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Application of Fuzzy Graph Theory to Successional Analysis of a Multispecies Trawl Fishery

by

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Abstract: Fuzzy graph theory is applicable to any dynamical system where the values of all state variables are known for at least two points in time. This type of analysis is useful for detecting early trends in successional changes of assemblages of organisms. Seventeen successive years of research vessel trawl survey data from the Gulf of Thailand involving 38 species or species groups were found to be amenable to this form of analysis. The compositional dynamics of the species were examined by using three fuzzy relations to describe succession from the same data set. Although fuzzy graphs resulting from these relations showed that successional trends depended somewhat upon the characteristics of the chosen relation, consistent succession to a relatively few short-lived opportunistic species was demonstrated for these data. Time variance of the system was also examined, and it indicated that after the initial perturbation the system was not strongly time varying and that some prediction was possible from a short data set. This application of some methods and algorithms of fuzzy graph theory to analysis of multispecies fishery dynamics suggests some utility for preliminary interpretation of trends in such data.

The response of multispecies fish assemblages to sustained perturbations, such as exploitation effects, pollution, habitat degradation, global climate or sea level changes and destructive fishing practices, has attracted the attention of fishery scientists during the past few decades. Some methods for analyzing the dynamics of multispecies assemblages are beginning to emerge from these investigations. Specific procedures have included various multivariate statistical analyses (primarily clustering techniques), as well as mathematical models of varying sophistication (Larkin and Gazey 1982). A review of some of these procedures, as well as a detailed analysis of successional changes in multispecies assemblages, are reported by Saila and Erzini (1987). Sparre et al. (1989) provide a brief section on multispecies/ multifleet problems in their manual on tropical fish stock assessment with special emphasis on surplus production models.

Methods for studying the dynamics of multispecies fish assemblages are a subset of broader ecosystem studies. Ecosystem studies tend to be complicated by the imprecise estimates of the many possible interactions involved, as well as by elements of subjectivity in model construction and field observations. It is generally recognized that the precision of variables decreases as the size of the ecosystem model increases. Thus, many concepts and definitions in ecosystems science are imprecise and indefinite because ecosystems are large and loosely organized entities. Even when a substantial amount of simplification is involved, the modeling of subsystems, such as multispecies fish assemblages is a formidable undertaking by conventional modeling techniques. An example is provided by Pope (1979) who developed some extensions to the Schaefer stock production model in an effort to better understand multispecies fisheries in the Gulf of Thailand.

An extension to a standard population model can be stated as:

$$\frac{1}{P}\frac{dP}{dt} = a_1 - b_1 P - c_1 Q - q_1 E$$

$$\frac{1}{Q}\frac{dQ}{dt} = a_2 - b_2 Q - c_2 P - q_2 E,$$

where:

P = population size of species P (biomass),

Q = population size of species Q (biomass),

b_1, b_2 = intraspecific competition coefficients,

c_1, c_2 = interspecific competition coefficients,

E = fishing effort, and

q_1, q_2 = catchability coefficients.

In the above, if c_1 and c_2 are positive, the two species (P and Q) are competitors. If c_1 and c_2 have opposite signs, then the species with a negative sign for c is a predator, and the species with a positive c value is the prey species. It is evident from the above equations that the problem of real world parameter estimation for the model is difficult even in the two species case. It becomes virtually intractable when the number of interacting species is increased to a more realistic number.

If we assume that a multispecies assemblage consists of N species, and we wish to use a set of Lotka-Volterra equations to model the assemblage, then the number of interaction parameters alone is given by N factorial. Bosserman and Ragade (1982) have effectively described some of the practical limitations of conventional ecosystem analyses for relatively large systems. In summary, it seems that there is still a need for exploring new approaches to the understanding of multispecies assemblages, especially multispecies fisheries where there is often only a relatively small amount of detailed information available.

The purpose of this work is to introduce fuzzy graph theory as a tool which may be suitable for preliminary interpretation of multispecies fishery dynamics. It has been shown by Roberts (1989) that fuzzy graph theory provides a useful tool for mapping the dynamics of poorly known systems, such as forest succession. This approach seems particularly useful because it requires only data on changes of relative abundance over time and requires no knowledge of the equations governing the dynamics of the system. The fuzzy graph

method provides maps of the system dynamics produced from an analysis of repeated measurements of the state variables which can be related to successional changes. However, these repeated measurements need not meet the more stringent requirements of multispecies time series analysis or of Markov process models.

This application of fuzzy graph theory to the dynamics of fish assemblages from the Gulf of Thailand closely follows the methodology developed by Roberts (1989). Some duplication of his methodology will be necessary because an effort is made to provide the minimal background for understanding to those totally unfamiliar with any aspect of fuzzy set theory.

Background for Application of Fuzzy Graphs—

In classical set theory, every element can be classified as to whether or not it belongs to a particular set. In fuzzy set theory membership in a set is less clear. Zadeh (1965) first introduced fuzzy set theory, and for those who wish to pursue this subject further, books by Kaufmann (1976) and Zimmermann (1983) are useful. Bosserman and Ragade (1982) provide an introduction to fuzzy set theory from an ecological point of view, and Giering and Kandel (1983) demonstrate an application of fuzzy set theory by modeling competition in an ecological system.

Suppose that A represents the set of fish of a given species in a sample which are exactly 25.0 cm long. The membership of a fish in A is completely specified by the classical characteristic function:

$$f_A(x) = \begin{pmatrix} 1 \text{ if } h(x) = 25.0 \\ 0 \text{ otherwise} \end{pmatrix}$$

where x is any fish in the sample and h(x) is the length of x. A is called a crisp or non-fuzzy set, where x either belongs to A ($f_A = 1$) or x does not belong ($f_A = 0$). Next consider a set A' of all fish which are nearly 25.0 cm in length. Now there is a level of uncertainty about membership in A' which is caused by the fuzzy concept "nearly" This mathematical imprecision can be captured by extending the range of the membership

function $f_{A'}$ of x from the two points (0 and 1) to the entire interval from 0 to 1. For example, it is possible to state the following:

$$f_{A'}(x) = \left| \begin{array}{l} \vdots \\ 0.8 \text{ if } h(y) = 26.0 \text{ cm} \\ 0.9 \text{ if } h(y) = 25.5 \text{ cm} \\ 1.0 \text{ if } h(y) = 25.0 \text{ cm} \\ 0.9 \text{ if } h(y) = 24.5 \text{ cm} \\ 0.8 \text{ if } h(y) = 24.0 \text{ cm} \\ \vdots \end{array} \right.$$

The number $f_{A'}(x)$ is the grade of membership of x in the fuzzy set A'. If x belongs to A, then x belongs to A', but the converse is not true. The advantage of the fuzzy set A' is a gain in information conveyed by the model of the process it represents. For example, from $f_A(y) = 0$ we infer that h(y) is not 25.0 cm. However, from $f_{A'}(y) = 0.4$ we know that y is either considerably shorter or longer than 25.0 cm.

Just as in classical set theory, there are operators such as intersection, union, and complement which operate on fuzzy sets and which produce the same results. Fuzzy set relations are a generalization of classical set relations. They can be thought of as ordered pairs, where the ordered pair is assigned a value in the interval [0,1] which specifies the degree to which the ordered pair satisfies the relation. Directed fuzzy graphs can be developed from fuzzy relations using an algorithm described by Roberts (1989), and this will be briefly described in a later section.

Data—

Data from the Gulf of Thailand were used for this study because they represent the longest record of tropical demersal multispecies trawl data available. Specifically, a summary table from Pauly (1988) was converted from mean catch in kg per trawling hour to proportional abundance for 37 groups of fish and invertebrates identified to various taxonomic levels ranging from species to broad categories, such as crabs and shrimp. In addition, one miscellaneous fish group included unidentified trash fish and juvenile food

fish. The surveys were conducted by Thai research vessels in coastal areas of the Gulf of Thailand. The data consisted of a record of 19 years of annual surveys involving several hundred stations extending from 1961-1982. Of these data, 17 years were in a continuous annual record (1966-1982). The other two surveys were conducted in 1961 and 1963. Table 1 provides the summary data of Pauly (1988) expressed as proportions by weight for the 38 groups of organisms classified during the surveys. Since I was interested in examining changes in relative abundance, it was necessary to adjust for the dramatic changes in catch-per-unit effort (cpue) and absolute weights observed over the time history of the surveys. Similar dramatic changes in demersal fishery cpue and biomass declines have been documented in areas such as Georges Bank, Southeast Nova Scotia, Gulf of St. Lawrence, Newfoundland and the Grand Banks. Changes in relative species composition have also been found for Georges Bank and the Flemish Cap area.

