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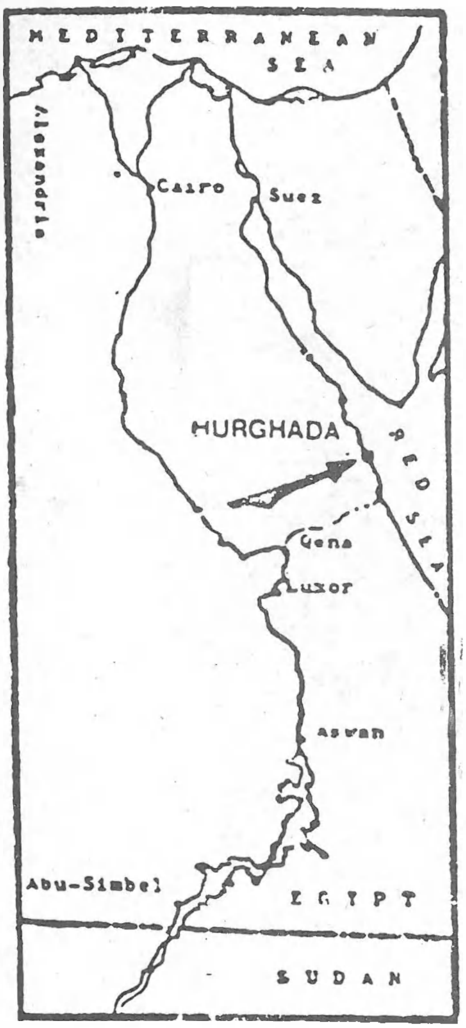


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# ANALYSIS OF A CORAL REEF FISH COMMUNITY IN SHALLOW WATERS OF NUWEIBA, GULF OF AQABA, RED SEA

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"Five visual fish censuses were conducted in coastal waters of the Gulf of Aqaba, Red Sea, from July 1977 to November 1981. In total 73 species were counted in three habitats of the investigated site of an area of 74 $m^2$. The highest species diversity, species richness, and standing crop were found on the forereef, less on the knoll and on the seagrass-sand bed. The average standing crop amounted to 962 kg $h^{-1}$. For further analysis of variations in species composition and number of individuals with time and habitat, indexes of coefficient of community, species diversity, and equitability were calculated. Some observations on the seasonal occurrence of the common fish in the study site are given."

## Introduction

There is an increasing interest in animal communities associated with the Red Sea coral reefs. Among them fish have received a large share of attention. Clark et al. (1968) presented data on the structure and standing crop of a shallow-water coastal fish community along the coast of Ethiopia, southern Red Sea. Bouchon-Navaro and Harmelin-Vivian (1981) studied the numerical abundance of herbivorous reef fish near the Gulf of Aqaba, and Edwards and Rosewell (1981) investigated the numerical abundance and vertical zonation of 38 common reef fish near Port Sudan. Gunderman and Popper (1975) analyzed the influence of cases of pollution on fish communities near Eilat. And several papers in recent years dealt with various aspects of biology and behavior of fish in the Gulf of Aqaba (Bouchon-Navaro, 1980; Fishelson, 1977; Fishelson et al., 1974; Fricke, 1973; Karplus and Algom, 1981).

The advent of scuba-diving equipment and the recognition of the scientific, commercial, and esthetic values of coral reefs have brought about the publication of a considerable number of papers on fish communities of natural and artificial reefs. Some of the recent ones (Brock et al., 1979; Heatwole et al., 1981; Molles, 1978; Ogden and Ebersole, 1981; Sale and Dybdahl, 1978; Talbot et al., 1978) contain most of the relevant bibliographic references.

Both physical and biological oceanographers have stressed the uniqueness of the enclosed, highly saline Red Sea. Its special place is accentuated by its predominantly north-south geographic orientation and its remoteness from the faunistic centers of the Indo-Pacific Ocean. The narrow Gulf of Aqaba at the northern end of the Red Sea adds to the unusual features of the region. It also forms one of the most northern extensions of the coral reef habitat of the

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west Indian Ocean.

Do these exceptional conditions affect the abundance and structure of the coral reef fish community? This paper summarizes some observations and quantitative data obtained in a fish census study on a small section of a typical reef, as preliminary information for a comparative study with other regions of tropical seas.

## Materials and Methods

This study began on August 12, 1977 (day 1), when the first visual census and pronoxfish collection (commercial chemical based on rotenone emulsion) were carried out at the selected site. Four censuses followed: on April 20, 1978 (day 251), October 9, 1978 (day 454), on March 17, 1979 (day 613), and on November 14, 1981 (day 1220). Pronoxfish collections followed the last two.

