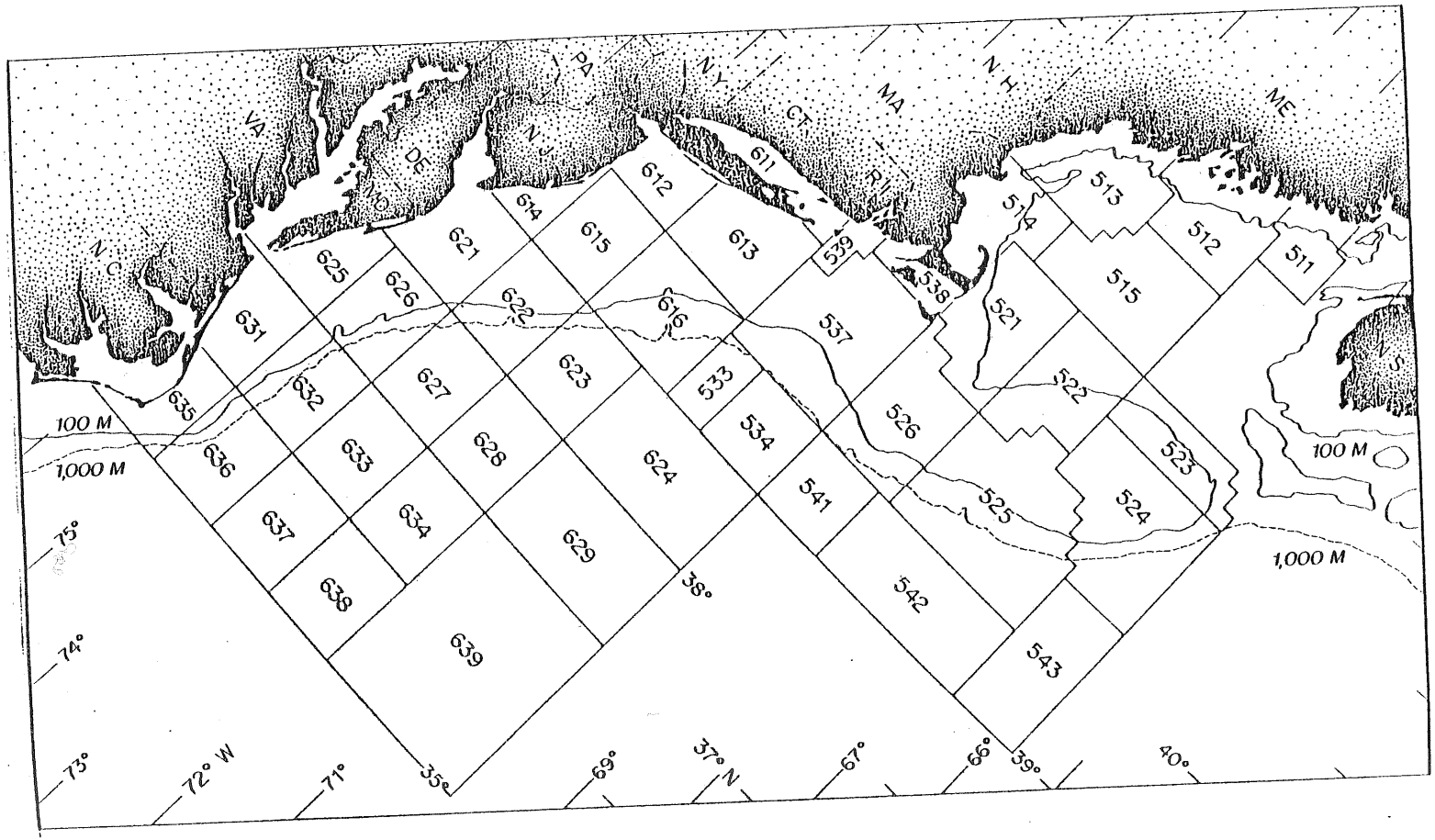
List of Figures

Figure 1. National Marine Fisheries Service statistical areas used to designate location of capture of fin-fish and shellfish landings off the Northeast coast of the United States.

Figure 2. Cluster analysis dendrogram illustrating the relationship between 46 arbitrary groups of area/depth/month cases. Group designations are based on similarity of species composition of landings. Vertical scale is the distance (see text) at which groups were separated. Width of rectangles corresponding to numbered groups is proportional to the number of cases in each group. Branching within groups (relationships of cases within clusters) is not shown. Total number of cases is 576.