Visual inspection of Table 1 shows some of the more obvious changes in relative abundance for the various groups. The difference between 1982 and 1966 was negative in 22 cases (58%), positive in 14 cases (37%), and no change was observed in 2 cases (5%). The highest relative losses occurred in the Leiognathidae, which decreased from about 15% by weight in 1966 to approximately 7% in 1982. A high increase was found for miscellaneous fish (trash fish and miscellaneous juvenile food fishes) from about 9½% by weight to 19%. Squid on the genus *Loligo* spp. also increased from about 6% initially to nearly 20% by weight. *Rachycentron canadus* and Cynoglossidae did not show any change between the two periods. *Lactarius lactarius* declined to extinction during the observation period. However, extinction in this case only means that this species was not found during the last observation period. Apparent temporary extinctions occurred for other groups including Tachysuridae, *Pampus* spp, Rhinobatidae, *Anadontostoma* spp. and Bothidae as measured by their absence in survey data for certain years. Only Tachysuridae occurred in reasonable abundance in 1966 when it comprised about 1.7% by weight of the annual catch. With the exception of Bothidae, which occurred initially (1966) at 0.5% by

weight, the other groups were found in initial abundances of less than 0.5% by weight. In general, from the last column of Table 1 it is seen that many of the observed differences from 1966-1982 were very small. Twenty-three were less than 1% in spite of a reduction in cpue to one-third of the starting values of 1966. Since each entry in Table 1 was an average from several hundred trawl hauls, some credibility can be given to these relative changes.

Methods—

Three fuzzy relations are defined for relative changes in abundance, and these are identical to those proposed by Roberts (1989) for forest succession. These fuzzy relations express the degree to which a given species (group) x is being replaced by species (group) y by assigning to the relation $R_{x,y}$ a number in the interval [0,1]. The three fuzzy relations used herein reflect three different definitions of succession. The first is:

$$R_{x,y} = \text{MAX}\,(0, \text{MIN}\,[x_o, d_y]);\ d_y = y_1 - y_o \qquad (1)$$

where:

x_o = abundance of species (group) x at the start of the period,

y_o = abundance of species (group) y at the start of the period, and

y_1 = abundance of species (group) y at the end of the period.

The definition requires that for species (group) x to replace species (group) y:

species (group) x must be present at the start (time 0), and

species (group) y must increase in the interval from time t_o to time t_1.

The degree to which species (group) x is replaced by y is the minimum of species (group) x at time t_o and the positive change in abundance of species (group) y from time t_o to t_1. This replacement relation is potentially symmetric with respect to y and x.

The second definition is more rigorous in terms of replacement of x by y.

$$\begin{aligned} &\text{if } x \neq y, \text{ then} \\ &R_{x,y} = \text{MAX}(0, d_y - d_x); \\ &\text{if } x = y, \text{ then} \\ &R_{x,y} = \text{MAX}(0, d_x) \end{aligned} \tag{2}$$

For x to be replaced by y, this definition requires that:

y must increase faster than x, or

x must decrease faster than y.

The rate at which x is replaced by y is equal to the magnitude of the difference of the above two conditions. The above definition is not symmetric. Therefore, it is not possible for species x to succeed to y and for y to succeed to species x. It is possible, however, for one (x or y) to replace the other even if both decline in abundance over the interval of interest.

Definition three is the most rigorous.

$$R_{x,y} = \text{MAX}(0, \text{MIN}[-d_x, d_y]) \tag{3}$$

For x to be replaced by y, this requires that:

x must decrease in the interval t_0 to t_1

y must increase in the interval t_0 to t_1.

The rate at which x succeeds to y is the minimum of the above two requirements.

The respective fuzzy relations were calculated for each of the three definitions by computing the value of the relation for all possible ordered pairs. The transition relations calculated for the above three definitions are shown in Tables 2, 3, and 4 respectively. These tables may be loosely interpreted as follows. Rows indicate succession to and columns indicate succession from a given species (group). That is, a given column indicates that a species (group) replaces the species (group) indicated by the row number. The key which identifies species (group) numbers by name is found on the leftmost column of the tables.

A fuzzy graph can be constructed from a given fuzzy relation by means of an iterative algorithm described by Roberts (1989). The steps in constructing fuzzy graphs from fuzzy relations, such as Tables 2, 3, and 4 are:

a) Set values in the diagonal to 1.0

b) Develop a reachable set by scanning across the row corresponding to that species (group) and list all species (groups) to which the species (group) is succeeding:

$$([x, y_{i\,i=1,n}] > 0).$$

c) Develop a precedent set by scanning the column values corresponding to each species (group) in turn, and list all species succeeding to the referent species.

$$([x_{i\,i=1,n}, y)] > 0).$$

d) For each species form the intersection of the reachable and precedent sets.

e) Find all species (groups) in which the intersection is equal to the reachable set and place at the top of the graph.

f) Delete these species from the reachable and precedent sets of all other species, and repeat steps e) and f) to produce the next tier.

g) Draw an arrow from each species (group) to all species (groups) in the tier above which are in reachable set until all species (groups) are included in the graph.

The fuzzy graphs illustrated in this paper were produced using a computer program developed by Roberts (1989). The program operates on any set of state variables at two points in time and produces the transition relations according to any of the definitions used herein. It also produces the transitive closure of the transitive relation using any specified threshold. From the transitive closure relation the program determines the reachable set for each state variable and the intersection of the reachable and precedent set for each state

variable. An algorithm within the program then determines the tiers of the fuzzy graph and omits species below any specified threshold level.

The procedure for producing fuzzy directed graphs may be modified by listing in the reachable set or precedent set of a given species (group) only those species (groups) having a value in the relation at or above a specified threshold, which is called an alpha-cut. By varying the value of the threshold dominant trends can be isolated and insignificant values can be suppressed. There is some question about what values of alpha are appropriate for a given situation. In this example, sample sizes are large and variances should have stabilized. However, access to the raw data was not available for calculating empirical estimates of variance. It is also recognized that estimating sample size requirements for rare species is a formidable problem. In view of the above, it was decided to use conservative values for thresholds similar to those used by Roberts.

Another aspect of this study was to employ the same definitions of succession for different periods of time to determine if the dynamics of the multispecies assemblage changed with time. Two periods (1961-1966 and 1966-1972) were examined with this objective in mind.

Results—

This study was oriented primarily toward looking for dominant trends in changes of relative abundance by the species or groups listed in the Thai trawl survey. Although three model definitions and three levels of threshold (alpha-cut) were considered, emphasis in interpretation and application is given to the higher threshold values and the more rigorous models because these were thought to be the most realistic. It should be appreciated that in all the fuzzy graphs to be illustrated herein, species (group) pairs with values of the defined relation which are less than the indicated threshold value are not entered into the reachable and precedent sets of the species (groups). This accounts for the absence of some species (groups) in the figures provided.

The results from the first definition of changes in relative abundance (succession) are shown in Figure 1. In Figure 1a, which illustrates a threshold value of 0.005 for inclusion, the fuzzy graph has three tiers. Species group 22, which includes all shrimp species, illustrates a group which is changing rapidly, although it is relatively low in absolute abundance. This change is captured by the low threshold value used in Figure 1a. At the second level all seven species groups which are increasing in relative abundance are also succeeding to each other, as well as to shrimp (22). Note that this level includes (9) *Loligo* spp., (11) Priacanthus spp, and (38) miscellaneous fish, as well as four other species groups. The lowest tier contains species (groups) which have declined in abundance or remained the same.

Figure 1b illustrates a fuzzy graph for the first model definition, but with a higher threshold of 0.025. Here we have only two tiers, with species (group) 9-*Loligo* spp., 11-*Priacanthus* spp. and 38-miscellaneous fishes demonstrating rapid changes in abundance and succeeding to each other. The other nine species (groups) in the lowest tier are declining or remaining relatively stable.

In Figure 1c we again have three tiers, with the same three species (groups) illustrated in Figure 1b changing most in relative abundance. However, in this instance *Loligo* spp. and miscellaneous fishes are succeeding to each other, and both are succeeding to *Priacanthus* spp. The declining or relatively stable species (groups) in the figure are only five, as seen in the lowest tier.