Usually four scuba divers (the authors) worked, one for each habitat to conduct the one-hour census. We recorded names and numbers of fish and estimated their sizes with a pencil and a PVC slate underwater. All censuses were conducted during midday or early afternoon hours. Defaunation was performed by application of pronoxfish to the three studied habitats. Since differential collecting from separate habitats was not feasible due to their relative proximity, we decided to treat all three simultaneously and pool the collected fish. Collecting was carried out with dipnets, although some of the larger specimens were speared. To facilitate species identification during censuses, we took photographs with a Nikonos II camera with Oceanic 2000 strobe. The museum collections of the Hebrew University of Jerusalem have preserved the fish.

## The Study Area

The area selected for the study (Figure 1) is in the Gulf of Aqaba along the eastern coast of Sinai Peninsula (28°54'N, 34°37'E), 10 km south of Nuweibá and about 80 km south of Eilat (Elat). Its general structure and biotic characteristics are typical of a shallow-water coral habitat of the Gulf of Aqaba.

The study site was 74 $m^2$ in area, consisting of a narrow fringing reef separated from shore by a shallow, 7-8-m-wide rocky lagoon and 10-12 m of reef flat (Figure 2). On its seaward side the reef flat drops abruptly as a steep vertical forereef front about 2.5 m high, which forms a spurred cliff perforated by crevices and small caves. A 10.5-m-long stretch of this forereef -- with a surface area of 25 $m^2$ -- was chosen for investigation.

There is an isolated knoll of cylindrical shape (patch reef), 10.0 m in perimeter and

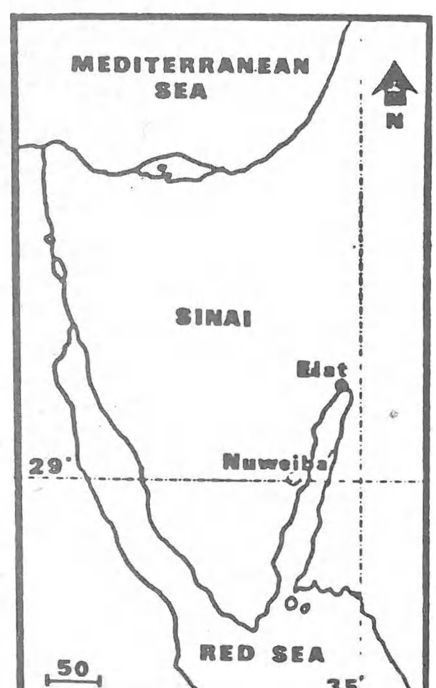


FIGURE 1. Map of the Gulf of Suez and Gulf of Aqaba, showing the investigated area south of Nuweibá.

25 $m^2$ in surface area, some 4-6 m farther seaward. The base of the knoll constitutes the deepest part (4.2 m deep), taken as an average between low and high tides. Surrounding the knoll is a flat sandy bottom, partly covered by dense patches of the seagrass *Halophila stipulacea* and to a lesser extent by *Halodule uninervis*. From this biotope we selected a rectangle of about 24 $m^2$ for the study. Beyond this site the sandy bottom gradually descends to about 40 m, then drops steeply some 70 m from shore.

The forereef and knoll are covered by numerous colonies of scleractinian corals, predominantly *Acropora* spp., *Stylophora pistillata*, and to a lesser extent *Favia* spp. and *Platygyra lamellina*. Also abundant, particularly on the upper parts of the area, are large colonies of the hydrozoan *Millepora platyphylla*.

The adjacent reef flat, 190 $m^2$ in area, forms a large component of the shallow-water habitat (Figure 2). It is covered with dead coral debris, cemented into a platform by calcareous algae. On its seaward side the reef flat gradually becomes richer in live corals and forms a vertical wall of the forereef.

