FISH SPECIES DIVERSITY ON MODEL AND NATURAL PATCH REEFS: EXPERIMENTAL INSULAR BIOGEOGRAPHY

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FISH SPECIES DIVERSITY ON MODEL AND NATURAL PATCH REEFS: EXPERIMENTAL INSULAR BIOGEOGRAPHY

by

Manuel Carl Molles, Jr.

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I hereby recommend that this dissertation prepared under my direction by Manuel Carl Molles, Jr.

entitled Fish Species Diversity on Model and Natural Patch Reefs: Experimental Insular Biogeography

be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

D A Thomson
Dissertation Director

8 Dec. 1975
Date

After inspection of the final copy of the dissertation, the following members of the Final Examination Committee concur in its approval and recommend its acceptance:*

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*This approval and acceptance is contingent on the candidate's adequate performance and defense of this dissertation at the final oral examination. The inclusion of this sheet bound into the library copy of the dissertation is evidence of satisfactory performance at the final examination.

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SIGNED: Manuel C Molles Jr.

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ABSTRACT

Fish communities of model and natural patch reefs were examined to test the effects of heterogeneity, area and isolation on the properties of insular systems. The relative effects of season and succession on the structure of fish communities of model patch reefs were also examined. Patterns of fish immigration and extinction were followed to determine if numbers of fish species in these habitats can be viewed as a balance between immigration and local extinction.

Virtually no positive relationship was found between reef heterogeneity (interspace size diversity) and fish species diversity or richness on either model or natural patch reefs. Interspace size diversity had no significant effects on the species composition of fish communities on the model patch reefs. A slightly higher mean number of individuals was recorded on small interspace model reefs.

Significant positive correlations were found between reef area and fish species richness on natural patch reefs for late spring and midsummer censuses. Significant positive correlations between reef height and fish species

richness were found for midsummer censuses. The combination of reef height and area were consistent predictors of fish species diversity on natural patch reefs. The vertical distributions of selected fish species on the model patch reefs support the conclusion that vertical zonation is a means of resource partitioning in patch reef fish communities.

A negative correlation was found between reef isolation and fish species richness on natural patch reefs in most of the cases examined. However, the negative correlation between reef isolation and fish species diversity appeared to be stronger prior to summer colonization.

Significant seasonal fluctuations in numbers of individuals and species on the model patch reefs were observed. Fish species diversity on the model patch reefs was subject to less seasonal fluctuation. A similar pattern of fluctuations in these parameters was observed on the natural patch reefs. Season had more of an effect on the structure of fish communities on the model patch reefs than did succession.

Immigration and local extinction of fish species occurred on the model patch reefs throughout the study. The relationships between rates of immigration and extinction and the number of fish species on the model patch reefs were similar to the predictions of the MacArthur-Wilson equilibrium model of insular zoogeography during the summer months of the study when species turnover was highest.

CHAPTER 1

INTRODUCTION

The study of island biogeography was largely descriptive until the publication of MacArthur and Wilson's (1963) equilibrium theory of insular zoogeography. Their model viewed the number of species on an island as the result of a balance between immigration and extinction. Rates of immigration and extinction were predicted to be dependent upon island area and isolation. Immigration rates were predicted to fall off with increased isolation and extinction rates to decrease with increased island area. In addition, it was postulated (MacArthur and Wilson 1967, p. 8) that area does not exert a direct influence on species diversity but that its effects are related to the addition of new habitats with increased area.

Since the appearance of the MacArthur-Wilson model, the study of island biogeography has become increasingly theoretical and experimental. In this period of time, the effects of island size and isolation have received the greatest amount of research attention (for review see Simberloff 1974). The main focus of the present study was therefore, the relationship between island, spatial heterogeneity and species diversity.

The study of spatial heterogeneity is mainly concerned with a search for those environmental variables relevant to the prediction of community structure. It involves a search for those resources being subdivided in a particular community. For example, MacArthur and MacArthur (1961) and Recher (1969) found forest, bird species diversity to be most highly correlated with foliage height diversity. The species diversity of the forest vegetation was irrelevant to the prediction of bird species diversity. Presumably, vertical foraging zones are a means of resource partitioning in these forest bird communities. However, bird communities in desert scrub appear to be organized in an entirely different fashion. Bird species diversity in desert scrub was found to be most highly correlated with physiognomic coverage diversity (Tomoff 1974), not foliage height diversity. It seems that the members of these bird communities utilize specific plant growth forms (spinescent, succulent etc.) for nesting and foraging.

Studying the effects of spatial heterogeneity on island communities is therefore, working at the point of convergence of two sets of theory. The first views diversity on islands as the result of the processes of colonization and extinction (MacArthur and Wilson 1963, 1967). The other body of theory is concerned with competition and treats numbers of coexisting species as the outcome of competition for limited resources (MacArthur and Levins 1967, Levins 1968, Vandermeer 1970, May 1973, Roughgarden 1974 and Pulliam 1975). Clearly, these theories do not deal with independent phenomena. The possibility of working toward their synthesis should stimulate research in this area.

The island systems chosen for study were patch reef, fish communities. Patch reefs are patches of solid substrate (coral, rock or man made materials) that are isolated from other reefs by sand or mud flats. Their physical isolation places them in the category of small scale insular systems as defined by several authors (e.g., Cairns et al. 1969, Maguire 1971, Schoener 1974, Brown and Kodric-Brown n.d., etc.). Their small size and isolation also eases sampling and characterization of the associated fish community. As in the case of other islands, patch reefs vary in size, degree of isolation and structure. The effects of these variables (particularly structure) on the diversity of associated fish communities is the subject of the present investigation.

The aspect of patch reef heterogeneity which I chose for intensive study was interspace size diversity.

Interspaces (pockets or invaginations in a reef surface) serve as shelter, spawning and foraging sites for fishes. They are therefore of potentially great importance in determining the distribution of reef fishes. Despite speculation by several authors on the importance of interspace or shelter availability in determining the structure of reef fish communities (e.g., Randall 1963, Storr 1964, Smith and Tyler 1972), a search of the literature reveals very few studies that have dealt specifically with the effects of interspace variety on fish communities. McVey (1970) found higher fish diversity and biomass in reef areas that had a higher complexity of concrete pipe shelter arrangement. Hiatt and Strasburg (1960) found more species of fish associated with coral heads with many interspaces for shelter than coral heads with few or no interspaces. Risk (1972) found a significant positive correlation between coral reef topographic complexity and fish species diversity (presumably topographic complexity is related to interspace diversity).

Another aspect of reef heterogeneity examined is patch reef height. Aquarium experiments have shown that some fishes are more attracted to reef models of higher relief (Ogawa and Onada 1966, Ogawa 1967). These results are supported by the field observations of Kami (1971) who recorded more fishes on a high relief artificial reef than on one of lower profile. A positive correlation has also been found between coral reef height diversity and numbers of fish species (Frantz and Swank 1975).

The effects of patch reef area and isolation on fish species diversity are also explored in the present study. The relationship between these two factors and species diversity has been investigated in several insular systems (Simberloff 1974). However, the relationships between patch reef area and isolation and fish species diversity are virtually unexplored topics.

Seasonal and successional effects are investigated to assess the relative contributions of these two factors to the structure of patch reef, fish communities. Hedgepeth (1957) concluded that season is a more pervasive factor than succession in marine communities and that the physical and biological changes taking place during marine succession are small and rapid when compared to the results of terrestrial and freshwater succession. However, he ignored succession in mangrove, saltmarsh and coral reef communities and succession in tropical marine communities in general. McVey (1970) and Tsuda and Kami (1973) found succession to be the dominant factor determining the structure of algal and invertebrate communities on some tropical artificial reefs. McVey (1970) also found successional changes in fish biomass, numbers and species composition on

Hawaiian artificial reefs. In contrast, Hastings (1972) found season to be the dominant factor controlling the number of fish species on a Gulf of Mexico jetty. The difference between the results of these investigations is undoubtedly due to differences in the seasonality of the study areas.

In summary, the following are the main objectives of the study:

1. Examine the relationship between interspace size diversity and fish species richness and diversity on model and natural patch reefs.

2. Determine the effects of interspaces on fish species composition and number of individuals in the fish communities of model patch reefs.

3. Examine the relationship between reef area, height and isolation and fish species richness and diversity on natural patch reefs.

4. Examine the effects of season and succession on the structure of the fish communities of model patch reefs.

5. Determine whether numbers of coexisting fish species on model patch reefs can be viewed as a balance between immigration and extinction.

CHAPTER 2

MATERIALS AND METHODS

All work was done in the Guaymas-San Carlos area of the central Gulf of California (Fig. 1). The Gulf is a long, narrow sea extending from the Colorado River delta in the north to an imaginary line demarcating its southern mouth at approximately 22° north latitude. The western boundary of the Gulf is formed by the Baja California peninsula. The Mexican mainland states of Sonora and Sinaloa form its eastern coastline.

Model Patch Reef Study Area

Bahia Bacochibampo, near Guaymas, Sonora, Mexico, was the site of the model patch reef study (Fig. 2). Bahia Bacochibampo is a well protected embayment. The mouth of the bay is approximately two kilometers in width. Its maximum depth is 18 meters and its shoreline is fringed with rocky reefs. The floor of the bay is mostly sand or mud with some scattered patch reefs.

Model Patch Reef Construction and Placement

Three structural types of model patch reefs were constructed using concrete blocks and Portland cement

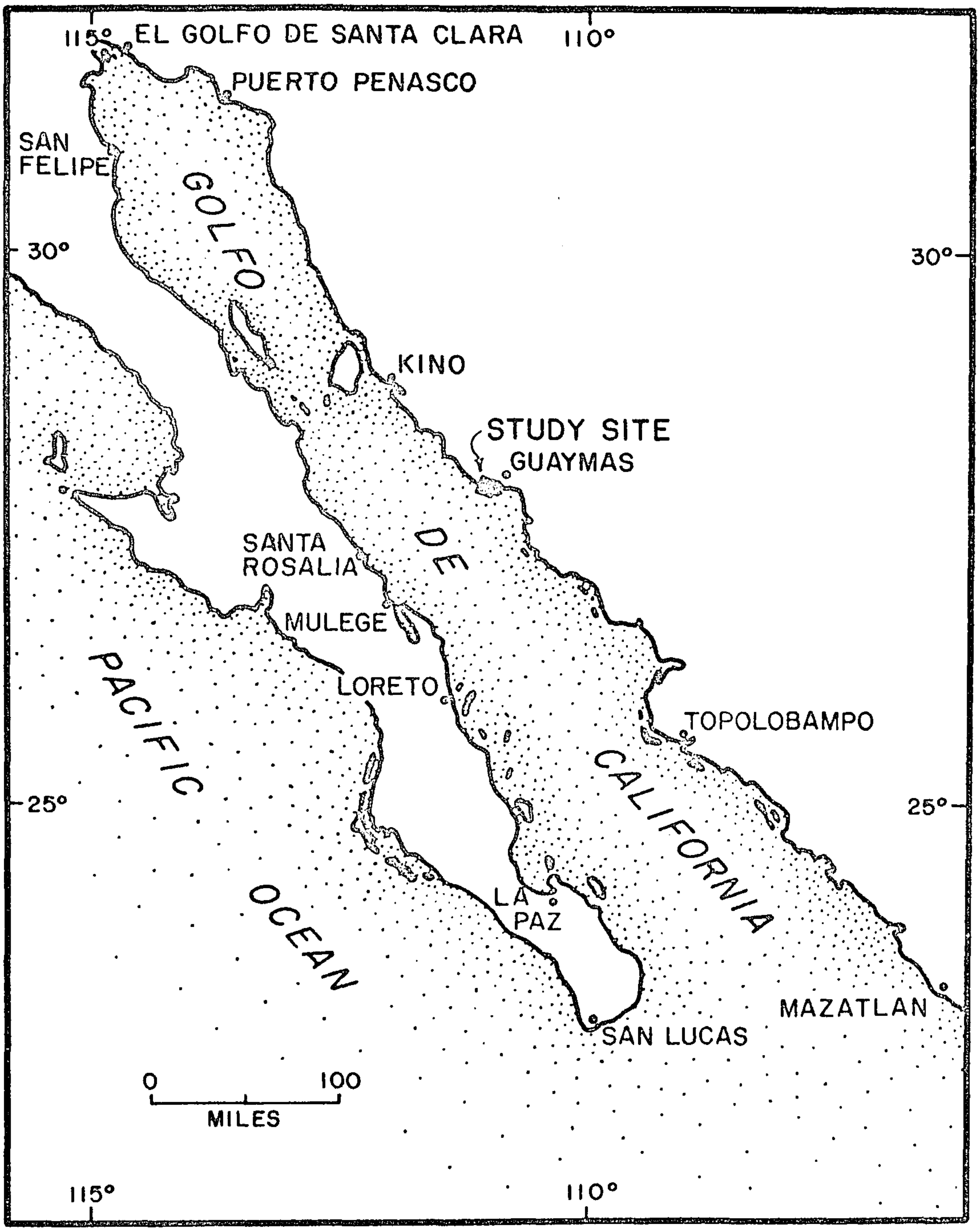

Fig. 1. Map of the Gulf of California showing the Guaymas study site.

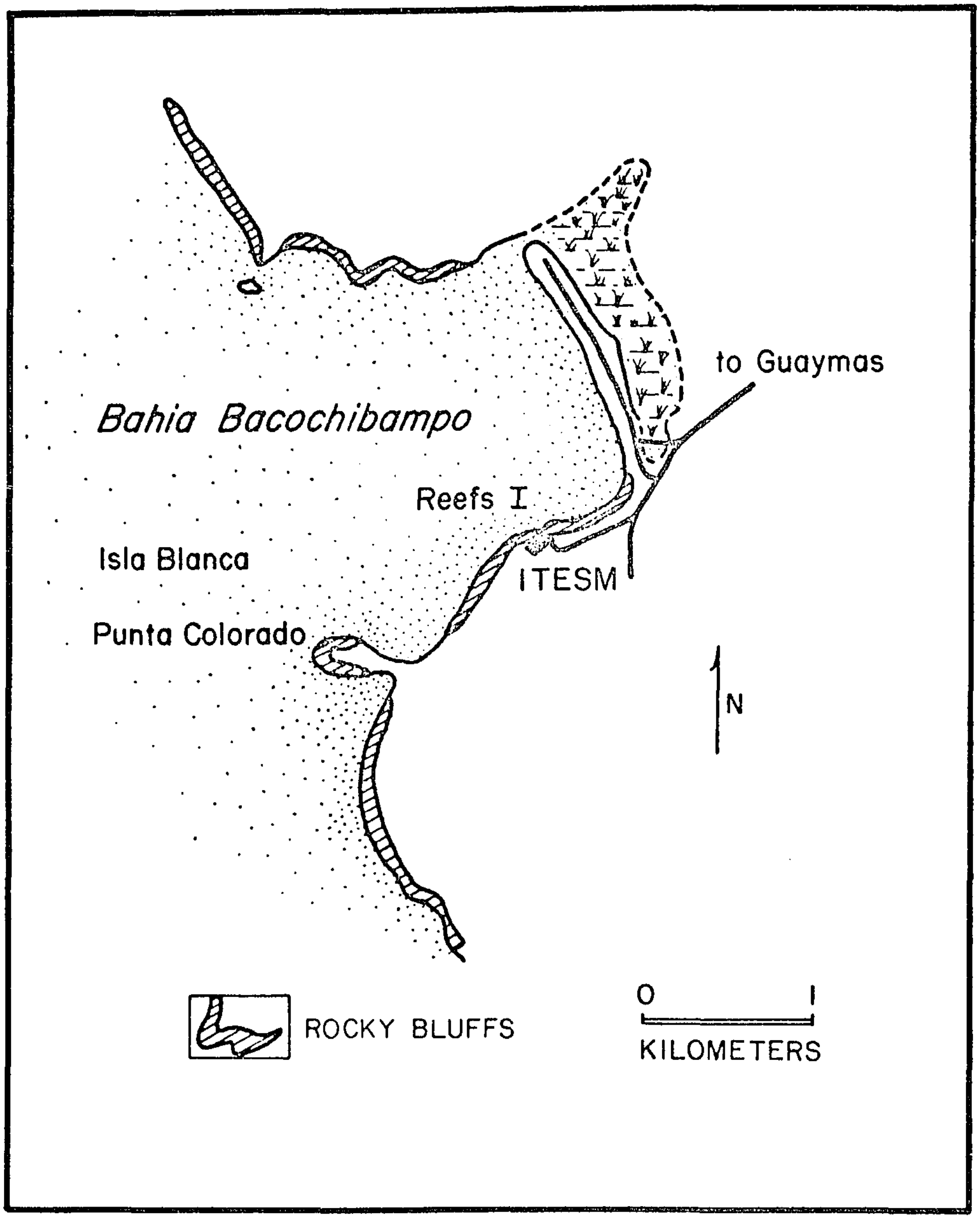

Fig. 2. Map of Bahia Bacochibampo showing model reef placement area.

(Figs. 3 and 4). The reef types were: (1) large interspace (L), (2) small interspace (S), and (3) mixed interspace (M). Reef type L had 12 large interspaces with cross sectional areas of 179 cm^2 and lengths of 38 cm. Reef type S contained 60 small interspaces with cross sectional areas of 5.2 cm^2 and lengths of 38 cm. Reef type M had 30 small and 6 large interspaces of the dimensions given above. All interspaces were open at both ends. The total surface areas of reef types L, S and M were approximately the same (4.5, 4.8 and 4.7 m^2 respectively).

Interspace dimensions were planned to accommodate the local, reef fish fauna. The larger interspaces were intended to accommodate larger fishes such as sea basses and scorpionfishes. The smaller interspaces were intended for habitation by small blennioid and gobioid fishes.

Three replicates of each type of model patch reef were placed in Bahia Bacochibampo with the permission of Dr. Henry Schafer, Director of the Instituto Tecnologico de Alimentos y Escuela de Estudias Superiores de Monterrey (ITESM) of Guaymas, Sonora, Mexico. They were placed in open sand in a line (30^{o} east of north) parallel to a line of natural patch reefs (Fig. 5). Positioning was done with a 10-meter measuring line and a hand-held, underwater compass. These nine reefs were lowered into place as

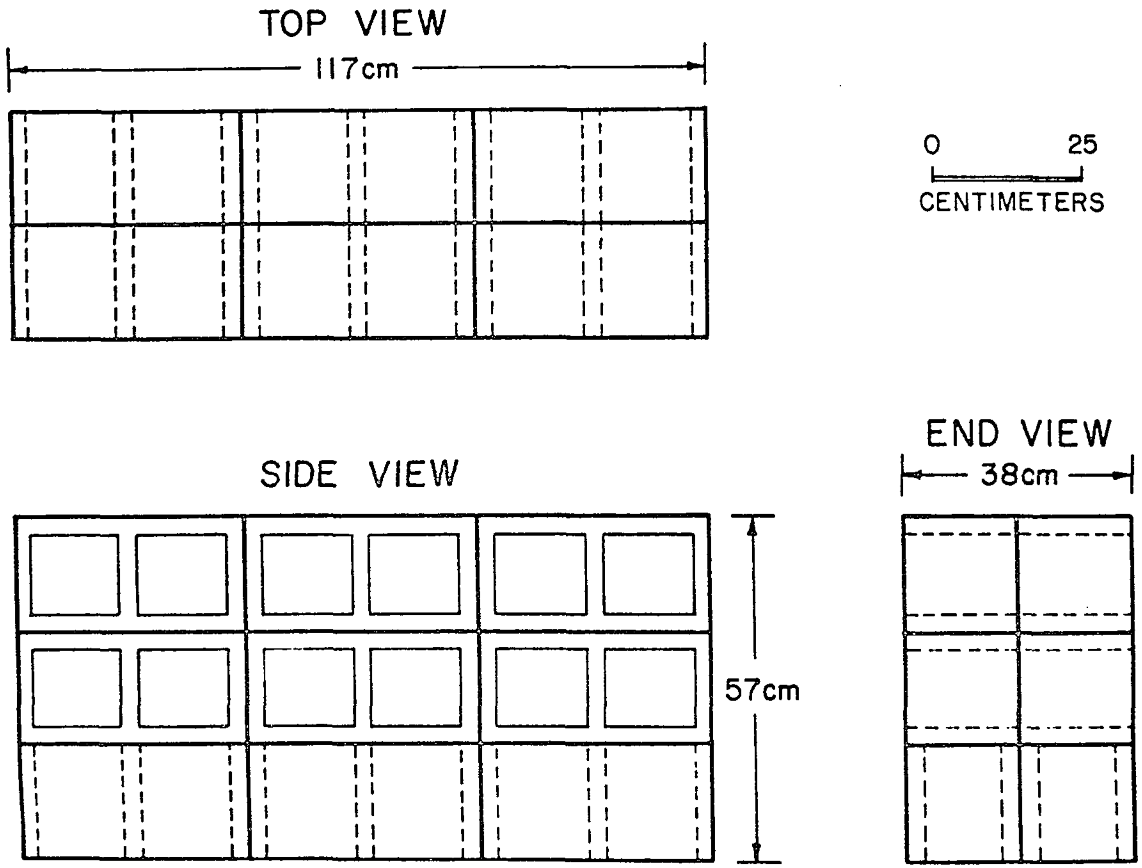

Fig. 3. Basic model reef design.

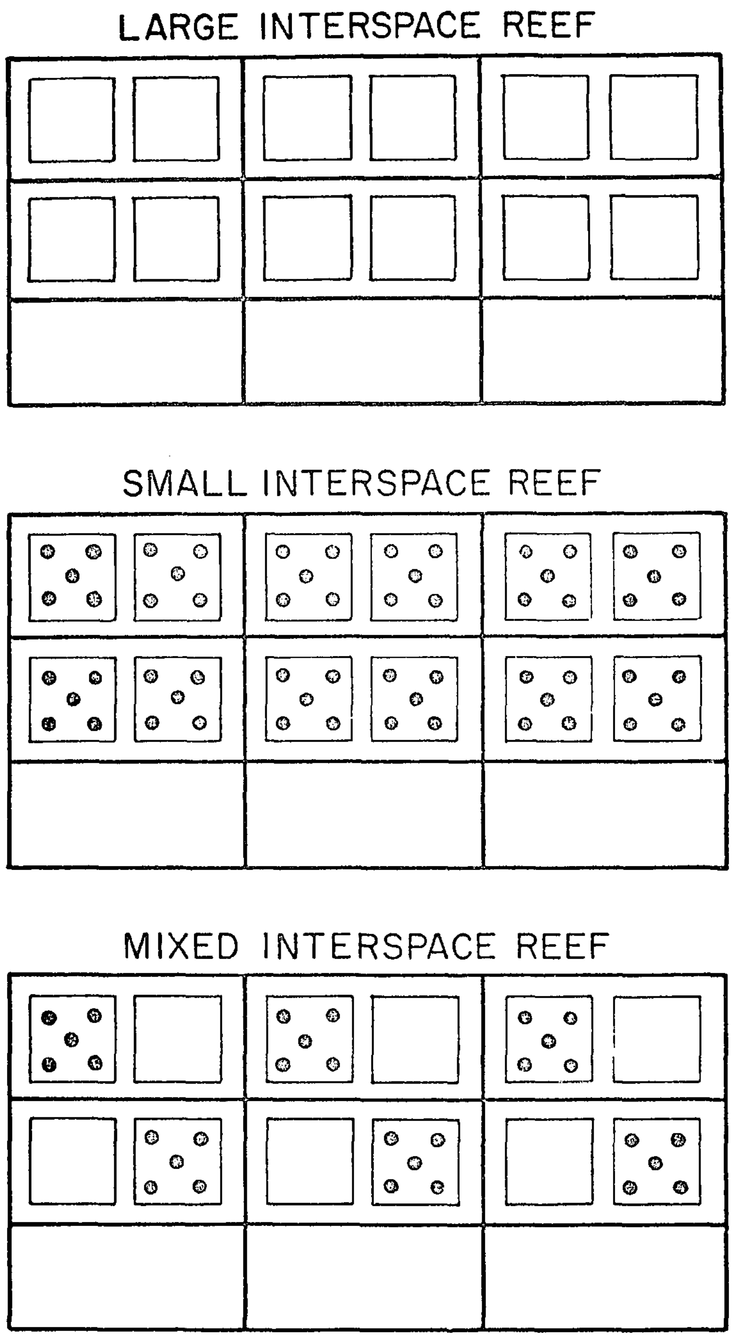

Fig. 4. Large, small, and mixed interspace reef types.

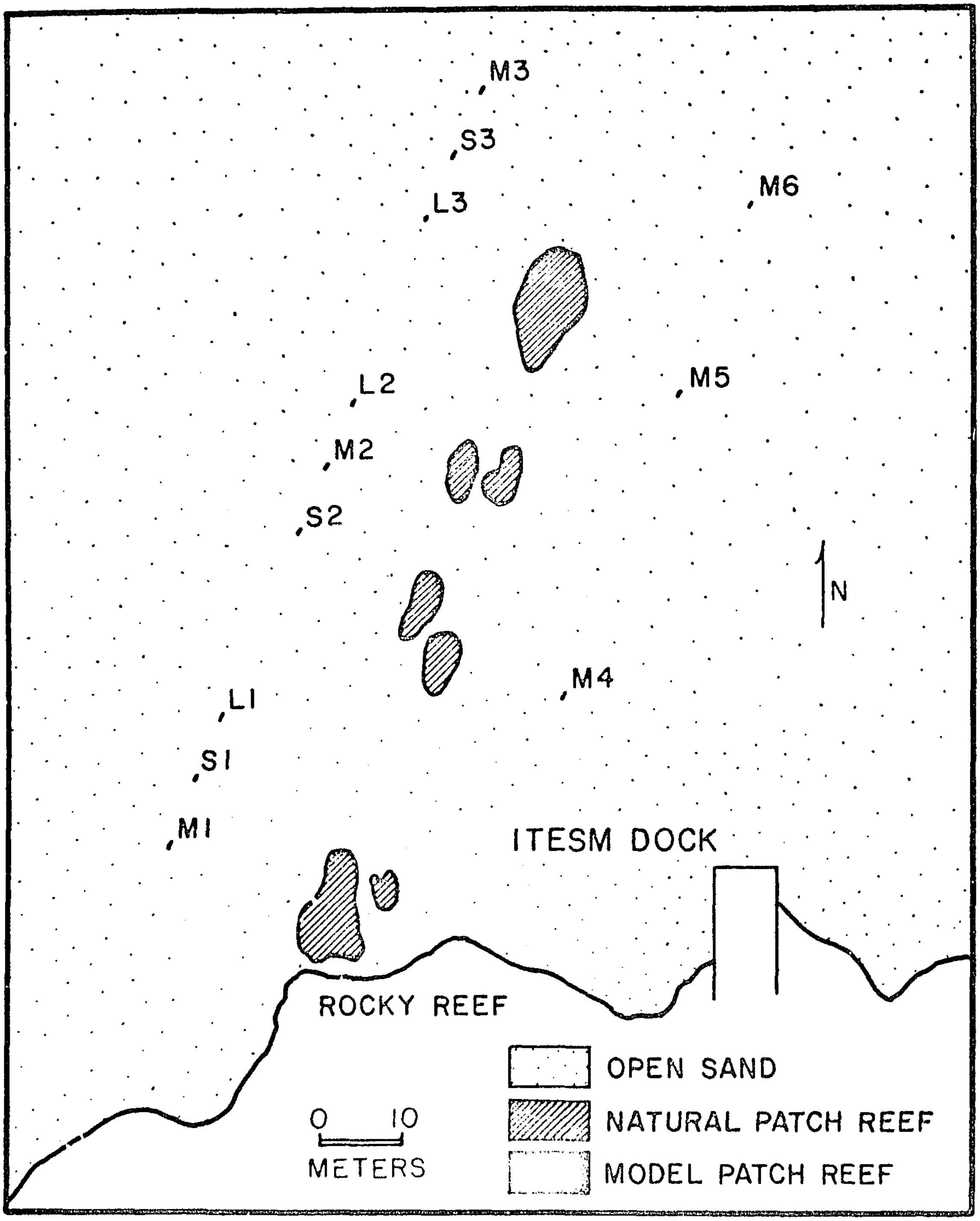

Fig. 5. Diagrammatic map of model reef placement area showing positions of winter-placed reefs (L1-3, S1-3 and M1-3) and summer-placed reefs (M4-6).

individual blocks on June 18, 1973. They were assembled and secured with polypropylene rope on June 19 and 20.

Placement of the initial nine (initially-placed) reefs followed a randomized, complete-block design (Steel and Torrie 1960, p. 133). Replicates of each reef type were placed in closely grouped blocks (1, 2 and 3) to expose them to as similar biotic and abiotic environments as possible. The positions of reef types within a block were chosen by casting a die. Since all reef types appear in each block, variability among blocks should not affect differences in treatment means.

