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ICHTHYOFAUNAL COLONIZATION OF A NEW ARTIFICIAL REEF IN THE NORTHERN GULF OF MEXICO

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ABSTRACT Ichthyofaunal colonization of a new artificial reef was monitored from June 1975 through September 1977. Direct observations were accomplished using SCUBA. Theories of colonization and species equilibrium of islands and islandlike habitats were applied to the colonization data from the artificial reef. Sixty species of fishes from 33 families were recorded at the reef. Fifty-two percent of these species were primary reef fishes and 48% were secondary. Colonization data were produced only from the occurrence of primary reef fish. Data indicate that ichthyofaunal communities in the northern Gulf of Mexico are heavily influenced by seasonal changes in temperature, and that colonization by reef fish in that area does not conform to theories of immigration and extinction for island biotas. These results concur with similar work conducted on reef ichthyofauna in the eastern Gulf of Mexico.

INTRODUCTION

Ichthyofaunal colonization of a new artificial reef in the northern Gulf of Mexico was conducted from June 1975 through September 1977.

Theories of colonization and species equilibrium of islands and islandlike habitats have been discussed by MacArthur and Wilson (1967), Simberloff (1968), and Shoener (1974a, 1974b). Cairns et al. (1969) developed a method of estimating rates of immigration and extinction, calling them colonization and decolonization rates, respectively. Smith (1979) applied these theories to the ichthyofaunal colonization of patch reefs in the eastern Gulf of Mexico.

This study attempts to apply the above theories of colonization and species equilibrium of island habitats to the colonization of a Liberty ship artificial reef in the northern Gulf of Mexico.

METHODS AND MATERIALS

This study was conducted on the scrapped hull of the BENJAMIN WATERHOUSE, a World War II Liberty ship. The scrapped ship, sunk on June 10, 1975, lies in 14 m of water about 8 km south of the western end of Horn Island (Figure 1), and represents approximately 76,200 m^2 of hard substrate.

Monthly ichthofaunal observations began on July 21, 1975, using conventional sportfishing techniques and SCUBA diving. Hydrographic data, including temperature and salinity, were obtained for surface and bottom water masses during each survey. Turbidity of surface and bottom water masses was measured using a secchi disc.

A list of fish species for each observation dive was compiled on underwater paper attached to a clipboard. Also, a debriefing session for divers/observers was held immediately after each dive.

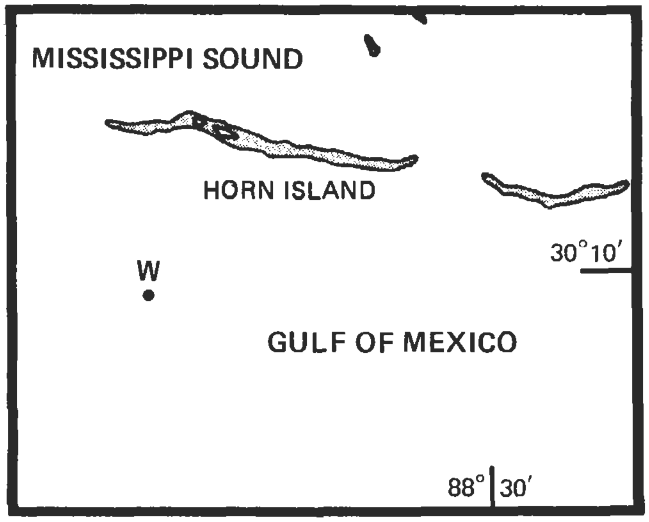

Figure 1. Waterhouse Reef (W) site.

A list was compiled of all species of fishes observed on any part of the artificial reef, and it included estimates of size and abundance. Whenever identification of a fish was uncertain, attempts were made to capture the specimen using hand nets, pole spears, and slurp guns.

Turbidity was highly variable. Whenever water clarity was adequate, 35 mm photographs were taken of reef fishes. When water visibility was less than approximately 3 m, no sampling was conducted due to increased difficulty in making accurate observations.