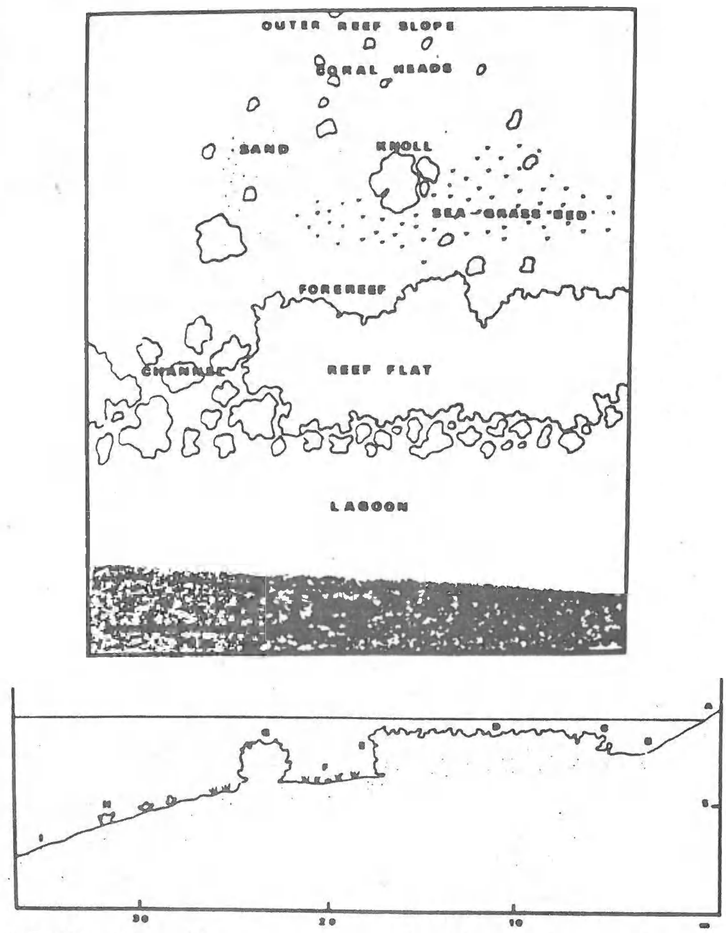


FIGURE 2. Top: Map of the investigated area. Bottom: Transverse section of the investigated area, showing (A) intertidal zone, (B) lagoon, (C) back reef margin, (D) reef flat, (E) forereef, (F) seagrass-sand bed, (G) knoll, (H) coral head, and (I) outer reef slope.

The shallow reef flat is strongly influenced by waves and tides, causing difficulties in visual counts of fish populations. Also visiting the area are schools of fish like acanthurids, siganids, mullids, and sparids, which frequently cross the site in their constant movements along the reef flat in north-south or south-north directions. Prolonged observations would be needed to evaluate correctly their biomass per unit of area. Thus, in order to avoid misinterpretation of the data, we did not include the counts carried out on the reef in our analysis of the population structure.

## Results

### Species Composition

The visual censuses recorded 73 species during the study (Table 1): 54 species (74.0 percent) in the forereef, 53 (72.6 percent) on the knoll, and 32 (43.8 percent) on the seagrass-sand bed. Labridae comprised the largest proportion of species (17.8 percent of the total observed), followed by Pomacentridae (15.1 percent) and Blennidae (9.6 percent); Serranidae, Apogonidae, and Chaetodontidae comprised 6.8 percent each. These six families account for 62.9 percent of the total number of species.

The largest number of species was found on the forereef and on the knoll, considerably less on the seagrass-sand habitat. There are differences in the composition of the fish assemblages among the three areas -- forereef, knoll, and seagrass-sand; serranids (particularly *Anthias squamipinnis*), *Thalassoma klunzingeri*, and *Chromis dimidiata* were found on the forereef and knoll only; mullids and siganids on the seagrass-sand bed.

### Distribution of Fish

The most abundant fish was *Anthias squamipinnis*, feeding in groups of 20-120 individuals in the water column near the forereef and knoll. Among the pomacentrids, *Chromis caerulea* was counted in two censuses but not seen in the three others, probably hiding in the branches of *Acropora*.

*Chromis dimidiata* appeared in all censuses, generally close to the forereef and knoll in groups of 10-30 individuals; *Pomacentrus sulfureus* was less abundant, appearing in pairs or threes. This species ventured out to the surrounding seagrass-sand bed, but usually stayed near turrets of fire coral (*Millepora platyphylla*). Of the chaetodontids, the commonest was *Chaetodon paucifasciatus*, which was seen on the forereef and knoll, patroling in pairs or small groups. *Chaetodon austriacus*, as well as *C. auriga*, were seen in the forereef only, living in pairs. A single specimen of *Megaprotodon trifascialis* was recorded on the forereef.

The most common apogonid was *Apogon cyanosoma*, hiding in caves and crevices of the forereef and knoll, usually in groups of 10-40 individuals, but in one census 112 were observed. Of the labrids, *Gomphosus caeruleus*, a transient species, was found in summer near forereef and knoll, but was absent during winter censuses.