Reefs within a block were placed as close together as possible while attempting to minimize exchange of colonists between them. Ten meters was chosen for the distance between members of a block because underwater visibility in Bahia Bacochibampo rarely exceeds 5 m. It was thought that colonist exchange between block members would be reduced if the fishes could not see from one reef to another. The distance between blocks was set at 30 m to lessen the possibility of exchanges of fishes between blocks. The minimum distance of any of the model reefs from a natural patch reef was 15 m.

The bottom sloped gently from block 1 to 3. The depth of the water overlying each of the reefs was determined using a diver's depth gauge calibrated in feet.

The low tide depth at block 1 was approximately 16 feet (4.9 m), at block 2, 18 feet (5.1 m) and at block 3, 19 feet (5.8 m).

Three additional replicates of the more heterogeneous reef type (M4, M5 and M6) were placed in the positions shown on Fig. 5 on January 25, 1974. This was done to have a basis for separating out seasonal and successional events. The distance between M5 and M6 was 30 m. The distance between reefs M4 and M5 was 50 m. At the time of construction, there was a large patch of *Sargassum* sp. growing in the line of placement which prevented placing reef M4 and closer to M5.

Model Patch Reef Census Technique

The fish populations of the initial nine, model patch reefs were visually censused 20 times during a period of 563 days after placement. The winter placed reefs were censused 10 times. I tried to census each reef at least once per month, depending upon weather and sea conditions. All census data were recorded underwater on formica slates.

I considered any fish seen within one meter of a reef to be associated with it and included it in my census. However, passing schools of pelagic fishes, such as jacks and anchovies, were not included.

I censused fishes associated with the model patch reefs in three stages. During the first stage, I censused the larger species such as the sea basses, grunts and triggerfish. These fishes often fled at the close approach of a diver. I, therefore, approached a reef cautiously, stopping to count these larger fishes from the maximum distance at which I could see them clearly. In the second stage of the census, I simultaneously censused the small fishes on the sandy perimeter around each reef and any larger species that were on the reef surface or in large shelters. Such fishes were generally disturbed during closer inspection of a model reef. The third and final stage which involved a search of the reef for small cryptic fishes was terminated when five minutes had elapsed after last recording a new species.

Species were placed in one of three residency categories based upon their behavior during censuses. A species which sought shelter within the reef or remained within one meter of a reef during a census, 50% or more of the times it was observed, was classified as a primary resident. Species which did so less than 50% of the time were recorded as secondary residents. Species which consistently fled the reef at my approach were grouped as visitors. This residency classification system is based on one proposed by Thomson and Lehner (in press). They placed intertidal fishes in primary resident, secondary resident and transient categories according to their degree of mobility and time spent in a particular habitat. A similar classification system was used by Smith and Tyler (1972) in their study of a Caribbean, patch reef, fish community. The residency categories they used were resident, visitor and transient; corresponding roughly to my primary resident, secondary resident and visitor groups.

The physical data taken at the time of a census were water temperature and visibility. Temperature was taken with a hand-held thermometer calibrated in degrees centigrade and accurate to ± 0.5°C. Visibility was measured as the distance at which I could distinguish fine details on the reefs. I approached a reef until the edges of the reef and larger algae such as *Padina* sp. and *Sargassum* sp. were in sharp focus. The distance from that point to the edge of the reef was measured using a lead line or metal rule. Measurements were accurate to approximately ± 0.1 m.

The conditions of the model patch reef at the time of the censuses are given in Tables 1 and 2. All nine of the initially-placed reefs were censused in a single day. However, the winter-placed reefs were sometimes censused on a second day. The total census time varied from between 1.5 and 5.5 hours depending on the number of model patch

Table 1. Conditions at time of visual censuses of summer-placed reefs (L1-3, S1-3 and M1-3).

Census Number	Date	Days After Reef Placement	Days After Last Census	Length of Census (hrs)	Sea Temp. °C	Visibility (meters)
1	7-8-73	20	20	1.5	30	1.5
2	7-22-73	34	14	2.0	30	1.8
3	8-5-73	48	14	2.5	31	7.6
4	8-19-73	62	14	1.5	31	1.2
5	9-14-73	88	26	1.5	29	4.6
6	10-12-73	116	28	2.0	22	1.5
7	11-10-73	144	28	2.0	21	6.1
8	12-22-73	186	42	3.75	17	2.1
9	1-20-74	215	29	2.5	16	3.1
10	3-22-74	276	61	2.5	16	1.2
11	4-20-74	304	28	4.5	17	1.2
12	5-24-74	338	34	3.5	18	1.5
13	5-29-74	343	5	3.5	23	5.5
14	6-19-74	364	21	4.0	28	3.7
15	7-7-74	382	18	4.5	30	2.5
16	7-18-74	393	11	4.5	29	3.1
17	7-31-74	406	13	5.5	30	2.1
18	8-9-74	415	9	6.0	30	3.7
19	10-18-74	485	70	4.5	26	2.5
20	1-4-75	563	78	4.0	15	1.5

Table 2. Conditions at time of visual censuses of winter-placed reefs (M4-6).

Census Number	Date	Days After Reef Placement	Days After Last Census	Length of Census (hrs)	Sea Temp. °C	Visibility (meters)
1	3-22-74	56	56	0.5	18	1.2
2	4-20-74	84	28	1.0	17	1.2
3	5-24-74	118	34	1.0	18	1.5
4	6-19-74	144	26	1.0	28	3.7
5	7-5-74	160	16	1.5	30	3.7
6	7-19-74	174	14	1.0	29	2.1
7	8-1-74	186	12	1.5	30	3.1
8	8-10-74	195	9	1.0	30	4.6
9	10-18-74	264	69	1.0	26	2.5
10	1-4-74	342	78	0.75	15	1.5

reefs censused, the number of fishes inhabiting the reefs, and the water conditions. The interval between censuses ranged from 5 to 78 days. Visibility ranged from 1.2 to 7.6 m (av. 2.9 m). Water temperature during the study varied from 15°C to 31°C (av. 24.5°C) (Fig. 6).

Fish Defaunation of Model Patch Reefs

Two days after the nineteenth visual census, model patch reefs L1, L2, S1, S2, M1 and M2 were sampled with Chem Fish Collector, a rotenone-based ichthyocide manufactured by the Chemical Insecticide Corporation of Metuchen, New Jersey. This provided a good estimate of the numbers of the more cryptic fish species and served as a check of the visual census technique. Approximately one pint of Chem Fish Collector was applied to each reef with a polyethylene squeeze bottle. Two divers with hand nets participated in each collection. Fishes were collected until five of ten minutes had passed after collecting a fish. The model patch reefs were small enough so that only 30 to 45 minutes of collecting time per reef was required. Specimens collected during the census were preserved in a 10% seawater-formalin solution. They were later counted and identified and are now curated in the University of Arizona Fish Collection.

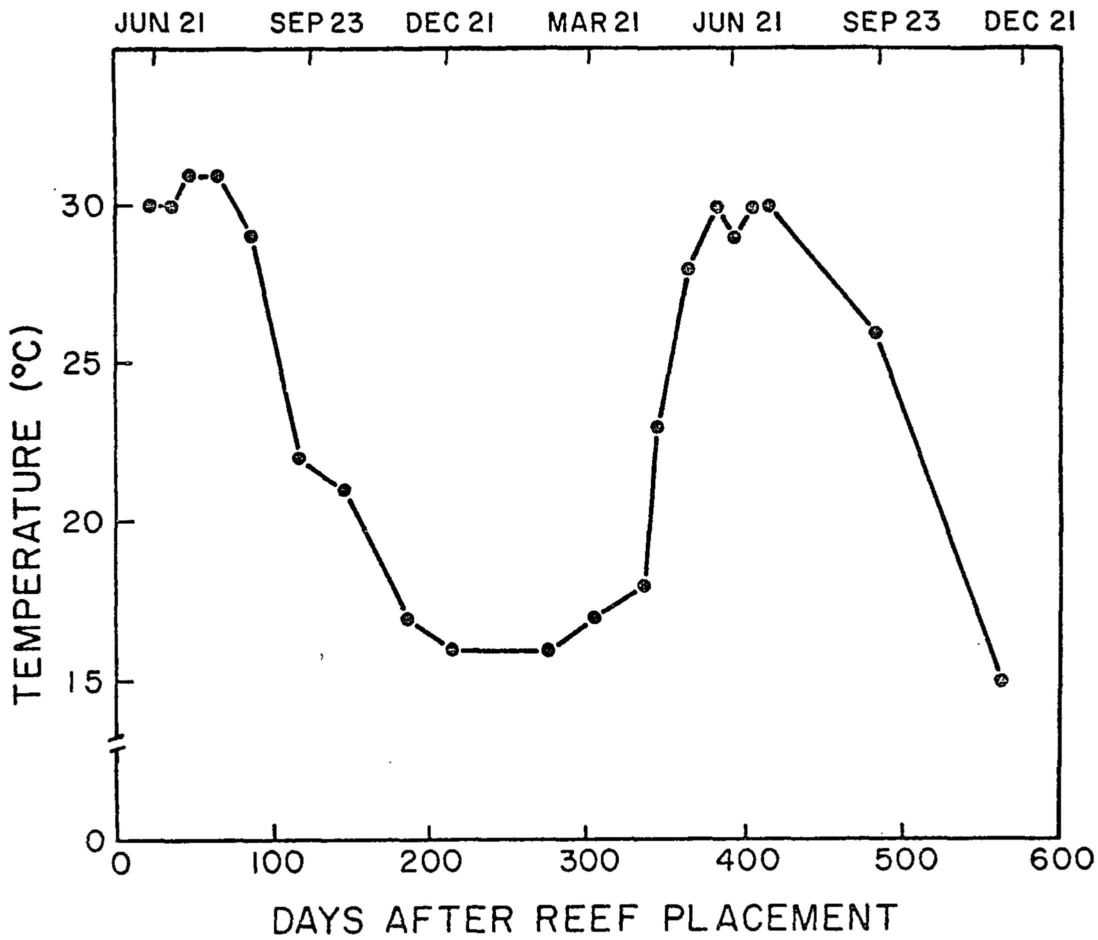

Fig. 6. Temperature record for the period of the model reef study.

Species Diversity

Most of the analysis of species diversity in this study, centers around species richness estimates based on visual counts. Visual data were also used to calculate the commonly used Shannon-Wiener index (Shannon and Weaver 1949). This index, $H' = -\Sigma p_i \ln p_i$, where p_i is the proportion of the *i*th species in the community and $\ln p_i$ is the natural logarithm of p_i, combines species richness and evenness.

Species counts and Shannon-Wiener diversity indices based on combined visual and rotenone data were also calculated. Since some fishes are more easily counted visually and others are best sampled with rotenone, these were probably the most accurate estimates of the study. The visual and rotenone data were combined for the calculation of Shannon-Wiener indices by using data from the method that gave the highest estimate for each species' population size. For example, more individuals of most secondary resident species were recorded visually than were collected with rotenone. Therefore, visual estimates of these species abundances were used in the calculation of H' values.

Habitat Utilization on Model Patch Reefs

The distributions of individuals of some of the more common species of fishes among vertical zones on the model patch reefs were studied. This was done to form a basis for evaluating the possible importance of reef height to fishes. The data taken consisted of a set of frequencies of observation of each species in each of five vertical zones. The five zones were sand, first, second and third levels of blocks, and the reef top.

A fish was assigned to a vertical position according to the following criteria: (1) If an individual was stationary when sighted, its vertical position at that point was recorded; (2) if a fish was moving when discovered, its vertical position where it came to a stop was recorded; (3) if a fish was stationary when sighted but began to move, it was recorded in the zone in which it was first seen and in the zone in which it came to a stop if it crossed into another strata as a consequence of moving. All habitat utilization observations were conducted in July and August of 1974.

Overlaps in the vertical distributions of certain species of fish were calculated using an index suggested by Schoener (1968):

$$D = 1 - 1/2 \sum_{h} |p_{ih} - p_{jh}|,$$

where p_{ih} and p_{jh} are the frequencies for species i and j respectively, recorded from the _h_th height zone.

Immigration and Extinction Rates on Model Reefs

In order to estimate the immigration and extinction rates as defined by MacArthur and Wilson (1963, 1967), one would need a knowledge of all potential immigrants landing on an island and all subsequent extinctions. Mean daily immigration and extinction rates calculated by comparing the results of successive censuses, as was done in this study, are minimal estimates of these rates. Schoener (1974) called such estimates colonization and decolonization rates. However, I prefer to use MacArthur and Wilson's original terminology with the understanding that the discussion is based on minimal estimates of true immigration and extinction rates.

Immigration rate (I) was calculated as the number of new fish species added to a patch reef community since a previous census divided by the number of days between the two censuses. Extinction rate (E) was estimated by dividing the number of species not recorded in a census but which had been observed in the previous one, by the number of days between the two censuses. The units of both I and E are species per day. Calculations were limited to primary resident species. Visitor and secondary resident species were excluded because calculations of their immigration and extinction rates would be subject to more error due to their greater mobility.

Analysis of Model Patch Reef Data

The effect of reef type on species composition was analyzed using a randomized, complete-block, analysis of variance (Steel and Torrie 1960, p. 134). However, when considering changes in numbers of individuals or species, over time, the time factor was considered as a subtreatment and a split-plot, in time, analysis of variance was used (Steel and Torrie 1960, p. 242).

All of the model patch reef data analyzed were counts of numbers of fish species or individuals. Count data usually follows a Poisson distribution. However, such data can be normalized by taking square roots of the raw data. Analyses are then performed on the transformed data. This procedure was followed in the analyses of this investigation.

Natural Patch Reef Study Area

Observations on natural patch reefs were conducted in Bahia Algodones, approximately nine miles northwest of the model patch reef study site (Fig. 7). The positions of the Algodones patch reefs studied are shown in Fig. 8. These reefs consisted of a single piece of consolidated rock and a few smaller satellite rocks. They were composed of granite with overlying beach rock. The beach rock consisted of shell fragments and quartz and

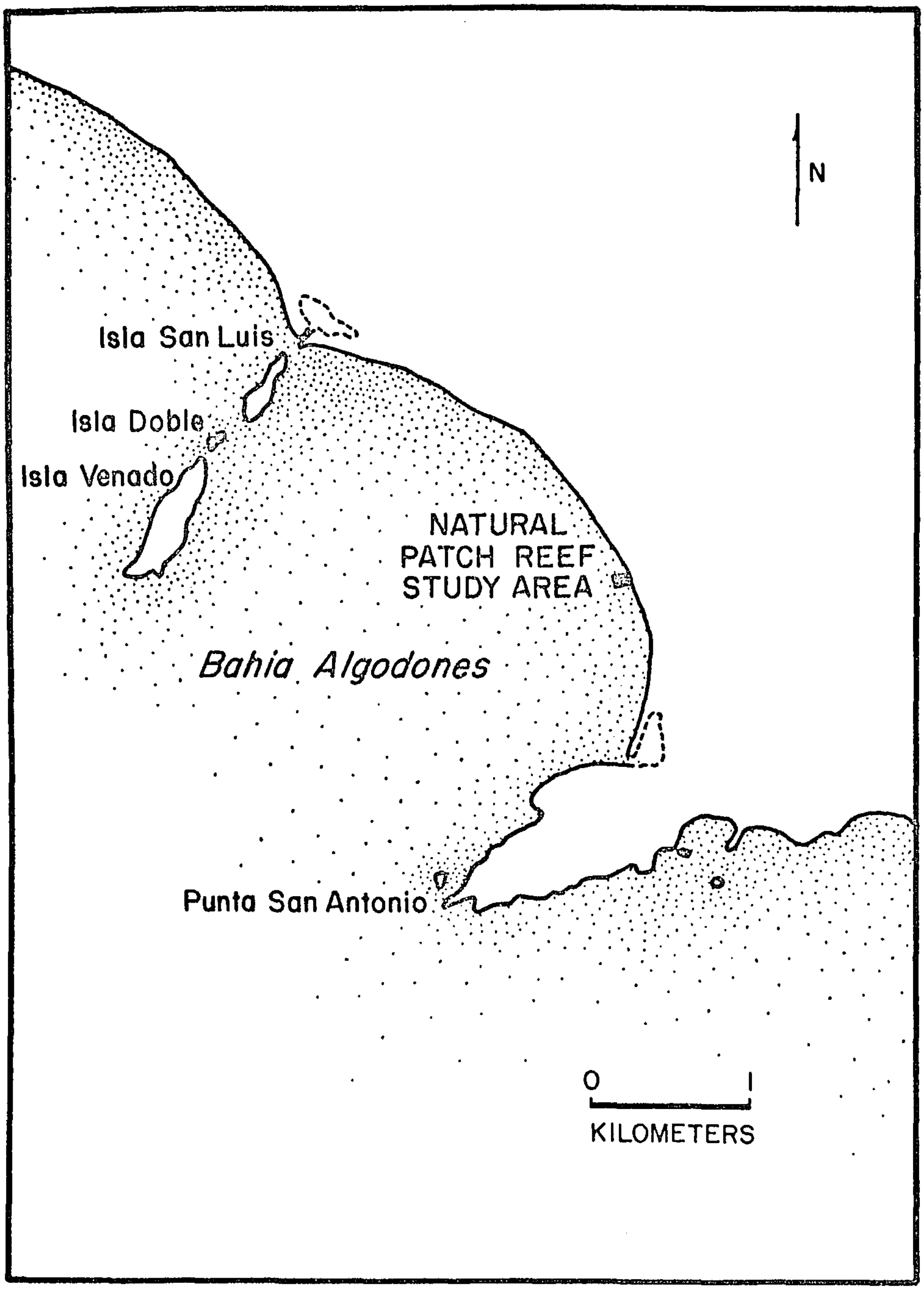

Fig. 7. Map of Bahia Algodones showing natural patch reef study site.

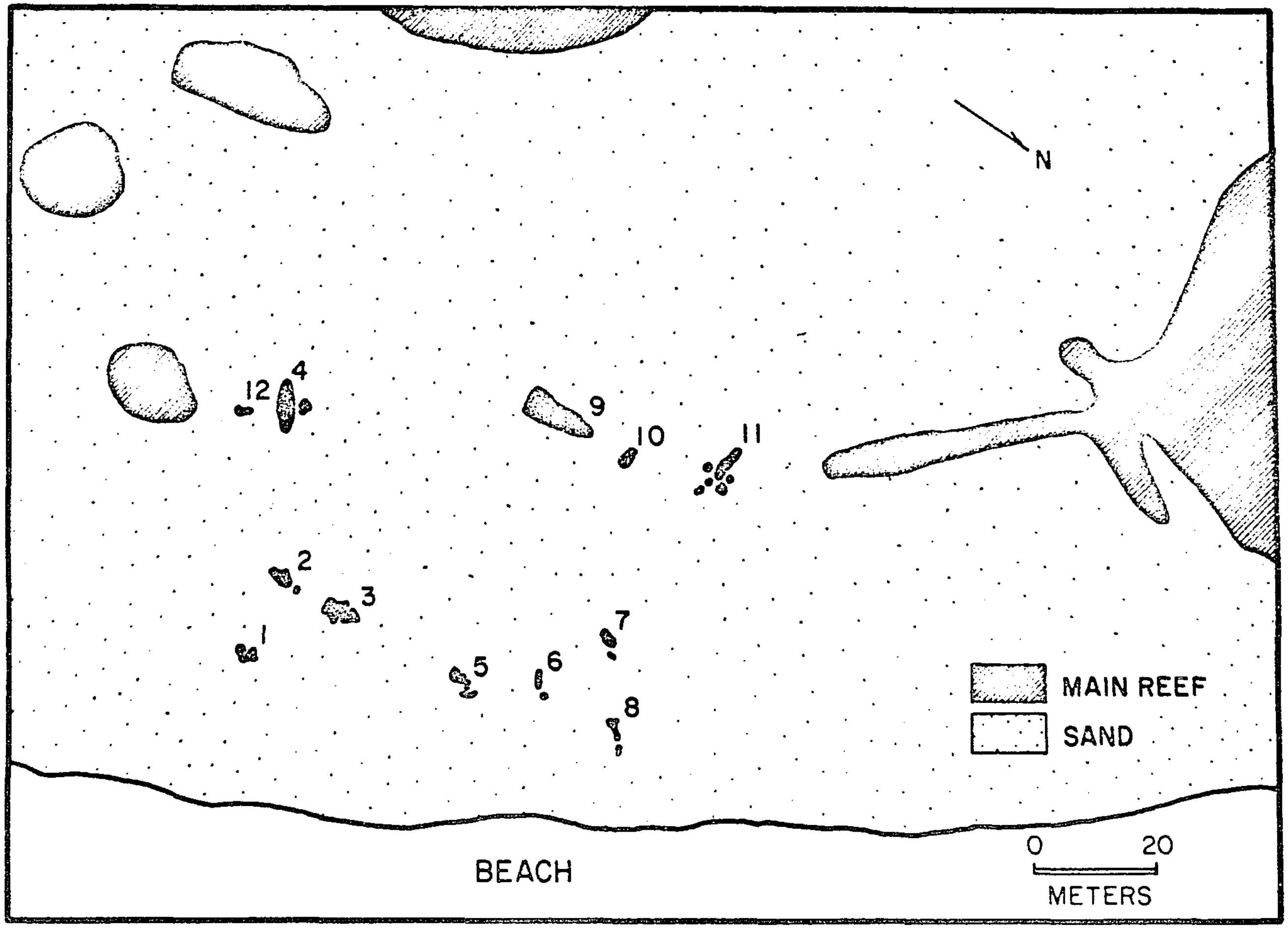

Fig. 8. Map of natural patch reef study site.

feldspar sand cemented together with calcium carbonate. The natural patch reefs of Bahia Bacochibampo were not used for this portion of the study because they were structurally very different from the model patch reefs. They were made up of loosely associated aggregations of small boulders.

Censuses of Natural Patch Reefs

Two visual censuses were made of the fish populations of each of nine of the Algodones patch reefs. Two counts were made to compare the distributions of patch reef fishes before and after summer colonization. The first census was made in late spring (5-30-74 to 6-1-74). The second was made in midsummer (8-5-74 to 8-11-74). An additional three reefs were sampled during the second census.

The visual census technique used was the same as described for the model patch reefs (see Model Patch Reef Census Technique, above), except species associated with natural patch reefs were not placed into primary and secondary resident categories. Differentiation was made only between residents and visitors. Visitors were those species which consistently fled over the sand at my approach. Insufficient observations were made to make the finer distinction between primary and secondary residents.

Measurements on Natural Patch Reefs

Distances between reefs were measured using a ten-meter lead line and a hand-held, underwater compass. Reef height measurements were made using a graduated lead-line and a metal rule. Mean reef height was estimated from five height measurements taken on the long axis of the largest rock of a reef. These measurements were taken at quarter meter intervals, beginning at the east or south end of the rock.

Surface area measurements of natural patch reefs included the large main rock of a reef and any smaller satellite rocks. Reef area was estimated using graduated lead lines. The longest dimension of a rock was found and a lead line was placed across the widest point perpendicular to this length. The width line was placed so it followed the contours of the rock surface. Length measurements, which also followed surface contours, were made at half-meter intervals marked on the width line. A series of surface area estimates of dimensions 0.5 m by L m and < 0.5 m by L m were thus obtained. The sum of this series was taken as an estimate of the surface area of a rock. The sum of the surface areas of the main rock and any satellite rocks was taken as the total patch reef surface area.

Any pocket or invagination in the surface of a reef was called an "interspace". Depth and width measurements were used as an index of interspace size. Interspaces had to be at least 0.5 cm in depth and width to be included in the estimate of interspace size diversity. This was the minimum size thought to be useful to at least the smaller species of fish in the area. All interspace measurements were made on the large main rock of a patch reef.

Sixty interspaces were measured on each reef--30 vertically oriented and 30 horizontally oriented. The orientation of an interspace was determined using a plumb line made from a lead weight on a nylon line. A metal rule was placed across the opening of an interspace. If the angle made by the intersection of one end of this rule with the plumb line was between 45° and 135°, the interspace was placed in the vertically oriented category. If the angle was outside of this range it was placed in the horizontal category.

All vertical interspaces were measured on the top of each reef, along a transect line placed along a reef's longest dimension. Measurements were begun at the most southerly or easterly end of the line. Vertical interspaces were measured in the order in which they appeared beginning at the reef-sand interface. The measurements of any horizontally oriented interspaces encountered were also taken and recorded. However, most horizontal interspace measurements were made along the vertical sides of a reef. These measurements were made up the side of a reef at 0.25 m intervals, beginning at the point of highest relief and proceeding in a clockwise direction until the dimensions of 30 horizontal interspaces had been obtained.

Width and depth measurements were made using a metal rule and a 0.5 cm by 0.5 m dowel. The rule was placed on the surface of a reef. Its angle relative to the plumb line was noted. Any spaces under the rule large enough to slide the dowel into, were measured as interspaces. The distance under the length of the rule through which the dowel could slide was taken as the width of an interspace. Depth was taken as the greatest depth, perpendicular to the width measuring rule, to which the dowel could be pushed.

Interspaces were assigned to width and depth classes of five centimeter increments. The smallest category was 0.5-5.0 cm by 0.5-5.0 cm. Interspace size diversity was calculated using the Shannon-Wiener diversity index: $H' = -\Sigma p_i \ln p_i$, where p_i was the proportion of interspaces which fell in the ith size class and $\ln p_i$ was the natural logarithm of p_i. The diversities of vertical and horizontal interspaces were calculated and analyzed separately.

Physical Characteristics of Natural Patch Reefs

The areas of the Algodones reefs varied from 2.5 m^2 to 60 m^2 (ave. = 17.6, S.D. = 15.3) (Table 3). Mean reef heights ranged from 0.10 m to 0.50 m (ave. = 0.30 m S.D. = 0.16 m). The minimum distance of a patch reef from the nearest main was 6 m. The maximum distance of a patch reef from a main reef was 60 m (ave. = 35.8 m, S.D. = 17.8 m). The diversity of vertical interspaces from H' = 1.197 to 2.132 (ave. = 1.884, S.D. = 0.704). The diversity of horizontal interspaces varied from H' = 0.146 to 2.681 (ave. = 1.707, S.D. = 0.316).

Analysis of Natural Patch Reef Data

Patterns of fish, species diversity on the Algodones patch reefs were analyzed using a stepwise, multiple linear, regression analysis (Nie et al. 1975). In this analysis, number of species or Shannon-Wiener diversity values were the dependent variables. Reef area, distance from "main" reefs, diversity of vertical interspaces, and diversity of horizontal interspaces were the independent variables. The relationships between the independent variables and total number of species and numbers of resident species were analyzed separately. Only one analysis was necessary for the late spring census since no visitor species were recorded during that census. Shannon-Wiener

Table 3. Physical characteristics of natural patch reefs.

Reef Number	Depth (m)	Area (m^2)	Mean Height (m)	Distance (m)	DVI[1]	DHI[2]
1	2.0	14.5	0.35	38	1.886	2.220
2	2.5	15.9	0.25	30	1.721	2.681
3	2.5	21.6	0.40	38	1.948	2.502
4	3.5	19.7	0.40	12	1.784	2.562
5	2.25	17.3	0.40	60	2.050	1.515
6	2.0	5.0	0.25	58	1.922	1.213
7	2.0	2.5	0.20	45	1.560	1.438
8	2.0	7.9	0.50	55	2.132	2.007
9	3.5	60.0	0.10	39	1.231	0.146
10	3.5	16.9	0.10	33	1.197	1.390
11	3.5	26.5	0.60	15	1.724	2.214
12	3.5	3.5	0.10	6	1.325	1.718

1. DVI = diversity of vertical interspaces.

2. DHI = diversity of horizontal interspaces.

calculations were based on the total fish community as they were in the model reef portion of the study.

CHAPTER 3

RESULTS

A section on the colonists of the model patch reefs is presented first. This is done to provide background information that will be useful in interpreting subsequent results sections. Results are explained as presented when such explanation adds to clarity.

Colonization of Model Patch Reefs

Fifty-seven species of fishes belonging to 23 families were recorded on model patch reefs during the study (Table 4). Of these, 37 species were primary residents, 10 were recorded as secondary residents and 10 as visitors. Fig. 9 gives the order in which these fish species were recorded on the nine summer-placed reefs. Also given is a record of their presence during the study. A species is indicated as being present if it was recorded on at least one of the initial nine reefs during a census. Individual colonization histories for each of the model reefs are given in Appendix A.

One of the most salient features of this pooled colonization record is the seasonal occurrence of many

Table 4. Colonists of summer and winter-placed model patch reefs.