It is evident from examining the three threshold levels that the lowest values include the largest number of species (groups). However, at all alpha levels the same three species (groups), namely 9, 11, and 38 were found to be consistently changing most rapidly in relative abundance. In addition the species (groups) which showed persistent declines in realtive abundance include (1) Leiognathidae, (2) Carangidae, (3) *Nemipterus* spp., (6) Rays, and (33) Gerridae at all threshold levels.

For the second definition of succession, the results were more complex in terms of the number of tiers found. The number of tiers were 17, 7, and 5 for threshold values of 0.005, 0.025, and 0.05 respectively. A possible reason for the increased complexity is that a difference operator is used instead of a MIN operator, as in the first model. When comparisons were made among the species (groups) which exhibited the greatest trends in relative abundance, it was clear that the results were fairly similar to those achieved in Figure 1. However, they were even more internally consistent with respect to the most rapidly changing species (groups) at all alpha levels. Miscellaneous fishes (38), *Loligo* spp. (9), and *Priacanthus* spp. (11) were in essentially similar order of succession in the three cases examined. Only the greatest threshold value of 0.05 is illustrated in Figure 2 for the second model definition. Note that the lowest tier contains three species (groups) Leiognathidae (1), Rays (6), and Gerridae (33) which were consistently found in Figure 1.

Figure 3 shows relative changes for the three thresholds based on the third definition of succession. It is evident that there are only two tiers in each fuzzy graph. However, the three most rapidly changing groups from the previous figures appear in similar positions in these graphs as well. That is, *Loligo* spp. (9), *Priacanthus* spp. (11), and miscellaneous fishes (38) are again included in the most rapidly changing groups. However, at the lowest threshold of 0.005, five other species (groups) are included in the first tier. They are *Saurida* spp. (7), Trichiuridae (17), crabs (20), shrimps (22), and *Sepia* spp. (37). Those species (groups) found in the second tier were either declining in relative abundance or were stable. The persistence of species groups 1, 6, and 33 in the lowest tiers is again noted.

Time Variance—

Only the third fuzzy relation, considered to be the most rigorous, was calculated for the time variance study for the periods 1961-1966 and 1966-1972. The values of thresholds were restricted to 0.025 and 0.05. Figure 4 illustrates the four fuzzy graphs resulting from these. The 1961-1966 data for the threshold values of 0.025 and 0.05

reflect a trend toward rapid change in relative abundance by *Loligo* spp. and includes Mullidae and rays for the 0.025 value. Only *Loligo* spp. are found to demonstrate rapid change for the 0.05 threshold. The same model and thresholds for the period 1966-1972 show most rapid changes in relative abundance by *Loligo* spp. and miscellaneous fishes with *Sepia* spp. included in the 0.025 value. At the 0.05 threshold the major dynamic changes occurred among *Loligo* spp. and miscellaneous fishes. The trend in rapid changes by species (groups) included *Loligo* spp. in all cases where some change was indicated at the respective threshold levels. It is also evident that some indication of declines in realtive abundance could be shown from these analyses. Groups which seemed to reflect persistent declines included Leiognathidae (1) and rays (6). These results also suggest that it may be possible to obtain useful information about tropical demersal fish assemblage dynamics after only a relatively short period of observation since the high rate of squid succession, as well as declines in Leiognathidae and rays were indicated very quickly.

Discussion—

One important aspect of studying dynamics of multispecies fish assemblages with fuzzy graph theory is that explicitly defined concepts of replacement (succession) are required. Three definitions have been utilized in this study, and the results are based on these using three levels of threshold below which changes in relative abundance are not considered to be meaningful.

Clearly, *Loligo* spp. have emerged as one of the most rapidly increasing species in all of the analyses made herein. However, no causal explanation is possible from this type of analysis. Pauly (1979) and Gazey and Larkin (1982) have postulated that the so-called "squid outburst" in the Gulf of Thailand was due to a release of predatory control on undeveloped eggs and prerecruits by virtual elimination of the predators. This is believed to be a rational explanation for the results observed in this study in addition to a relatively short life history cycle. Available unpublished information indicates that squid are still a very important component of the current demersal trawl catch in the Gulf of Thailand.

It is also interesting to note that some common species in the current by-catch in the southeast Asia region trawl fishery (Anonymous 1989) consist of threadfin bream (*Nemipterus* spp.), bigeye snapper (*Priacanthus* spp.), lizardfish (*Saurida* spp.), and glassfish (*Pentaprion longispinus*) which are used for surimi production. Both *Priacanthus* spp. and *Saurida* spp. were found to be included in rapidly increasing groups based on the fuzzy graphs derived from the historical Thai trawl data base. *Nemipterus* spp. experienced decline during the period of observation as shown in Table 1. *Pentaprion longispinus* was not explicitly included in the available data base.

Initially, it seemed paradoxical that *Saurida* spp. would have been included among the rapidly increasing species from these analyses. Lizardfishes are considered to be relatively large and long-lived species which were expected to quickly decline in abundance with increased exploitation. A possible explanation to this anomaly is as follows. Thresher et al. (1986) studied life history strategies and recent changes in population structure of the lizardfish genus *Saurida* on the Australian northwest shelf area. They found that the large *Saurida* species were replaced by other *Saurida* species which reached sexual maturity in a few months and rarely lived more than one year. If a similar replacement occurred in the Gulf of Thailand, it could explain the persistence and increase of *Saurida* spp.

The results of this series of analyses using fuzzy graph theory on the 1966-1982 data may be compared to studies of dominance by Pauly (1979). He plotted the natural logarithm of the mean catch per effort against effort. The slopes of these plots were used as an indication of the rate at which a given species group increased or decreased. Six groups were formed and Pauly included squid with pelagic fishes not affected by demersal trawling. In this study, increases by *Loligo* spp. and the miscellaneous group of fishes were found consistently. However, the number of species groups which exhibited very small changes in relative abundance under exploitation was found to be high. In addition, it seemed evident that trends of change in abundance could be detected from a relatively

short-time series, and the system did not seem to be a strongly time varying after the initial perturbation.

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Table 1. Relative catch composition (proportions by weight) of identified groups of fish and invertebrates obtained by trawl surveys in coastal waters of the Gulf of Thailand from 1966 to 1982, derived from Pauly's (1988) Table 13.2. Values marked by an asterisk (*) contained very small amounts of the indicated group, but less than 0.0005 by weight.

ID#	Groups identified	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1982-1966
1	Leiognathidae	0.153	0.045	0.136	0.103	0.105	0.045	0.077	0.216	0.047	0.054	0.046	0.059	0.055	0.058	0.064	0.083	0.071	-0.082
2	Carangidae	0.076	0.079	0.094	0.090	0.093	0.059	0.061	0.055	0.075	0.050	0.033	0.047	0.045	0.049	0.049	0.030	0.030	-0.046
3	*Nemipterus* spp.	0.117	0.103	0.071	0.092	0.089	0.110	0.075	0.062	0.053	0.125	0.100	0.114	0.077	0.096	0.098	0.113	0.087	-0.030
4	Sciaenidae	0.020	0.040	0.025	0.006	0.015	0.009	0.011	0.003	0.003	0.003	0.003	0.006	0.049	0.001	0.008	0.004	0.002	-0.018
5	Mullidae	0.045	0.085	0.069	0.060	0.039	0.041	0.030	0.038	0.015	0.034	0.027	0.023	0.023	0.013	0.016	0.013	0.009	-0.036
6	Rays	0.074	0.042	0.021	0.029	0.029	0.020	0.019	0.030	0.016	0.024	0.011	0.013	0.022	0.006	0.004	0.008	0.002	-0.072
7	*Saurida* spp.	0.041	0.039	0.051	0.052	0.068	0.046	0.053	0.036	0.040	0.035	0.051	0.064	0.053	0.054	0.070	0.070	0.062	+0.021
8	Tachysuridae	0.017	0.019	0.017	0.013	0.015	0.015	0.007	0.012	0.002	0.007	0.005	0.005	0.007	0.005	0.005	0.004	0.000*	-0.017
9	*Loligo* spp.	0.061	0.080	0.100	0.113	0.088	0.166	0.225	0.191	0.248	0.137	0.162	0.177	0.172	0.131	0.145	0.188	0.199	+0.138
10	*Scolopsis* spp.	0.036	0.029	0.025	0.038	0.027	0.029	0.022	0.019	0.012	0.016	0.015	0.015	0.012	0.007	0.011	0.014	0.011	-0.025
11	*Priacanthus* spp.	0.031	0.062	0.059	0.073	0.076	0.079	0.030	0.042	0.094	0.045	0.050	0.050	0.060	0.07[illegible]	0.085	0.114	0.087	+0.056
12	Sharks	0.014	0.014	0.010	0.006	0.008	0.009	0.009	0.009	0.005	0.003	0.004	0.006	0.003	0.004	0.001	0.005	0.003	-0.011
13	*Sphyraena* spp.	0.013	0.012	0.007	0.011	0.015	0.005	0.005	0.003	0.004	0.003	0.003	0.004	0.007	0.010	0.006	0.009	0.007	-0.006
14	*Thenus* spp.	0.006	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.002	0.002	0.003	-0.003
15	Lutjanidae	0.036	0.035	0.036	0.029	0.023	0.015	0.009	0.010	0.007	0.009	0.013	0.004	0.010	0.015	0.010	0.013	0.021	-0.015
16	Plectorhynchidae	0.009	0.012	0.009	0.011	0.006	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.00[illegible]	0.001	0.004	-0.005
17	Trichiuridae	0.008	0.001	0.014	0.007	0.010	0.010	0.013	0.020	0.015	0.061	0.033	0.027	0.019	0.041	0.008	0.007	0.017	+0.009
18	Serranidae	0.009	0.012	0.010	0.009	0.009	0.008	0.005	0.006	0.004	0.010	0.009	0.013	0.008	0.013	0.013	0.012	0.010	+0.001
19	*Rastrelliger neglectus*	0.002	0.003	0.005	0.010	0.016	0.006	0.003	0.004	0.001	0.003	0.002	0.002	0.004	0.008	0.004	0.004	0.006	+0.004
20	Crabs	0.007	0.005	0.007	0.008	0.014	0.017	0.026	0.018	0.028	0.021	0.013	0.018	0.017	0.022	0.022	0.017	0.013	+0.005
21	*Lactarius lactarius*	0.004	0.002	0.002	0.001	0.002	0.004	0.002	0.000*	0.000*	0.000*	0.002	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	-0.004