Two cleaning stations were observed consistently throughout the study: one on the east side of the knoll, the other on the north side of the forereef. Each station contained 2-6 individuals of *Labroides dimidiatus*, which occasionally moved away from the station as far as 4 m into the seagrass flat to clean fish. *Thalassoma klunzingeri* was one of the commonest species encountered. *Thalassoma lunare* was rare, and appeared only in the spring censuses. Mullids were observed over the seagrass-sand bed. The most common were *Mulloides flavolineatus* in groups of 10-25 and *Parupeneus forsskali* in groups of 2-12. Less common were *P. cyclostomus* and *P. macronema*. Syngnathids were encountered in the seagrass bed; *Dunckerocampus multiannulatus* was seen in summer months only, whereas *Yozia bicoarctata* appeared in all other censuses, except during the spring. *Acanthurus nigrofuscus* and *Ctenochaetus striatus* were seen in

TABLE 1. Species recorded in five visual censuses on knoll (K), seagrass-sand bed (G), and forereef (R).

| Family and Species | August 12, 77 | | | April 20, 78 | | | October 9, 78 | | | March 17, 79 | | | November 14, 81 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | G | R | K | G | R | K | G | R | K | G | R | K | G | R |
| Muraenidae | | | | | | | | | | | | | | | |
| Unidentified muraenid | | | | | | 1 | | | | | | | | | |
| Holocentridae | | | | | | | | | | | | | | | |
| *Adioryx diadema* | 1 | | 2 | 1 | 1 | 2 | | | | | | | | | 1 |
| Syngnathidae | | | | | | | | | | | | | | | |
| *Dunckerocampus multiannulatus* | | | | 2 | 1 | 2 | | | | 2 | 3 | 15 | | | |
| *Corythoichthys flavofasciatus* | | | | | 2 | | | | | | | | | | |
| *Yozia bicoarctata* | | 2 | 2 | | | | 6 | 1 | 3 | | | | 6 | 2 | |
| Scorpaenidae | | | | | | | | | | | | | | | |
| *Pterois volitans* | 1 | | 2 | 1 | | 2 | 2 | | | 1 | | | 1 | | 3 |
| *Pterois radiata* | | | | | | | | | | | | | | | 1 |
| Platycephalidae | | | | | | | | | | | | | | | |
| *Platycephalus tuberculatus* | | | | | | | 1 | | | | | | | | |
| Serranidae | | | | | | | | | | | | | | | |
| *Anthias squamipinnis* | 50 | | 31 | 40 | | 126 | 34 | | 40 | 34 | 1 | 16 | 40 | | |
| *Cephalapholis miniata* | | | | | | | | | | | | | 1 | | |
| *Epinephelus fasciatus* | 2 | 4 | 5 | 1 | 1 | 1 | 5 | | | 1 | 2 | 1 | 1 | | 3 |
| *Epinephelus tauvina* | | | 1 | | | | | | 1 | | | | | | |
| *Grammistes sexlineatus* | | | 2 | | | | | | 1 | | | 1 | 2 | | |
| Pseudochromidae | | | | | | | | | | | | | | | |
| *Pseudochromis fridmani* | | | 5 | 1 | | 7 | | | 7 | | | 4 | 5 | | 1 |
| *Pseudochromis olivaceus* | | | 2 | | | | | | | | | | | | 2 |
| Apogonidae | | | | | | | | | | | | | | | |
| *Apogon hyalosoma* | | | 16 | | | | | | | | | | | | |
| *Apogon cyanosoma* | | | | | | | 4 | | 35 | 8 | 17 | 10 | 112 | | 16 |
| *Apogon angustatus* | 1 | 16 | 10 | | | | | | | | | | 15 | | 4 |
| *Apogon* sp. | | 20 | | | | | | | 12 | | | | | | |
| *Cheilodipterus quinquelineatus* | | | | | | 2 | | | | | 5 | | 5 | | 6 |
| Mullidae | | | | | | | | | | | | | | | |
| *Mulloides flavolineatus* | | 25 | | | 14 | | | | | | | | | | |
| *Parupeneus forsskali* | | 16 | | | 10 | | | | | | 3 | | | 2 | 6 |

TABLE 1. Continued. (Key: K = knoll, G = seagrass-sand bed, R- forereef)