Family	Common Family Name	Species Name	Numbers[1] S	Numbers[1] W	Residency[2]	Age[3]
Muraenidae	Moray eels	*Gymnothorax castaneus*	30	8	P	A
		Muraena lentiginosa	1	-	P	A
Syngnathidae	Pipefishes	*Syngnathus* sp.	9	-	P	A
Serranidae	Sea basses	*Paralabrax maculatofasciatus*	329	64	S	J,A
		Serranus fasciatus	141	7	P	J,A
		Diplectrum sp.	46	-	P	J
		Epinephelus analogus	36	1	P	J
		E. niveatus	28	-	P	J
		Mycteroperca rosacea	24	14	S	J,A
		M. jordani	2	2	V	J
		Alphestes multiguttatus	2	1	P	J
Grammistidae	Soapfishes	*Rypticus bicolor*	5	1	P	A
		R. nigripinnis	1	-	P	J
Lutjanidae	Snappers	*Lutjanus guttatus*	118	1	V	J
		L. argentiventris	6	-	S	J
		Hoplopagrus guntheri	2	12	S	J
Apogonidae	Cardinalfishes	*Apogon retrosella*	206	22	P	J,A
Haemulidae	Grunts	*Haemulon sexfasciatum*	100	57	V	A
		Lythrulon flaviguttatum	2	-	V	A

Table 4. Colonists of summer and winter-placed model patch reefs (continued).

Family	Common Family Name	Species Name	Numbers[1] S	Numbers[1] W	Residency[2]	Age[3]
Scianidae	Croakers	Pareques viola	3	-	P	J
Sparidae	Porgies	Calamus brachysomus	51	25	V	A
Pomacanthidae	Angelfishes	Pomacanthus zonipectus	70	2	P	J
Pomacentridae	Damselfishes	Eupomacentrus rectifraenum	4	-	P	J
		Abudefduf troschelii	1	2	V	A
Labridae	Wrasses	Halichoeres dispilus	76	3	S	J,A
		H. semicinctus	11	6	V	A
		H. nicholsi	4	3	V	A
		H. chierchiae	3	2	V	A
		Bodianus diplotaenia	4	-	P	J
Scaridae	Parrotfishes	Nicholsina denticulata	91	25	S	J,A
		Scarus perrico	11	11	S	J
Gobiidae	Gobies	Coryphopterus urospilus	837	50	P	J,A
		Gobiosoma chiquita	48	-	P	J,A
		Lythrypnus dalli	23	-	P	J,A
		Gobulus crescentalis	10	-	P	J,A
		Barbulifer pantherinus[4]	7	-	P	J,A
		Elacatinus punticulatus	4	-	P	J,A?

Table 4. Colonists of summer and winter-placed model patch reefs (continued).

Family	Common Family Name	Species Name	Numbers[1] S	Numbers[1] W	Residency[2]	Age[3]
		E. digueti[4]	3	-	P	J,A?
		Aruma histrio	3	-	P	J,A?
Blenniidae	Combtooth blennies	*Hypsoblennius gentilis*	494	57	P	J,A
Clinidae	Clinids	*Exerpes asper*	2841	69	P	J,A
		Xenomedea rhodopyga	142	16	P	J,A
		Paraclinus sini	81	13	P	J,A
		Malacoctenus hubbsi	66	9	P	J,A
		M. margaritae	5	-	P	J
Chaenopsidae	Tube blennies	*Protemblemaria bicirris*	557	48	P	J,A
		Emblemaria hypacanthus	459	29	P	J,A
		Chaenopsis alepidota	215	39	S	J,A
		Acanthemblemaria crockeri	58	-	P	J,A
Tripterygiidae	Triplefin blennies	n. gen. n. sp. (Lizard triplefin)[5]	199	211	P	J,A
Ophidiidae	Brotulas	*Ogilbia* sp.	4	-	P	J,A
Scorpaenidae	Scorpionfishes	*Scorpaena mystes*	88	7	S	J,A
		Scorpaenodes xyris	31	2	P	J,A
		Scorpaena sonorae[4]	2	-	P?	A
Balistidae	Triggerfishes	*Balistes polylepis*	197	156	S	A

Table 4. Colonists of summer and winter-placed model patch reefs (continued).

Family	Common Family Name	Species Name	Numbers[1] S	Numbers[1] W	Residency[2]	Age[3]
Tetraodontidae	Pufferfishes	Sphoeroides annulatus	1	-	V	A
Batrachoididae	Toadfishes	Porichthys notatus	1	-	P?	A

1. S = number on summer placed reefs. W = numbers on winter placed reefs.

2. P = primary resident. S = secondary resident. V = visitor. See Species Classification System in Materials and Methods for explanation.

3. A = adult. J = juvenile.

4. Indicates that a species was collected during fish defaunation with "Chem Fish Collector" but was never observed visually on the model patch reefs.

5. This new genus, new species tripterygiid (Rosenblatt 1959) will be referred to as the lizard triplefin.

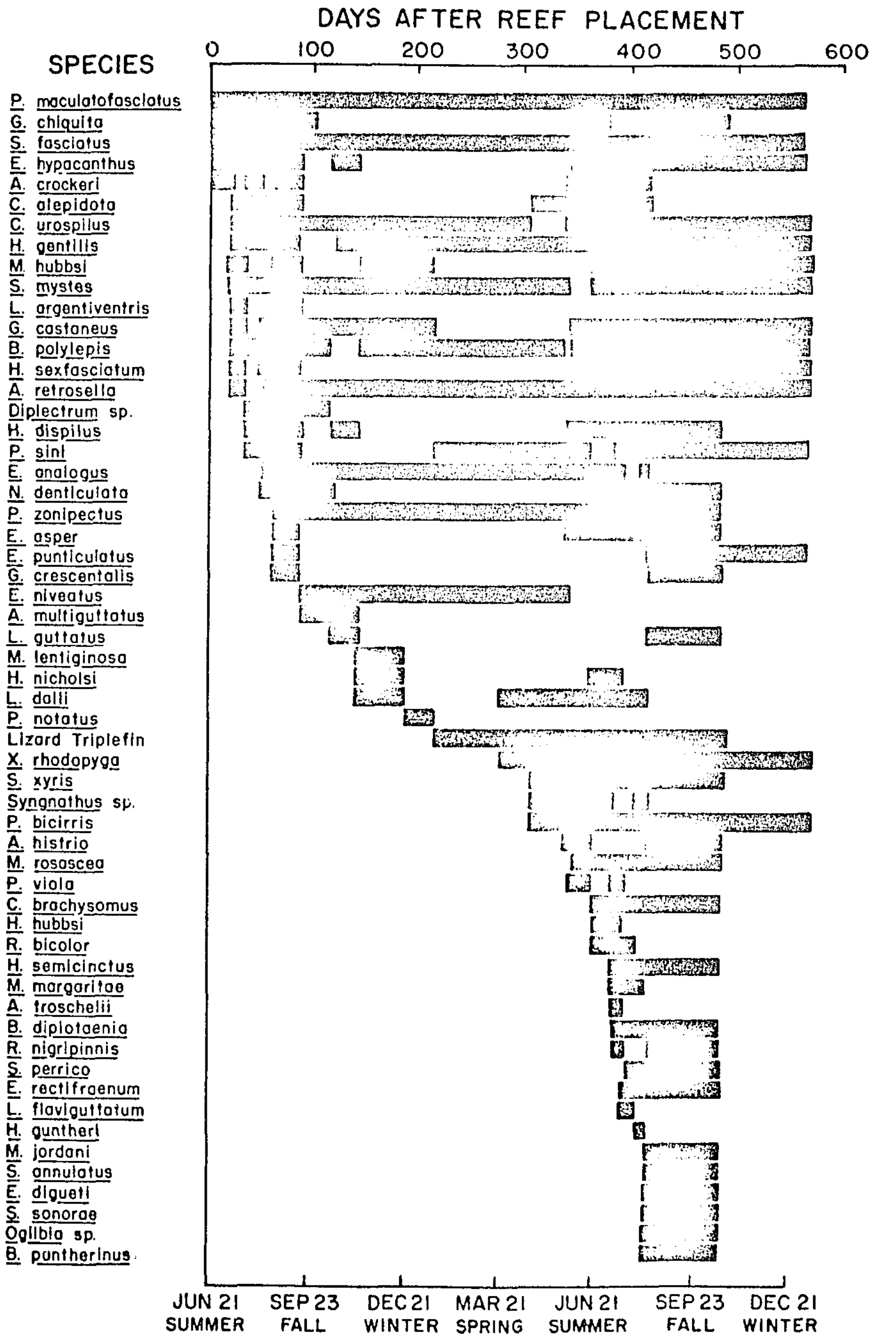

Fig. 9. Pooled colonization record for the nine winter-placed, model reefs.

species. Fifteen of 24 species disappeared from the model reefs after the first fall of the study. Thirteen of these species were recorded again the following summer. During the second fall 18 of 33 species apparently became locally extinct on the model patch reefs. (The last four species listed on the colonization record are not included here because they were never recorded during a visual census.) Some of the apparent extinctions during the second fall may have been due to a reduction of sample size. Only three undisturbed model reef communities remained for censusing after fish defaunations on day 487.

Thirty of the species recorded on the nine summer-placed reefs comprised 99% of the individuals observed. A list of these species with their mean abundances on each reef type is given in Table 5. A randomized, complete-block, analysis of variance (Steel and Torrie 1960, p. 134) of these abundances yielded no significant reef type-species interaction ($p < 0.05$). These species were found in approximately the same proportions on all reef types. Inspection of their distributions among model reef types (Fig. 10) leaves one with the impression of remarkable homogeneity.

However, differences in the distribution of certain species among reef types did exist. One-way analyses of variance (Steel and Torrie 1960, p. 101) of individual species distributions among reef types showed significant

Table 5. List of the 30 most common fish species on the summer-placed reefs--means of raw counts and means of square-root transformed counts on large, small and mixed interspace reef types.

	Large Interspace		Small Interspace		Mixed Interspace	
Species	Mean	Trans. Mean	Mean	Trans. Mean	Mean	Trans. Mean
Exerpes asper	264.33	16.18	442.33	20.85	240.33	15.42
Coryphopterus urospilus	93.33	9.64	89.00	9.26	98.33	9.87
Protemblemaria bicirris	50.00	7.07	59.00	7.59	76.67	8.71
Hypsoblennius gentilis[1]	40.00	6.32	83.00	9.08	41.67	6.42
Emblemaria hypacanthus	62.00	7.60	61.00	7.61	33.67	5.45
Paralabrax maculatofasciatus	40.67	6.21	38.67	5.99	30.33	5.44
Chaenopsis alepidota	13.67	3.61	35.00	5.91	23.00	4.62
Apogon retrosella	16.00	3.90	23.00	4.60	29.67	5.25
Lizard triplefin	16.00	3.77	28.00	5.02	22.00	3.75
Balistes polylepis	25.67	4.39	22.00	4.10	18.00	3.94

Table 5. Common fish species on summer-placed reefs (continued).

Species	Large Interspace Mean	Large Interspace Trans. Mean	Small Interspace Mean	Small Interspace Trans. Mean	Mixed Interspace Mean	Mixed Interspace Trans. Mean
Xenomedea rhodopyga	9.00	2.87	24.33	4.93	14.00	3.69
Serranus fasciatus	16.67	4.05	16.00	3.99	14.33	3.76
Lutjanus guttatus	17.67	2.93	15.00	2.24	6.67	2.11
Haemulon sexfasciatum	9.33	2.90	13.00	3.43	11.00	3.09
Nicholsina denticulata	7.67	2.74	11.00	3.31	11.67	3.15
Scorpaena mystes	11.00	3.30	8.00	2.81	10.33	3.20
Paraclinus sini	8.33	2.88	13.00	3.58	5.67	2.37
Halichoeres dispilus	8.67	2.82	9.00	2.96	7.67	2.68
Pomacanthus zonipectus[1]	4.00	1.88	4.67	1.91	14.67	3.74
Malacoctenus hubbsi	11.00	3.30	6.33	1.99	4.67	2.03
Acanthemblemaria crockeri[1]	4.33	1.94	11.00	3.26	4.00	1.88
Calamus brachysomus	6.33	2.49	5.00	2.23	5.67	2.38

Table 5. Common fish species on summer-placed reefs (continued).

Species	Large Interspace Mean	Large Interspace Trans. Mean	Small Interspace Mean	Small Interspace Trans. Mean	Mixed Interspace Mean	Mixed Interspace Trans. Mean
Gobiosoma chiquita	3.33	1.82	9.33	2.93	3.33	1.75
Diplectrum sp.	6.00	2.43	5.67	2.37	3.67	1.81
Epinephelus analogus	3.33	1.81	4.67	1.97	4.00	1.96
Scorpaenodes xyris	0.67	0.67	5.67	2.32	4.00	1.96
Gymnothorax castaneus	2.33	1.47	3.33	1.75	4.33	2.02
Epinephelus niveatus	0.00	0.00	3.00	1.41	6.33	1.96
Mycteroperca rosacea	2.67	1.32	1.00	1.00	4.33	1.94
Lythrypnus dalli[1]	0.67	0.67	6.33	2.46	0.67	0.47

1. Differences in abundance of species between reef types is significant ($p < 0.05$).

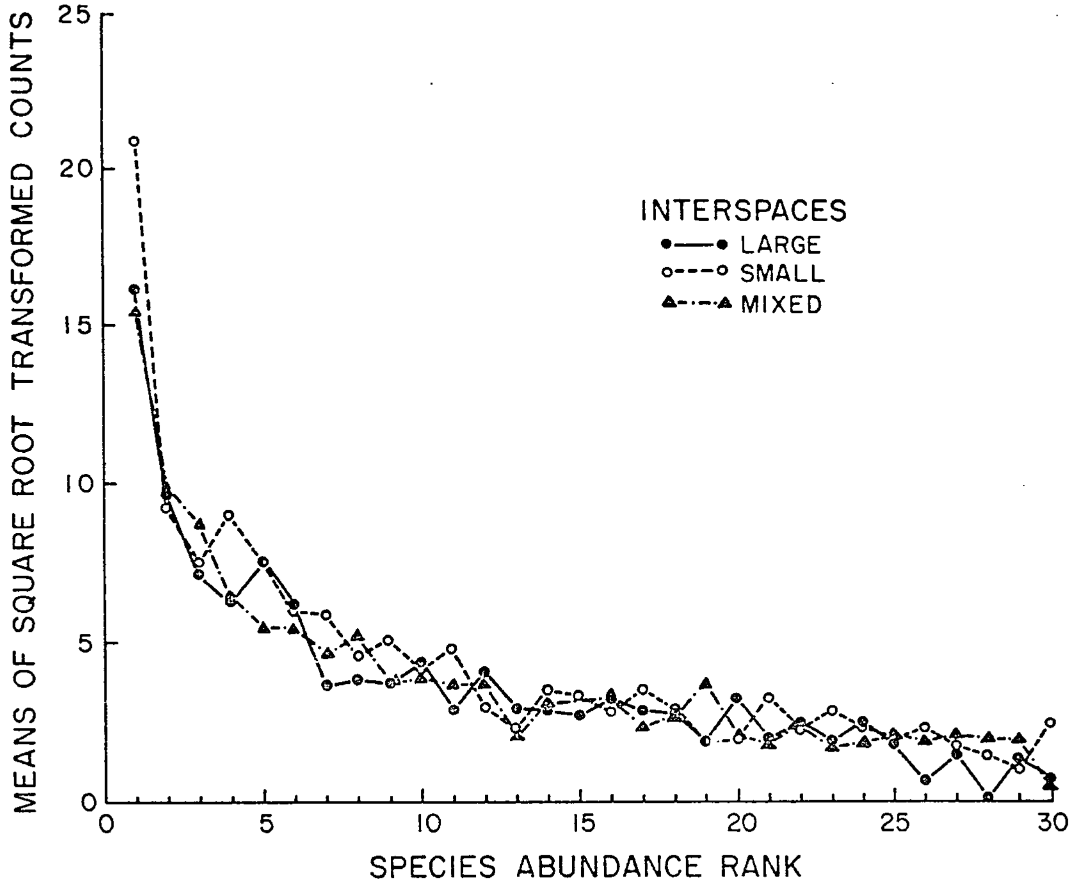

Fig. 10. Distribution of 30 most common fish species among model reefs L1-3, S1-3 and M1-3.

($p < 0.05$) differences for four of the 30 most common species. These species were: Hypsoblennius gentilis, Pomacanthus zonipectus, Lythrypnus dalli and Acanthemblemaria crockeri. H. gentilis, L. dalli and A. crockeri were most commonly observed on small interspace reefs. Most observations of P. zonipectus were on mixed interspace reefs.

Model Reef Type and Number of Individuals

A randomized, complete-block design, analysis of variance of the distributions of individuals of the 30 most common species listed in Table 5 indicated significant ($p < 0.05$) differences between reef types. The mean number of individuals per species for these fishes on each reef type were: $\bar{L} = 14.18$, $\bar{S} = 19.62$ and $\bar{M} = 15.16$.

In contrast to the above results, a split-plot, in time, analysis of variance (Steel and Torrie 1960, p. 242) showed no significant differences in mean number of individuals between reef types for any residency category (Figs. 11-14). This difference in results is due chiefly to the fewer degrees of freedom of the split-plot design analysis of variance compared to the randomized, complete-block analysis (2,4 vs. 2,178).

Figs. 11-14 also show pronounced seasonal fluctuations in numbers of individuals. The second peak in numbers of individuals was higher than the first for all residency categories. A split-plot, in time, analysis of

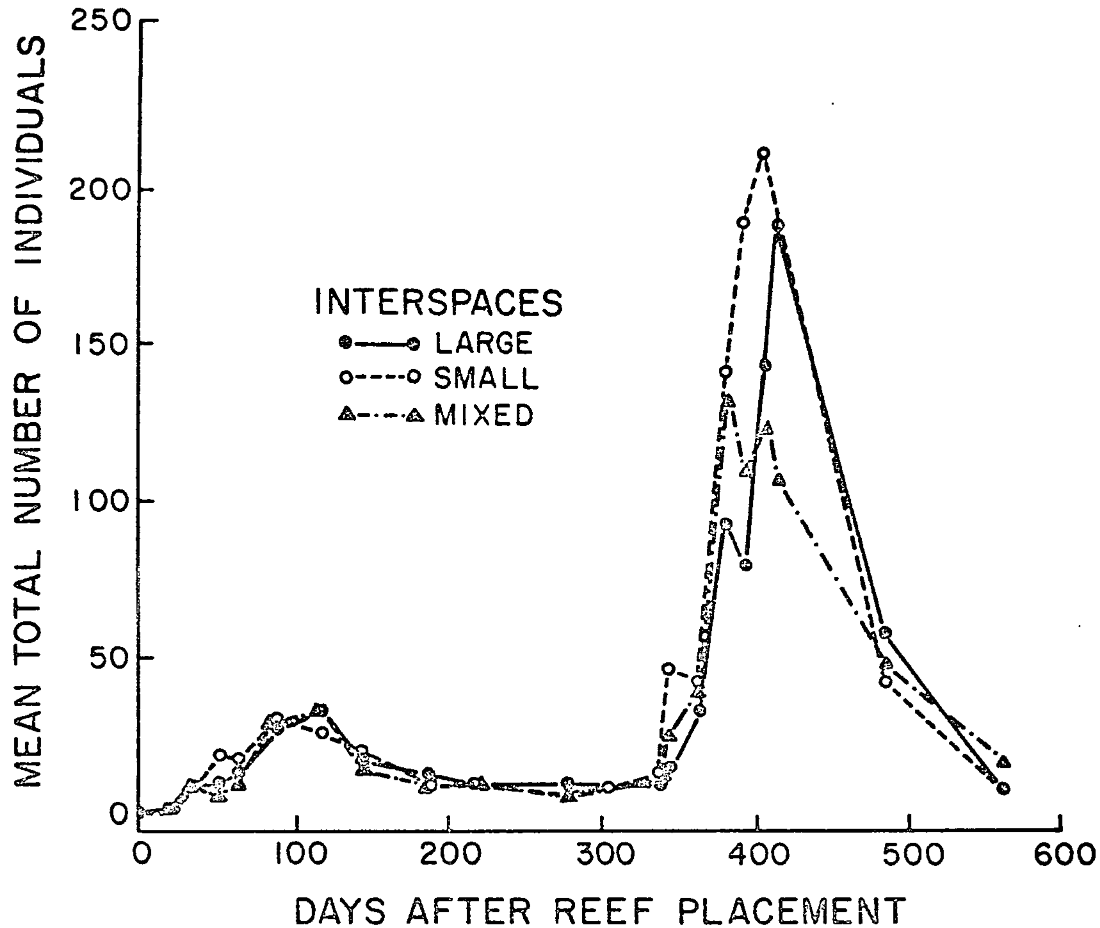

Fig. 11. Mean total number of individuals over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

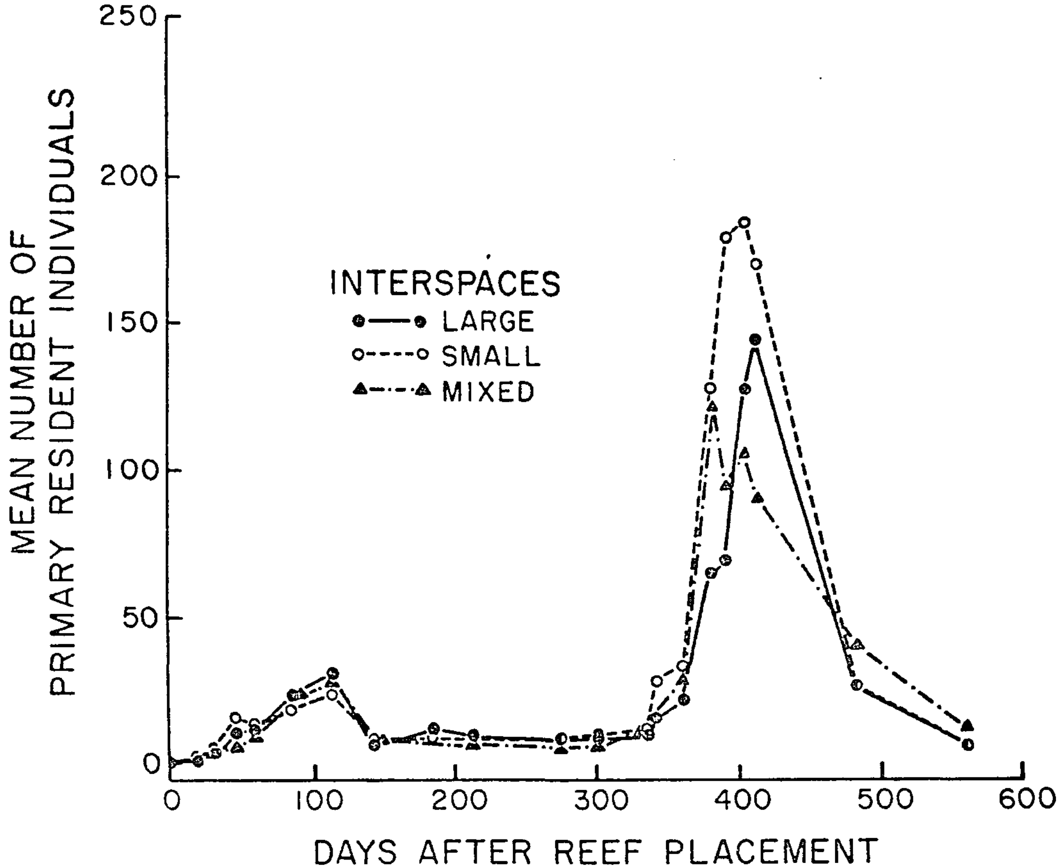

Fig. 12. Mean number of primary resident individuals over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

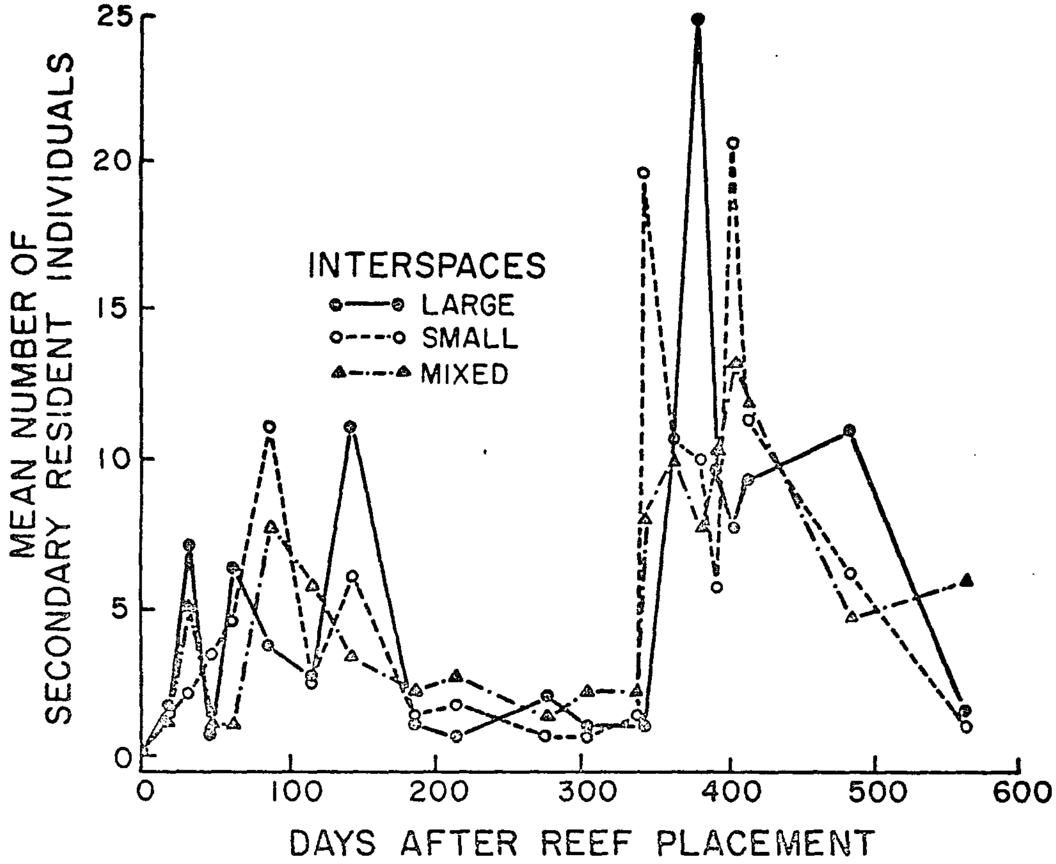

Fig. 13. Mean number of secondary resident individuals over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

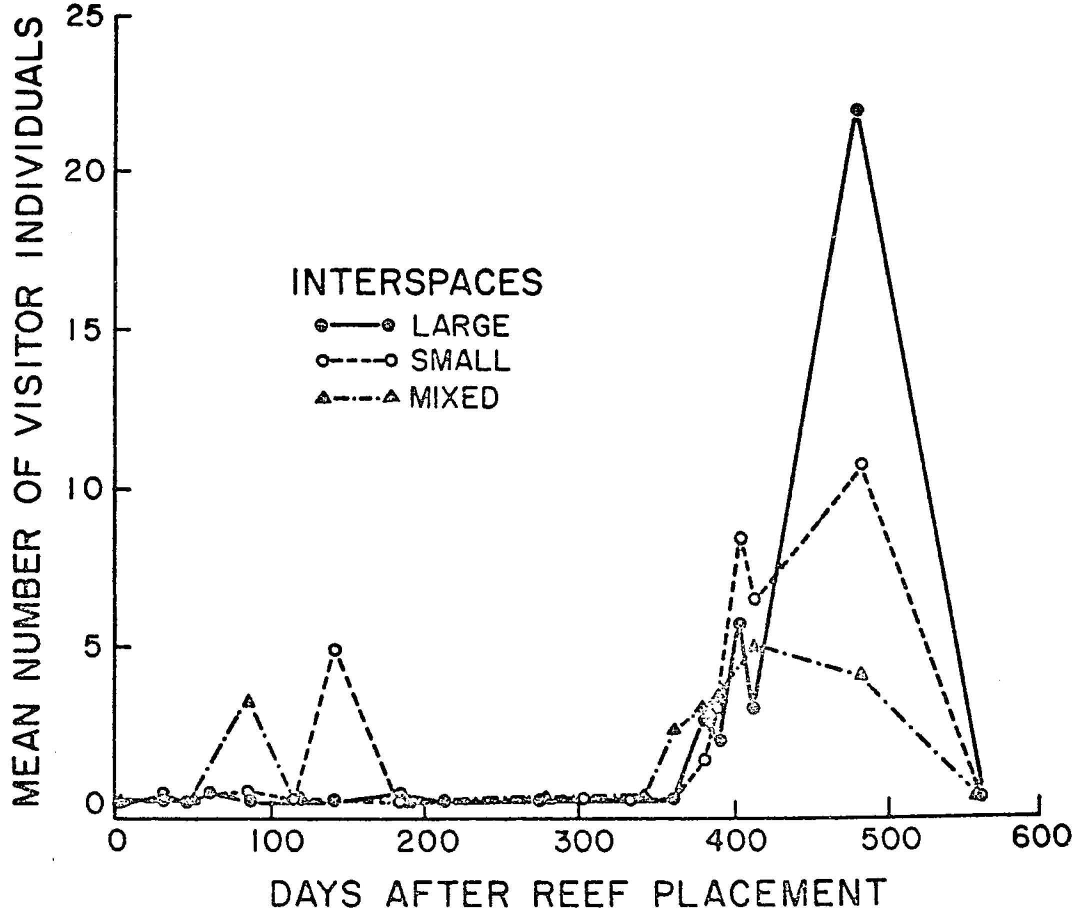

Fig. 14. Mean number of visitor individuals over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

variance (Steel and Torrie 1960, p. 242) showed these fluctuations to be significant ($p < 0.005$). This analysis also indicated that reef type-time interactions were significant ($p < 0.05$) for the total and primary resident counts. Therefore, differences in timing of peak numbers of these two species groups on the three reef types (Figs. 11 and 12) were probably significant.