RESULTS

Hydrography

Temperature and salinity from surface and bottom water were measured monthly at Waterhouse Reef from July 1975 through September 1977 (Table 1). Bottom water visibility ranged from 0 to 14 m. These data compare favorably with data from previous years (Christmas and Eleuterius 1973).

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TABLE 1.

Surface (S) and bottom (B) water temperatures ($^{\circ}$C), and salinity (ppm) at Waterhouse Reef.

	1975				1976				1977				1978			
	Temperature		Salinity		Temperature		Salinity		Temperature		Salinity		Temperature		Salinity	
Month	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
January	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
February	–	–	–	–	14.3	17.0	32.0	35.0	–	–	–	–	–	–	–	–
March	–	–	–	–	19.0	19.0	26.0	34.0	–	–	–	–	–	–	–	–
April	–	–	–	–	23.1	20.4	19.0	34.0	21.0*	19.0	23.0	35.0	–	–	–	–
									24.0	22.5	28.0	31.0				
May	–	–	–	–	24.2	22.0	27.0	35.0	25.0	24.0	18.0	28.0	–	–	–	–
June	–	–	–	–	25.3	23.1	24.0	30.0	28.0	25.0	28.0	34.0	–	–	–	–
July	28.8	25.8	29.5	35.0	28.6	22.0	26.0	38.0	30.0	30.0	34.0	35.0	–	–	–	–
August	20.0*	26.9	24.0	32.0	–	–	–	–	–	–	–	–	–	–	–	–
	30.0	25.8	24.0	38.0												
September	29.5	29.5	28.0	28.0	29.2*	28.6	32.0	34.0	30.0	29.0	31.0	32.0	–	–	–	–
					27.0	27.5	30.0	31.0								
October	22.8*	23.0	28.0	29.0	24.7	25.3	33.0	33.0	–	–	–	–	–	–	–	–
	23.0	23.0	25.0	30.0												
November	23.0*	23.0	28.0	30.0	19.2	19.8	32.0	30.0	–	–	–	–	22.0	25.0	32.0	32.0
	19.3	19.8	33.0	34.0												
December	16.0	17.8	29.0	31.0	14.0*	15.0	29.0	29.0	–	–	–	–	–	–	–	–
					13.0	15.0	30.0	38.0								

*Hydrography measured twice in month.

Species Composition

All fishes identified from Waterhouse Reef were classified according to Starck (1968) into two groups: primary reef fishes, and secondary reef fishes (Table 2). Primary reef fishes are those which almost exclusively are found inhabiting reef or reeflike habitats. Secondary reef fishes are those which can be found on reefs but are more numerous at other habitat types, i.e., grassbeds, sand or mud flats, or open water. Smith (1976), working in the eastern Gulf of Mexico, also used the groupings developed by Starck (1968). For those species not covered by Starck or Smith, I consulted work by Hastings (1972), Christmas et al. (1973) Walls (1975), and Hoese and Moore (1977).

Sixty species of fishes from 33 families occurred at Waterhouse Reef (Table 2). Fifty-two percent were primary reef fishes and 48% were secondary reef fishes. Nearly half of the secondary reef fish group was composed of pelagic species.

Colonization of Primary Reef Fish

Colonization of a habitat and the approach of species equilibrium within that habitat can be followed by calculating immigration and extinction rates, described by the rate at which new species enter a habitat and old species leave it. Lapses of time between observations in this study made it impossible to calculate the actual rates of immigration and extinction. Therefore, I followed a method developed by Cairns et al. (1969) for calculating colonization and decolonization rates, a method which compensates for those time gaps between observations.

The colonization curve, colonization rate curves, and decolonization rate curves (Figures 2, 3, 4, 5, and 6) were produced from the occurrence of primary reef fish listed in Table 2.