| Family and Species | August 12, 77 | | | April 20, 78 | | | October 9, 78 | | | March 17, 79 | | | November 14,81 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | G | R | K | G | R | K | G | R | K | G | R | K | G | R |
| Mullidae | | | | | | | | | | | | | | | |
| *Parupeneus marcronema* | | | | | 2 | | | | | | 1 | | | | |
| *Parupeneus cyclostomus* | | | | | | | 1 | 2 | | | | | | | 1 |
| Chaetodontidae | | | | | | | | | | | | | | | |
| *Chaetodon auriga* | | | 2 | | | 2 | | | | | | | | | |
| *Chaetodon austriacus* | | | 4 | 4 | | 1 | | | | | | | | 1 | |
| *Chaetodon paucifasciatus* | 2 | 1 | 4 | 12 | | 2 | 2 | 3 | 5 | | | | 1 | | 3 |
| *Chaetodon fasciatus* | | | 2 | | | 2 | | 2 | 2 | 1 | | | | | |
| *Megaprotodon trifascialis* | | | | | | 1 | | | | | | | | | |
| Pomacentridae | | | | | | | | | | | | | | | |
| *Abudefduf vaigiensis* | | | 4 | | 2 | | | | 6 | | | | | | 6 |
| *Abudefduf* sp. | | | | | | | | | | | | 5 | | | |
| *Amblyglyphidodon leucogaster* | 1 | | | | | | | | | | | | | | |
| *Amblyglyphidodon* sp. | | | | 2 | 2 | | 2 | | | | 5 | | | | |
| *Chromis caerulea* | | | 50 | | | | | | | 200 | 25 | | | | |
| *Chromis dimidiata* | 12 | 4 | 26 | 6 | | 26 | 21 | | 27 | 22 | | 14 | 8 | | 2 |
| *Dascyllus marginatus* | 1 | | | | | | | | | | | | | | |
| *Dascyllus trimaculatus* | | | 6 | | 1 | 4 | | | | | | | | | |
| *Pomacentrus aquilus* | | | 2 | | | | | | | | | | | | |
| *Pomacentrus sulfureus* | | 4 | 14 | 6 | | 21 | 1 | 2 | 11 | | | 6 | 8 | | 9 |
| *Pomacentrus trichourus* | 2 | 2 | 8 | 2 | 4 | | | 1 | | 1 | 4 | 1 | 6 | | 2 |
| Labridae | | | | | | | | | | | | | | | |
| *Anampses meleagrides* | | | | | | | | | | | | | 1 | | |
| *Cheilio inermis* | | | | | | 4 | | | | | 2 | 2 | 1 | | |
| *Coris aygula* | 4 | | | 1 | | 5 | 2 | | 6 | 4 | 4 | | 4 | | 4 |
| *Coris* sp. | | | | | | | | 1 | | | | | 1 | | |
| *Gomphosus caeruleus* | 1 | 2 | 4 | 1 | 2 | 4 | 1 | 1 | 2 | 1 | 1 | 9 | 1 | | |
| *Halichoeres hortulanus* | | | | 1 | | 6 | | | | | | | | | |
| *Labroides dimidiatus* | 3 | 1 | 3 | 3 | | 1 | 2 | | 5 | 6 | | 1 | 3 | | 1 |
| *Halichoeres scapularis* | | | | 15 | | 2 | | | | | | | | | |
| *Pseudocheilinus hexataenia* | | | | | | | | | | 2 | | 1 | | | |
| *Stethojulis albovittatus* | | | | | | | | | | | | | | | 1 |
| *Thalassoma lunare* | | | | 6 | 4 | 15 | | 1 | | 9 | 1 | 2 | | | |

TABLE 1. Continued. (Key: K = knoll, G = seagrass-sand bed, R = forereef)

| Family and Species | August 12, 77 | | | April 20, 78 | | | October 9, 78 | | | March 17, 79 | | | November 14,81 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | G | R | K | G | R | K | G | R | K | G | R | K | G | R |
| Labridae | | | | | | | | | | | | | | | |
| *Thalassoma purpureum* | | | 2 | | | | | | | | | | | | |
| *Thalassoma klunzingeri* | 6 | 1 | 13 | 6 | 10 | 45 | 16 | 3 | 37 | 28 | 3 | 31 | 5 | 10 | 21 |
| Scaridae | | | | | | | | | | | | | | | |
| (5 species) | | | 10 | | | 2 | | 3 | | | | | 5 | 2 | 3 |
| Blennidae | | | | | | | | | | | | | | | |
| *Aspidontus taeniatus* | | | 3 | | | | | | | | | 2 | | | |
| *Ecsenius frontalis* | 2 | | 12 | | | | | | | | | 4 | | | |
| *Ecsenius* sp. | 1 | 11 | 5 | | | 4 | 2 | | 9 | 2 | 4 | | 2 | | 3 |
| *Exallias brevis* | | | | | | | | | | 2 | | 3 | | | 1 |
| *Istiblennius* sp. | | | | | | | | | | | | | 2 | | |
| *Plagiotremus rhinorhynchus* | | | | | | 1 | | | | | | | | | |
| *Plagiotremus tapeinosoma* | | | | | | | | | | | | 1 | | | |
| Acanthuridae | | | | | | | | | | | | | | | |
| *Acanthurus nigrofuscus* | 2 | 6 | 14 | 3 | 8 | 38 | | | 41 | | | 8 | 38 | 15 | 3 |
| *Zebrasoma xanthurum* | | | | | | 5 | 4 | | | | | | | | |
| Siganidae | | | | | | | | | | | | | | | |
| *Siganus luridus* | | 4 | | | 4 | | | 10 | | | 2 | | | | 5 |
| *Siganus rivulatus* | | | | | 2 | | | | | | 14 | | | 6 | |
| Balistidae | | | | | | | | | | | | | | | |
| *Pseudobalistes fuscus* | | | | | | | | | | | | | 1 | | |
| Monacanthidae | | | | | | | | | | | | | | | |
| *Oxymonocanthus halli* | | | | | | | | | | | | | 2 | | |
| Tetraodontidae | | | | | | | | | | | | | | | |
| *Arothron diadematus* | | | 1 | | | | | | | | | | | | |
| *Canthigaster margaritata* | | | | | | | | | 1 | | | | | | |

schools of up to 50 individuals in all habitats of the investigated site.