Model Reef Type and Fish Species Diversity

A split-plot, in time, analysis of variance (Steel and Torrie 1960, p. 242) showed no significant differences in numbers of species between reef types for any species residency group. Plots of mean species counts over time for each reef type and species residency class are shown in Figs. 15-18. An examination of Figs. 15-18 shows the number of species on each reef type to be very similar in all cases.

Figs. 15-18 also show seasonal fluctuations in species richness similar to those observed above for numbers of individuals. The second peak in richness was higher than the first in all residency categories. A split-plot analysis of variance (Steel and Torrie 1960, p. 242) indicated that these fluctuations in time were significant ($P < 0.005$). However, reef type-time interactions were not significant. Peaks and lows in numbers

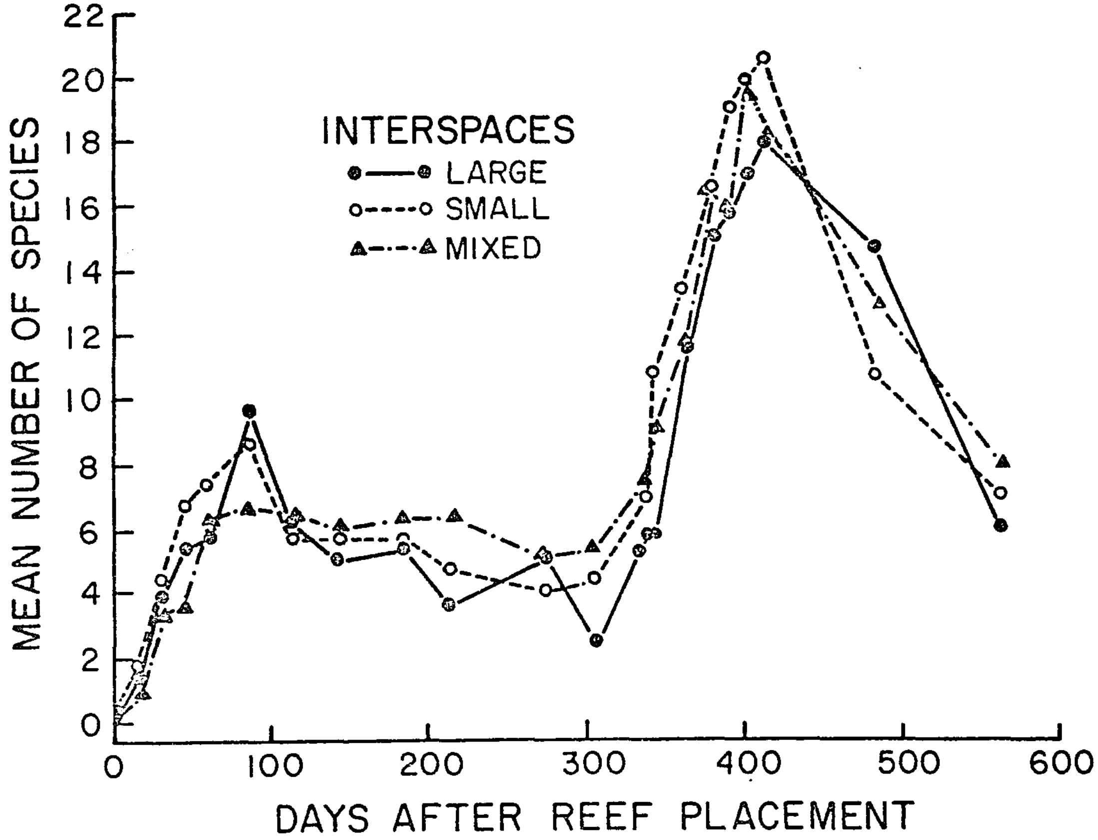

Fig. 15. Mean total number of species over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

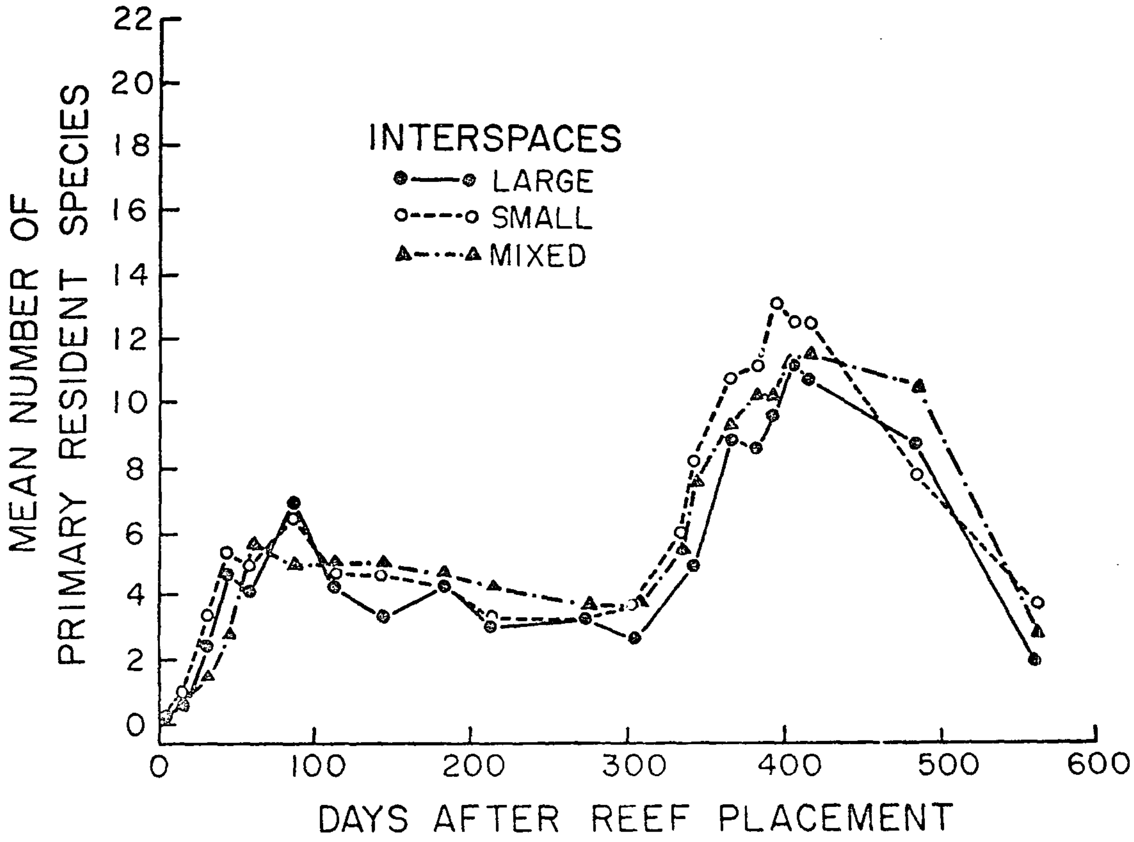

Fig. 16. Mean number of primary resident species over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

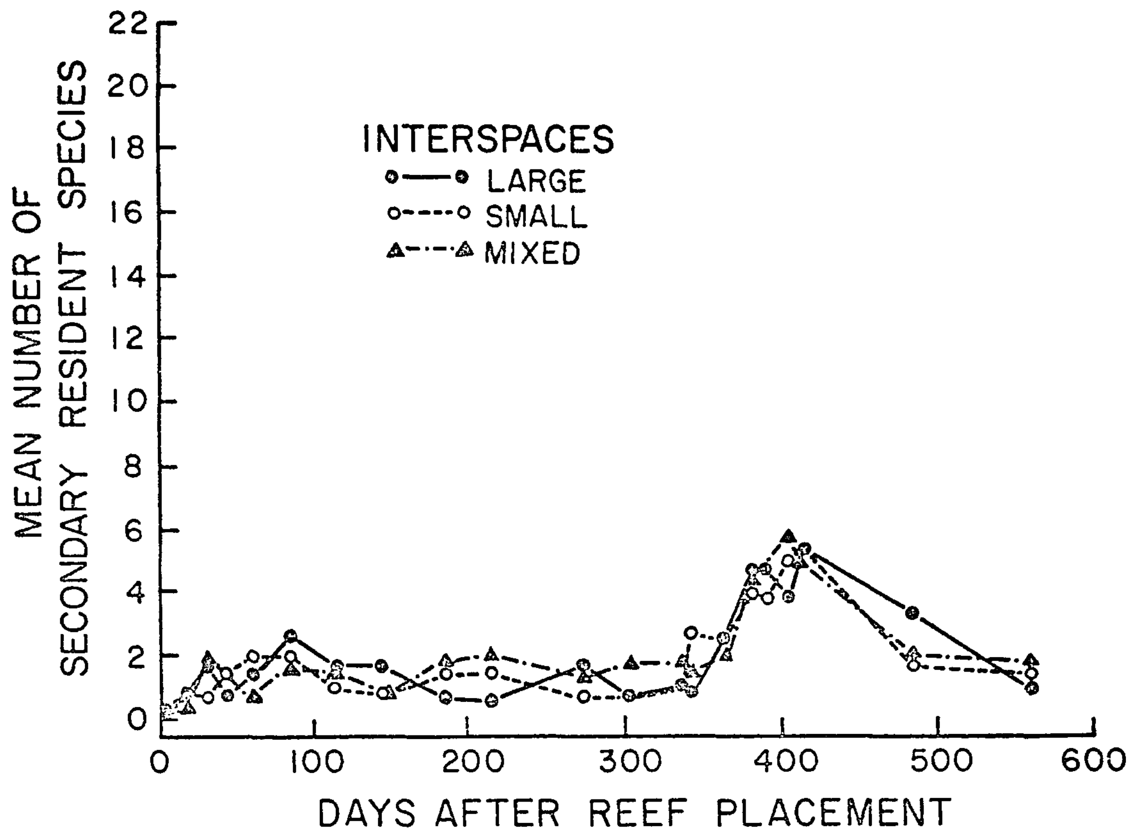

Fig. 17. Mean number of secondary resident species over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

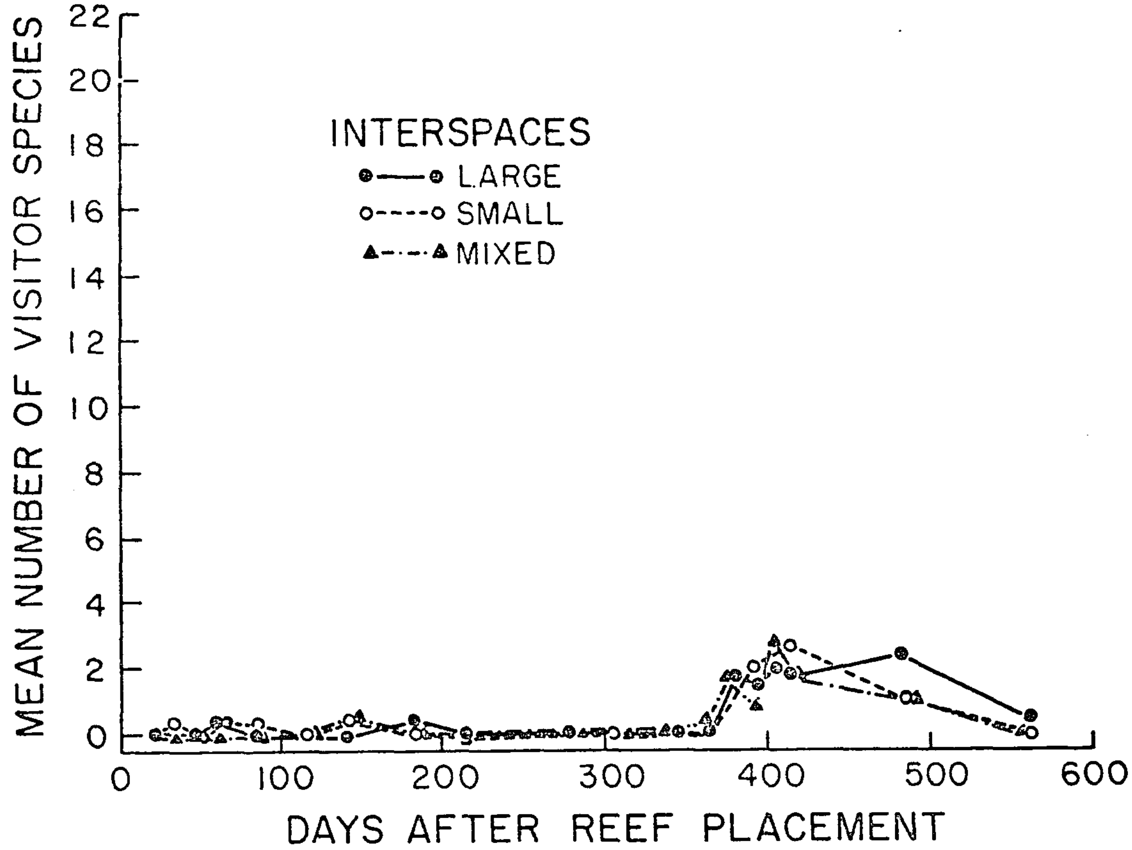

Fig. 18. Mean number of visitor species over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

of species occurred at approximately the same time on all reef types.

Shannon-Wiener diversity values were highest on the mixed interspace reef type for the majority (55%) of the time of the study (Fig. 19). They were highest on the mixed interspace reef type from day 116 to day 304 and from day 406 to day 485 for a total of 267 days. The 563 day data points were excluded from consideration since they were based on only one replicate of each reef type.

In contrast to the pronounced seasonal fluctuations in number of species and numbers of individuals, fluctuation in mean H' values were remarkably slight (Fig. 19). The absence of summer peaks in H' values was due to summer lows in species evenness. A summary of species diversity and evenness on each of the summer-placed model reefs is given in Appendix B.

Fish Defaunation of Model Patch Reefs

The results of the visual census of the model reefs conducted on day 485 and the rotenone census of day 487 are compared in Table 6. The largest source of error in the visual estimates of species richness was in counts of the number of primary resident species. An average of 33.9% fewer primary resident species were recorded visually than were collected with rotenone. The smallest difference between the rotenone and visual counts of primary resident

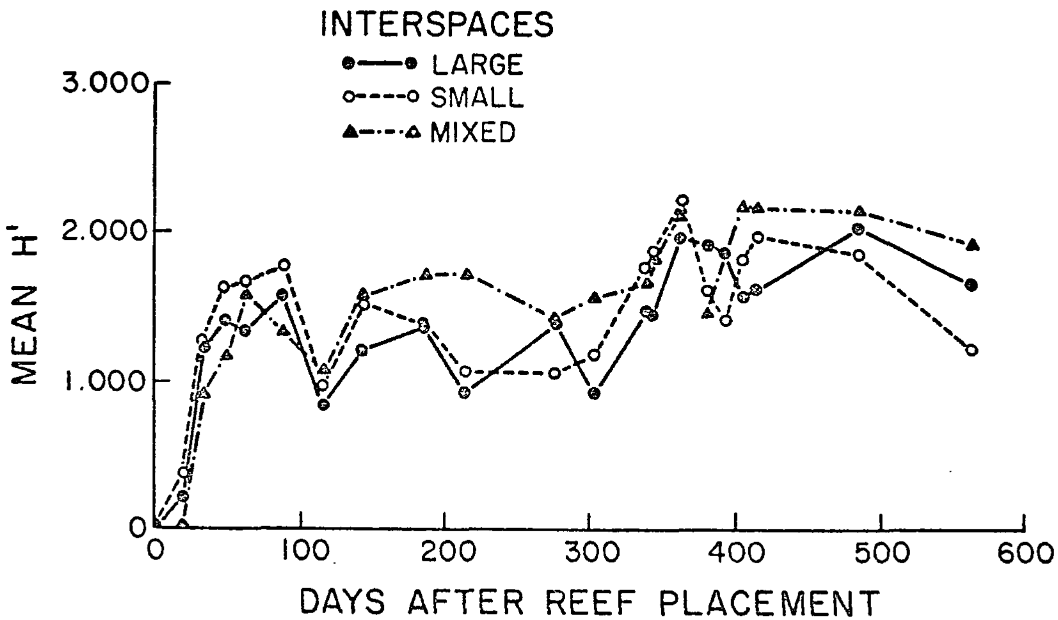

Fig. 19. Mean H' values over time on large, small, and mixed interspace model reefs (L1-3, S1-3 and M1-3).

Table 6. Numbers of species (S), number of individuals (N) and Shannon-Wiener diversity values (H') resulting from visual (V), rotenone (R) and combined (C) counts on reefs L1, L2, S1, S2, M1 and M2.

Count Type	Reef Number					
	L1	L2	S1	S2	M1	M2
Total S, V	15	16	12	12	14	14
Total S, R	13	17	14	18	17	13
Total S, C	20	23	17	20	19	17
(V-C/C)x100	-25.0%	-30.4%	-29.4%	-40.0%	-26.3%	-17.6%
1^o Res. S, V	9	10	9	11	11	11
1^o Res. S, R	12	16	14	17	15	12
1^o Res. S, C	14	17	14	18	15	14
(V-C/C)x100	-35.7%	-41.2%	-35.7%	-38.9%	-26.7%	-21.4%
2^o Res. S, V	4	3	3	1	2	2
2^o Res. S, R	1	1	0	1	1	1
2^o Res. S, C	4	3	3	2	3	2
(V-C/C)x100	0	0	0	-50.0%	-33.3%	0
Visitor S, V	2	2	0	0	1	1
Visitor S, R	0	0	0	0	0	0
Visitor S, C	2	2	0	0	1	1
(V-C/C)x100	0	0	0	0	0	0

Table 6. (continued)

	Reef Number					
Count Type	L1	L2	S1	S2	M1	M2
Total N, V	42	51	41	41	58	50
Total N, R	70	83	74	89	101	77
Total N, C	94	109	88	102	130	97
(V-C/C)x100	-55.3%	-53.2%	-53.4%	-59.8%	-55.3%	-48.5%
H' Visual	2.042	2.258	2.115	2.230	2.157	2.248
H' Rotenone	2.115	2.290	2.212	2.292	2.208	2.105
H' Combined	2.364	2.574	2.358	2.481	2.412	2.423
(V-C/C)x100	-13.6%	-12.3%	-10.3%	-10.1%	-10.6%	-7.2%

species occurred on the mixed interspace reef type (ave. = 24.1%). The average differences between the rotenone and visual estimates of numbers of primary resident species on the large and small interspace reef types were 38.5% and 37.3% respectively.

Visual counts were more effective in estimating numbers of secondary resident and visitor species. More secondary resident species were counted visually than were captured with rotenone on five of the reefs. The two techniques resulted in the same count of secondary residents species in the sixth case. No visitor species were collected using rotenone. Visitors were recorded visually on four of the six reefs.

The largest source of error in the visual census was in the estimation of total numbers. Total numbers of individuals recorded visually were approximately one half of the numbers collected with rotenone.

The results of the fish defaunation collections show no positive relationship between interspace size diversity and species richness or diversity. The highest total species count based on combined rotenone and visual sampling was recorded on a large interspace reef (23 species). Higher mean, total numbers of species were found on large interspace and small interspace reef types

($\bar{L}$ = 21.5, $\bar{S}$ = 18.5, $\bar{L}$ = 18.0). Highest H' values were also obtained on large and small interspace reefs.

Season and Succession and Fish Communities of Model Patch Reefs

Several pieces of evidence demonstrate the high degree of seasonal influence on the patch reef fish communities studied. A greater percentage of fish species were shared by summer-placed and winter-placed reefs when sampled during the same season than when they were sampled the same time after reef placement (Fig. 20). Species richness on these same two sets of reefs was also found to be much more similar when plotted against season than when plotted against reef age (Figs. 21 and 22). The same result was obtained in a comparison of mean total number of individuals (Figs. 23 and 24).

While succession apparently had less of an effect on the above factors than season, it was undoubtedly of some importance. The association of certain species of fish with encrusting organisms probably ties their successful colonization to successional events. For example, though numbers of individuals on winter-placed versus summer-placed reefs were more similar when compared on a seasonal basis (Figs. 23 and 24) differences still existed between them. This difference was mostly due to the low

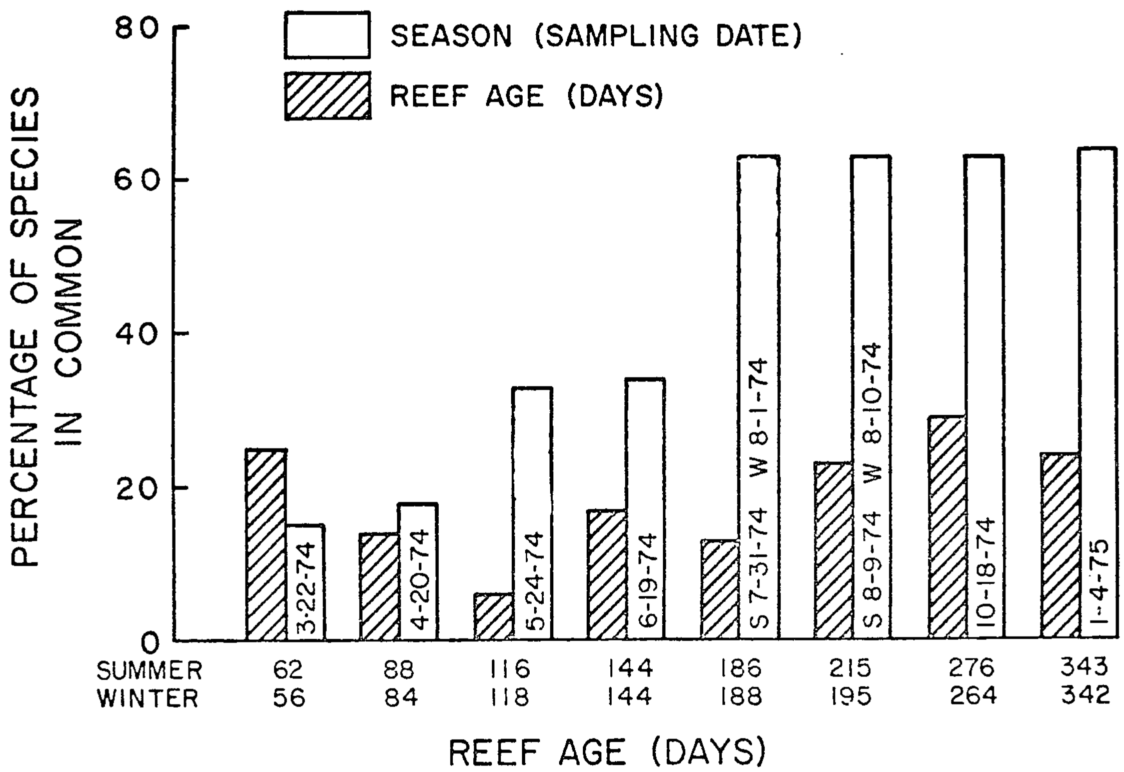

Fig. 20. Percentage of species shared between summer and winter-placed model reefs when compared on the basis of season and reef age.

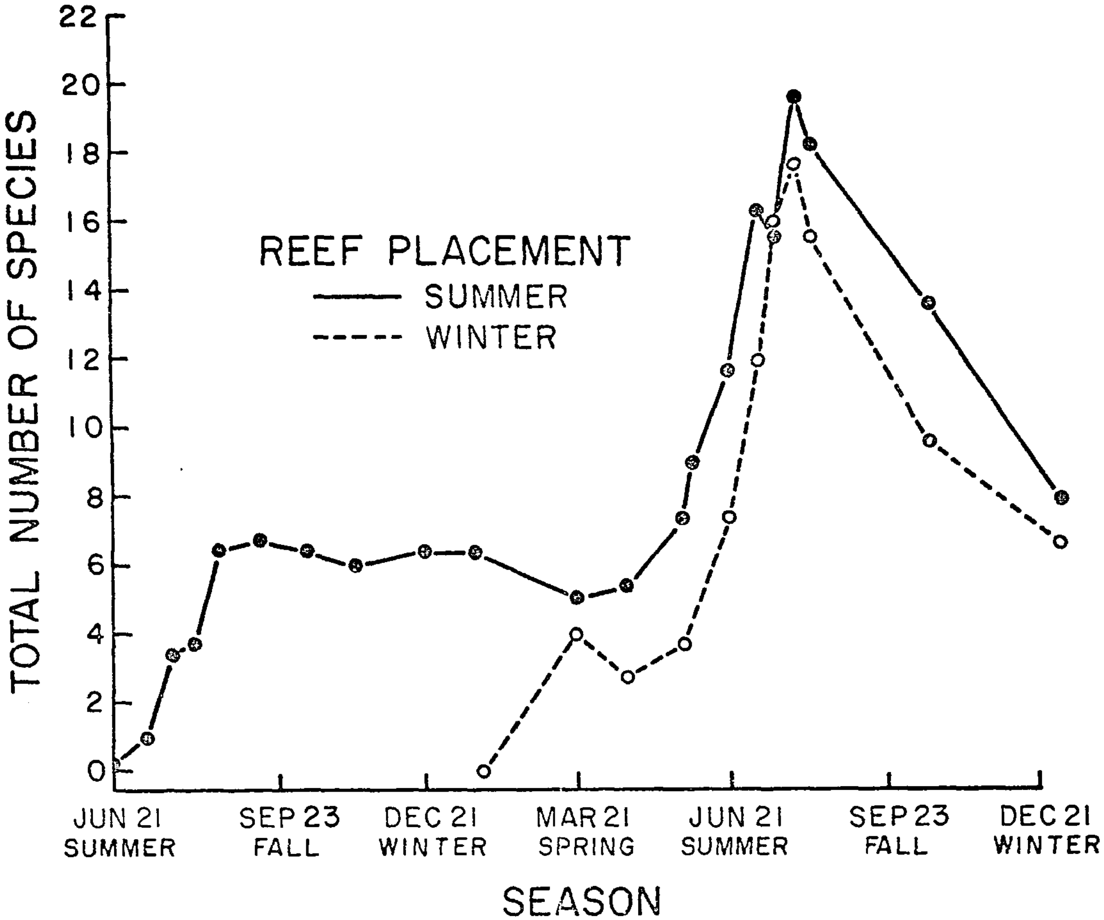

Fig. 21. Mean total number of species on summer and winter-placed reefs plotted against season.

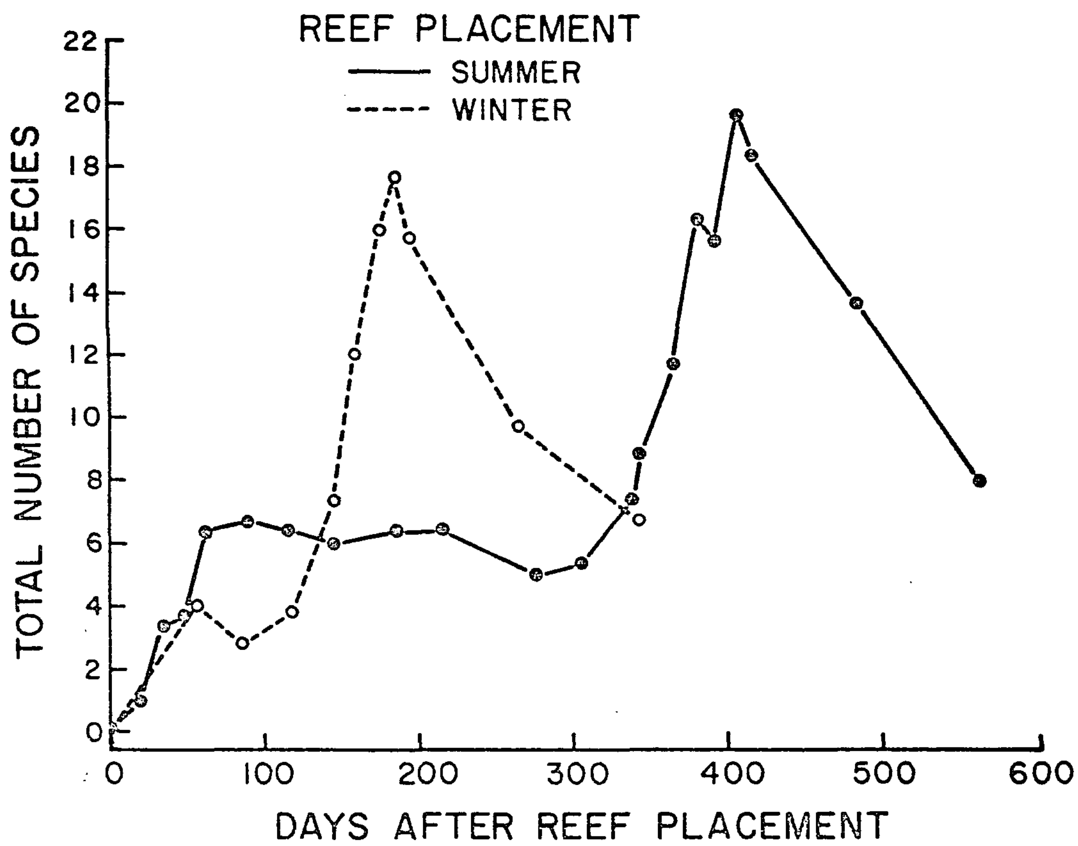

Fig. 22. Mean total number of species on summer and winter-placed reefs plotted against reef age.