The colonization curve (Figure 2) increased rapidly during the first 14 months of the study, then began to level off, and finally achieved an asymptote at the 17th month. The colonization rate for Waterhouse Reef was calculated by combining new species per observation with recurring species (those species which disappeared from the reef but later reappeared), and dividing by the amount of time between observations. Figure 3 represents the rate of colonization of fish species per day (scatter plot) plotted over the duration of the study. An exponential curve (solid

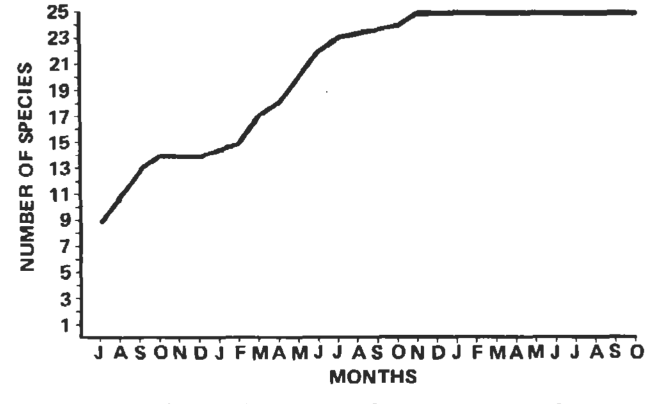

Figure 2. Colonization curve for Waterhouse Reef.

TABLE 2.

List of fish species from Waterhouse Reef classified as primary and secondary reef fishes following Starck (1968).

PRIMARY REEF FISH

Family	Species	Common name
Antennariidae	*Antennarius ocellatus*	Ocellated frogfish
Serranidae	*Centropristis philadelphica*	Rock sea bass
	Diplectrum formosum	Sand perch
	Epinephelus nigritus	Warsaw grouper
	Mycteroperca microlepis	Gag
	Serraniculus pumilio	Pygmy sea bass
	Serranus subligarius	Belted sandfish
Grammistidae	*Rypticus maculatus*	Whitespotted soapfish
Priacanthidae	*Priacanthus arenatus*	Bigeye
Apogonidae	*Apogon pseudomaculatus*	Twospot cardinalfish
Lutjanidae	*Lutjanus campechanus*	Red snapper
	L. griseus	Gray snapper
	L. synagris	Lane snapper
Pomadasyidae	*Haemulon aurolineatum*	Tomtate
	Orthopristis chrysoptera	Pigfish
Sparidae	*Archosargus probatocephalus*	Sheepshead
	Diplodus holbrooki	Spottail pinfish
	Lagodon rhomboides	Pinfish
Sciaenidae	*Equetus umbrosus*	Cubbyu
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterflyfish
	Holocahthus bermudensis	Blue angelfish
Pomacentridae	*Pomacentrus partitus*	Bicolor damselfish
	P. variabilis	Cocoa damselfish
Labridae	*Halichoeres bivittatus*	Slippery dick
	H. caudalis	Painted wrasse
Sphyraenidae	*Sphyraena barracuda*	Great barracuda
Blenniidae	*Blennius marmoreus*	Seaweed blenny
	Hypleurochilus geminatus	Crested blenny
Gobiidae	*Gobiosoma longipala*	Twoscale goby
Balistidae	*Balistes capriscus*	Gray triggerfish

SECONDARY REEF FISH

Family	Species	Common name
Carcharhinidae	*Carcharhinus maculipinnis*	Spinner shark
	Rhizoprionodon terranovae	Atlantic sharpnose shark
Sphyrnidae	*Sphyrna* sp.	Hammerhead shark
Clupeidae	*Harengula jaguana*	Scaled sardine
Ariidae	*Arius felis*	Sea catfish
Antennariidae	*Antennarius radiosus*	Singlespot frogfish
Ophidiidae	*Brotula barbata*	Bearded brotula
Syngnathidae	*Hippocampus zosterae*	Dwarf seahorse
Serranidae	*Diplectrum bivittatum*	Dwarf sand perch
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Rachycentridae	*Rachycentron canadum*	Cobia
Echeneidae	*Echeneis naucrates*	Sharksucker
Carangidae	*Caranx crysos*	Blue runner
	C. hippos	Crevalle jack
	Seriola zonata	Banded rudderfish
	Trachurus lathami	Rough scad
	Vomer setapinnis	Atlantic moonfish
Coryphaenidae	*Coryphaena hippurus*	Dolphin
Sparidae	*Stenotomus caprinus*	Longspine porgy
Sciaenidae	*Bairdiella chrysoura*	Silver perch
	Leiostomus xanthurus	Spot
	Micropogonias undulatus	Atlantic croaker
Scombridae	*Scomberomorus* sp.	Mackerel
Stromateidae	*Peprilus burti*	Gulf butterfish
Scorpaenidae	*Scorpaena brasiliensis*	Barbfish
Bothidae	*Paralichthys lethostigma*	Southern flounder
Balistidae	*Monacanthus hispidus*	Planehead filefish
Tetraodontidae	*Sphoeroides parvus*	Least puffer