Table 1 (cont'd). Relative catch composition (proportions by weight) of identified groups of fish and invertebrates obtained by trawl surveys in coastal waters of the Gulf of Thailand from 1966 to 1982, derived from Pauly's (1988) Table 13.2. Values marked by an asterisk (*) contained very small amounts of the indicated group, but less than 0.0005 by weight.

ID#	Groups identified	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1982-1966
22	Shrimps	0.002	0.001	0.001	0.001	0.002	0.004	0.003	0.002	0.002	0.003	0.004	0.007	0.005	0.005	0.009	0.007	0.009	+0.007
23	*Pomadasys* spp.	0.003	0.003	0.002	0.003	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.004	0.002	0.004	0.000*	0.001	-0.002
24	*Scomberomorus* spp.	0.005	0.004	0.008	0.001	0.006	0.005	0.006	0.011	0.008	0.006	0.005	0.006	0.005	0.007	0.011	0.005	0.009	+0.004
25	*Panus* spp.	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.001	0.001	0.002	0.004	0.000*	0.004	+0.002
26	*Psettodes erumei*	0.008	0.005	0.005	0.006	0.006	0.011	0.008	0.006	0.004	0.008	0.004	0.005	0.004	0.003	0.004	0.004	0.002	-0.006
27	*Chirocentrus* spp.	0.002	0.001	0.003	0.002	0.002	0.002	0.002	0.003	0.004	0.003	0.003	0.004	0.004	0.008	0.005	0.006	0.005	+0.003
28	*Rachycentron canadus*	0.002	0.003	0.002	0.002	0.003	0.001	0.002	0.002	0.003	0.004	0.002	0.002	0.001	0.002	0.001	0.001	0.002	+0.000
29	Lethrinidae	0.004	0.007	0.003	0.003	0.003	0.002	0.003	0.001	0.001	0.001	0.003	0.002	0.001	0.002	0.003	0.003	0.001	-0.003
30	*Muraenesox* spp.	0.005	0.001	0.002	0.006	0.003	0.004	0.003	0.002	0.002	0.006	0.003	0.004	0.003	0.002	0.003	0.003	0.003	-0.002
31	Rhinobatidae	0.004	0.006	0.008	0.004	0.004	0.007	0.001	0.002	0.002	0.002	0.003	0.002	0.004	0.002	0.002	0.000*	0.000*	-0.004
32	*Anadontostoma* spp.	0.002	0.001	0.003	0.004	0.002	0.002	0.003	0.002	0.002	0.002	0.000*	0.000*	0.000*	0.000*	0.001	0.000*	0.001	-0.001
33	Gerridae	0.052	0.052	0.030	0.030	0.026	0.022	0.013	0.009	0.024	0.015	0.019	0.017	0.010	0.001	0.002	0.002	0.001	-0.051
34	*Rastrelliger kanagurta*	0.003	0.006	0.006	0.009	0.009	0.007	0.006	0.005	0.005	0.004	0.003	0.006	0.009	0.008	0.005	0.005	0.005	+0.002
35	Bothiddae	0.005	0.003	0.004	0.003	0.003	0.008	0.009	0.005	0.003	0.007	0.003	0.003	0.000*	0.000*	0.00	0.000*	0.000*	-0.005
36	Cynoglossidae	0.001	0.001	0.004	0.001	0.001	0.004	0.005	0.003	0.001	0.008	0.002	0.002	0.002	0.002	0.003	0.003	0.001	+0.000
37	*Sepia* spp.	0.021	0.016	0.020	0.023	0.027	0.034	0.045	0.036	0.054	0.049	0.042	0.051	0.047	0.046	0.038	0.044	0.029	+0.008
38	Miscellaneous fish	0.094	0.108	0.131	0.144	0.156	0.189	0.206	0.232	0.239	0.244	0.323	0.239	0.264	0.306	0.290	0.209	0.287	+0.193

Table 2. Transition relation for MAX (0, MIN(z_o, d_y)) for 1966–1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Leiognathidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	13.72%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
2	Carangidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	7.55%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
3	*Nemipterus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	11.69%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
4	Sciaenidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.99%	0.00%	1.99%	0.00%	1.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
5	Mullidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	4.50%	0.00%	4.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
6	Rays	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	7.35%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
7	*Saurida* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	4.08%	0.00%	4.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
8	Tachysuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.70%	0.00%	1.74%	0.00%	1.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
9	*Loligo* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	6.14%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
10	*Scolopsis* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.05%	0.00%	3.62%	0.00%	3.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
11	*Priacanthus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	3.11%	0.00%	3.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
12	Sharks	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.42%	0.00%	1.42%	0.00%	1.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
13	*Sphyraena* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.33%	0.00%	1.33%	0.00%	1.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
14	*Thenus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.00%	0.55%	0.00%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.10%	0.43%
15	Lutjanidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	3.63%	0.00%	3.63%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
16	Plectochynchidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.89%	0.00%	0.89%	0.00%	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%	0.89%	0.10%	0.43%
17	Trichiuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.77%	0.00%	0.77%	0.00%	0.77%	0.00%	0.00%	0.00%	0.00%	0.00%	0.77%	0.10%	0.43%
18	Serranidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.94%	0.00%	0.94%	0.00%	0.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.94%	0.10%	0.43%
19	*Rastrelliger neglectus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.00%	0.15%	0.00%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.10%	0.15%
20	Crabs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%	0.00%	0.70%	0.00%	0.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%	0.10%	0.43%
21	*Lactarius lactarius*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.45%	0.00%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.10%	0.43%
22	Shrimps	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.10%	0.21%
23	*Pomadasys* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.00%	0.31%	0.00%	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.10%	0.31%

Table 2 (cont'd). Transition relation for MAX (0, MIN[x_o, d_y]) for 1966–1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
24	*Scomberomorus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.00%	0.47%	0.00%	0.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.10%	0.43%
25	*Pamus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.10%	0.21%
26	*Psettodes erumei*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.76%	0.00%	0.76%	0.00%	0.76%	0.00%	0.00%	0.00%	0.00%	0.00%	0.76%	0.10%	0.43%
27	*Chirocentrus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.00%	0.15%	0.00%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.10%	0.15%
28	*Rachycentron canadus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.18%	0.00%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.10%	0.18%
29	Lethrinidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.36%	0.00%	0.36%	0.00%	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.36%	0.10%	0.36%
30	*Muraenesox* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.00%	0.50%	0.00%	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.10%	0.50%
31	Rhinobatidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.00%	0.47%	0.00%	0.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.10%	0.43%
32	*Anadontostoma* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.18%	0.00%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.10%	0.18%
33	Genidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	5.16%	0.00%	5.16%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
34	*Rastrelliger kanagurta*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%	0.00%	0.32%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%	0.10%	0.32%
35	Bothidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.48%	0.00%	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.10%	0.43%
36	Cynoglossidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.09%	0.00%	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.09%	0.09%
37	*Sepia* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	2.14%	0.00%	2.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
38	Miscellaneous fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	9.44%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
max =>		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	13.72%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.50%