We observed schools of juveniles of several species during summer months, considered to be the peak of the breeding season of many coral reef fish; *Apogon cyanosoma* (20-30 mm), *Stethojulis albavittatus* (30-65 mm), *Chaetodon austriacus* (30-70 mm), *C. auriga* (20-70 mm), *C. paucifasciatus* (10-60 mm), *Epinephelus fasciatus* (30-80 mm), *Siganus luridus, S. rivulatus,* and *S. argenteus* (25-60 mm), and *Acanthurus nigrofuscus* (35-65 mm). Many of the Pomacentridae were juveniles, and this was evident particularly with *Chromis dimidiata* (25-30 mm), *C. caerulea* (25-35 mm), and *Amblyglyphidodon leucogaster* (30-40 mm).

In the spring several other juveniles were collected: *Grammistes sexlineatus* (30-60 mm), *Epinephelus fasciatus* (35-55 mm), *Synodus variegatus* (43-58 mm), a brotulid *Bidenichthys capensis* (32-47 mm), *Antennarius* sp. (43-60 mm), and *Scorpaenopsis diabolus* (21-70 mm). Juvenile chaetodontids were present also during March -- *Chaetodon austriacus* (35-60 mm) and *C. paucifasciatus* (47 mm)--but in this season there were relatively more adults (110 mm). Two juvenile specimens of a pomacantid *Centropyge multispinus* (32, 34 mm) were also present.

In November, juveniles of different species were found. *Acanthurus nigrofuscus* (20-100 mm), *Thalassoma klunzingeri* (10-45 mm), *Coris aygula* (30-32 mm), *Labroides dimidiata* (30-35 mm), *Pomacentrus sulfureus* (10-45 mm), *Chromis dimidiata* (30-35 mm), *Pterois volitans* (30 mm), scarids (60-70 mm), *Parupeneus forsskali* (50-55 mm), *Apogon angustatus* (15-20 mm), muraenids (80-130 mm), and *Paracirrhites forsteri* (45 mm). Some found in the spring and summer months reappeared -- *Bidenichthys capensis* (27-42 mm) and siganids (15-80 mm) --yet others, such as *Epinephelus fasciatus* (90-400 mm), were represented by large individuals only.

Species richness, species diversity, and equitability of the initial forereef community (August 12, 1977, day 1) were the highest values encountered for any of the individual assemblages during the entire study. Since all calculations were based on noncryptic, diurnal species, and since censuses were carried out in different months of the year, it is difficult to attempt to draw any definite conclusions regarding the determinants of the overall species composition. Sale (1980) experimentally denuded patch reefs and demonstrated that both defaunated and control reefs exhibited significant community-structure changes throughout a 28-month period. He concluded that the species composition of fish assemblages around small coral patch reefs is best understood in terms of chance colonization and mortality.

The results of our study agree with this theory, suggesting that small-scale reef-fish communities tend to display low stability but high resilience. The species composition of the Nuweiba forereef and knoll should reflect the relative abundance of the local fish inventory, while physical and biotic fluctuations of the environment determined the variations of a given assemblage with time. Such variations (up to 3.5-fold) were observed in the fish number in both forereef and knoll during our censuses, while the number of fish species was more consistent (Table 2).

The species composition of these habitats, as reflected by the degree of similarity (Table 3), demonstrated low constancy. Any given assemblage of these two habitats had changed significantly by the time of the next surveillance. The coefficient of community (Table 3), which measures the amount of

TABLE 2. Species diversity (H'), equitability (J'), number of families, number of species, and number of individuals by habitat and date of census.