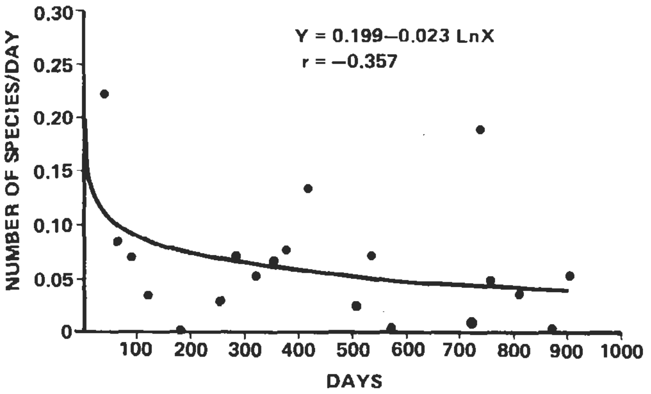

Figure 3. Colonization rate for Waterhouse Reef (using recurring species).

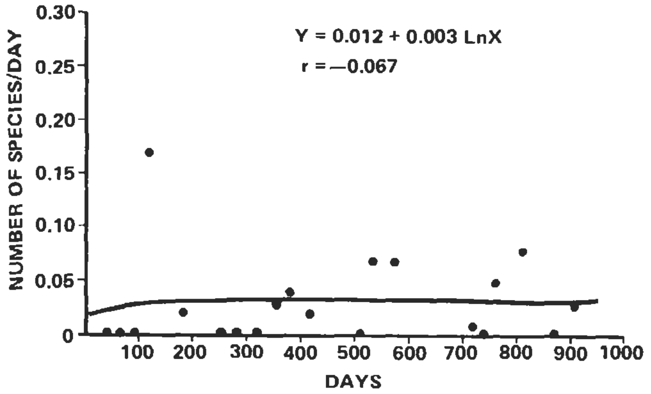

Figure 4. Decolonization rate for Waterhouse Reef (with recurring species).

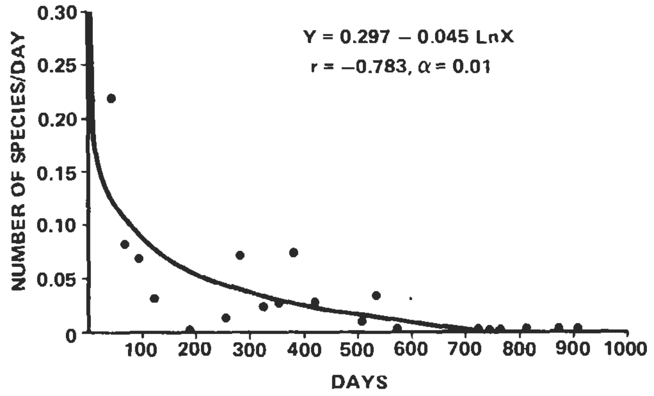

Figure 5. Modified colonization rate for Waterhouse Reef (without recurring species).

line) was fitted to the colonization rate by regressing the number of species colonized per day on the logarithm of time ($r = -0.357$). The decolonization rate (Figure 4, scatter plot) was calculated by determining the number of species eliminated from the reef per observation, and dividing by the time between observations. An exponential curve (solid line) was fitted to the decolonization rate by regressing the number of species eliminated from the reef per day on the logarithm of time ($r = -0.067$). Neither of these regressions proved significant ($\alpha = 0.05$).