Table 2. (cont'd) Transition relation for MAX (0, MIN[x_o, d_y]) for 1966–1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	Leiognathidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	15.28%
2	Carangidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	7.55%
3	*Nemipterus* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	11.69%
4	Sciaenidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.99%
5	Mullidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	4.50%
6	Rays	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	7.38%
7	*Saurida* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	4.08%
8	Tachysuridae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.74%
9	*Loligo* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	6.14%
10	*Scolopsis* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	3.62%
11	*Priacanthus* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	3.11%
12	Sharks	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.42%
13	*Sphyraena* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.33%
14	*Thenus* spp.	0.55%	0.00%	0.55%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	0.55%
15	Lutjanidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.55%	0.55%
16	Plectorhynchidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	3.63%
17	Trichiuridae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	0.89%
18	Serranidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.77%	0.77%
19	*Rastrelliger neglectus*	0.15%	0.00%	0.15%	0.00%	0.15%	0.20%	0.00%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	0.94%
20	Crabs	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.00%	0.00%	0.15%	0.15%
21	*Luctarius lactarius*	0.45%	0.00%	0.45%	0.00%	0.45%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.70%	0.70%
22	Shrimps	0.21%	0.00%	0.21%	0.00%	0.21%	0.20%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.45%	0.45%
23	*Pomadasys* spp.	0.31%	0.00%	0.31%	0.00%	0.31%	0.20%	0.00%	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.31%	0.31%

Table 2. (cont'd) Transition relation for MAX (0, MIN{x_o, d_y}) for 1966–1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
24	*Scomberomorus* spp.	0.47%	0.00%	0.47%	0.00%	0.47%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.47%	0.47%
25	*Pamus* spp.	0.21%	0.00%	0.21%	0.00%	0.21%	0.20%	0.00%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.21%	0.21%
26	*Psettodes erumei*	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.76%	0.76%
27	*Chirocentrus* spp.	0.15%	0.00%	0.15%	0.00%	0.15%	0.20%	0.00%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.00%	0.00%	0.15%	0.15%
28	*Rachycentron canadus*	0.18%	0.00%	0.18%	0.00%	0.15%	0.20%	0.00%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.00%	0.18%	0.18%
29	Lethrinidae	0.36%	0.00%	0.36%	0.00%	0.36%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.36%	0.36%
30	*Muraenesox* spp.	0.18%	0.00%	0.50%	0.00%	0.18%	0.20%	0.00%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.00%	0.50%	0.50%
31	Rhinobatidae	0.47%	0.00%	0.47%	0.00%	0.47%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.47%	0.47%
32	*Anadontostoma* spp.	0.18%	0.00%	0.18%	0.00%	0.18%	0.20%	0.00%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.00%	0.18%	0.18%
33	Gerridae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	5.16%
34	*Rastrelliger kanagurta*	0.32%	0.00%	0.32%	0.00%	0.32%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.32%	0.32%
35	Bothiddae	0.48%	0.00%	0.48%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.48%	0.48%
36	Cynoglossidae	0.09%	0.00%	0.09%	0.00%	0.09%	0.20%	0.00%	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.00%	0.09%	0.09%
37	*Sepia* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	2.14%
38	Miscellaneous fish	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	9.44%
max =>		0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	15.28%

Table 3. Transition relation for MAX (0, dy - dx) for 1966-1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Leiognathidae	0.00%	3.60%	5.20%	6.40%	4.60%	1.00%	10.30%	6.50%	22.00%	5.70%	13.80%	7.10%	7.60%	7.90%	6.70%	7.70%	9.10%	8.30%	8.60%
2	Carangidae	0.00%	0.00%	1.60%	2.80%	1.00%	0.00%	6.70%	2.90%	18.40%	2.10%	10.20%	3.50%	4.00%	4.30%	3.10%	4.10%	5.50%	4.70%	5.00%
3	*Nemipterus* spp.	0.00%	0.00%	0.00%	1.20%	0.00%	0.00%	5.10%	1.30%	16.80%	0.50%	8.60%	1.90%	2.40%	2.70%	1.50%	2.50%	3.90%	3.10%	3.40%
4	Sciaenidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.90%	0.10%	15.60%	0.00%	7.40%	0.70%	1.20%	1.50%	0.30%	1.30%	2.70%	1.90%	2.20%
5	Mullidae	0.00%	0.00%	0.60%	1.80%	0.00%	0.00%	5.70%	1.90%	17.40%	1.10%	9.20%	2.50%	3.00%	3.30%	2.10%	3.10%	4.50%	3.70%	4.00%
6	Rays	0.00%	2.60%	4.20%	5.40%	3.60%	0.00%	9.30%	5.50%	21.00%	4.70%	12.80%	6.10%	6.60%	6.90%	5.70%	6.70%	8.10%	7.30%	7.60%
7	*Saurida* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.10%	0.00%	11.70%	0.00%	3.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	Tachysuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.80%	0.00%	15.50%	0.00%	7.30%	0.60%	1.10%	1.40%	0.20%	1.20%	2.60%	1.80%	2.10%
9	*Loligo* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	*Scolopsis* spp.	0.00%	0.00%	0.00%	0.70%	0.00%	0.00%	4.60%	0.80%	16.30%	0.00%	8.10%	1.40%	1.90%	2.20%	1.00%	2.00%	3.40%	2.60%	2.90%
11	*Priacanthus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.20%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	Sharks	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.20%	0.00%	14.90%	0.00%	6.70%	0.00%	0.50%	0.80%	0.00%	0.60%	2.00%	1.20%	1.50%
13	*Sphyraena* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.70%	0.00%	14.40%	0.00%	6.20%	0.00%	0.00%	0.30%	0.00%	0.10%	1.50%	0.70%	1.00%
14	*Thenus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.40%	0.00%	14.10%	0.00%	5.90%	0.00%	0.00%	0.00%	0.00%	0.00%	1.20%	0.40%	0.70%
15	Lutjanidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.60%	0.00%	15.30%	0.00%	7.10%	0.40%	0.90%	1.20%	0.00%	1.00%	2.40%	1.60%	1.90%
16	Plectorhynchidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.60%	0.00%	14.30%	0.00%	6.10%	0.00%	0.00%	0.20%	0.00%	0.00%	1.40%	0.60%	0.90%
17	Trichiuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.20%	0.00%	12.90%	0.00%	4.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	0.00%	0.00%
18	Serranidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.00%	0.00%	13.70%	0.00%	5.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.80%	0.10%	0.30%
19	*Rastrelliger neglectus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.70%	0.00%	13.40%	0.00%	5.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.00%	0.40%
20	Crabs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.50%	0.00%	13.20%	0.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.00%
21	*Lactarius lactarius*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.50%	0.00%	14.20%	0.00%	6.00%	0.00%	0.00%	0.10%	0.00%	0.00%	1.30%	0.50%	0.80%
22	Shrimps	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.40%	0.00%	13.10%	0.00%	4.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%
23	*Pomadasys* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.30%	0.00%	14.00%	0.00%	5.80%	0.00%	0.00%	0.00%	0.00%	0.00%	1.10%	0.30%	0.60%