| Habitat and Date | H'[a] | J'[b] | No. of Families | No. of Species | No. of Individuals |
|---|---|---|---|---|---|
| Forereef | | | | | |
| Aug. 12, 1977 | 3.2617 | 0.9328 | 13 | 33 | 267 |
| Apr. 20, 1978 | 2.2683 | 0.6736 | 12 | 29 | 334 |
| Oct. 9, 1978 | 2.4966 | 0.8077 | 10 | 19 | 251 |
| March 17, 1979 | 2.5465 | 0.8364 | 8 | 21 | 137 |
| Nov. 14, 1981 | 2.7988 | 0.8695 | 11 | 25 | 108 |
| Knoll | | | | | |
| Aug. 12, 1977 | 1.7448 | 0.6158 | 9 | 17 | 92 |
| Apr. 20, 1978 | 2.3038 | 0.7690 | 10 | 20 | 114 |
| Oct. 9, 1978 | 2.1502 | 0.7589 | 11 | 17 | 106 |
| March 17, 1979 | 1.4718 | 0.5092 | 8 | 18 | 324 |
| Nov. 14, 1981 | 2.1719 | 0.6590 | 13 | 27 | 277 |
| Seagrass | | | | | |
| Aug. 12, 1977 | 2.3672 | 0.8538 | 10 | 16 | 119 |
| Apr. 20, 1978 | 2.5685 | 0.9066 | 7 | 17 | 70 |
| Oct. 9, 1978 | 2.1654 | 0.8714 | 7 | 12 | 30 |
| March 17, 1979 | 2.3854 | 0.8253 | 8 | 18 | 97 |
| Nov. 14, 1981 | 1.4878 | 0.1428 | 7 | 7 | 37 |

[a] $H' = \sum_{i=1}^{s} P_i \ln P_i$ (species diversity, given in nats).

[b] $J' = \frac{H'}{\max(H')}$ (equitability).

species shared by two assemblages (Pielou, 1974), averaged 0.307 ± 0.06 for the knoll and 0.255 ± 0.04 for the forereef when each census was compared to its predecessor. A comparison of the initial census to each of the ensuing ones showed even less similarity. Percent similarity was used here to measure the similarity between species quantities (Molles, 1978). There is an obvious decrease in percent similarity (Table 3) in the knoll, whereas in the forereef this measure fluctuated around a mean of 0.5322 ± 0.1.

Our findings agree with those of Sale and Dybdahl (1978), Sale (1980), and Talbot et al. (1978). The colonization would be determined by such factors as the time of denudation, potential colonizers locally available, order of recruitment, and the size of the colonizers. The longer the duration between censuses, the greater the probability of a species absent from the original assemblage to appear and establish itself on the site.

The number of species and individuals observed in the seagrass-sand bed was highly variable (Table 2). These assemblages consisted mainly of feeding transient species (siganids, acanthurids, mullids), typical grass inhabitants

TABLE 3. Coefficient of community and percent similarity for census 2, 3, 4, and 5 and two different habitats: knoll and forereef.

| Census | Coefficient of Community[a] A[c] | Coefficient of Community[a] B | Percent Similarity[b] A | Percent Similarity[b] B |
|---|---|---|---|---|
| Knoll | | | | |
| 2 | 0.2600 | 0.2600 | 0.5825 | 0.5825 |
| 3 | 0.2444 | 0.2449 | 0.6307 | 0.5744 |
| 4 | 0.2222 | 0.4000 | 0.2968 | 0.3351 |
| 5 | 0.2414 | 0.3235 | 0.3125 | 0.1830 |
| Forereef | | | | |
| 2 | 0.2051 | 0.2051 | 0.4493 | 0.4493 |
| 3 | 0.2466 | 0.2154 | 0.5526 | 0.6163 |
| 4 | 0.1940 | 0.3030 | 0.4636 | 0.6375 |
| 5 | 0.2266 | 0.2777 | 0.3455 | 0.4257 |

[a]Coefficient of community (CC) is calculated as $CC = \frac{N_c}{N_i + N_s - N_c}$, where $N_c$ is species in common; $N_i$ is initial number of species (first census); and $N_s$ is subsequent number of species.

[b]Percent similarity ($C_{ic}$) is calculated as $C_{ic} = 1 - 1/2 \sum_{k=1}^{n} |P_{ik} - P_{sk}|$, where $P_{ik}$ and $P_{sk}$ are proportions of species k found in a given habitat at census i and s.

[c]A = relative to initial census i = 1; B = relative to previous census i = s - 1.

such as *Cheilio inermis*, or stray species from the adjacent coral habitats. The fish here did not constitute a "community" in the normal sense, but rather an arbitrary assemblage determined by space and time (i.e., area and duration of census). In four out of five cases, the surveyed seagrass-sand assemblage had high values of species diversity and equitability (Table 2). The pronoxfish-collected fish demonstrate that juveniles of many species were present in the study area primarily during spring and summer months and, to a lesser extent, during early winter. Unfortunately, juveniles are largely overlooked during visual censuses due to their cryptic behavior and small size. A thorough investigation of the recruitment patterns of such juvenile coral fish would greatly enhance our understanding of the dynamics and species composition of fish communities supported by coral reefs.