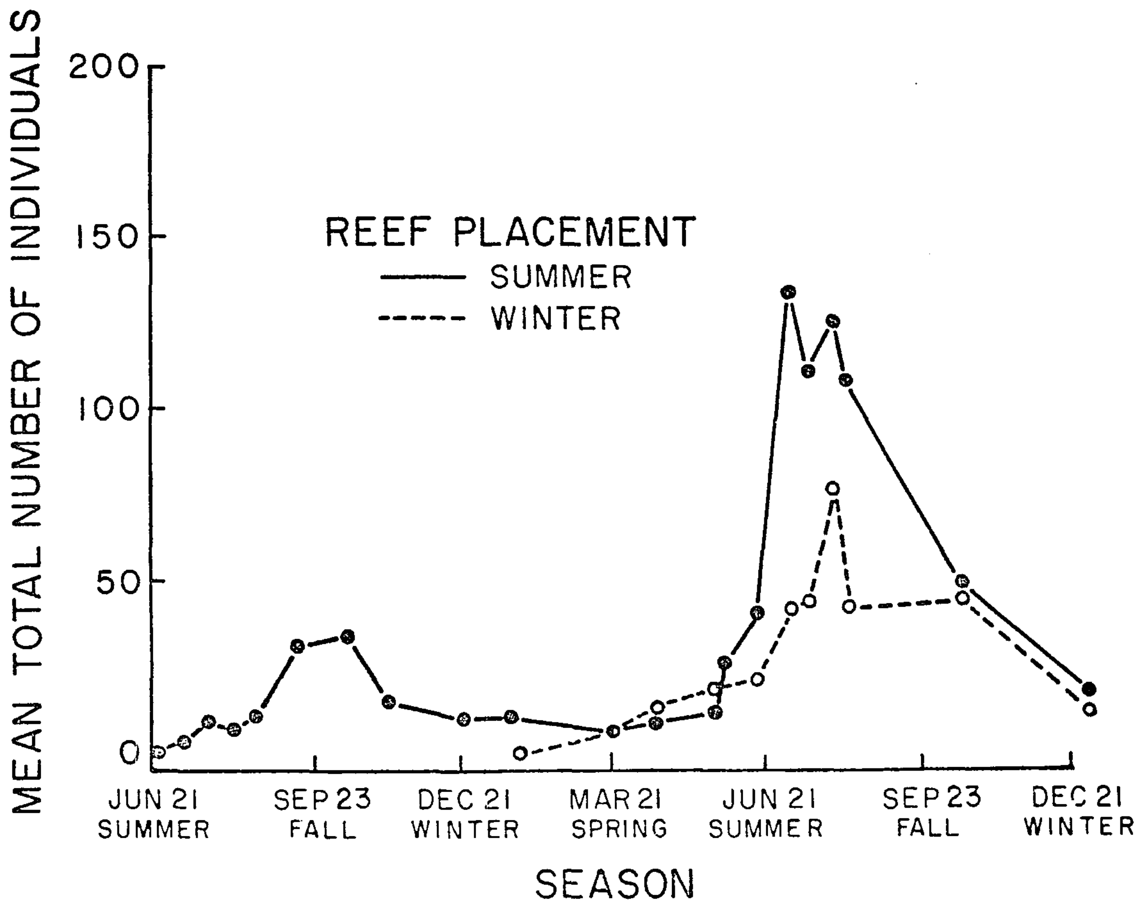

Fig. 23. Mean total number of individuals on summer and winter-placed reefs plotted against season.

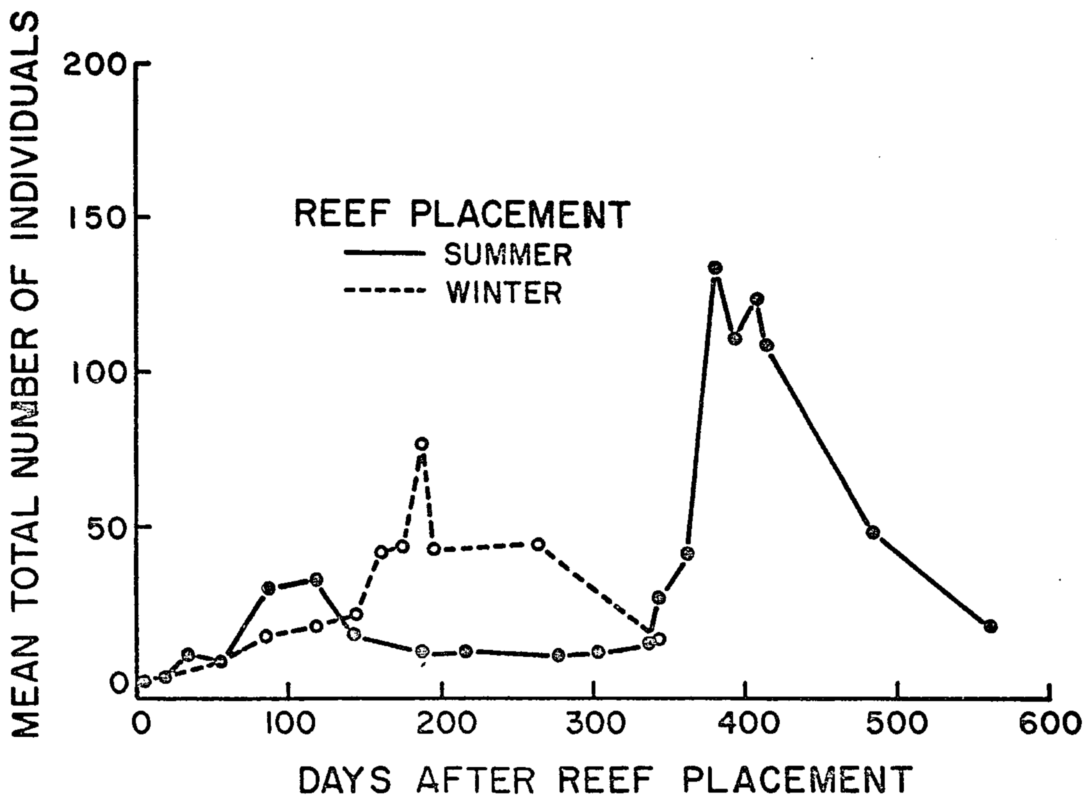

Fig. 24. Mean total number of individuals on summer and winter-placed reefs plotted against reef age.

numbers of *Exerpes asper*, an algae-associated species, on the winter placed reefs (see Table 4).

Habitat Utilization on Model Patch Reefs

The vertical distributions of the two sea basses studied had approximately 50% overlap (Fig. 25, D = 0.54). *Paralabrax maculatofasciatus*, the larger of the two serranids, was most commonly found resting on the sand floor next to a reef (zone I). However, it was also observed resting on the sides or in the interspaces of all three layers of cement blocks (zones II, III and IV). *Serranus fasciatus*, the smaller of the two serranids, was observed with equal frequency on sand and on reef tops (zone V).

The two species of gobies observed, *Gobiosoma chiquita* and *Coryphopterus urospilus*, were both found almost entirely on the sand flats adjoining the model reefs (Fig. 25). *C. urospilus* was the only one of these two species to use the vertical aspect of the reefs. Overlap of these two species was high, D = 0.89.

The vertical distributions of the three species of chaenopsid blennies observed had distinct modes (Figs. 25 and 26). *Emblemaria hypacanthus* was found most frequently on sand (zone I) and was the only chaenopsid to make use of the first level of blocks (zone II). *Acanthemblemaria crockeri* was most common in zone III. *Protemblemaria bicirris* was recorded with the greatest

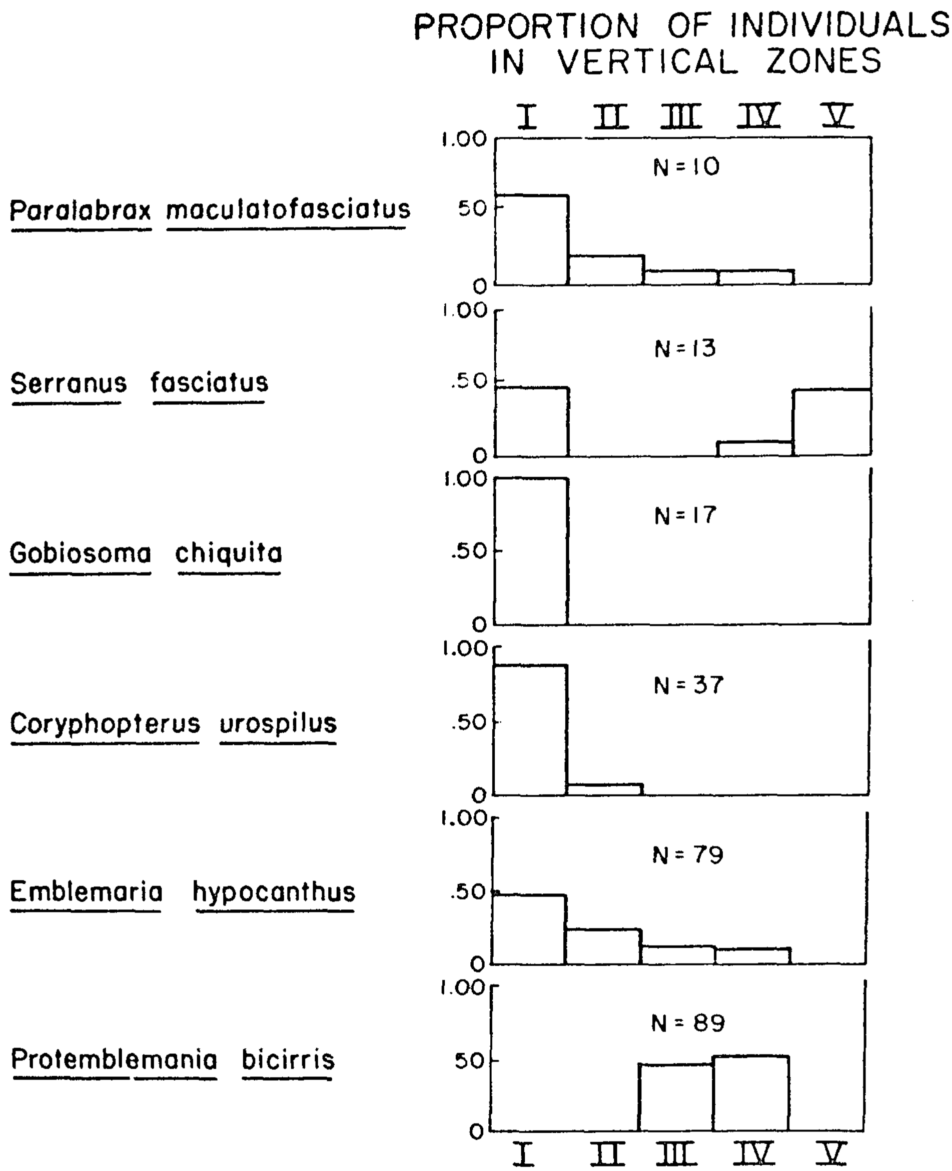

Fig. 25. The distributions of individuals of six species of fishes among five vertical zones on model patch reefs.

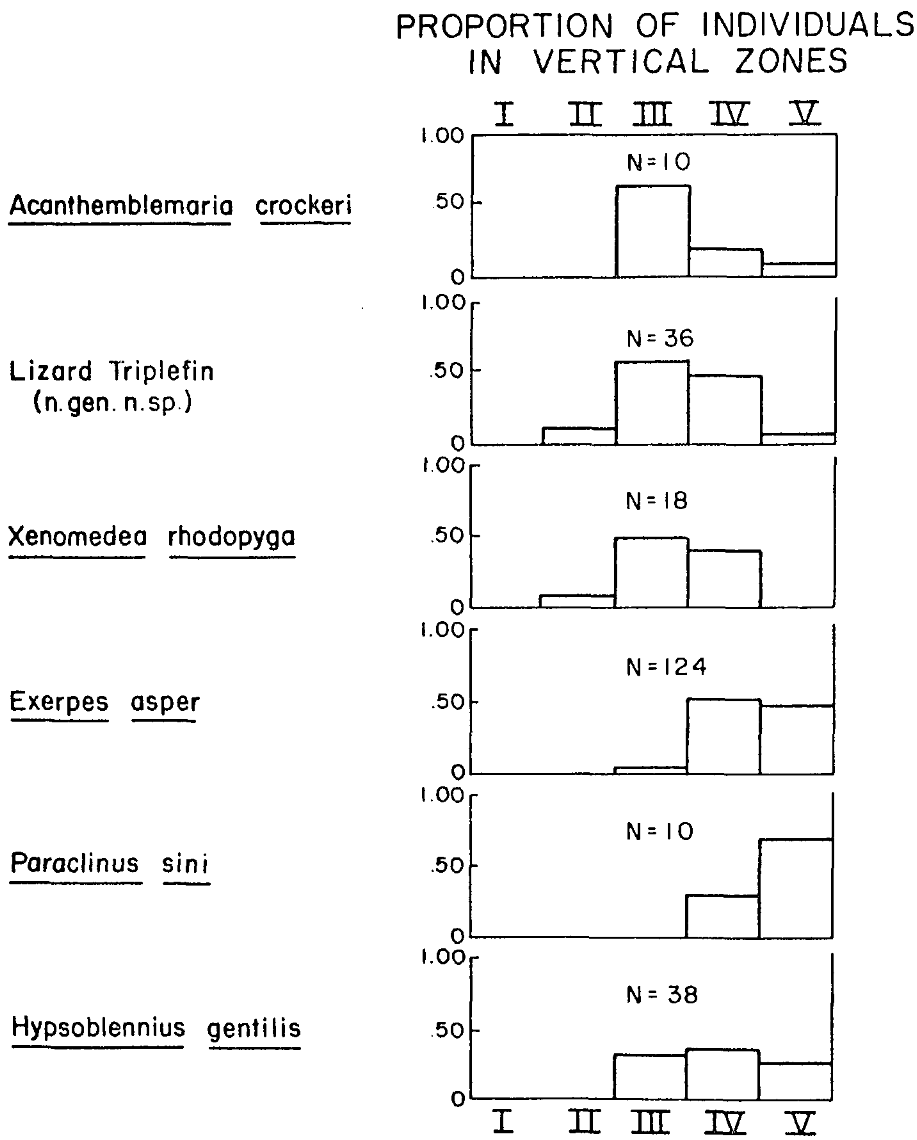

Fig. 26. The distributions of individuals of six species of fishes among five vertical zones on model patch reefs.

frequency in zone IV. The overlaps between E. hypacanthus and P. bicirris and between E. hypacanthus and A. crockeri were the same (D = 0.27). Overlap between P. bicirris and A. crockeri was much higher (D = 0.73).

The distributions of members of the family Tripterygiidae and Clinidae were confined to the reef proper (Fig. 26). The lizard triplefin and the clinid Xenomedea rhodopyga, had almost identical distributions (D = 0.94). The largest number of individuals for both of these species were found in zone III. Zone IV had the next largest proportion of each of these species. Exerpes asper was most commonly associated with zone IV and zone V where it could be observed hovering in and over the algae of these strata. Paraclinus sini was most frequently recorded on the tops of the model patch reefs. However, this species is so cryptic that the reliability of this observation must be questioned. P. sini may have just been more easily detected on reef tops.

The only member of the family Blenniidae recorded in the study, Hypsoblennius gentilis, ranged widely over the reef surface (Fig. 26). The proportions of H. gentilis recorded from zones III, IV and V were 0.34, 0.37 and 0.29 respectively.

Immigration and Extinction on Model Patch Reefs

Seasonal fluctuations in extinction and immigration were observed on all three reef types (Figs. 27, 28 and 29). In each case, there was an initial peak in rates of immigration (I) and extinction (E) that extended from about day 34 to day 116. This was followed by a relatively long period of time during which immigration and extinction proceeded at a much lower rate. This period of low activity was in turn followed by a second peak in immigration and extinction between days 343 and 415.

The relationship between I and E and the number of primary resident species on a reef was analyzed separately for each of the three periods discussed above. A correlation of I as dependent variable versus number of primary resident species in the previous census (S_{pr}) was done for each period. The relationship between E and S_{pr} was analyzed in the same fashion. The 343 day census data was excluded from the analysis of the second peak because of the short interval between that census and the previous one, 5 days. The average time between the other censuses of this period (day 343 to 415) was 14.5 days.

A strong relationship between I and S_{pr} and between E and S_{pr} was found for both peaks of immigration and extinction (Tables 7 and 8). A significant ($p < 0.05$) positive correlation was found between E and S_{pr} in all cases

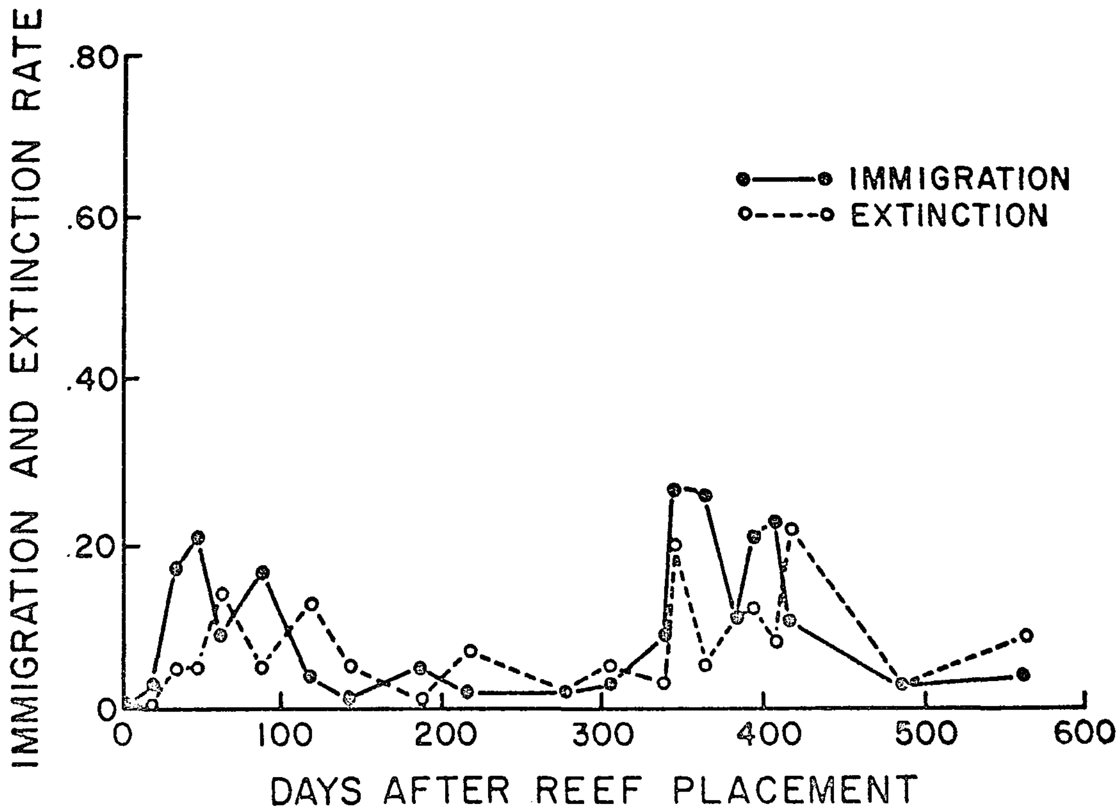

Fig. 27. Mean immigration and extinction rates over time on large interspace reefs L1-3.

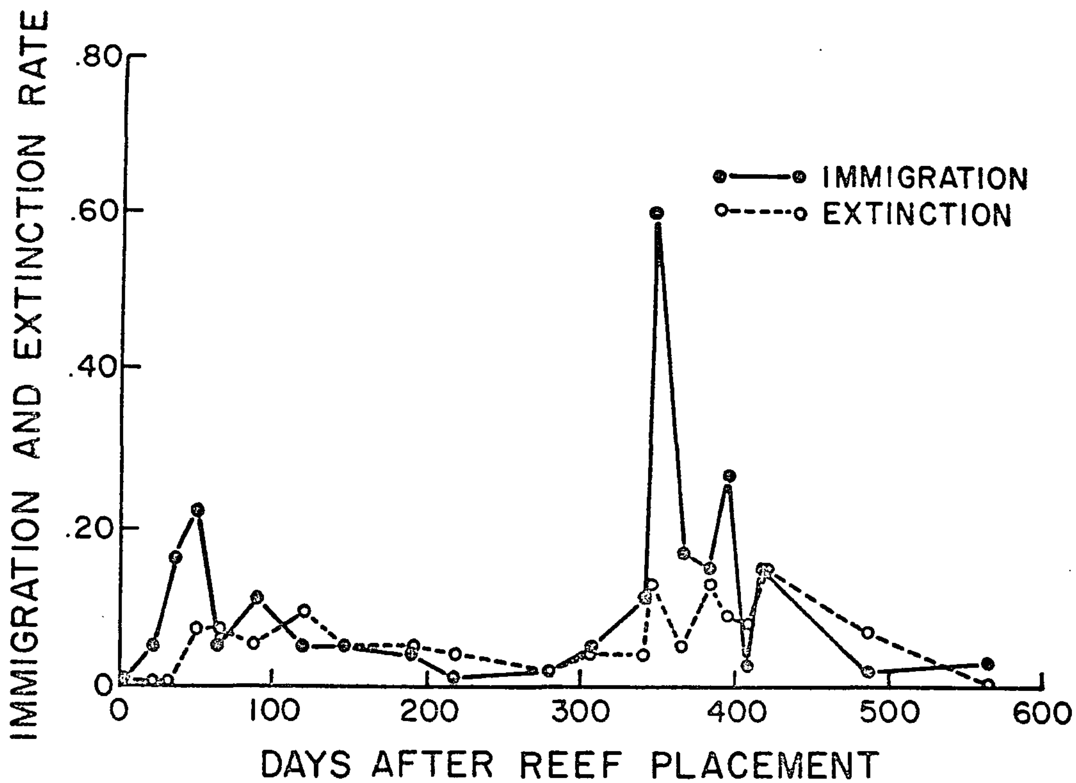

Fig. 28. Mean immigration and extinction rates over time on small interspace reefs S1-3.

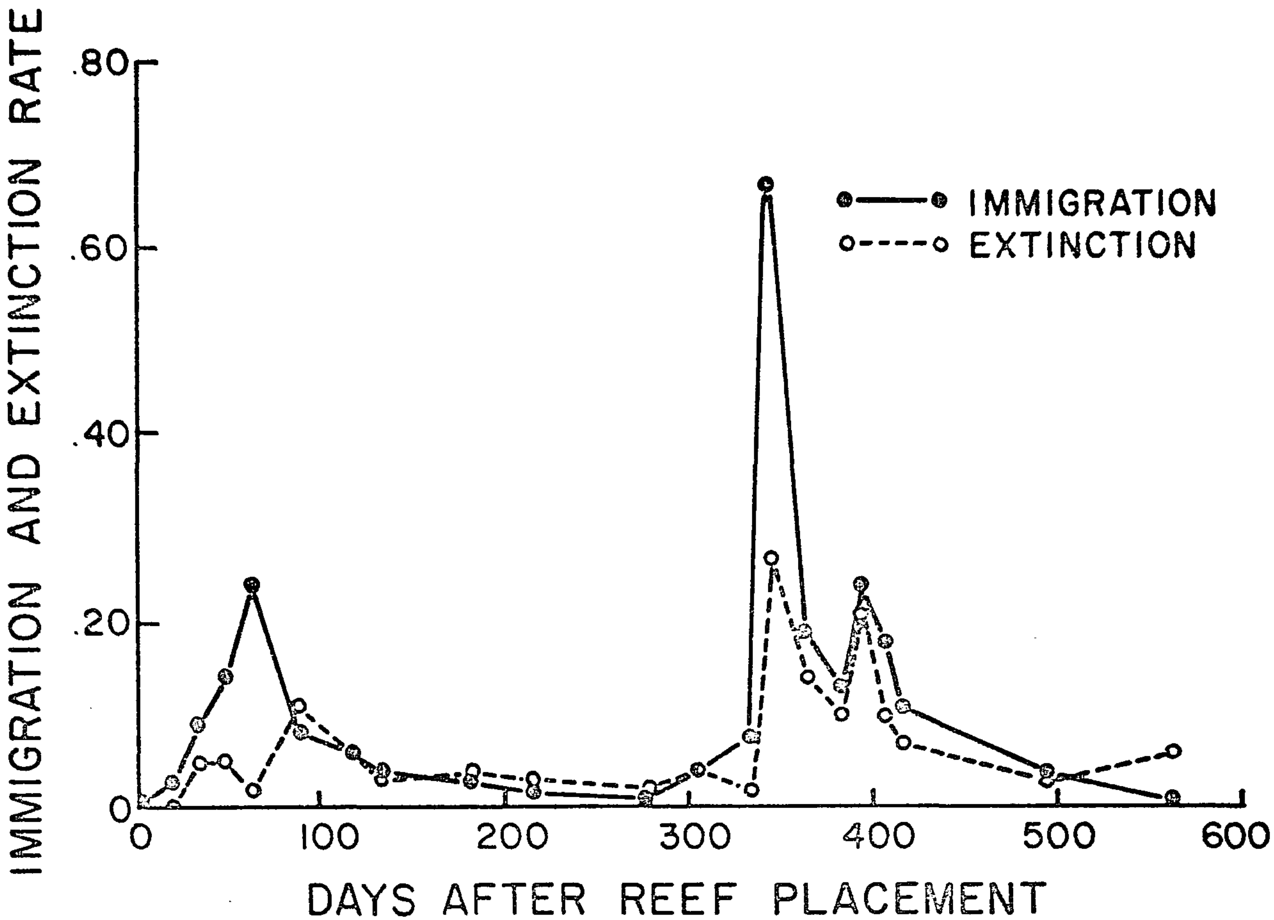

Fig. 29. Mean immigration and extinction rates over time on mixed interspace reefs M1-3.

Table 7. Correlation and regression analysis of extinction data from model patch reefs L1-3, S1-3, and M1-3.

Reef Type	Correlation Coefficient	Significance	Y intercept	Slope	Degrees of Freedom
		34-116 Days			
Large Interspace	0.723	0.01	0.015	0.019	13
Small Interspace	0.602	0.05	0.009	0.016	13
Mixed Interspace	0.613	0.05	0.020	0.012	13
		144-304 Days			
Large Interspace	0.332	---	-0.0001	0.011	14
Small Interspace	0.022	---	0.037	0.001	14
Mixed Interspace	0.201	---	0.019	0.003	14
		364-415 Days			
Large Interspace	0.659	0.01	-0.114	0.026	14
Small Interspace	0.553	0.05	-0.115	0.019	14
Mixed Interspace	0.321	---	0.013	0.011	14

Table 8. Correlation and regression analysis of immigration data from model patch reefs L1-3, S1-3 and M1-3.

Reef Type	Correlation Coefficient	Significance	Y intercept	Slope	Degrees of Freedom
		34-116 Days			
Large Interspace	-0.527	0.05	0.207	-0.019	14
Small Interspace	-0.569	0.05	0.209	-0.022	14
Mixed Interspace	-0.312	---	0.155	-0.011	14
		144-304 Days			
Large Interspace	-0.476	---	0.064	-0.010	14
Small Interspace	-0.146	---	0.049	-0.004	14
Mixed Interspace	-0.640	0.01	0.116	-0.020	14
		364-415 Days			
Large Interspace	-0.562	0.05	0.359	-0.020	14
Small Interspace	-0.386	---	0.377	-0.020	14
Mixed Interspace	-0.504	0.05	0.388	-0.022	14

examined from the first peak. A significant ($p < 0.05$) negative correlation was found between I and S_{pr} in two of the three cases analyzed for this same period. The correlation between I and S_{pr} in the third case, though not significant, showed the same trend as the significant cases. Data analyzed from the 364-415 day period yielded a significant ($p < 0.05$) negative correlation between I and S_{pr} and a significant ($p < 0.05$) positive correlation between E and S_{pr} in two of three cases. The correlation between E and S_{pr} on the mixed interspace reef type and between I and S_{pr} on the small interspace reef type were not significant for this period.