Colonization and decolonization rates also were calculated for these data without considering recurring species. Instead, if a species disappeared and reappeared regularly, initial colonization was the only one considered. An exponential curve was fitted to the modified colonization rate (Figure 5) by regressing the number of new species per day on the logarithm of time ($r = -0.783$, $\alpha = 0.01$). An exponential curve was fitted to the modified decolonization rate (Figure 6) by regressing the number of species eliminated per day on the logarithm of time ($r = -0.390$, $\alpha = 0.10$).

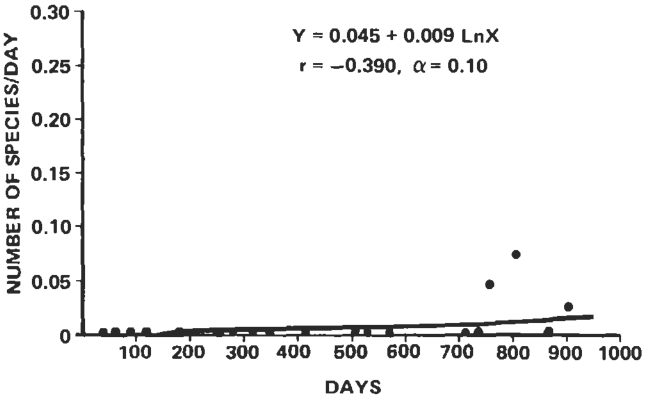

Figure 6. Modified decolonization rate for Waterhouse Reef (without recurring species).

DISCUSSION

Recruitment

Rate of recruitment of species (all species observed) to Waterhouse Reef throughout the 28 months of the study was approximately two species per month. A 28-month study of a Liberty ship reef in Alabama waters revealed a recruitment rate of almost five species per month (Crozier 1977), and an inshore jetty in northern Florida showed a recruitment rate exceeding eight species per month over 31 months (Hastings 1972). The Alabama and Florida artificial reefs mentioned apparently exhibited higher rates of recruitment because of their proximity to other recruitment areas and to deeper water. In each case, observed recruitment was decreased or eliminated during winter months, as reported in this study, but as water temperature increased above 20°C, recruitment increased considerably.

Colonization and Species Equilibrium

MacArthur and Wilson (1967) postulated that an island community proceeds through a series of successional changes leading to a point of equilibrium whereby immigration of new species is offset by extinction of other species. At the point of equilibrium, species composition is dynamic over time, theoretically a slow process, as some species are replaced by others.

I classified Waterhouse Reef as an island because there is a vast expanse of flat bottom consisting of mud and silt surrounding the artificial substrate. The study reef is at least 9 km from the nearest hard substrate.

For this discussion, only primary reef fish species (Table 2) were considered. A species was considered an unsuccessful colonizer if it appeared only once.

Since observations of Waterhouse Reef ichthyofauna began immediately after the hull was sunk, the fish population was monitored from its inception through 28 months of colonization. Colonization of Waterhouse Reef was initially rapid and decreased with time. The cessation of colonization is illustrated by the asymptote on the colonization curve (Figure 2). The two depressions in this curve that precede the asymptote were the result of decreased recruitment of new species during winter months. Several species unsuccessfully attempted to colonize after month 17 of the study which could indicate that the maximum number of species for that habitat had been approached by that time. Some of these species, such as ***Pomacentrus partitus*** and ***Halichoeres caudalis,*** possibly reacted negatively to several factors in combination which resulted in their failure to colonize. Increased species number and temperature changes are possibly two of those factors, and a third factor may have been competition from congeners (*P. variabilis* and *H. bivittatus*) present prior to their arrival.