Figure 3. Comparison of the relationships of individual statistical area/depth/month cases exhibiting a high proportion of summer flounder (Table 3), from cluster dendrograms employing standardized percentage species composition (ℓ), and arcsin transform species composition data (r).

Figure 4. Frequency distributions of average within-group dispersions around mean species compositions for 46 initial groups of statistical area/depth/month cases identified by cluster analysis, and 29 final groups (sub-fisheries). Measures of dispersion are standardized sums of squares distances (see text) of individual cases from mean within-group species composition.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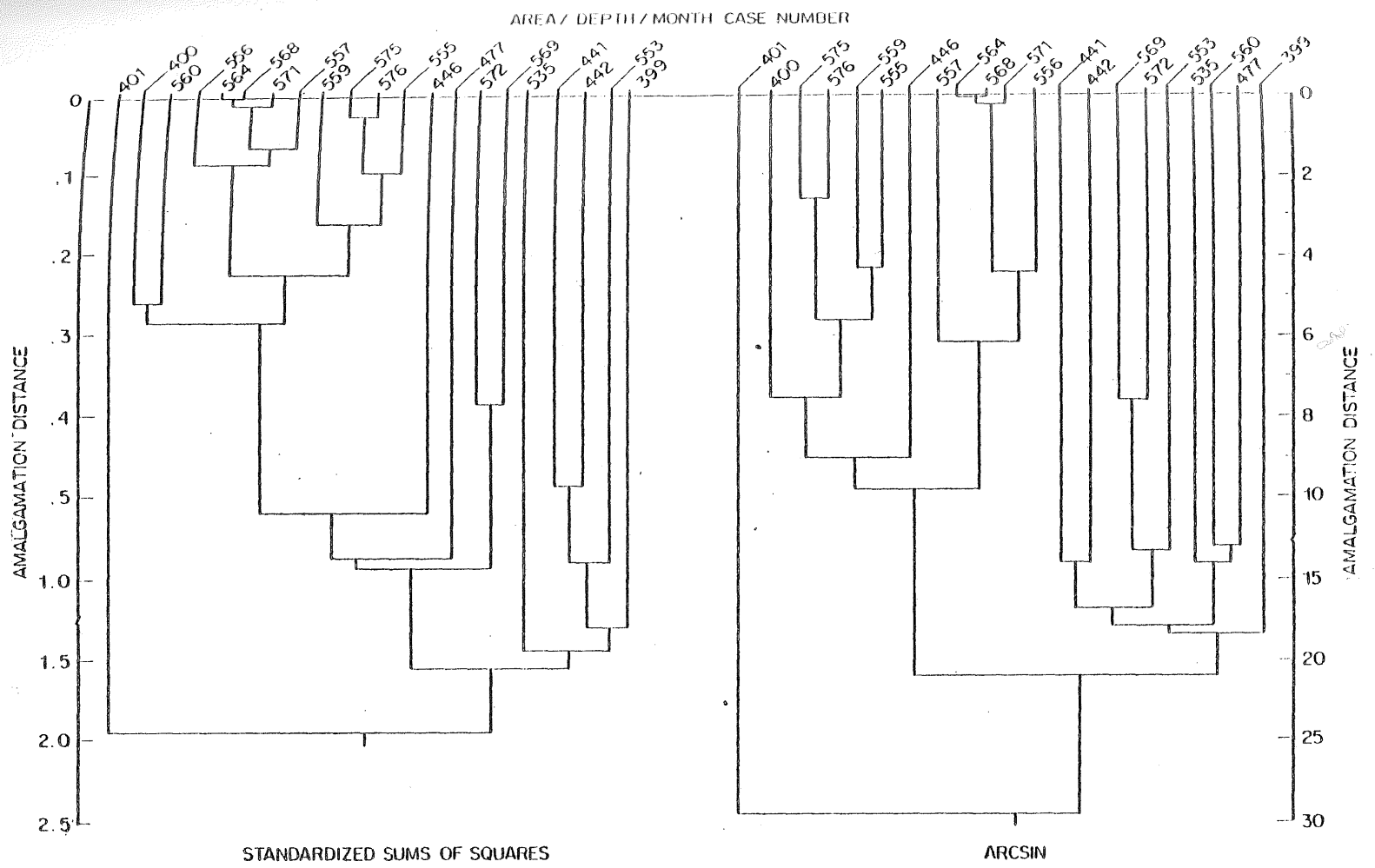
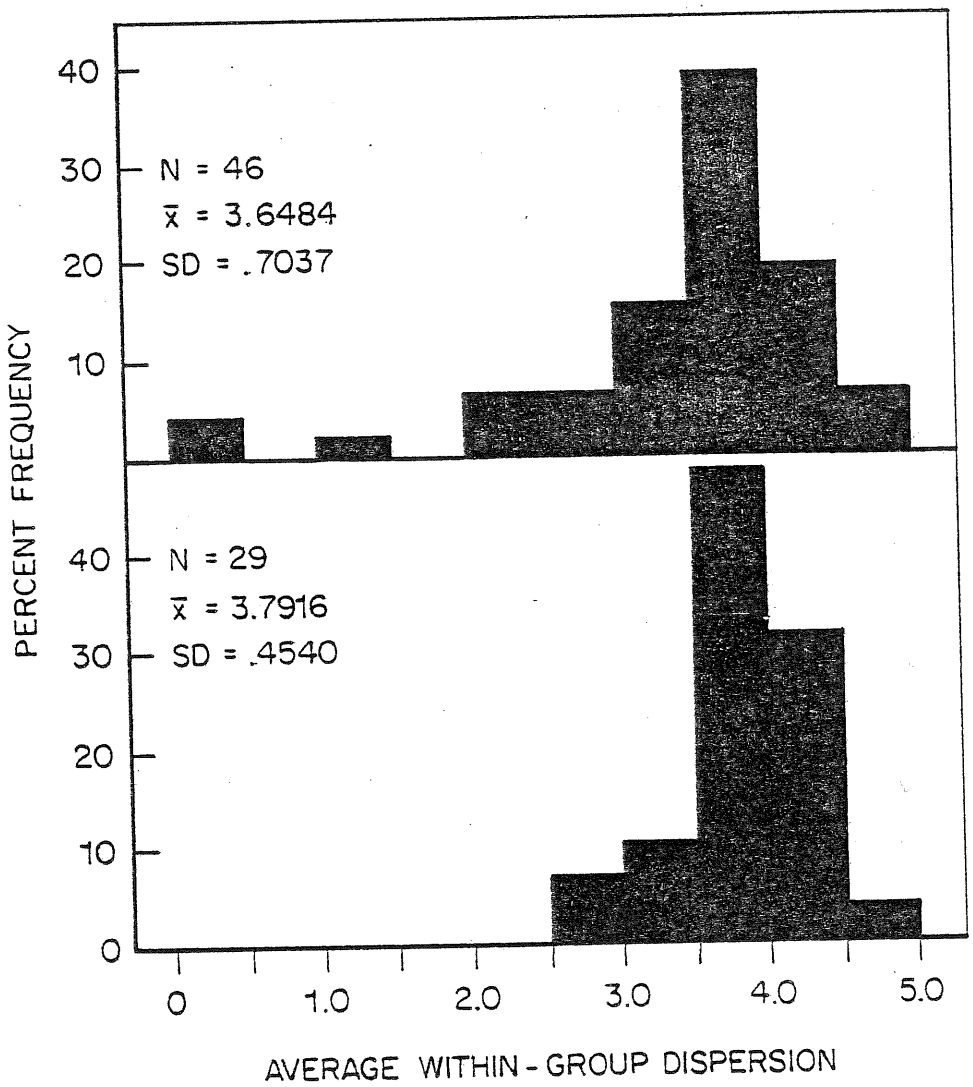
40°
38°


AREA/ DEPTH/MONTH CASE NUMBER
401
400
560
566
564
568
571
557
559
575
576
555
446
477
572
569
535
441
442
553
399
AMALGAMATION DISTANCE
0
.1
.2
.3
.4
.5
1.0
1.5
2.0
2.5
STANDARDIZED SUMS OF SQUARES
401
400
575
576
559
555
446
557
564
568
571
556
441
442
569
572
553
535
560
477
399
AMALGAMATION DISTANCE
0
2
4
6
8
10
15
20
25
30
ARCSIN


40
30
20
10
N = 46
x̄ = 3.6484
SD = .7037
PERCENT FREQUENCY
40
30
20
10
0
N = 29
x̄ = 3.7916
SD = .4540
0
1.0
2.0
3.0
4.0
5.0
AVERAGE WITHIN-GROUP DISPERSION