Table 3 (cont'd). Transition relation for MAX (0, dy - dx) for 1966-1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
24	*Scomberomorus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.70%	0.00%	13.40%	0.00%	5.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.00%	0.00%
25	*Pamus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.90%	0.00%	13.60%	0.00%	5.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%	0.00%	0.20%
26	*Psettodes erumei*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.70%	0.00%	14.40%	0.00%	6.20%	0.00%	0.00%	0.30%	0.00%	0.10%	1.50%	0.70%	1.00%
27	*Chirocentrus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.80%	0.00%	13.50%	0.00%	5.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.60%	0.00%	0.10%
28	*Rachycentron canadus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.10%	0.00%	13.80%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	0.10%	0.40%
29	Lethrinidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.40%	0.00%	14.10%	0.00%	5.90%	0.00%	0.00%	0.00%	0.00%	0.00%	1.20%	0.40%	0.70%
30	*Muraenesox* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.30%	0.00%	14.00%	0.00%	5.80%	0.00%	0.00%	0.00%	0.00%	0.00%	1.10%	0.30%	0.60%
31	Rhinobatidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.50%	0.00%	14.20%	0.00%	6.00%	0.00%	0.00%	0.10%	0.00%	0.00%	1.30%	0.50%	0.80%
32	*Anadontostoma* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.20%	0.00%	13.90%	0.00%	5.70%	0.00%	0.00%	0.00%	0.00%	0.00%	1.00%	0.20%	0.50%
33	Gerridae	0.00%	0.50%	2.10%	3.30%	1.50%	0.00%	7.20%	3.40%	18.90%	2.60%	10.70%	4.00%	4.50%	4.80%	3.60%	4.60%	6.00%	5.20%	5.50%
34	*Rastrelliger kanagurta*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.90%	0.00%	13.60%	0.00%	5.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.70%	0.00%	0.20%
35	Bothidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.60%	0.00%	14.30%	0.00%	6.10%	0.00%	0.00%	0.20%	0.00%	0.00%	1.40%	0.60%	0.90%
35	Cynoglossidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.10%	0.00%	13.80%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	0.10%	0.40%
37	*Sepia* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.30%	0.00%	13.00%	0.00%	4.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.00%	0.00%
38	Miscellaneous fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
max =>		0.00%	3.60%	5.20%	6.40%	4.60%	1.00%	10.30%	6.50%	22.00%	5.70%	13.80%	7.10%	7.60%	7.90%	6.70%	7.70%	9.10%	8.30%	8.60%

Table 3. (cont'd) Transition relation for MAX (0, dy - dx) for 1966-1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	Leiognathidae	8.80%	7.80%	8.00%	8.00%	8.60%	8.40%	7.60%	8.50%	8.20%	7.90%	8.00%	7.80%	8.10%	3.10%	8.40%	7.70%	8.20%	9.00%	27.50%
2	Carangidae	5.20%	4.20%	5.30%	4.40%	5.00%	4.80%	4.00%	4.90%	4.60%	4.30%	4.40%	4.20%	4.50%	0.00%	4.80%	4.10%	4.60%	5.40%	23.90%
3	*Nemipterus* spp.	3.60%	2.60%	3.70%	2.80%	3.40%	3.20%	2.40%	3.30%	3.00%	2.70%	2.80%	2.60%	2.90%	0.00%	3.20%	2.50%	0.30%	3.80%	22.30%
4	Sciaenidae	2.40%	1.40%	2.50%	1.60%	2.20%	2.00%	1.20%	2.10%	1.80%	1.50%	1.60%	1.40%	1.70%	0.00%	2.00%	1.30%	1.80%	2.60%	21.10%
5	Mullidae	4.20%	3.20%	4.30%	3.40%	4.00%	3.80%	3.00%	3.90%	3.60%	3.30%	3.40%	3.20%	3.50%	0.00%	3.80%	3.10%	3.60%	4.40%	22.90%
6	Rays	7.80%	6.80%	7.90%	7.00%	7.60%	7.40%	6.60%	7.50%	7.20%	6.90%	7.00%	6.80%	7.10%	2.10%	7.40%	6.70%	7.20%	8.00%	26.50%
7	*Saurida* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	17.20%
8	Tachysuridae	2.30%	1.30%	2.40%	1.50%	2.10%	1.90%	1.10%	2.00%	1.70%	1.40%	1.50%	1.30%	1.60%	0.00%	1.90%	1.20%	1.70%	2.50%	21.00%
9	*Loligo* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.50%
10	*Scolopsis* spp.	3.10%	2.10%	3.20%	2.30%	2.90%	2.70%	1.90%	2.80%	2.50%	2.20%	2.30%	2.10%	2.40%	0.00%	2.70%	2.00%	2.50%	3.30%	21.80%
11	*Priacanthus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.70%
12	Sharks	1.70%	0.70%	1.80%	0.90%	1.50%	1.30%	0.50%	1.40%	1.10%	0.80%	0.90%	0.70%	1.00%	0.00%	1.30%	0.60%	1.10%	1.90%	20.40%
13	*Sphyraena* spp.	1.20%	0.20%	1.30%	0.40%	1.00%	0.80%	0.00%	0.90%	0.60%	0.30%	0.40%	0.20%	0.50%	0.00%	0.80%	0.10%	0.60%	1.40%	19.90%
14	*Thenus* spp.	0.90%	0.00%	1.00%	0.10%	0.70%	0.50%	0.00%	0.60%	0.30%	0.00%	0.10%	0.00%	0.20%	0.00%	0.50%	0.00%	0.30%	1.10%	19.60%
15	Lutjanidae	2.10%	1.10%	2.20%	1.30%	1.90%	1.70%	0.90%	1.80%	1.50%	1.20%	1.30%	1.10%	1.40%	0.00%	1.70%	1.00%	1.50%	2.30%	20.80%
16	Plectorhynchidae	1.10%	0.10%	1.20%	0.30%	0.90%	0.70%	0.00%	0.80%	0.50%	0.20%	0.30%	0.10%	0.40%	0.00%	0.70%	0.00%	0.50%	1.30%	19.80%
17	Trichiuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.40%
18	Serranidae	0.00%	0.00%	0.60%	0.00%	0.30%	0.10%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.60%	0.10%	0.00%	0.00%	0.70%	19.20%
19	*Rastrelliger neglectus*	0.20%	0.00%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	18.90%
20	Crabs	0.60%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	18.70%
21	*Lactarius lactarius*	1.00%	0.00%	1.10%	0.20%	0.80%	0.60%	0.00%	0.70%	0.40%	0.10%	0.20%	0.00%	0.30%	0.00%	0.60%	0.00%	0.40%	1.20%	19.70%
22	Shrimps	0.00%	0.00%	0.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	18.60%
23	*Pomadasys* spp.	0.80%	0.00%	0.90%	0.00%	0.60%	0.40%	0.00%	0.50%	0.20%	0.00%	0.00%	0.00%	0.10%	0.00%	0.40%	0.00%	0.20%	1.00%	19.50%

Table 3. (cont'd) Transition relation for MAX (0, dy - dx) for 1966-1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
24	*Scomberomorus* spp.	0.20%	0.30%	0.00%	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	18.90%
25	*Pamus* spp.	0.40%	0.00%	0.50%	0.00%	0.20%	0.20%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.60%	19.10%
26	*Psettodes erumei*	1.20%	0.20%	1.30%	0.40%	1.00%	0.80%	0.00%	0.90%	0.60%	0.30%	0.40%	0.20%	0.50%	0.00%	0.80%	0.10%	0.60%	1.40%	19.90%
27	*Chirocentrus* spp.	0.30%	0.00%	0.40%	0.00%	0.10%	0.00%	0.00%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	19.00%
28	*Rachycentron canadus*	0.60%	0.00%	0.70%	0.00%	0.40%	0.20%	0.00%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.80%	19.30%
29	Lethrinidae	0.90%	0.00%	1.00%	0.10%	0.70%	0.50%	0.00%	0.60%	0.30%	0.00%	0.10%	0.00%	0.20%	0.00%	0.50%	0.00%	0.30%	1.10%	19.60%
30	*Muraenesox* spp.	0.80%	0.00%	0.90%	0.00%	0.60%	0.40%	0.00%	0.50%	0.20%	0.00%	0.00%	0.00%	0.10%	0.00%	0.40%	0.00%	0.20%	1.00%	19.50%
31	Rhinobatidae	1.00%	0.00%	1.10%	0.20%	0.80%	0.60%	0.00%	0.70%	0.40%	0.10%	0.20%	0.00%	0.20%	0.00%	0.60%	0.00%	0.40%	1.20%	19.70%
32	*Anadontostoma* spp.	0.70%	0.00%	0.80%	0.00%	0.50%	0.30%	0.00%	0.40%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.10%	0.90%	19.40%
33	Gerridae	5.70%	4.70%	5.80%	4.90%	5.50%	5.30%	4.50%	5.40%	5.10%	4.80%	4.90%	4.70%	5.00%	0.00%	5.30%	4.60%	5.10%	5.90%	24.40%
34	*Rastrelliger kanagurta*	0.40%	0.00%	0.50%	0.00%	0.20%	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.60%	19.10%
35	Bothidae	1.10%	0.10%	1.20%	0.30%	0.90%	0.70%	0.00%	0.80%	0.50%	0.20%	0.30%	0.10%	0.40%	0.00%	0.70%	0.00%	0.50%	1.30%	19.80%
36	Cynoglossidae	0.60%	0.00%	0.70%	0.00%	0.40%	0.20%	0.00%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.80%	19.30%
37	*Sepia* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.80%	18.50%
38	Miscellaneous fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	19.30%
max =>		8.80%	7.80%	8.00%	8.00%	8.60%	8.40%	7.60%	8.50%	8.20%	7.90%	8.00%	7.80%	8.10%	3.10%	8.40%	7.70%	8.20%	9.00%	27.50%