Smith et al. (1975) concluded that fluctuating water temperature, turbidity, red tides, and anoxia following phytoplankton blooms were the major stress factors operating on the ichthyofaunal communities in the eastern Gulf of Mexico. Temperature fluctuations appeared to be the major stress factor operating on the ichthyofauna of Waterhouse Reef. Decreasing water temperature during winter periods markedly affected the species composition of the study reef. Many species, such as *Pomacentrus variabilis, Chaetodon ocellatus,* and *Holocanthus bermudensis,* disappeared from the reef during the winter months. An influx of recurring species occurred as water temperature rose in spring and summer. Although the recruitment process of the recurring species was repeated each year, the resources sustaining a particular species were not being depleted by new species having the same niche requirements; therefore, competitive exclusion from the community was not occurring. Seasonal disappearance and reappearance of many of the same species at Waterhouse Reef could affect the pattern of colonization if recurring and new species were given the same importance. The colonization rate curve (Figure 3) does not accurately describe colonization of new species on the reef. The reason for this is the importance placed on recurring species in the formula used to calculate that rate.

The decolonization rate curve (Figure 4) also provides an inaccurate view of actual decolonization due to the recurring species phenomenon.

If seasonal reoccurrance of a species is not new colonization but rather is continued utilization of a resource already colonized, then it is necessary to consider the rates of colonization and decolonization disregarding recurring species. These modified colonization and decolonization rates are calculated as described above with the exception that recurring species are not given the same importance as new species. The modified colonization rate (Figure 5) adequately represents the colonization of new species to the study reef, and is consistent with the colonization theory as set forth by MacArthur and Wilson (1967). These findings agree also with those of Smith (1979), who did a similar study on patch reefs in the eastern Gulf of Mexico.

The modified decolonization rate (Figure 6) does increase with time as stated by the MacArthur-Wilson theory; however, there are factors which indicate that this curve does not represent the actual decolonization of Waterhouse Reef ichthyofauna. Six species reported as eliminated from the reef fauna were *Lutjanus synargris, Diplodus holbrooki, Epinephelus nigritus, Serraniculus pumilio, Holocanthus bermudensis,* and *Blennius marmoreus. Lutjanus synagris, D. holbrooki, S. pumilio, H. bermudensis,* and *B. marmoreus* frequently were present on the reef but were never abundant. I believe they probably were overlooked in sampling rather than actually eliminated from the reef fauna. *Epinephelus nigritus* was one of the initial colonizers and, with few exceptions, always was present during my observations. Juveniles of this species (200 to 250 mm total length) were recorded initially; however, the size of the fish observed increased with time during the study. As the size of fish observed increased, their abundance decreased. *Mycteroperca microlepis,* another grouper, began to colonize the reef in July 1976. It is possible that due to the low numbers of *E. nigritus, M. microlepis* was able to displace the former. Because of behavioral differences between the two species, that conclusion is unlikely. Rather, it is more probable that *E. nigritus* was overlooked in sampling because of its decreased numbers and its secretive behavior. If these assumptions are valid, virtually no decolonization took place on the artificial reef during this study.

The dynamic species composition expected from the MacArthur-Wilson theory was not evident at Waterhouse Reef, but rather, as Smith (1979) found, species composition exhibited considerable stability, with 92% of the reef fish reported herein already having been colonized by the end of the first year. Those species continued to dominate the primary reef fish group throughout the remainder of the study.

CONCLUSIONS

My findings coincide with those of Smith (1979), indicating that reef-fish communities in the northeastern Gulf of Mexico do not conform to the MacArthur-Wilson model of immigration and extinction for island biotas. It was necessary to disregard recurrent species for these data to correspond to the findings of Smith (1979); however, I believe this was justified because of the strong seasonal influence operating on the ichthyofauna of Waterhouse Reef, coupled with the lack of species replacement when life-sustaining resources were abandoned by a seasonally absent species. These findings in no way refute the theory proposed by MacArthur and Wilson (1967), and it is probable that the strong influence exerted by temperature changes on the study reef make such an equilibrium situation impossible to attain.

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