In contrast to the results of the analyses of data from the peaks in immigration and extinction, only one of the cases from the period of low turnover was significant. None of the correlations between E and S_{pr} were significant and correlations between I and S_{pr} were significant only for the mixed interspace reef type ($p < 0.01$).

Regression lines for I versus S_{pr} and E versus S_{pr} for the 34-116 and 364-415 day periods were plotted on the same axis for each of the reef types (Figs. 30, 31 and 32). The points at which the immigration and extinction lines cross in each of these figures is the predicted equilibrium species number. These predicted means along with the actual mean number of primary residents observed

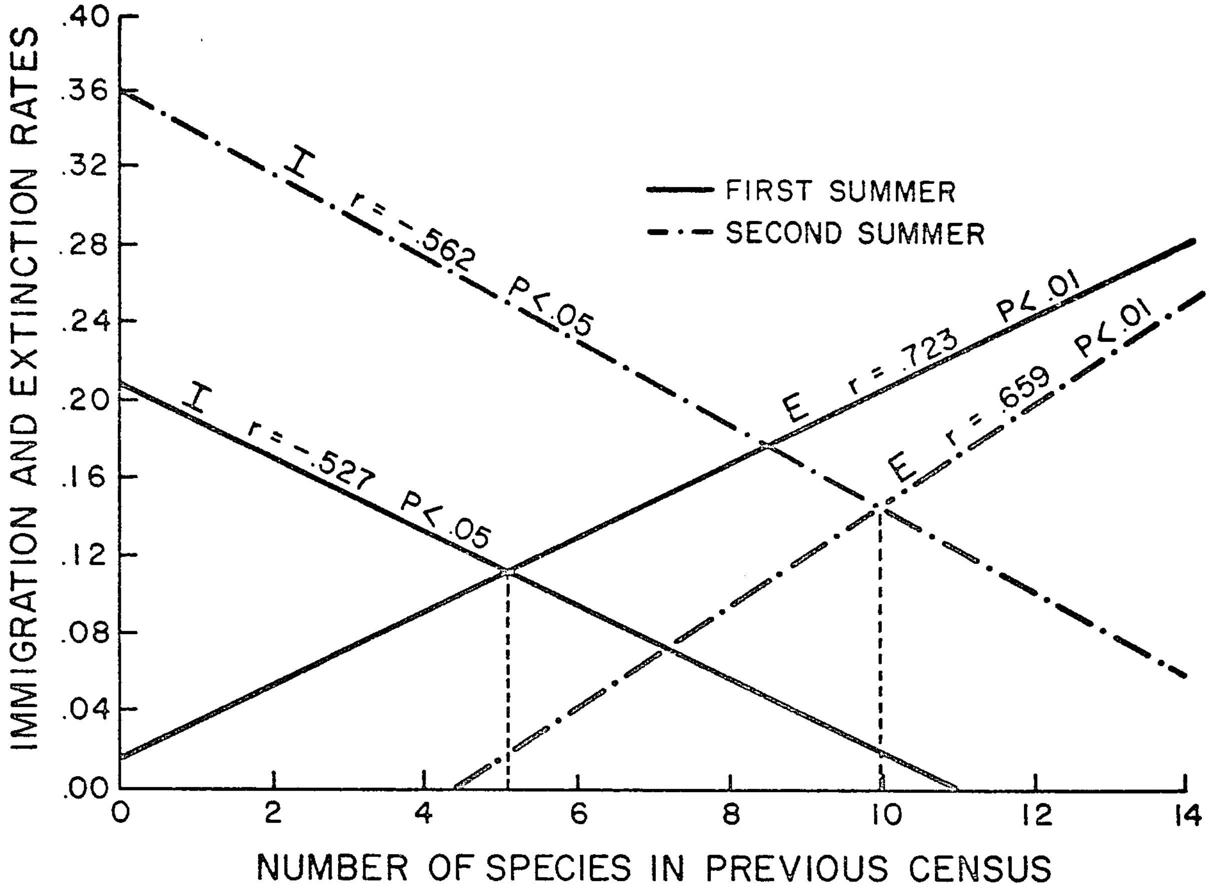

Fig. 30. Immigration and extinction regression lines for large inter-space reefs L1-3 for the first and second summers of the study.

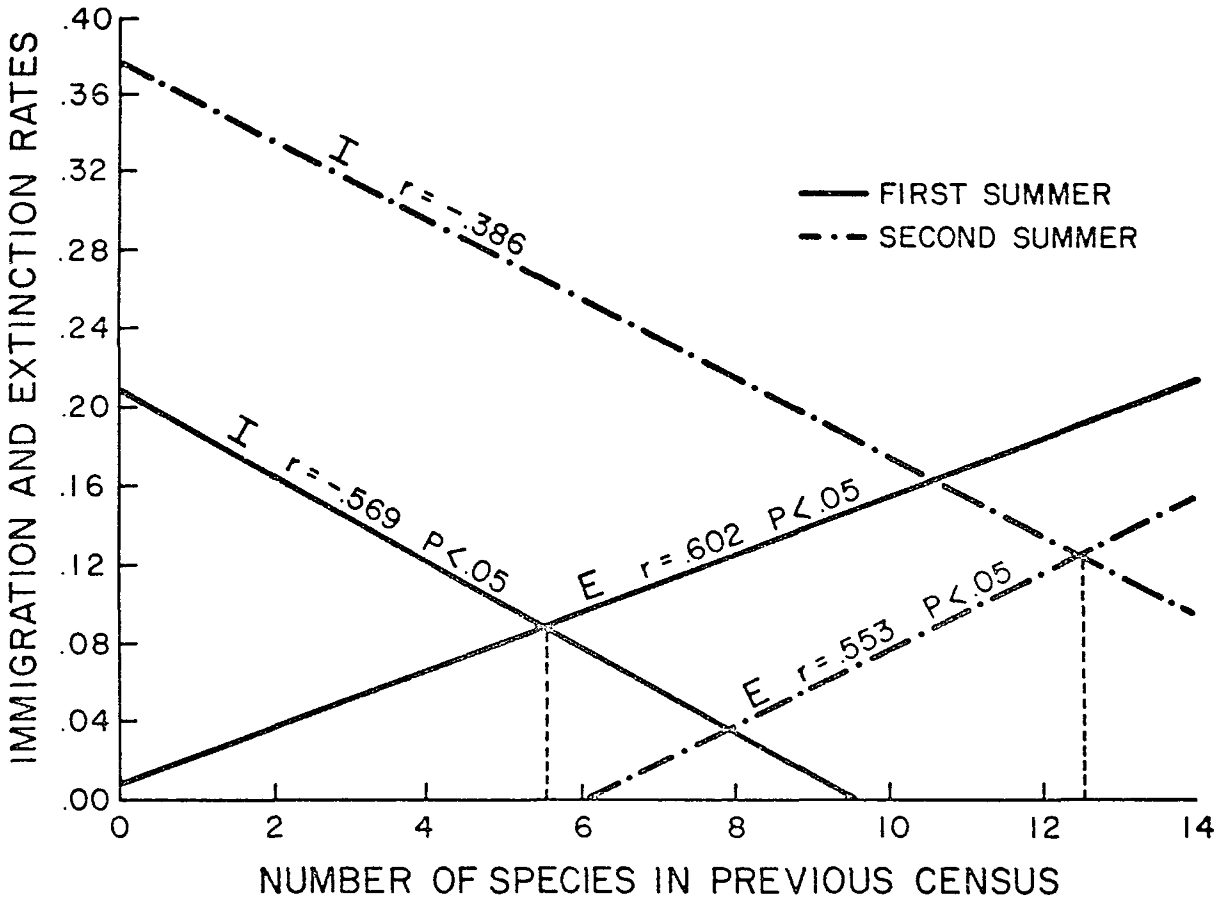

Fig. 31. Immigration and extinction regression lines for small interspace reefs S1-3 for the first and second summers of the study.

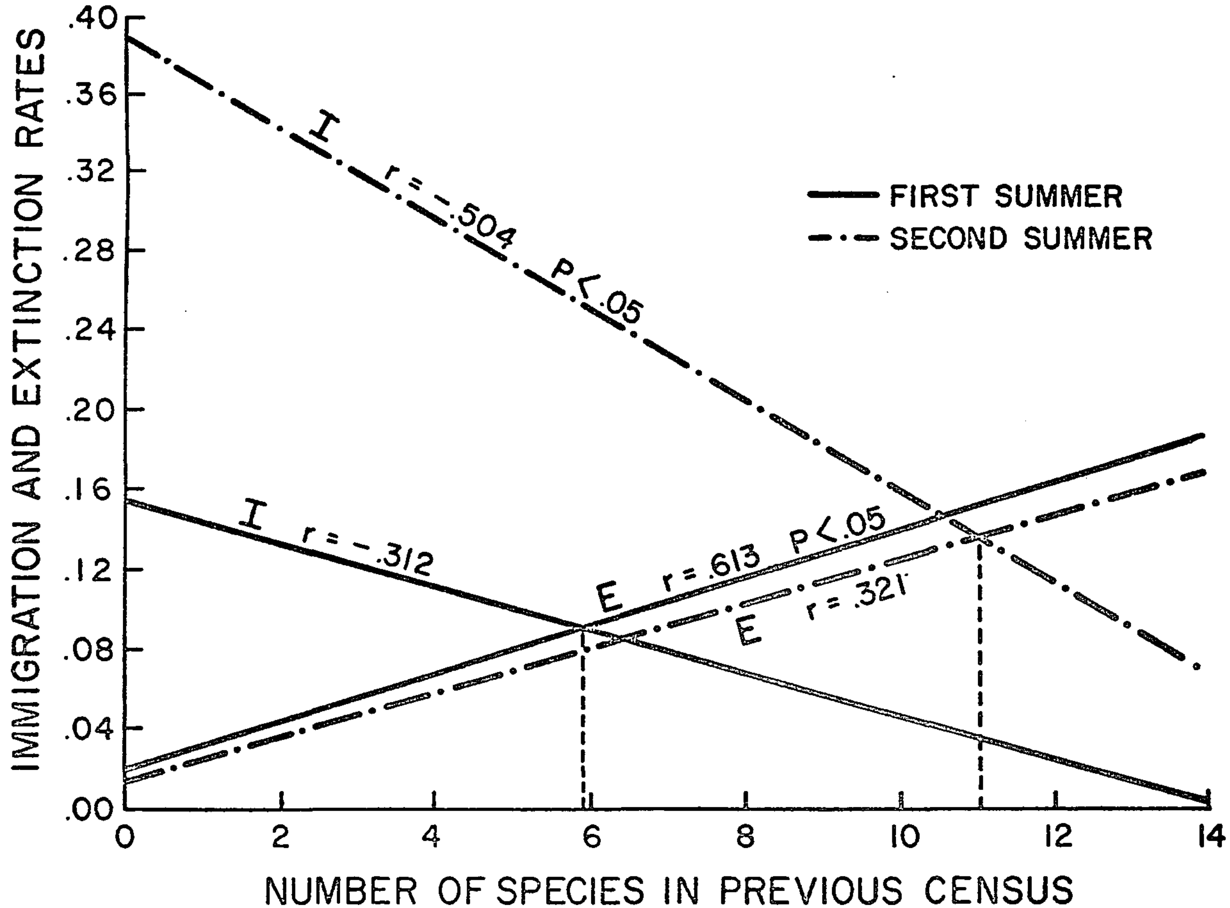

Fig. 32. Immigration and extinction regression lines for mixed inter-space reefs M1-3 for the first and second summers of the study.

on each reef type for the 34-116 and 364-415 day periods are given in Table 9. The average difference in these values for the first peak is 1.05 species. The average difference for the second peak is 0.28 species.

Natural Patch Reef Fish Community

The composition of the fish fauna associated with the Bahia Algodones patch reefs was very similar to the model patch reef fish community. Thirty eight species of fish belonging to 17 families were observed on the Algodones patch reefs (Table 10). Thirty one of these species (84%) were also recorded on the model patch reefs. The six species that were not observed on the model patch reefs comprise less than 7% of the individuals recorded on the Algodones reefs. Species recorded on individual, natural patch reefs during the late spring and midsummer censuses are listed in Appendix C.

Despite similarities in species composition, there were some striking differences in the relative abundances of certain species on the model and natural patch reefs (Table 11). Some of the most pronounced differences between the two sets of reefs were found in the family Clinidae. The most numerous species on the natural patch reefs, the clinid *Malacoctenus hubbsi*, ranked 20th in abundance on the model reefs. The clinids, *Labrisomus xanti*, *Malacoctenus margaritae* and *Malacoctenus tetranemeus*,

Table 9. Predicted and observed mean species number for model patch reefs L1-3, S1-3 and M1-3 for the first and second summer of the study.

Reef Type	Predicted $\bar{S}$	Observed $\bar{S}$	Difference
	34-116 Days		
Large Interspace	5.09	4.47	0.62
Small Interspace	5.49	4.93	0.56
Mixed Interspace	5.90	3.93	1.97
		Mean Difference =	1.05
	364-415 Days		
Large Interspace	9.90	9.93	0.03
Small Interspace	12.60	12.20	0.40
Mixed Interspace	11.02	10.60	0.42
		Mean Difference =	0.28

Table 10. Species recorded on natural patch reefs.

Family	Common Family Name	Species Name	Numbers[1] L	Numbers[1] M	Age[2]
Muraenidae	Moray eels	Gymnothorax castaneus	3	-	A
Serranidae	Sea basses	Paralabrax maculatofasciatus	2	35	J,A
		Mycteroperca rosacea	-	5	J,A
		Alphestes multiguttatus	2	1	J,A
		Serranus fasciatus	2	-	A
		Epinephelus labriformis	1	-	J
Lutjanidae	Snappers	Lutjanus guttatus	-	28	J
		L. argentiventris	-	4	J
		Hoplopagrus guntheri	-	3	J
Apogonidae	Cardinalfishes	Apogon retrosella	6	18	J,A
Haemulidae	Grunts	Lythrulon flaviguttatum[3]	-	8	A
Sciaenidae	Croakers	Pareques viola	8	35	J
Mullidae	Goatfishes	Mulloidichthys dentatus[3]	-	8	J
Sparidae	Porgies	Calamus brachysomus[3]	-	19	J,A
Pomacentridae	Damselfishes	Pomacentrus rectifraenum	3	7	J
		P. flavilatus	-	1	J
		Abudefduf troschelii	4	134	J,A

Table 10. Species recorded on natural patch reefs (continued).

Family	Common Family Name	Species Name	Numbers[1] L	Numbers[1] M	Age[2]
Labridae	Wrasses	*Halichoeres dispilus*	2	17	J,A
		H. nicholsi	-	6	J
Scaridae	Parrotfishes	*Nicholsina denticulata*	4	20	J,A
Gobiidae	Gobies	*Gobiosoma chiquita*	1	65	J,A
		Coryphopterus urospilus	2	39	J,A
		Elacatinus punticulatus	1	6	A
Blennidae	Combtooth blennies	*Hypsoblennius gentilis*	50	33	J,A
Clinidae	Clinids	*Malacoctenus hubbsi*	38	233	J,A
		M. margaritae	15	15	J,A
		M. tetranemeus	3	4	A
		Labrisomus xanti	18	24	J,A
		Paraclinus sini	10	18	J,A
		Exerpes asper	-	6	A
		Xenomedea rhodopyga	1	1	A
Chaenopsidae	Tube blennies	*Acanthemblemaria crockeri*	3	7	A
		Emblemaria hypacanthus	2	3	A
		Chaenopsis alepidota	2	3	A

Table 10. Species recorded on natural patch reefs (continued).

Family	Common Family Name	Species Name	Numbers[1] L	Numbers[1] M	Age[2]
Tripterygiidae	Triplefin blennies	n. gen. N. sp. Lizard triplefin[4]	2	8	A
		Axoclinus carminalis	-	3	A
Scorpaenidae	Scorpionfishes	Scorpaena mystes	7	9	A
Balistidae	Triggerfishes	Balistes polylepis	2	1	A

1. L = late spring; M = midsummer.

2. A = adult; J = juvenile.

3. Visitor species.

4. This new genus, new species triptergiid (Rosenblatt 1959) will be referred to as the Lizard triplefin.

Table 11. The 30 most common fish species on the natural patch reefs and a comparison of their ranks in abundance on the model patch reefs.

Species	Total Numbers	Rank on Natural Reefs	Rank on[1] Model Reefs
Malacoctenus hubbsi	271	1	20
Abudefduf troschelii	138	2	+
Hypsoblennius gentilis	83	3	4
Gobiosoma chiquita	66	4	23
Pareques viola	43	5	+
Labrisomus xanti	42	6	-
Coryphopterus urospilus	41	7	2
Paralabrax maculatofasciatus	37	8	6
Malacoctenus margaritae	30	9	+
Lutjanus guttatus	28	10	13
Paraclinus sini	28	10	17
Nicholsina denticulata	24	12	15
Apogon retrosella	24	12	8
Calamus brachysomus	19	14	22
Halichoeres dispilus	19	14	18
Scorpaena mystes	16	16	16
Acanthemblemaria crockeri	10	17	21
Lizard triplefin	10	17	9
Eupomacentrus rectifraenum	10	17	+
Mulloidichthys dentatus	8	20	-

Table 11. (continued)

Species	Total Numbers	Rank on Natural Reefs	Rank on Model Reefs[1]
Lythrulon flaviguttatum	8	20	+
Malacoctenus tetranemeus	7	21	-
Elacatinus punticulatus	7	21	+
Halichoeres nicholsi	6	24	+
Exerpes asper	6	24	1
Chaenopsis alepidota	5	26	7
Mycteroperca rosacea	5	26	29
Emblemaria hypacanthus	5	26	5
Lutjanus argentiventris	4	29	+
Gymnothorax castaneus	3	30	27
Alphestes multiguttatus	3	30	+
Hoplopagrus guntheri	3	30	+
Axoclinus carminalis	3	30	-
Balistes polylepis	3	30	10

1. + = recorded on model patch reefs but did not rank in the top 30 species. - = not recorded on the model patch reefs.

either were not recorded on the model reefs or did not rank with the 30 most abundant species on the model reefs. However, they were ranked 6, 9 and 21 respectively on the natural patch reefs. Another member of this family, Xenomedea rhodopyga, was ranked 11th in abundance on the model patch reefs and only recorded twice on the natural patch reefs. Exerpes asper, another clinid, ranked first in abundance on the model reefs but was in position 24 on the natural patch reefs.

Two of the gobies recorded from the two sets of reefs also show shifts in relative abundance. Coryphopterus urospilus was number two in abundance on the model patch reefs and seventh on the natural reefs. Gobiosoma chiquita was the 23rd most numerous species on the model reefs but ranked fourth in abundance on the natural patch reefs.

Species Richness on Natural Patch Reefs

The total number of species recorded on the nine natural patch reefs censused during late spring varied from 1 to 19 (ave. = 7.9, S.D. = 5.2) (Table 12). In midsummer, the total number of species on these reefs ranged from 9 to 20 (ave. = 14.6, S.D. = 3.0) and the number of resident species varied from 7 to 20 (ave. = 13.3, S.D. = 3.5). The average total number of species and number of resident species on all 12 reefs censused during midsummer were 13.6 (S.D. = 4.7) and 14.7 (S.D. = 4.4) respectively. The

Table 12. Number of species (S) and Shannon-Wiener diversity values (H') recorded from the natural patch reefs during the late spring and mid-summer censuses.

Reef Number	Late Spring (S)	Midsummer Resident (S)	Midsummer Total (S)	Late Spring (H')	Mid-summer (H')
1	9	15	16	1.869	1.862
2	8	14	15	1.812	2.181
3	8	14	15	1.860	2.037
4	19	20	20	2.699	2.332
5	6	14	15	1.285	1.938
6	3	11	12	0.868	1.842
7	1	7	9	0.000	1.891
8	6	12	13	1.673	1.805
9	11	13	16	1.996	2.417
10	-	11	13	---	1.941
11	-	24	24	---	2.881
12	-	8	8	---	1.591

maximum number of species (24) observed on a natural patch reef was recorded on one of the reefs sampled only during midsummer.

The results of the stepwise, multiple regression analysis (Nie et al. 1975) of the natural patch reef richness data (Table 13) agree remarkably well with the results of the model patch reef study. Diversity of horizontal interspaces (DHI), as measured on the Algodones patch reefs, was analogous to the interspace variable treated experimentally with the model reefs. This variable was a significant ($p = 0.014$) addition to a regression equation only for the late spring counts when it accounted for 8.5% of the variation in species number. However, the coefficient of the late spring DHI term was negative. Therefore, DHI did not have a significant positive effect on species richness in any of the cases examined. Diversity of vertical interspaces (DVI) accounted for a significant ($p = 0.037$) portion of the variation in species number only for the late spring counts, when it accounted for 16.7% of the variance in species richness.

Area was positively correlated with species richness in both late spring and midsummer counts. Area accounted for 7.5% of the variation in species richness in the late spring census. However, the addition of the area term to the late spring, regression equation was significant

Table 13. Summary of stepwise multiple linear regression analysis of species richness patterns on the natural patch reefs.

Independent[1] Variables	Simple R	Multiple R	Multiple R Squared	Significance	Regression Coefficient	Significance
			Late Spring Residents[2] (Reefs 1-9)			
D	-0.809	0.809	0.654	0.008	-0.509	0.001
A	0.480	0.854	0.729	0.244	0.119	0.024
DVI	-0.166	0.946	0.895	0.037	20.887	0.002
DHI	0.280	0.990	0.980	0.014	-5.243	0.014
H	0.178	0.990	0.980	0.846	---	---
			Midsummer Residents (Reefs 1-9)			
D	-0.661	0.661	0.437	0.045	-0.151	0.045
H	0.404	0.798	0.636	0.107	---	---
A	0.285	0.876	0.767	0.138	---	---
DVI	0.158	0.944	0.892	0.075	---	---
DHI	0.467	0.970	0.941	0.171	---	---

Table 13. (continued)

Independent Variables[1]	Simple R	Multiple R	Multiple R Squared	Significance	Regression Coefficient	Significance
			Midsummer Residents (Reefs 1-12)			
H	0.720	0.720	0.519	0.008	22.201	0.000
A	0.385	0.845	0.714	0.035	0.126	0.016
D	-0.364	0.924	0.854	0.024	-0.010	0.024
DHI	0.440	0.926	0.857	0.702	---	---
DVI	0.285	0.926	0.858	0.921	---	---
			Midsummer Total Species (Reefs 1-12)			
H	0.662	0.662	0.439	0.019	18.709	0.002
A	0.514	0.872	0.760	0.007	0.161	0.007
D	-0.290	0.917	0.841	0.077	---	---
DHI	0.254	0.931	0.866	0.293	---	---
DVI	0.220	0.949	0.900	0.206	---	---

1. H = mean reef height; A = reef area; D = distance to nearest "main" reef; DHI = diversity of horizontal interspaces; DVI = diversity of vertical interspaces.

2. Only resident species observed on the natural patch reefs during the late spring census.

(p = 0.023) only after the addition of a DVI term. Area accounted for 32% (p = 0.007) of the variation in the midsummer data when all species were included in the analysis and for 19% (p = 0.035) when only resident species were considered.

Distance from large "main" reefs accounted for the greatest variation in numbers of species in the late spring counts (65.4%, p = 0.008). However, it only accounted for 14% (p = 0.024) of the variation in numbers of midsummer, resident species. Distance was not a significant (p = 0.077) addition to the midsummer regression equation when total numbers of species were considered.

The value of mean reef height for predicting numbers of fish species on the Algodones patch reefs also changed from late spring to midsummer. However, the direction of change was the opposite of that observed for distance. Mean reef height accounted for no significant variation in late spring richness (p = 0.846). In contrast, it accounted for 51.8% (p = 0.008) of the variation observed in numbers of resident species during the midsummer counts. Mean reef height accounted for somewhat less of the variation in total species counts for the same period (43.9%, p = 0.019).

Some of the differences between the late spring and midsummer analyses were due to the inclusion of the three additional patch reefs in the midsummer census. The results of a stepwise, multiple regression analysis (Nie et al. 1975) of midsummer resident species counts on reefs 1-9 differ from those obtained when all 12 patch reefs were included in the analysis. However, a similar change in the correlation between distance and species richness was observed. The variation in richness accounted for by distance decreased from 65.4% during late spring ($p = 0.008$) to 43.7% in midsummer ($p = 0.045$). There was also a difference in the order in which the height term was entered into the late spring and midsummer regression equations. It was the last variable entered into the equation in the late spring analysis and the second variable entered into the midsummer equation. This indicates that reef height accounted for a greater amount of the residual variance in richness during the midsummer period (Nie et al. 1975, p. 345).

Shannon-Wiener Diversity on Natural Patch Reefs

Distance accounted for the greatest amount of variation in fish species diversity in the late spring census (41.5%, see Table 14). Mean reef height accounted for an additional 12.9% of the variation in late spring diversity. The addition of distance and height terms were not significant until the addition of area to the regression equation.

Table 14. Summary of stepwise multiple linear regression analysis of species diversity (H') patterns on the natural patch reefs.

Independent Variables[1]	Simple R	Multiple R	Multiple R Squared	Significance	Regression Coefficient	Significance
			Late Spring, Total Species (Reefs 1-9)			
D	-0.645	0.645	0.416	0.061	-0.026	0.029
H	0.319	0.738	0.545	0.239	4.065	0.015
A	0.497	0.932	0.869	0.017	0.030	0.017
DVI	0.025	0.971	0.944	0.084	---	---
DHI	0.221	0.971	0.944	0.908	---	---
			Midsummer, Total Species (Reefs 1-12)			
A	0.647	0.647	0.419	0.023	0.011	0.027
H	0.425	0.803	0.645	0.040	2.114	0.005
DVI	-0.089	0.895	0.800	0.038	-0.767	0.038
DHI	0.002	0.918	0.843	0.207	---	---
D	-0.347	0.932	0.868	0.334	---	---

1. D = distance to nearest "main" reef; H = mean reef height; A = reef area; DVI = diversity of vertical interspaces, DHI = diversity of horizontal interspaces.

Area accounted for 32.4% ($p = 0.017$) of the variation in late spring diversity. The combination of distance, height and area terms produced a regression equation which accounted for 86.9% ($p = 0.012$) of the variation in fish species diversity for the late spring period. Neither diversity of vertical interspaces nor diversity of horizontal interspaces were significant additions to the late spring regression equation ($p = 0.084$ and 0.908 respectively).

Area accounted for the greatest amount of variation in Shannon Wiener diversity for the midsummer census (41.8%, $p = 0.023$). Mean reef height accounted for the next greatest amount of variation in diversity for the same period (22.6%, $p = 0.04$) and was followed by diversity of vertical interspaces (15.5%, $p = 0.035$) which was negatively correlated with diversity. The combination of area, height and DVI terms produced a regression equation which accounted for approximately 80% of the variation in midsummer species diversity. Neither diversity of horizontal interspaces nor distance were significant additions to the midsummer regression equation ($p = 0.207$ and 0.334 respectively).

CHAPTER 4

DISCUSSION AND SUMMARY

In the discussion and summary which follows, an attempt is made to integrate the results of various portions of the study.

Species Composition on Model and Natural Patch Reefs

Something in addition to refugia size must have influenced the distributions of species which were nonrandomly distributed among reef types. *Hypsoblennius gentilis*, *Lythrypnus dalli* and *Acanthemblemaria crockeri* were all found in greatest abundance on small interspace model reefs (Table 5). *H. gentilis* and *L. dalli* used the small interspaces for shelter. In addition, H. gentilis was observed spawning in them. *A. crockeri* is a tube dwelling species. These are possible reasons for the higher mean abundances of these species on small interspace reefs. However, despite differences in the availability of small interspaces, each of these species was found in approximately equal numbers on mixed and large interspace reefs. *P. zonipectus* was found in greatest abundance on mixed interspace reefs (Table 5). This was in spite of the fact that *P. zonipectus* consistently sought refuge in large interspaces, which were most abundant on large interspace reefs. However, this species is a grazer that feeds largely on sponges (Reynolds and Reynolds n.d.) and heavy sponge growth occurred on the vertical reef face around small interspaces. Perhaps the combination of these foraging areas with large interspaces for shelter made the mixed interspace reef type ideal for this species.

The above discussion of the nonrandom distributions of four fish species on the model reefs must be taken with some reservation. The reasons offered are based on limited observation and it is always possible to rationalize results after the fact. In addition, using a significance level of 0.05, one would expect approximately two of the 30 species distributions analyzed to show significant differences due to chance alone (Sokal and Rohlf 1969, p. 156).