Table 4. Transiton relation for MAX (0, MIN [-dx, dy]) for 1966-1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Leiognathidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	8.20%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
2	Carangidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	4.55%	0.00%	4.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
3	*Nemipterus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	2.99%	0.00%	2.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
4	Sciaenidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.82%	0.00%	1.82%	0.00%	1.82%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
5	Mullidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	3.65%	0.00%	3.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
6	Rays	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	7.12%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
7	*Saurida* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
8	Tachysuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.70%	0.00%	1.70%	0.00%	1.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
9	*Loligo* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
10	*Scolopsis* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	2.51%	0.00%	2.51%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	*Priacanthus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
12	Sharks	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.14%	0.00%	1.14%	0.00%	1.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13	*Sphyraena* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.64%	0.00%	0.64%	0.00%	0.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
14	*Thenus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.00%	0.27%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.64%	0.10%	0.43%
15	Lutjanidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.58%	0.00%	1.58%	0.00%	1.58%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.10%	0.27%
16	Plectorhynchidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.50%	0.00%	0.55%	0.00%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
17	Trichiuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.10%	0.43%
18	Serranidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	0.00%	0.00%
19	*Rastrelliger neglectus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.00%
20	Crabs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.43%
21	*Lactarius lactarius*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.45%	0.00%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	Shrimps	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.10%	0.43%
23	*Pomadasys* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.20%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.10%	0.20%

Table 4 (cont'd). Transiton relation for MAX (0, MIN [-dx, dy]) for 1966-1982.

ID #	Groups identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
24	*Scomberomorus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
25	*Panus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
26	*Psettodes erumei*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.00%	0.55%	0.00%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.10%	0.^3%
27	*Chirocentrus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
28	*Rachycentron canadus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
29	Lethrinidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.00%	0.27%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.10%	0.27%
30	*Muraenesox* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.10%	0.20%
31	Rhinobatidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.00%	0.47%	0.00%	0.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	0.10%	0.43%
32	*Anadontostoma* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	0.11%	0.00%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.10%	0.11%
33	Gerridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	5.07%	0.00%	5.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%
34	*Rastreiliger kanagurta*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
35	Bothiddae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.48%	0.00%	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.10%	0.43%
36	Cynoglossidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
37	*Sepia* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
38	Miscellaneous fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
max =>		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.82%	0.00%	7.63%	0.00%	5.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.96%	0.10%	0.43%

Table 4. (cont'd) Transition relation for MAX (0, MIN [-dx, dyj) for 1966-1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	Leiognathidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	8.20%
2	Carangidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	4.55%
3	*Nemipterus* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	2.99%
4	Sciaenidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.82%
5	Mullidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	3.65%
6	Rays	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	7.12%
7	*Saurida* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	0.00%
8	Tachysuridae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.74%
9	*Loligo* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	*Scolopsis* spp.	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	2.51%
11	*Priacanthus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	Sharks	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.14%
13	*Sphyraena* spp.	0.61%	0.00%	0.64%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.64%	0.64%
14	*Thenus* spp.	0.27%	0.00%	0.27%	0.00%	0.27%	0.20%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.27%	0.27%
15	Lutjanidae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	1.58%
16	Plectorhynchidae	0.61%	0.00%	0.50%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.50%	0.55%
17	Trichiuridae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
18	Serranidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	*Rastrelliger neglectus*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	Crabs	0.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	*Lactarius lactarius*	0.45%	0.00%	0.45%	0.00%	0.45%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.45%	0.45%
22	Shrimps	0.00%	0.00%	0.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
23	*Pomadasys* spp.	0.20%	0.00%	0.20%	0.00%	0.20%	0.20%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.20%	0.20%

Table 4. (cont'd) Transiton relation for MAX (0, MIN [-dx, dy]) for 1966-1982.

ID #	Groups identified	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
24	*Scomberomorus* spp.	0.00%	0.00%	0.00%	0.00%	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
25	*Panus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
26	*Psettodes erumei*	0.55%	0.00%	0.55%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
27	*Chirocentrus* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.55%	0.55%
28	*Rachycentron canadus*	0.02%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.00%	0.00%
29	Lethrinidae	0.27%	0.00%	0.27%	0.00%	0.27%	0.20%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%
30	*Muraenesox* spp.	0.20%	0.00%	0.20%	0.00%	0.20%	0.20%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.27%	0.27%
31	Rhinobatidae	0.47%	0.00%	0.47%	0.00%	0.47%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.20%	0.20%
32	*Anadontostoma* spp.	0.11%	0.00%	0.11%	0.00%	0.11%	0.20%	0.00%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.47%	0.47%
33	Gerridae	0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%	0.11%	0.11%
34	*Rastrelliger kanagurta*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.79%	5.07%
35	Bothiddae	0.48%	0.00%	0.48%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%
36	Cynoglossidae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.48%	0.48%
37	*Sepia* spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
38	Miscellaneous fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.79%	0.00%
max =>		0.61%	0.00%	0.65%	0.00%	0.48%	0.20%	0.00%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.00%	0.79%	19.30%

Figure 1. Fuzzy graph of succession for three levels of threshold (α) for the period 1966-1982. For $R_{x,y} = MAX\ (0, MIN\ [x_o, d_y])$, $d_y = y_1 - y_o$. The lower case letters refer to the three threshold values used. Connections between the bottom tier and middle tier numbers should resemble those of species (group) 13. They were omitted for clarity of presentation.

Figure 2. Fuzzy graph of succession for threshold (α) of 0.05 for the period 1966-1982. For $x \neq y$, $R_{x,y} = MAX\ (0, d_y - d_x)$; for $x = y$, $R_{x,y} = MAX\ (0, d_x)$. Connections among numbered species (groups) are incomplete between tier 4 and 5, as well as between tier 4 and 3 for clarity of presentation.

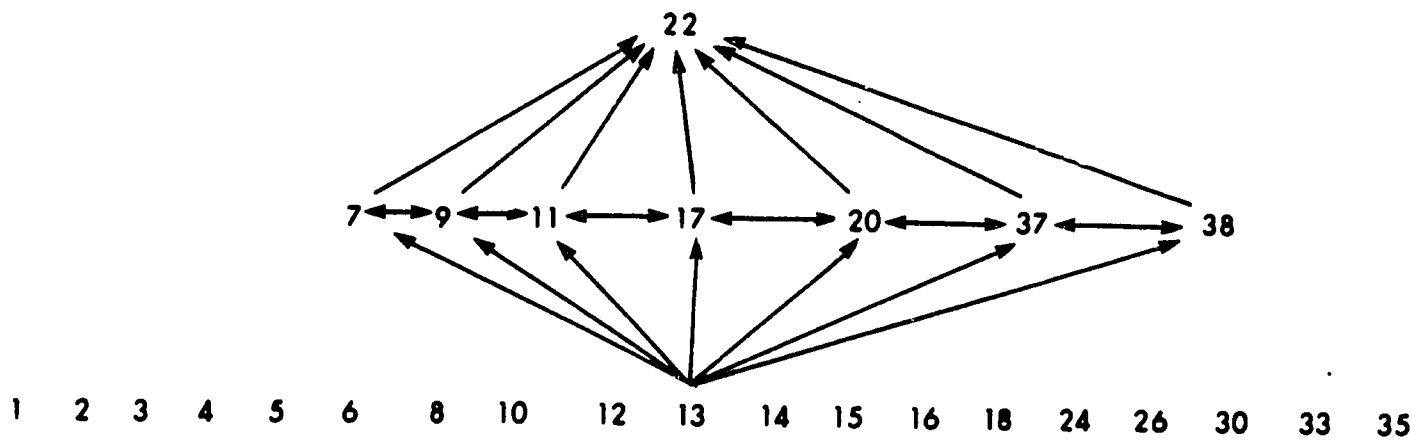
Figure 3. Fuzzy graph of succession for three levels of threshold (α) for the period 1966-1982. For $R_{x,y} = MAX\ (0, MIN\ [-d_x, d_y])$. Connections between numbered groups in Figure 3a are incomplete for clarity of presentation.