## Fish Biomass and Standing Crop

We estimated the fish biomass from the weight of fish recorded by the visual census taken on July 12, 1977 and November 14, 1981. Such an estimation

TABLE 4. Area, weight, and estimated standing crop of fish in various habitats.

| Habitat | Area ($m^2$) | July 12, 1977 Weight (kg) | July 12, 1977 Standing Crop ($kg/ha^{-1}$) | November 14, 1981 Weight (kg) | November 14, 1981 Standing Crop ($kg/ha^{-1}$) | Average Weight (kg) | Average Standing Crop ($kg/ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| Forereef | 25 | 3316 | 1330 | 2643 | 1060 | 2979 | 1192 |
| Knoll | 25 | 1476 | 590 | 3890 | 1560 | 2683 | 1073 |
| Seagrass-sand | 24 | 1916 | 800 | 1000 | 420 | 1458 | 607 |
| Total or average | 74 | 6708 | 910 | 7533 | 1020 | 7120 | 962 |

was made possible by weighing and comparing material collected during pronoxfish defaunation on the same date in the same area. The total weight (the biomass) of fish counted in all three habitats amounted to 6708 g in the first census in 1977 and 7533 g in the last one in 1981 (Table 4).

The surface of these habitats was 74 $m^2$. Thus the wet-fish standing crop amounted in the same years to 910 kg $ha^{-1}$ and 1020 kg $ha^{-1}$, with an average of 962 kg $ha^{-1}$, almost three times the value (350 kg $ha^{-1}$) obtained in a census in the Dahlak Archipelago, southern Red Sea (Clark et al., 1968). However, the selected habitats in the two regions differed. Our study site in the Gulf of Aqaba was composed mostly of live coral walls rich in organic production; that in the southern Red Sea was mostly shallow water, sandy beach, and reef flat with scattered coral heads and small rocks. As stressed by several authors (e.g., Odum and Odum, 1955; Randall, 1963), the physical structure of the reef habitat and its position in relation to the open sea currents are important factors in the development of a fish assemblage. Important also are the methods employed in visual fish censuses and in collected fish from the defined area. Compiled from various sources, the wet standing crop can vary between 175 and 2000 kg $ha^{-1}$ (Brock et al., 1979).

The results of our study show that on average the forereef and the knoll yielded a much higher standing crop (1085 kg $ha^{-1}$) than the seagrass-sand habitat (607 kg $ha^{-1}$). The difference in standing crop of the knoll and the adjacent grass-sand in 1977 and 1981 (Table 4) is explained by the occurrence of groups of mobile fish, like mullids and acanthurids, which on different dates were spotted in varying numbers (Table 1) on the seagrass-sand bed, and a large *Pseudobalistes fuscus* observed on one occasion feeding on the knoll. Fishelson (1977), in his observations of feeding behavior of coral fish near Eilat, noted that the forereef wall was the richest in species and quantities. Further studies are needed to compare the standing crop of the predominantly territorial fish assemblages of our study with the standing crop of mobile species feeding near the bottom or in the water column (Davis and Birdsong, 1973; Randall, 1963, 1967).

## Discussion

The majority of the censused species were relatively sedentary fish, living in a restricted territory of a particular habitat. Mobile species, like acanthurids, siganids, and mullids were mainly on the seagrass and sandy patches or on the reef flat, but seldom on the knoll and the forereef.

Not all of the observed species were collected with pronoxfish. The efficiency of pronoxfish collection consists of three main factors: fresh and potent ichthyocide, currentless water, and correct application of the chemical. We collected some 70 percent of the species present on a coral reef section. Repopulation in tropical waters is usually quick, taking much less than a year (Brock et al., 1979; Smith and Tyler, 1975). Our results show that, although we observed a combined total of 73 species in all censuses, we collected 103 species with the three pronoxfish treatments of the investigated area. Obviously, some of the collected but not seen fish, by reason of their habitat or behavior (nocturnal, cryptic), originated from the territory of the study site. However, they cannot be separated from other fish of the neighboring areas, and therefore were not included in the analysis of the results. Thus, the biomass calculated in this paper is underestimated. The difference is probably small since the collected fish, not seen in the study site, were small and weighed little; however, they could add considerably to the species diversity results obtained here.

The high number of species and the high standing crop of the study site is explained by the character of the selected section of the reef. Undoubtedly, the forereef and the adjacent knoll belong to one of the most productive and rich in species. They have the advantage of topographic position in comparatively shallow waters and complexity of structure, full of gullies and crevices, providing shelters and territories. It is a stable habitat, out of the danger of occasional exposures during exceptional low tides (Fishelson, 1973; Loya, 1972), in contrast to the "disturbed site" character of the reef flat. The high number of fish species -- 73 observed and 10 or 15 more collected -- in an area of 74 $m^2$ demonstrates the complexity and richness of the fish community, closely associated with the coral reefs in the Gulf of Aqaba.

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