Most of the differences in species composition between the model, and natural patch reefs were probably due to differences in the depths and exposure of the two sets of reefs. The mean water depth over the model reefs was approximately 5 m. The average depth of the water overlying the natural patch reefs was 2.75 m. The area in which the Algodones patch reefs were found was much more exposed to wave action. Both depth and exposure to wave action have been shown to be important in influencing the distributions of the rocky shore fishes of the Guaymas-San Carlos region (Critchlow 1972).

Interspace Size Diversity and Fish Species Diversity

Evidence against a positive relationship between interspace size diversity and fish species richness comes from both the model and natural patch reef portions of the present study. The results of both visual and rotenone sampling failed to demonstrate higher richness on the mixed interspace, model reefs. Diversity of vertical interspaces (DVI) was the only interspace variable found to have a significant positive correlation with numbers of fish species on natural patch reefs (Table 13). DVI accounted for approximately 17% of the late spring variation in species richness. However, it did not account for a significant portion of the variation in the mid-summer's data. Diversity of horizontal interspaces (DHI) was not significantly correlated with numbers of fish species in any of the natural patch reef cases examined.

The relationship between interspace size diversity and the Shannon-Wiener diversity of patch reef fish communities is less clear. Mean H' values were higher on the mixed interspace reef type during most of the study (Fig. 19). This may have been due to a greater accuracy of visual species counts on mixed interspace reefs

(Table 6). H' values calculated from combined rotenone and visual sampling were highest on the small and large interspace reef types, not on the mixed interspace reefs (Table 6). No significant positive correlation between interspace size diversity and H' values were found on the natural patch reefs. If there is a positive relationship between interspace size diversity and fish species diversity on patch reefs, it appears to be a slight one.

However, all of the foregoing evidence does not indicate that interspaces are not important determinants of fish species diversity on patch reefs. The conclusions reached relate to the effects of interspace size diversity only. The above results suggest that most of the fish species encountered in the present study were rather generalized with regard to their interspace needs. This conclusion is supported by the great similarity in species composition found for the three model reef types (Fig. 10). Also, other microhabitats such as algae, barnacles etc. may perform many of the functions ascribed to substrate interspaces at the outset of this study. The utilization of space by reef fishes needs further research.

Interspaces have been considered valuable to reef fishes mainly for providing shelter from predators. For example, Randall (1963), suggested that the absence of certain fish species on a concrete-block reef in the

Caribbean was due to a lack of small interspaces for protection from predation. However, small fish species were not lacking on large interspace model reefs in the present investigation and the interspaces provided were the same size as in Randall's study. It's possible that predation pressure is greater in the Caribbean. However, darting into a small interspace wouldn't necessarily result in predator avoidance even in the central Gulf of California. A number of small predatory fish species were observed using small interspaces on the model reefs (e.g., *Serranus fasciatus* and *Scorpaenodes xyris*). The density of other forms of cover such as algae and invertebrates may have also been lower on the Caribbean artificial reef. The relative roles played by other forms of cover and protective coloration in predator avoidance by reef fishes needs further investigation.

Patch Reef Isolation, Area and Height and Fish Species Diversity

The effect of isolation on the diversity of fishes (H' values) on natural patch reefs was significant for both late spring and midsummer censuses (Table 14). Isolation also accounted for a significant portion of the variation in species richness in three of the four cases examined (Table 13). The case in which the correlation between isolation and richness was not significant (p =

0.077) was the one in which visitor species were included in the analysis. Presumably, the movement of these species over sand is less constrained than it is for resident species.

In all analyses, the correlation between distance and richness or H' values was negative. These results underscore the insularity of patch reefs. Patch reef isolation probably does not present as great a dispersal problem to fish colonists as is faced by other groups of organisms colonizing other types of islands (e.g., terrestrial species colonizing oceanic islands). However, the results of the present study show that there is some difficulty involved in the colonization of isolated reef habitats by reef fishes.

The significant positive relationship found between patch reef area and fish species diversity was as expected. Such a correlation has been found in virtually every island system examined (see Simberloff 1974). However, the interaction of area and height as predictors of Shannon-Wiener diversity of fishes is very interesting. Mean reef height did not account for a significant portion of the variation in species richness for the late spring period. However, the combination of height with reef area accounted for 46% of the variation in H' values for this same period. These two variables accounted for 64% of the variation H' values for the midsummer census. These results seem analogous to the relationship between foliage height diversity and forest, bird species diversity found in a number of geographical regions (MacArthur and MacArthur 1961, Recher 1969).

It is also interesting in the light of these results that Frantz and Swank (1975) found a significant positive correlation between coral reef height diversity and fish species richness but not overall diversity. A similar result was obtained in studies of a central Gulf of California boulder reef fish community (Molles n.d.a). Perhaps these results were due to the use of visual census techniques which were shown to provide inaccurate estimates of the abundances of many reef fish species (Table 6). The accuracy of visual counts would be expected to be even more limited in structurally complex boulder and coral reef habitats.

The importance of large scale vertical zonation patterns to fishes has been known for some time (Gosline 1965). However, the role of vertical zonation as a means of habitat subdivision on a smaller scale has only recently been suggested. Ron Nolan (personal communication), while doing graduate research at Scripps Institution of Oceanography, found that six species of the family Pomacentridae on Eniwetok atoll maintained distinct, vertical foraging zones in a manner that he suggested was similar to MacArthur's warblers (MacArthur 1958). The habitat utilization observations in the present study suggest that vertical zonation patterns are also a means of habitat subdivision in patch reef fish communities in the Gulf of California.

If vertical zonation is a means of resource partitioning within patch reef fish communities, one would expect species with high overlap in other resource dimensions to show low overlap in vertical distribution. Such a pattern was found by Critchlow (1972) in his study of reef fishes in the Guaymas area. An examination of the distributions of the three chaenopsid blennies encountered in the present study yields the expected pattern. *Acanthemblemaria crockeri*, *Emblemaria hypacanthus* and *Protemblemaria bicirris* all have similar food and shelter requirements (Lindquist 1975). The vertical distributions of these three species had distinct modes. There was a rather high overlap in the distributions of *P. bicirris* and *A. crockeri* (D = 0.73). However, *A. crockeri* was so rare that it probably exerted very little competitive pressure on either *P. bicirris* or *E. hypacanthus*. It is also possible that the low numbers of *A. crockeri* were due to competition with *E. hypacanthus* and *P. bicirris*. Working over a greater range of depths, Lindquist (1975) also found distinct vertical zonation patterns for several chaenopsid species.

Gobiosoma chiquita and *Coryphopterus urospilus* were found to have very high overlap in vertical distribution (D = 0.89). They are also very similar morphologically and utilize similar food resources (Molles n.d.b). They did not coexist on the reefs for long periods of time and one species (*C. urospilus*) eventually replaced the other. It is hypothesized that this replacement was due to competition.

Perhaps vertical zonation is a general means of habitat subdivision in reef fish communities. The above discussion draws evidence for such a conclusion from the Caribbean, Indo-Pacific and Gulf of California. Since similar widespread patterns of vertical zonation have been observed in forest bird communities (Recher 1969), this may be a highly efficient means of resource partitioning.

Seasonal and Successional Effects

Several pieces of evidence demonstrate the high degree of seasonal influence on the model patch reef fish communities. Species composition is most strongly affected by season (Fig. 20). The effect of season on species composition can also be seen in the colonization record given in Fig. 9. Large numbers of species disappeared just prior to both the first and second winters of the study. Mean total number of species were also found to be much more similar when plotted against season than when plotted against reef age (Figs. 21 and 22). A similar result was obtained when mean total number of individuals was examined (Figs. 23 and 24).

The conclusion that season was the more pervasive factor doesn't seem surprising considering the annual temperature range observed during the study (15-30^{o}C). Thomson and Lehner (in press) found fluctuations in the diversity of an intertidal fish community in the northern Gulf of California to be highly correlated with annual temperature and photoperiod cycles. Season also seemed to be the dominant factor controlling numbers of fish species on a Gulf of Mexico jetty (Hastings 1972).

Evidence from both model and natural patch reefs suggest that there may be seasonal changes in the dynamics of patch reef fish communities in the central Gulf of California. The high negative correlation found between reef distance and fish species diversity prior to summer colonization (Tables 13 and 14) indicates that diversity was controlled by external processes during the winter (i.e., by colonization rates). The lack of significant correlations between numbers of species and extinction rates on model patch reefs during the winter months is further evidence for the absence of strong competitive interactions during this period. The reduced correlation between distance and diversity and higher correlation between reef height and fish species diversity after summer colonization suggest that patch reef fish diversity was internally controlled by competition for vertical habitats at that time. The conclusion that competition is higher during the summer is also supported by the higher number of significant correlations found between numbers of fish species and immigration and extinction rates during that period. These changes in the intensity of density dependent interactions might have been predicted from an examination of seasonal changes in total numbers of fish species and individuals (Figs. 11 and 15).

Immigration and Extinction on Model Patch Reefs

The view of island diversity presented by MacArthur and Wilson (1963) as being the result of a balance between immigration and extinction has been supported by the results of several investigations (Diamond 1969, 1971, Simberloff and Wilson 1969, Heatwole and Levins 1972). Turnover on islands has been demonstrated. It must be noted however, that a number of insular systems have been examined which do not behave according to the predictions of the equilibrium model (Brown 1971, Culver, Holsinger and Baroody 1973, Barbour and Brown 1974, Brown and Kodric-Brown n.d.).

In addition to predicting turnover, the model suggests that at equilibrium rates of immigration should be inversely proportional to numbers of species on an island. Extinction, on the other hand, should be directly proportional to the number of species. Rates of immigration should fall off as the number of species on an island increases because fewer potential colonists remain in the species pool. Extinction rates should rise as the number of species increases due to interspecific competition for limited resources.

The trends predicted by the MacArthur-Wilson model were observed for both summer periods of the study (Figs. 30-32). However, the immigration and extinction lines were not the same for the first and second summer communities. All immigration lines were translated upward from the first summer to the second and all extinction lines were translated downward. The translation of immigration lines was greater than that for extinction in all cases.

The apparent increases in immigration rates during the second summer were probably, in part, an artifact of the shorter interval between censuses during the second summer ($D_1 = 19$ versus $D_2 = 14$). However, this difference would account for only a 26% increase in immigration rates. The immigration rates for the second summer were more than double those of the first summer (see Figs. 30-32). In addition, if the reason for the higher immigration rates of the second summer were an artifact of smaller sampling intervals, one would also observe higher extinction rates. However, lower extinction rates were actually found for the second summer period.

Immigration and extinction rates are not independent phenomena. This fact and its effect on small scale insular communities has recently been examined by Brown (n.d.) and Brown and Kodric-Brown (n.d.). The conclusions drawn by the above researchers seem most appropriate for consideration here. Patch reef fish communities like the small scale insular systems with which they worked (arthropods on thistles) are maintained almost totally by colonization from external sources. One of the major conclusions of these investigations was that high immigration rates can have the effect of depressing extinction rates. A species whose rate of immigration onto an island is very high has a reduced probability of going extinct even if turnover in individuals is high. An increased immigration rate at a given species density would reduce the apparent extinction rate at that density even without significant reductions in the probability of extinction of a single propagule.

The increase in immigration rates between the two summers may have been due to a carpet of detached macrophytic algae which extended from the ITESM dock to past the line of winter placed reefs (see Fig. 5) during the second summer of the study. This carpet of algae could have acted like a stepping stone island to increase immigration rates. Stepping stone islands have been shown to be of potential importance in increasing immigration rates to other islands (MacArthur and Wilson 1967).

However, the change in immigration rates being discussed may have also been due to successional changes on the model reefs. The number of propagules hitting a reef might not have changed between the two summers. However, the number of propagules staying after encountering a reef may have increased during the second summer due to favorable changes in the epilithic communities of the model reefs. The view of immigrants as passive propagules is probably not appropriate to the situation being considered. Adult fishes certainly have the ability to select more favorable habitats. This same ability, though perhaps to a more limited extent, is present in juvenile and larval fishes (see Reynolds 1973). Whether a fish encountering a patch reef stayed to colonize would probably be contingent upon certain characteristics of the biotic community associated with the reef.

Summary

The results of the study can be summarized as follows:

1. Interspace size diversity did not account for a significant portion of the variation in fish species richness on model patch reefs.

2. Interspace size diversity seems to have had a slight positive effect on fish species diversity (H' values) on model patch reefs. However, combined rotenone and visual sampling on the model reefs suggest that this result was an artifact of the visual census technique.

3. Diversity of vertical interspaces accounted for a significant portion of the variation in fish species richness on the natural patch reefs in one of five cases. No significant positive correlation was found between diversity of horizontal interspaces and fish species richness on the natural patch reefs.

4. Interspace size diversity was not significantly correlated with fish species diversity on the natural patch reefs.

5. Interspace size diversity had no significant effect on the species composition of fish communities on the model patch reefs.

6. A slightly higher mean number of individuals was recorded on the small interspace model reefs. This was probably a surface area effect.

7. Natural patch reef area accounted for a significant portion of the variation in fish species richness in late spring and in two of three midsummer cases.

8. A significant positive correlation was found between reef area and fish species diversity prior to, and after summer colonization.

9. Mean reef height was more highly correlated with fish species richness on the natural patch reefs after summer colonization than in late spring.

10. Mean reef height accounted for a significant portion of the variation in fish species diversity prior to and after summer colonization.

11. The combination of reef area and height as consistent predictors of fish species diversity on natural patch reefs suggests that vertical zonation is a means of resource partitioning in patch reef fish communities. The vertical distributions of selected fish species on the model patch reefs support this conclusion.

12. A significant negative correlation was found between reef isolation and fish species richness on the natural patch reefs in late spring and two of the three midsummer cases considered.

13. A significant negative correlation was found between reef isolation and fish species diversity on the natural patch reefs only for the late spring census.

14. Season had more of an effect on the structure of the fish communities of model patch reefs than did succession.

15. Immigration and local extinction of fish species occurred on the model patch reefs throughout the study.

16. The relationship of rates of immigration and extinction of fishes to the number of fish species on the model patch reefs most closely approximated the behavior of the equilibrium model of insular zoogeography during the summer months of the study when species turnover was highest.

APPENDIX A

COLONIZATION HISTORIES OF INDIVIDUAL MODEL REEFS

Table A-1. Colonization history of large interspace model reef number L1.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. maculatofasciatus	-	1	-	3	1	1	-	2	-	1	-	1	-	1	1	4	1	2	8	1	28
G. chiquita	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
S. fasciatus	-	2	-	-	2	1	2	-	1	-	-	-	3	1	-	-	1	1	- (3)	-	14
E. hypacanthus	-	-	-	-	-	-	-	-	-	-	-	-	-	6	12	5	21	25	2 (2)	-	71
A. crockeri	1	-	1	-	-	-	-	-	-	-	-	-	-	2	2	1	1	1	-	-	9
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	1	-	1	-	-	6
C. urospilus	-	1	1	3	12	20	2	-	-	-	-	-	-	-	4	5	6	8	13 (4)	-	75
H. gentilis	-	-	-	-	-	-	-	7	6	4	8	-	1	3	1	1	2	3	- (1)	2	38
M. hubbsi	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2	3	3 (3)	-	11
S. mystes	-	1	1	-	2	-	1	-	1	-	-	-	-	-	3	2	-	2	1 (1)	-	14
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. castaneus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2
B. polylepis	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	1	-	5
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	-	4
A. retrosella	-	-	-	-	1	2	-	-	-	-	-	-	1	-	-	1	-	-	2 (7)	-	7
Diplectrum sp.	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
H. dispilus	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	3	1	-	-	6

Table A-1. Model reef number L1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. sini	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	6 (29)	-	-	8
E. analogus	-	-	-	-	-	1	1	1	-	-	1	-	-	-	-	-	-	-	-	-	4
N. denticulata	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-	5
P. zonipectus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
E. asper	-	-	-	-	1	-	-	-	-	-	-	-	-	2	5	14	75	100	-	-	197
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
G. crescentalis	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
E. niveatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
L. dalli	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	1	-	3	9	3	3	3	4	3	2 (2)	-	31
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1 (7)	-	3
S. xyris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-1. Model reef number L1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
Syngnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	4	5	6	5	6	11	11	3 (12)	-	51
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	3
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	3	1	-	9
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-1. Model reef number L1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
M. jordani	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
S. annulatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E. digueti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
S. sonorae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ogilbia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	– (1)	–	–
B. pantherinus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	– (1)	–	–
Total Species	1	6	5	4	9	5	5	6	3	4	3	3	5	11	14	18	15	17	15 (13)	2	
Total Numbers	1	7	8	8	22	25	7	13	8	7	11	8	19	29	42	15	133	174	42 (70)	3	1067

*Numbers in parentheses are the defaunation counts.

Table A-2. Colonization history of large interspace model reef number L2.

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	
P. maculatofasiatus	1	-	-	-	1	2	4	-	-	1	-	1	-	-	2	2	4	1	5	2	26
G. chiquita	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
S. fasciatus	-	1	2	-	3	2	5	2	-	2	1	1	1	-	-	-	-	2	1 (3)	-	23
E. hypacanthus	1	-	1	-	-	-	-	-	-	-	-	-	-	3	9	9	15	21	1 (11)	-	60
A. crockeri	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	-	-	15	1	-	1	-	-	-	17
C. urospilus	-	1	7	10	9	30	-	2	-	3	3	-	-	3	4	5	4	7	16 (8)	-	104
H. gentilis	-	-	-	-	-	-	-	7	6	2	4	1	1	3	3	1	6	5	1	-	40
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	4	1	-	8
S. mystes	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	2	-	1	2 (3)	-	8
L. argentiventris	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
G. castaneus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
B. polylepis	-	-	-	-	-	-	-	-	-	1	-	1	-	-	3	2	2	-	-	-	9
H. sexfasciatum	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	6	2	8	1	18
A. retrosella	-	-	-	1	1	-	-	2	1	1	2	3	2	1	1	1	2	-	2 (5)	-	20
Diplectrum sp.	-	-	1	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
H. dispilus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-	-	-	4

Table A-2. Model reef number L2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. sini	-	-	-	-	-	-	-	-	-	-	2	1	-	1	-	1	2	3	-	-	10
E. analogus	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	4
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	4	1	-	10
P. zonipectus	-	-	-	-	1	2	1	1	-	-	-	-	-	-	-	-	-	1	1 (1)	-	7
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	40	120	75	- (1)	-	285
E. punticulatus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	1
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (2)	-	-
E. niveatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
L. dalli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1 (1)	-	3
Z. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	1	1	1	3	-	3	5	1 (5)	-	15
S. xyris	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1

Table A-2. Model reef number L2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-	-	-	-	-	4
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	3	4	7	7	6	7	14	6 (12)	-	54
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	-	-	-	5
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-2. Model reef number L2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (3)	-	-
Total Species	2	3	6	5	7	6	3	5	3	7	5	10	6	13	14	14	17	17	16 (17)	2	
Total Numbers	2	4	14	15	19	38	10	14	8	11	12	14	10	40	88	79	179	148	51 (83)	3	2934

*Numbers in parenthesis are the defaunation counts.

Table A-3. Colonization history of large interspace model reef number L3.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
P. maculatofasciatus	4	7	-	-	3	2	25	1	-	-	-	-	2	-	3	1	3	2	12	3	68
G. chiquita	-	-	1	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	4
S. fasciatus	-	-	-	-	1	2	2	1	2	1	-	1	-	-	-	1	-	-	2	-	13
E. hypacanthus	-	-	1	-	1	-	-	-	-	-	-	-	-	4	7	10	10	9	1	1	44
A. crockeri	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2
C. alepidota	-	-	-	2	1	-	-	-	-	-	-	-	1	10	4	-	-	-	-	-	18
C. urospilus	-	3	5	8	25	30	4	3	2	-	-	-	-	-	2	2	1	12	4	-	101
H. gentilis	-	-	-	1	-	-	-	6	8	6	5	3	2	4	3	2	1	1	-	-	42
M. hubbsi	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	2	4	3	3	-	14
S. mystes	-	-	-	-	-	-	2	-	-	-	1	-	-	-	1	2	1	3	1	-	11
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. castaneus	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	4
B. polylepis	-	10	-	-	-	-	-	-	-	2	-	-	-	-	50	-	-	1	-	-	63
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	2	-	-	6
A. retrosella	-	-	1	5	5	1	1	1	2	3	-	2	2	-	-	-	1	-	-	2	21
Diplectrum sp.	-	-	4	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
H. dispilus	-	-	1	1	1	-	-	-	-	-	-	-	-	-	5	3	3	2	-	-	16

Table A-3. Model reef number L3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
P. sini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3	-	-	7
E. analogus	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
N. denticulata	-	-	-	-	1	2	-	-	-	-	-	-	-	-	1	-	2	2	-	-	8
P. zonipectus	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	4
E. asper	-	-	-	-	1	-	-	-	-	-	-	-	-	-	60	75	75	100	-	-	311
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. niveatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	50
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	2	2	1	3	-	14
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	3	1	-	1	9
S. xyris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1

Table A-3. Model reef number L3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	3	9	3	8	8	5	4	4	1	45
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	2	-	-	-	5
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	1	1	-	5
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1	1	-	5
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	2
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1

Table A-3. Model reef number L3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Species	1	3	5	8	13	7	7	5	5	4	2	4	6	10	17	15	19	20	13	6	
Total Numbers	4	20	12	18	43	39	36	12	15	12	6	9	18	29	153	113	123	151	86	9	908

Table A-4. Colonization history of small interspace model reef number S1.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. maculato-fasciatus	-	-	-	1	2	1	-	1	1	1	-	1	3	2	1	1	-	1	2	-	18
G. chiquita	1	5	4	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
S. fasciatus	-	-	1	-	2	1	2	-	-	-	-	-	-	-	-	1	2	2	5 (4)	2	18
E. hypacanthus	-	-	1	3	3	-	2	-	-	-	-	-	-	2	17	15	18	25	- (3)	-	86
A. crockeri	-	-	1	-	-	-	-	-	-	-	-	-	-	4	4	3	2	1	-	-	15
C. alepidota	-	-	2	-	2	-	-	-	-	-	-	-	17	2	8	1	3	-	-	-	35
C. urospilus	-	2	8	9	12	10	2	-	-	-	-	-	-	-	1	1	-	1	14 (6)	-	60
H. gentilis	-	1	1	2	-	-	-	5	3	6	8	7	12	9	12	5	10	12	5 (5)	5	103
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-	-	5
S. mystes	-	-	1	1	-	-	-	1	-	-	1	-	-	-	-	1	-	1	-	2	8
L. argentiventris	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
G. castaneus	-	-	-	-	1	1	-	-	-	-	-	-	-	1	-	1	-	-	-	1	5
B. polylepis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2	2	-	-	7
A. retrosella	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	1	-	-	4 (5)	-	8
Diplectrum sp.	-	-	4	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
H. dispilus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	4	3	1	-	11

Table A-4. Model reef number S1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. sini	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	2	3	1 (19)	-	9
E. analogus	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	3
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	4	2	-	10
P. zonipectus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 (1)	-	1
E. asper	-	-	-	-	6	-	-	-	-	-	-	-	7	2	75	200	150	100	-	-	540
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. niveatus	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-	-	-	-	-	-	4
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	1	-	-	-	-	2	2	1	1	1	1	-	-	9
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	4	4	5	5	6	6	6	2 (2)	-	38
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	2	4	1	2	3	3	4	2 (8)	-	21
S. xyris	-	-	-	-	-	-	-	-	-	-	-	1	2	1	1	2	2	-	-	-	9

Table A-4. Model reef number S1 (continued).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
	Census Number																				
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	3	3	5	9	4	11	15	2	-	52
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	2
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	4
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	3
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-4. Model reef number S1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (2)	-	-
Total Species	1	3	9	8	11	5	5	7	3	3	2	6	11	14	15	23	18	20	12 (14)	5	
Total Numbers	1	8	23	20	34	14	9	11	5	8	9	18	56	38	139	256	224	186	41 (74)	11	2438

*Numbers in parentheses are the defaunation counts.

Table A-5. Colonization history of small interspace model reef number S2.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. maculato-fasciatus	3	-	-	3	2	2	5	1	1	-	-	1	-	-	2	1	1	1	5	3	31
G. chiquita	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	3
S. fasciatus	-	-	1	1	-	1	1	-	-	1	1	1	2	1	-	-	-	-	3 (6)	2	15
E. hypacanthus	-	1	-	-	-	-	-	-	-	-	-	-	-	2	8	13	22	22	2 (5)	-	70
A. crockeri	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	2	1	-	-	-	6
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	-	20	15	1	1	2	-	-	-	39
C. urospilus	-	2	6	4	5	24	3	3	1	1	2	-	1	4	11	8	12	14	8 (2)	-	109
H. gentilis	-	-	2	1	1	-	-	1	7	7	2	1	4	4	5	8	10	12	4 (4)	4	73
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4	4	2 (1)	-	14
S. mystes	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2	3	3	- (3)	-	10
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. castaneus	-	-	-	-	1	1	-	-	-	-	-	-	-	1	-	-	-	1	-	-	4
B. polylepis	-	2	-	-	-	-	-	-	2	-	-	-	-	-	5	-	30	2	-	-	41
H. sexfasciatum	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	7
A. retrosella	-	1	-	2	1	1	4	1	1	3	1	-	-	-	1	2	3	7	9 (29)	1	38
Diplectrum sp.	-	-	3	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
H. dispilus	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	5

Table A-5. Model reef number S2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. sini	-	-	1	-	-	-	-	-	-	-	-	1	1	-	-	3	3	4	- (14)	-	13
E. analogus	-	-	-	-	1	2	2	1	1	1	1	-	-	-	-	-	-	1	-	-	10
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	7	-	-	11
P. zonipectus	-	-	-	-	1	1	1	1	1	-	-	-	-	-	1	1	2	1	1 (1)	-	11
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	100	150	150	- (5)	-	500
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
E. niveatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
L. dalli	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	3
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	1	1	1	-	7
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	1	4	2	2	5	4	6	3 (6)	-	27
S. xyris	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	- (2)	-	3

Table A-5. Model reef number S2 (continued).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
	Census Number																				
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	3	13	7	8	17	21	13	2 (6)	-	84
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	1	1	-	-	6
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	- (1)	-	1
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-5. Model reef number S2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (1)	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Species	1	5	5	7	8	7	6	6	8	6	6	9	11	12	19	17	22	21	12 (18)	4	
Total Numbers	3	7	13	13	14	32	16	8	15	14	8	12	49	40	154	171	278	256	41 (89)	10	3545

*Numbers in parentheses are the defaunation counts.

Table A-6. Colonization history of small interspace model reef number S3.

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
P. maculato-fasciatus	1	-	5	4	14	4	16	1	-	-	1	2	1	-	-	1	3	2	10	2	67
G. chiquita	1	2	5	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
S. fasciatus	1	1	1	1	-	1	1	1	-	-	-	-	-	1	1	1	1	2	1	1	15
E. hypacanthus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	5	7	7	-	-	27
A. crockeri	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	2	2	2	-	-	12
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	-	15	10	5	-	-	1	-	-	31
C. urospilus	-	4	5	9	11	24	-	-	-	1	-	-	-	-	10	7	5	13	2	1	92
H. gentilis	-	-	-	-	-	-	-	9	11	2	3	2	3	6	9	7	7	14	-	-	73
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. mystes	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-	1	1	-	-	6
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. castaneus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
B. polylepis	-	4	2	2	15	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	24
H. sexfasciatum	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	15	7	-	-	25
A. retrosella	-	-	-	-	4	2	5	-	1	-	-	-	-	-	1	1	4	2	2	1	23
Diplectrum sp.	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
H. dispilus	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	4	4	-	-	11

Table A-6. Model reef number S3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
P. sini	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	3	4	6	-	1	17
E. analogus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	4	3	-	-	12
P. zonipectus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	7	80	100	60	40	-	-	287
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. niveatus	-	-	-	-	-	-	2	1	1	1	-	-	-	-	-	-	-	-	-	-	5
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	30	-	45
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	-	-	-	3	-	1	1	1	-	1	-	-	-	7
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	4	3	7	5	5	5	6	4	-	-	39
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	1	1	3	4	2	3	4	5	1	1	25
S. xyris	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	-	-	3

Table A-6. Model reef number S3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	2
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	1	2	10	7	4	9	7	-	1	41
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	2	-	-	5
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	3
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1

Table A-6. Model reef number S3 (continued).