Figure 4. Fuzzy graphs based on two thresholds (0.025 and 0.05) for time-variance analysis for two periods (1961-1966 and 1966-1972). For $R_{x,y} = MAX\ (0, MIN\ [-d_x, d_y])$

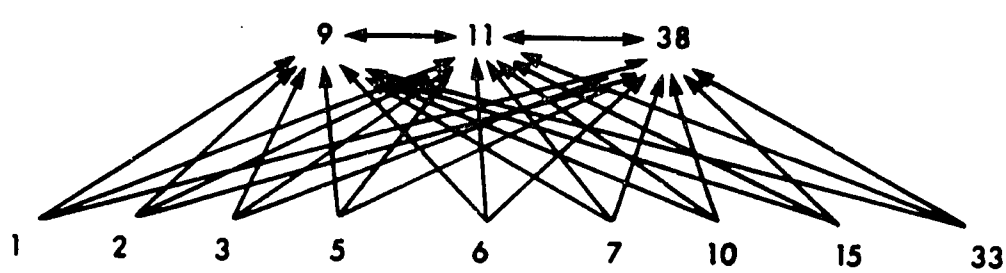
Figure 1

MODEL 1 (1966-1982)

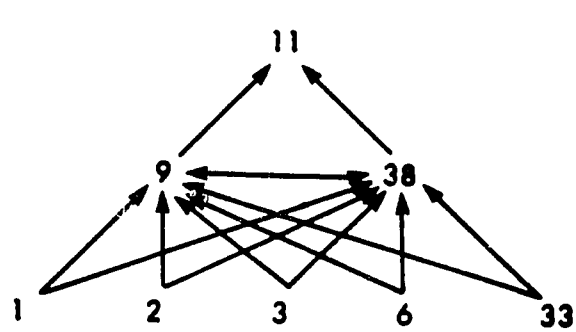
a) $\alpha = 0.005$



b) $\alpha = 0.025$

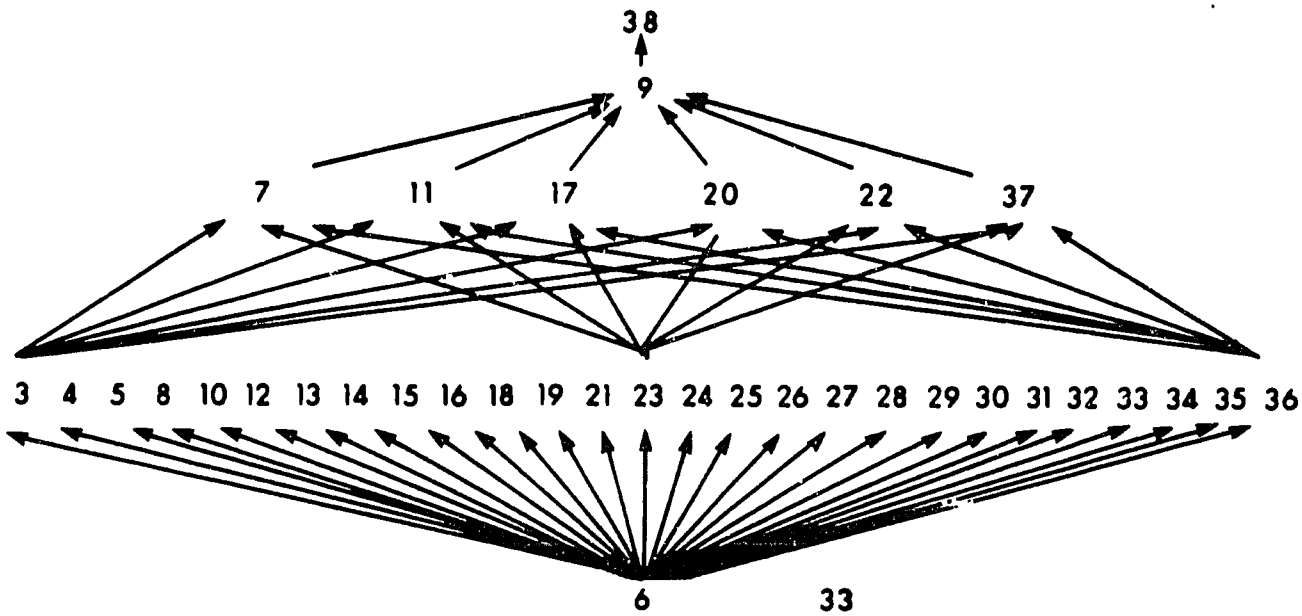


c) $\alpha = 0.05$



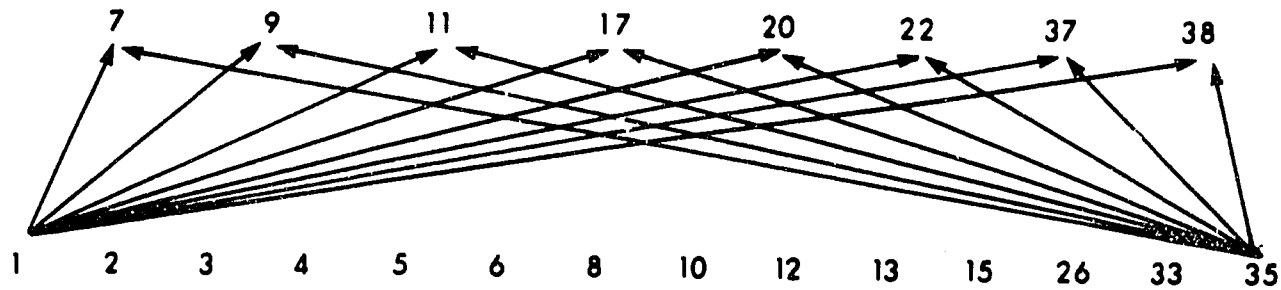
MODEL 2 (1966-1982)

$\alpha = 0.05$

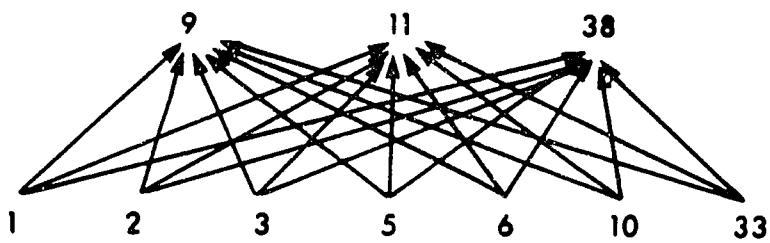


MODEL 3 (1966-1982)

a) $\alpha = 0.005$



b) $\alpha = 0.025$



c) $\alpha = 0.05$

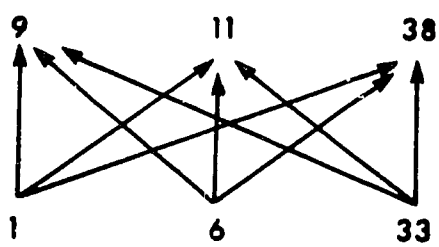
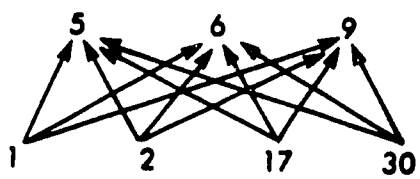


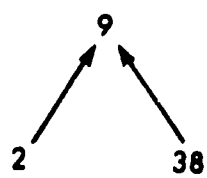
Figure 4

MODEL 3

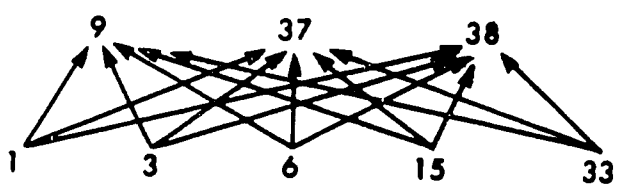
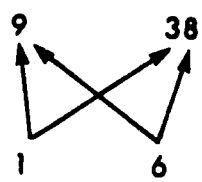
α = 0.025 (1961-1966)



α = 0.05 (1961-1966)



α = 0.025 (1966-1972)



α = 0.05 (1966-1972)