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Species	3	5	6	7	7	5	6	4	3	3	4	5	11	14	16	17	20	21	8	7	
Total Numbers	3	12	21	20	47	32	40	12	13	4	12	10	37	52	135	147	140	125	48	8	3123

Table A-7. Colonization history of mixed interspace model reef number M1.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. maculato- fasciatus	-	-	1	1	5	-	-	1	1	-	-	-	-	-	1	1	1	2	5	-	23
G. chiquita	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 (1)	-	4
S. fasciatus	-	-	2	1	-	-	1	2	-	-	2	2	-	2	1	2	1	1	2 (4)	-	19
E. hypacanthus	-	-	-	1	1	-	-	-	-	-	-	-	-	-	6	5	3	3	- (4)	-	19
A. crockeri	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	2	1	1	-	-	7
C. alepidota	-	5	-	-	9	-	-	-	-	-	-	-	4	-	1	-	-	-	-	-	19
C. urospilus	-	2	-	1	19	15	4	-	-	-	-	-	-	1	6	5	7	3	27 (7)	-	90
H. gentilis	-	-	-	-	-	-	-	5	2	1	1	3	2	2	7	5	2	-	1 (1)	-	31
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	2 (1)	-	7
S. mystes	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	4	1	-	- (1)	-	8
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. castaneus	-	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	1	-	7
B. polylepis	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	3
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2
A. retrosella	-	-	-	-	1	2	1	1	1	1	1	1	-	2	1	-	2	-	3 (8)	2	19
Diplectrum sp.	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
H. dispilus	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	3

Table A-7. Model reef number M1 (continued).

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	
P. sini	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	2	2	- (27)	-	7
E. analogus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	2
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2	3	-	-	8
P. zonipectus	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	1	3 (2)	-	7
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	3	80	50	20	35	-	-	188
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- (6)	-	-
E. niveatus	-	-	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	4
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	7	5	5	5	7	7	5	5 (8)	-	46
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	1	1	-	2	5	1	3	4 (8)	-	17
S. xyris	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-	-	4

Table A-7. Model reef number M1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	2	10	7	8	11	11	13	1 (19)	-	63
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	4
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	3	-	-	6
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1 (1)	-	3
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-7. Model reef number M1 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Species	1	2	4	7	7	4	6	6	5	5	4	8	8	11	16	16	20	17	14 (17)	2	
Total Numbers	1	7	7	7	37	19	9	11	6	5	5	18	25	27	123	104	69	82	58 (101)	3	4170

*Numbers in parentheses are the defaunation counts.

Table A-8. Colonization history of mixed interspace model reef number M2.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
P. maculato-fasciatus	-	-	-	-	3	2	3	1	-	-	-	-	-	-	2	3	3	2	2	3	24
G. chiquita	1	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
S. fasciatus	-	-	1	2	1	3	3	2	-	-	-	-	-	-	-	-	-	-	1	-	13
E. hypacanthus	-	-	-	1	-	-	-	-	-	-	-	-	-	5	15	9	23	13	2 (2)	-	68
A. crockeri	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	-	15	20	2	2	1	-	-	-	40
C. urospilus	-	6	5	8	18	30	-	1	1	-	-	-	-	4	9	8	10	20	5 (2)	-	125
H. gentilis	-	-	-	1	1	-	1	2	4	5	3	1	2	5	3	6	7	8	1 (3)	1	51
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
S. mystes	-	-	-	-	-	-	-	1	1	-	3	-	-	-	-	2	2	1	2 (3)	-	12
L. argentiventris	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
G. castaneus	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
B. polylepis	-	-	-	-	-	-	-	-	1	1	1	1	-	-	2	4	10	2	-	-	22
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	7	-	-	13
A. retrosella	-	-	-	1	4	1	3	2	4	2	3	3	3	2	2	1	4	3	13 (12)	2	53
Diplectrum sp.	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
H. dispilus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	4	-	-	9

Table A-8. Model reef number M2 (continued).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
	Census Number																				
P. sini	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	3	-	-	6
E. analogus	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-	-	-	1	-	-	6
N. denticulata	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	4	5	9	-	-	24
P. zonipectus	-	-	-	-	2	2	2	1	1	1	1	1	1	1	1	1	1	1	5 (3)	-	22
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	2	80	75	100	50	-	-	307
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. niveatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
L. guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	10
M. lentiginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. notatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	-	2	2	3	3	5	2	3 (2)	-	20
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	2	1	1 (2)	-	8
S. xyris	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1 (2)	-	3

Table A-8. Model reef number M2 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	7	7	9	7	8	21	6	3 (21)	-	68
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	5
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	4
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-8. Model reef number M2 (continued).

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	
M. jordani	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
S. annulatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E. digueti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	– (2)	–	–
S. sonorae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	– (1)	–	–
Ogilbia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
B. pantherinus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Species	1	3	4	6	8	7	6	7	6	6	6	6	10	11	16	19	21	20	14 (13)	3	
Total Numbers	1	9	11	15	33	41	13	10	12	11	12	14	34	54	134	135	208	138	50 (76)	6	939

*Numbers in parentheses are the defaunation counts.

Table A-9. Colonization history of mixed interspace model reef number M3.

Species	Census Number																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
P. maculatofasciatus	4	5	1	2	3	2	7	2	2	1	1	-	-	4	1	1	1	1	2	4	44
G. chiquita	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
S. fasciatus	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2	2	2	2	1	11
E. hypacanthus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	6	4	-	1	14
A. crockeri	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	-	-	-	-	-	4
C. alepidota	-	-	-	-	-	-	-	-	-	-	-	1	4	1	4	-	-	-	-	-	10
C. urospilus	-	3	2	5	16	20	-	-	-	-	-	-	-	-	3	2	7	11	11	-	80
H. gentilis	-	-	-	-	-	-	-	1	2	1	-	-	1	6	5	9	9	4	3	2	43
M. hubbsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	1	6
S. mystes	-	1	-	-	-	-	-	-	1	-	-	1	-	-	-	3	-	3	2	-	11
L. argentiventris	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
G. castaneus	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	4
B. polylepis	-	1	-	-	3	11	-	2	2	-	1	3	-	2	1	-	1	-	-	2	29
H. sexfasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	7	1	7	2	1	-	-	18
A. retrosella	-	-	-	1	-	1	1	-	1	-	1	-	-	-	-	-	3	2	4	3	17
Diplectrum sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
H. dispilus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	4	2	-	-	11

Table A-9. Model reef number M3 (continued).

Species	Census Number																				Total
	1	2	1	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
P. sini	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3	-	-	4
E. analogus	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4
N. denticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	3
P. zonipectus	-	-	-	-	1	2	2	1	1	1	1	1	1	1	1	1	-	-	1	-	15
E. asper	-	-	-	-	-	-	-	-	-	-	-	-	-	3	100	50	30	40	3	-	226
E. punticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crescentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. niveatus	-	-	-	-	-	1	4	2	2	2	2	1	1	-	-	-	-	-	-	-	15
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	10
M. lentiginosa	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. dalli	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	2
P. notatus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Lizard triplefin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
X. rhodopyga	-	-	-	-	-	-	-	-	-	-	-	1	1	2	3	-	4	5	1	-	17
S. xyris	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	2

Table A-9. Model reef number M3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Sygnathus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. bicirris	-	-	-	-	-	-	-	-	-	-	-	5	7	8	15	10	23	21	6	4	99
A. histrio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rosacea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2	1	2	-	-	8
P. viola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	1	-	-	-	6
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
R. bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
H. semicinctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
M. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. diplotaenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nigripinnis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
P. rectifraenum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H. guntheri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-9. Model reef number M3 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
M. jordani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
S. annulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. digueti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. sonorae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ogilbia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. pantherinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Species	1	5	3	6	5	8	6	6	8	4	6	8	9	13	17	12	18	18	13	8	
Total Numbers	4	11	4	11	24	39	25	9	12	5	7	14	18	40	146	92	98	108	39	18	1781

Table A-10. Colonization history of mixed interspace model reef number M4.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
P. maculato-fasciatus	1	-	-	3	1	3	3	1	2	4	18
H. gentilis	3	7	4	1	1	1	1	1	-	1	20
Lizard triplefin	2	13	12	10	8	12	8	6	4	-	75
E. hypacanthus	1	-	-	1	3	2	-	-	-	-	7
B. polylepis	-	-	-	-	-	-	75	-	-	-	75
S. fasciatus	-	-	-	-	-	-	-	-	1	-	1
S. mystes	-	-	1	-	-	-	-	-	1	1	3
P. bicirris	-	-	1	-	2	3	1	4	-	-	11
P. sini	-	-	1	1	2	1	2	-	-	1	8
G. castaneus	-	-	-	2	-	-	-	-	1	-	3
C. alepidota	-	-	-	3	8	1	-	-	-	-	12
M. rosacea	-	-	-	-	1	1	3	1	-	-	6
R. bicolor	-	-	-	-	-	-	-	-	-	-	-
E. asper	-	-	-	-	8	5	2	1	-	-	16

Table A-10. Colonization history of M4 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
X. rhodopyga	-	-	-	-	3	2	1	1	1	-	8
C. urospilus	-	-	-	-	2	-	2	1	3	-	8
A. retrosella	-	-	-	-	1	1	-	-	-	2	4
E. analogus	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	-	1	-	-	-	1
N. denticulata	-	-	-	-	-	-	2	2	-	-	4
H. guntheri	-	-	-	-	-	1	1	1	-	-	3
H. sexfasciatum	-	-	-	-	-	3	1	12	-	-	16
H. semicinctus	-	-	-	-	-	-	-	1	-	-	1
H. nicholsi	-	-	-	-	-	-	-	-	-	-	-
H. dispilus	-	-	-	-	-	-	-	-	-	-	-
M. hubbsi	-	-	-	-	-	-	-	2	-	1	3
P. zonipectus	-	-	-	-	-	-	-	-	-	-	-
H. chierchiae	-	-	-	-	-	1	-	-	-	-	1
S. perrico	-	-	-	-	-	-	-	1	3	-	4

Table A-10. Colonization history of M4 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
S. xyris	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	1	-	-	-	1
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-
M. jordani	-	-	-	-	-	-	-	-	-	-	-
L. guttatus	-	-	-	-	-	-	-	-	-	-	-
Total Species	4	2	5	7	12	14	15	14	8	6	
Total Numbers	7	20	19	21	40	37	104	35	16	10	310

Table A-11. Colonization history of mixed interspace model reef number M5.

Species	Census Number										Total
	1	2	3	4	5	6	7	8	9	10	
P. maculato-fasciatus	1	1	1	-	3	4	2	8	3	4	27
H. gentilis	1	2	1	1	-	-	1	-	-	4	10
Lizard triplefin	4	9	19	7	23	8	8	5	6	4	93
E. hypacanthus	1	-	-	1	6	2	1	1	-	-	12
B. polylepis	1	-	-	-	-	-	5	-	15	-	21
S. fasciatus	-	-	-	-	-	-	-	-	1	2	3
S. mystes	-	-	-	-	-	1	-	1	-	-	2
P. bicirris	-	-	-	2	2	2	5	2	1	-	14
P. sini	-	-	-	-	-	1	-	-	-	1	2
G. castaneus	-	-	-	1	1	-	-	-	-	1	3
C. alepidota	-	-	-	5	2	1	1	2	-	-	11
M. rosacea	-	-	-	1	1	1	1	1	-	-	5
R. bicolor	-	-	-	1	-	-	-	-	-	-	1
E. asper	-	-	-	-	12	1	7	1	2	-	23

Table A-11. Colonization history of M5 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
X. rhodopyga	-	-	-	-	1	-	2	2	-	-	5
C. urospilus	-	-	-	-	-	-	-	2	14	-	16
A. retrosella	-	-	-	-	1	1	-	1	5	2	10
E. analogus	-	-	-	-	1	-	-	-	-	-	1
C. brachysomus	-	-	-	-	4	1	3	1	-	-	9
N. denticulata	-	-	-	-	-	4	1	5	-	-	10
H. guntheri	-	-	-	-	-	3	2	2	-	-	7
H. sexfasciatum	-	-	-	-	-	4	8	16	-	-	28
H. semicinctus	-	-	-	-	-	-	-	-	1	-	1
H. nicholsi	-	-	-	-	-	-	1	-	-	-	1
H. dispilus	-	-	-	-	-	-	1	-	-	-	1
M. hubbsi	-	-	-	-	-	-	1	-	-	-	1
P. zonipectus	-	-	-	-	-	-	-	-	-	-	-
H. chierchiae	-	-	-	-	-	-	1	-	-	-	1
S. perrico	-	-	-	-	-	-	3	1	-	-	4

Table A-11. Colonization history of M5 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
S. xyris	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	-	-	-	-	-	1	-	-	-	1
A. multiguttatus	-	-	-	-	-	-	-	1	-	-	1
M. jordani	-	-	-	-	-	-	-	-	1	-	1
L. guttatus	-	-	-	-	-	-	-	-	1	-	1
Total Species	5	3	3	8	12	14	20	17	11	7	
Total Numbers	8	12	21	19	57	34	55	52	50	18	327

Table A-12. Colonization history of mixed interspace model reef number M6.

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
P. maculatofasciatus	3	1	-	1	1	6	1	3	1	2	19
H. gentilis	2	6	7	3	-	2	2	2	1	2	27
Lizard triplefin	1	4	7	6	7	5	5	6	-	2	43
E. hypacanthus	-	-	-	3	3	1	2	1	-	-	10
B. polylepis	-	-	-	-	4	2	1	2	50	1	60
S. fasciatus	-	-	-	-	-	-	-	-	3	-	3
S. mystes	-	-	1	-	-	1	-	-	-	-	2
P. bicirris	-	-	-	1	3	4	8	6	-	1	23
P. sini	-	-	-	-	1	-	2	-	-	-	3
G. castaneus	-	-	-	1	-	1	-	-	-	-	2
C. alepidota	-	-	-	11	2	1	2	-	-	-	16
M. rosacea	-	-	-	-	1	1	-	1	-	-	3
R. bicolor	-	-	-	-	-	-	-	-	-	-	-
E. asper	-	-	-	-	-	-	30	-	-	-	30

Table A-12. Colonization history of M6 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
X. rhodopyga	-	-	-	-	1	-	1	1	-	-	3
C. urospilus	-	-	-	-	2	4	8	8	4	-	26
A. retrosella	-	-	-	-	1	-	-	1	5	1	8
E. analogus	-	-	-	-	-	-	-	-	-	-	-
C. brachysomus	-	-	-	-	-	8	2	5	-	-	15
N. denticulata	-	-	-	-	3	5	1	1	1	-	11
H. guntheri	-	-	-	-	-	1	-	1	-	-	2
H. sexfasciatum	-	-	-	-	-	10	2	1	-	-	13
H. semicinctus	-	-	-	-	-	2	1	1	-	-	4
H. nicholsi	-	-	-	-	-	2	-	-	-	-	2
H. dispilus	-	-	-	-	-	2	-	-	-	-	2
M. hubbsi	-	-	-	-	-	1	1	-	2	1	5
P. zonipectus	-	-	-	-	-	1	-	-	1	-	2
H. chierchiae	-	-	-	-	-	-	-	-	-	-	-
S. perrico	-	-	-	-	-	-	3	-	-	-	3

Table A-12. Colonization history of M6 (continued).

Species	Census Number 1	2	3	4	5	6	7	8	9	10	Total
S. xyris	-	-	-	-	-	-	1	1	-	-	2
A. troschelii	-	-	-	-	-	-	-	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	-	-	-	-	-
M. jordani	-	-	-	-	-	-	-	-	1	-	1
L. guttatus	-	-	-	-	-	-	-	-	-	-	-
Total Species	3	3	3	7	12	20	18	16	10	7	
Total Numbers	6	11	15	26	29	60	73	41	69	10	341

APPENDIX B

SUMMARY OF SHANNON-WIENER DIVERSITY AND EVENNESS ON MODEL REEFS L1-3, S1-3 AND M1-3

Table B-1. Summary of Shannon-Wiener diversity on model reefs L1-3, S1-3 and M1-3.

Census Number	Reef Number											
	L1	L2	L3	$\bar{X}_L$	S1	S2	S3	$\bar{X}_S$	M1	M2	M3	$\bar{X}_M$
1	0.000	0.693	0.000	0.231	0.000	0.000	1.099	0.366	0.000	0.000	0.000	0.000
2	1.749	1.040	0.999	1.263	0.900	1.550	1.444	1.298	0.599	0.848	1.367	0.938
3	1.386	1.466	1.351	1.401	1.865	1.378	1.675	1.639	1.277	1.241	1.040	1.186
4	1.256	1.082	1.710	1.349	1.704	1.779	1.591	1.691	1.947	1.312	1.541	1.600
5	1.604	1.560	1.619	1.594	2.013	1.863	1.518	1.798	1.346	1.509	1.056	1.304
6	0.767	0.844	0.926	0.846	0.992	0.995	0.865	0.951	0.735	1.042	1.382	1.053
7	1.550	0.943	1.121	1.205	1.581	1.663	1.328	1.514	1.580	1.698	1.476	1.585
8	1.411	1.369	1.313	1.364	1.667	1.667	0.836	1.390	1.541	1.887	1.734	1.721
9	0.736	0.736	1.321	0.931	0.950	1.711	0.536	1.066	1.562	1.559	2.022	1.714
10	1.154	1.847	1.199	1.400	0.736	1.428	1.040	1.068	1.609	1.541	1.332	1.494
11	0.767	1.517	0.451	0.912	0.349	1.733	1.472	1.185	1.332	1.659	1.749	1.580
12	0.974	2.162	1.310	1.482	1.567	2.092	1.696	1.785	1.800	1.428	1.824	1.684
13	1.308	1.609	1.484	1.467	2.027	1.728	1.891	1.882	1.699	1.748	1.831	1.759
14	1.949	2.051	1.977	1.992	2.365	1.986	2.276	2.209	2.165	1.979	2.304	2.149
15	2.292	1.687	1.791	1.923	1.668	1.524	1.637	1.610	1.451	1.587	1.355	1.464
16	2.434	1.810	1.381	1.875	1.117	1.661	1.438	1.405	1.964	1.846	1.657	1.822

Table B-1. (Continued)

Census Number	Reef Number											
	L1	L2	L3	$\bar{X}_L$	S1	S2	S3	$\bar{X}_S$	M1	M2	M3	$\bar{X}_M$
17	1.601	1.442	1.704	1.582	1.444	1.801	2.195	1.813	2.404	1.969	2.175	2.183
18	1.608	1.820	1.450	1.626	1.755	1.731	2.438	1.975	2.096	2.242	2.151	2.163
19	2.264	2.258	1.605	2.042	2.115	2.230	1.211	1.852	1.961	2.248	2.261	2.157
20	---	---	1.676	---	---	---	1.906	---	---	---	1.939	---

Table B-2. Summary of evenness* values on model reefs L1-3, S1-3 and M1-3.

Census Number	Reef Number											
	L1	L2	L3	$\bar{X}_L$	L1	S2	S3	$\bar{X}_S$	M1	M2	M3	$\bar{X}_M$
1	0.000	1.000	0.000	0.333	0.000	0.000	1.000	0.333	0.000	0.000	0.000	0.000
2	0.976	0.947	0.909	0.944	0.819	0.963	0.897	0.893	0.864	0.772	0.849	0.828
3	0.861	0.818	0.839	0.839	0.849	0.856	0.935	0.880	0.921	0.895	0.947	0.921
4	0.906	0.672	0.822	0.800	0.819	0.914	0.818	0.850	1.000	0.732	0.860	0.864
5	0.730	0.802	0.631	0.721	0.839	0.896	0.780	0.838	0.692	0.726	0.656	0.691
6	0.477	0.471	0.476	0.475	0.616	0.511	0.537	0.555	0.530	0.535	0.665	0.577
7	0.963	0.858	0.576	0.799	0.982	0.911	0.741	0.878	0.882	0.948	0.824	0.885
8	0.787	0.851	0.816	0.818	0.857	0.930	0.603	0.797	0.860	0.970	0.968	0.933
9	0.670	0.670	0.815	0.718	0.865	0.823	0.488	0.725	0.971	0.870	0.972	0.938
10	0.832	0.949	0.865	0.882	0.670	0.797	0.947	0.805	1.000	0.860	0.961	0.940
11	0.698	0.943	0.651	0.764	0.504	0.967	0.915	0.795	0.961	0.926	0.976	0.954
12	0.887	0.939	0.945	0.924	0.875	0.952	0.947	0.925	0.866	0.797	0.877	0.847
13	0.813	0.898	0.828	0.846	0.845	0.721	0.789	0.785	0.817	0.759	0.833	0.803
14	0.846	0.800	0.859	0.835	0.896	0.799	0.862	0.852	0.903	0.825	0.898	0.875
15	0.868	0.639	0.632	0.713	0.616	0.518	0.590	0.575	0.523	0.572	0.478	0.524
16	0.842	0.686	0.510	0.679	0.356	0.586	0.508	0.483	0.708	0.627	0.667	0.667

Table B-2. (Continued)

Census Number	Reef Number											
	L1	L2	L3	$\bar{X}_L$	S1	S2	S3	$\bar{X}_S$	M1	M2	M3	$\bar{X}_M$
17	0.591	0.509	0.569	0.556	0.500	0.583	0.733	0.605	0.802	0.647	0.752	0.734
18	0.558	0.642	0.484	0.561	0.586	0.569	0.801	0.652	0.740	0.748	0.744	0.744
19	0.836	0.814	0.608	0.753	0.851	0.897	0.582	0.777	0.743	0.852	0.881	0.825
20	---	---	0.935	---	---	---	0.979	---	---	---	0.932	---

*Evenness = H'/H' max, H' max = ln S.

APPENDIX C

SPECIES OBSERVED ON INDIVIDUAL NATURAL PATCH REEFS DURING LATE SPRING AND MIDSUMMER CENSUSES

Table C-1. Species observed on individual natural patch reefs during late spring and midsummer censuses.

Species	Reef Number 1		2		3		4		5		6	
	L	M	L	M	L	M	L	M	L	M	L	M
G. castaneus	-	-	2	-	-	-	1	-	-	-	-	-
P. maculato-fasciatus	-	1	-	1	-	-	-	3	-	1	-	1
M. rosacea	-	-	-	-	-	-	-	1	-	-	-	-
A. multiguttatus	-	-	-	-	-	-	1	1	-	-	-	-
S. fasciatus	-	-	-	-	-	-	1	-	-	-	-	-
E. labriformis	-	-	-	-	1	-	-	-	-	-	-	-
L. guttatus	-	1	-	5	-	6	-	3	-	5	-	1
L. argentiventris	-	1	-	1	-	-	-	-	-	1	-	1
H. guntheri	-	-	-	-	-	1	-	-	-	-	-	-
A. retrosella	-	-	2	3	2	-	2	7	-	-	-	-
L. flaviguttatum	-	-	-	-	-	-	-	-	-	-	-	-
P. viola	-	-	-	5	-	4	1	2	-	-	-	-
M. dentatus	-	-	-	-	-	-	-	-	-	1	-	1

Table C-1. Species observed on individual natural patch reefs (continued).

Species	Reef Number 1		2		3		4		5		6	
	L	M	L	M	L	M	L	M	L	M	L	M
C. brachysomus	-	2	-	4	-	1	-	-	-	-	-	-
P. rectifraenum	-	2	-	-	-	-	3	3	-	1	-	-
P. flavilatus	-	-	-	-	-	-	-	-	-	-	-	-
A. troschelii	-	17	-	25	-	14	4	9	-	30	-	3
H. dispilus	-	-	-	1	-	1	2	-	-	1	-	1
H. nicholsi	-	-	-	1	-	2	-	-	-	1	-	1
N. denticulata	-	-	-	2	-	3	1	6	-	-	-	-
G. chiquita	1	14	-	4	-	4	-	1	-	12	-	5
C. urospilus	-	-	-	-	-	3	2	19	-	-	-	-
E. punticulatus	-	-	-	-	-	-	1	1	-	-	-	-
H. gentilis	7	1	2	-	1	1	6	-	10	5	1	3
M. hubbsi	2	32	7	11	6	33	7	32	1	23	1	19
M. margaritae	-	-	-	-	2	3	4	4	-	-	4	-
M. tetranemeus	1	1	-	-	-	-	-	-	-	-	-	-

Table C-1. Species observed on individual natural patch reefs (continued).

Species	Reef Number 1		2		3		4		5		6	
	L	M	L	M	L	M	L	M	L	M	L	M
L. xanti	1	2	7	6	5	4	2	-	3	4	-	-
P. sini	2	1	2	1	3	1	1	2	1	2	-	3
E. asper	-	-	-	-	-	-	-	2	-	-	-	-
X. rhodopyga	1	-	-	-	-	-	-	-	-	-	-	-
A. crockeri	1	-	-	-	-	-	1	1	1	1	-	-
E. hypacanthus	1	-	-	-	-	-	-	1	-	-	-	1
C. alepidota	-	1	-	-	-	-	-	-	-	-	-	-
Lizard triplefin	-	2	1	2	-	-	1	1	-	-	-	-
A. carminalis	-	-	-	-	-	-	-	-	-	-	-	-
S. mystes	-	1	-	-	1	-	2	1	1	1	-	-
B. polylepis	-	1	1	-	-	-	-	-	-	-	-	-
Total Species	9	16	8	15	8	15	19	20	6	15	3	12
Total Numbers	17	80	24	72	21	81	43	100	17	89	6	40

Table C-1. Species observed on individual natural patch reefs (continued).

Species	Reef Number 7		8		9		10*		11*		12*		Total
	L	M	L	M	L	M	L	M	L	M	L	M	
G. castaneus	-	-	-	-	-	-	-	-	-	-	-	-	3
P. maculato-fasciatus	-	-	-	1	2	18	-	6	-	1	-	2	37
M. rosacea	-	-	-	-	-	-	-	1	-	2	-	1	5
A. multiguttatus	-	-	-	-	1	-	-	-	-	-	-	-	3
S. fasciatus	-	-	-	-	1	-	-	-	-	-	-	-	2
E. labriformis	-	-	-	-	-	-	-	-	-	-	-	-	1
L. guttatus	-	-	-	2	-	-	-	-	-	5	-	-	28
L. argentiventris	-	-	-	-	-	-	-	-	-	-	-	-	4
H. guntheri	-	1	-	-	-	-	-	-	-	1	-	-	3
A. retrosella	-	-	-	-	-	-	-	-	-	8	-	-	24
L. flaviguttatum	-	-	-	-	-	8	-	-	-	-	-	-	8
P. viola	-	-	1	-	6	16	-	1	-	7	-	-	43
M. dentatus	-	1	-	-	-	4	-	1	-	-	-	-	8

Table C-1. Species observed on individual natural patch reefs (continued).

Species	Reef Number 7		8		9		10*		11*		12*		Total
	L	M	L	M	L	M	L	M	L	M	L	M	
C. brachysomus	-	4	-	1	-	6	-	1	-	-	-	-	19
P. rectifraenum	-	-	-	-	-	-	-	-	-	1	-	-	10
P. flavilatus	-	-	-	-	-	-	-	-	-	1	-	-	1
A. troschelii	-	-	-	30	-	-	-	1	-	5	-	-	138
H. dispilus	-	1	-	-	-	8	-	2	-	2	-	-	19
H. nicholsi	-	-	-	1	-	-	-	-	-	-	-	-	6
N. denticulata	-	-	-	-	3	6	-	1	-	2	-	-	24
G. chiquita	-	4	-	13	-	1	-	2	-	4	-	1	66
C. urospilus	-	-	-	-	-	3	-	-	-	11	-	3	41
E. punticulatus	-	-	-	-	-	-	-	-	-	5	-	-	7
H. gentilis	3	2	3	4	17	8	-	1	-	7	-	1	83
M. hubbsi	-	9	3	18	11	22	-	17	-	12	-	5	271
M. margaritae	-	-	-	-	5	7	-	-	-	-	-	1	30
M. tetranemeus	-	-	2	1	-	-	-	-	-	2	-	-	7

Table C-1. Species observed on individual natural patch reefs (continued).

Species	7 L	7 M	8 L	8 M	9 L	9 M	10* L	10* M	11* L	11* M	12* L	12* M	Total
L. xanti	-	-	-	1	-	2	-	-	-	5	-	-	42
P. sini	-	3	1	2	-	-	-	2	-	1	-	-	28
E. asper	-	-	-	-	-	2	-	2	-	-	-	-	6
X. rhodopyga	-	-	-	-	-	-	-	-	-	1	-	-	2
A. crockeri	-	-	-	1	-	-	-	-	-	4	-	-	10
E. hypacanthus	-	-	-	-	1	1	-	-	-	-	-	-	5
C. alepidota	-	-	-	-	3	1	-	-	-	-	-	-	5
Lizard triplefin	-	-	-	-	-	-	-	-	-	3	-	-	10
A. carminalis	-	-	-	-	-	-	-	-	-	2	-	1	3
S. mystes	-	1	-	3	3	-	-	-	-	2	-	-	16
B. polylepis	-	-	1	-	-	-	-	-	-	-	-	-	3
Total Species	1	9	6	13	11	16	-	13	-	24	-	8	
Total Numbers	3	26	11	78	53	113	-	38	-	94	-	15	1021

*Reefs 10, 11 and 12 censused only during midsummer.

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