# ANIMAL TREES, STONE PLANTS, AND TOY FISH: THE CHALLENGES AND SIGNIFICANCE OF CORAL REEF FISH COMMUNITIES

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"Reef environments are a renewable natural resource of great economic, aesthetic, and scientific value. The most important uses of reefs are fishing, tourism, research, and exploitation or destruction through dredging, mining, and construction activities. Accidental pollution, sometimes from distant sources, also threatens reef environments. The time has come not only to protect reefs, but also to manage them for the maximum benefit and sustainable yield. Because reef organisms have mobile life history stages, the most important part of any management attempt will be to set aside refuge areas that can serve as natural hatcheries and act as a source of organisms to replace those harvested and lost to natural mortality. Other uses can then be given appropriate priority on a local basis."

## Introduction

Even the most blasé observer soon recognizes that coral reefs dominate much of the Red Sea coastline. These reefs are a natural resource and, like other resources, they must be evaluated, protected, and perhaps managed to bring the greatest good to the greatest number of users.

Coral reefs are many things to many people. Traditionally, seafarers had the most contact with and the most knowledge of them. For navigators, reefs are a mixed blessing. They are unpredictable and dangerous, and at the same time benevolent protectors that absorb the force of the sea's fiercest waves and guard sheltered refuges, calm anchorages, and uneroded beaches. Fishermen have always recognized them as rich hunting grounds, where even the economically poorest with small boats and simple gear can find food for their families.

Today the boom in recreational diving and tourism has given reefs a new importance. They are a different world -- one of awesome strangeness and incredible beauty. With the ready availability of safe diving gear, reefs attract great numbers of tourists, who find pleasure and peace of mind and at the same time provide the basis of a major industry.

Coral reefs serve in lesser ways, too. There are small industries collecting marine curios to sell to nondiving tourists and shell collectors and supplying colorful fish for home and commercial aquariums. Sometimes the limestone for building highways and airport runways comes from reefs. This destructive use poses a serious threat to reefs in some areas. Although reefs are living, growing entities, which can repair themselves to some extent, they can also be killed by overharvesting, pollution, or drastic changes in physical environmental factors such as water circulation patterns, excessive freshwater, too much silt, and poisonous waste disposal outflows.

## Scientific Research

Reefs are valuable subjects for scientific study. They occur only where the water is warm and clear, which makes working in the field not only possible but (usually) pleasant, if no less hard work. Clear water is especially important because investigators can make direct in-situ observations and perform experiments that would not be possible in many other marine environments. The ability to move in three dimensions around the study area is another conspicuous advantage.

Of course, there are some disadvantages to working on coral reefs. Good reefs are seldom located near large cities, and the problems of everyday existence for the researcher are multiplied. There are few well-equipped laboratories near coral reefs, so that all equipment and supplies have to be brought in, with added expense and delays. Their remoteness from major libraries is certainly a handicap at times.

All of these considerations have served to limit coral reef research to short-term studies. Most coral reef laboratories have had a life span of less than 25 years. Although few individual research studies continue for more than a few years, building an adequate data base requires many studies conducted over a long period of time. The 50th anniversary of Al-Ghardaqa Marine Biological Station is indeed a landmark.

The reasons already given for studying coral reefs in their surrounding good weather and warm, clear water, of course, are secondary. The real significance of the reef communities is that they are both complex and compact. Their complexity provides abundant challenges and materials to study, and their compactness provides complete systems for examination in ways that would not be possible in most other marine ecosystems. We can, for example, look at a complete system of interacting infaunal fish species in a section of reef about the size of an office desk, where 35-50 species dwell together. An equivalent area for 35-50 species of fish in a temperate habitat would be impossible to enclose and manage, and the time and expense of sampling those 35-50 species scattered over many square kilometers of ocean would be prohibitive.

Since this is a birthday celebration it is appropriate to review briefly the accomplishments of the past, consider what we still need to know, determine what we must do to learn it, and then discern the possible benefits of this knowledge. For a full review of the literature on coral reef fish communities, see Sale (1980).

The studies of coral reefs fall into two natural groups. First, most of the studies of reef fish have been conducted on an expeditionary basis. We travel to reefs with our equipment, work hard for a few days, then move on to another site, and soon return to our home laboratories. Such expeditions have yielded a great deal of comparative information and a lot of specimens and descriptive data, which are valuable primarily for taxonomic and zoogeographic studies. Second, in contrast to this approach, there are intensive, long-term studies conducted from laboratories permanently located close to reef environments.

Originally field stations were used mainly for studies of captive organisms that could be trapped and brought into the laboratory and for in-situ observations limited to short sessions through a glass-bottom bucket. W.H. Longley and William Beebe used the diving helmet to study reef fish in the

1930s, but not until the advent of the demand-valve scuba after World War II did in-situ studies become a real possibility. These studies have progressed in depth and sophistication from simple species lists and descriptions of assemblages of fish associated with specific habitats, to field experiments of colonizations, sequences on natural and artificial structures, and investigations of the effects of specific habitat parameters on community structure.

Studies of life history and behavior patterns of individual species have also progressed in perceptiveness and complexity, as investigators have found new and significant questions to ask. The classic descriptive approach indicated a high degree of stability in reef fish communities. Each part of the environment seemed to shelter a predictable set of species. Soon, however, researchers noted that, although this is true in general, in actual practice there is considerable variation in each habitat. In other words, a stochastic rather than a deterministic process regulates communities. This finding led to finer observations, which determined that small patch reefs that could be studied in detail and in their entirety offered promise of revealing the important regulators of community structure. Although patch reefs are ideal for many kinds of studies, they are not suitable for studying the fundamental mechanisms of the maintenance of species diversity because they are not self-reproducing. Coral reef fish have planktonic egg or larval stages; therefore, fish rarely mature where they were hatched. Thus, patch reefs are not the basic structural unit of the reef environment for fish.

We are now beginning to have enough data so that we can review individual phenomena through entire communities with a view to understanding if and how the species interact to form a cohesive, working community. In other words, we are reaching a stage where it is meaningful to search for a general theory of reef fish community structure. The central point of such a theory will be to determine how the diversity of the fish community is established and maintained.

In an early effort to determine how reef resources are partitioned among potentially competing species, Smith and Tyler (1973) attempted to describe the space allocation among the species of a small patch reef. Although they provided a description of a single established community, they did not address the mechanisms that led to the establishment and maintenance of the community. This descriptive approach was soon followed by experiments designed to trace the development of communities on artificial reef structures and natural reefs from which the fish were removed artificially. One series of experiments led Sale and Dybdahl (1978) to propose that the composition of the community is determined by random colonization events coupled with a strong advantage to the first arrivals. In Sale's view the adaptations of individual species are less than the sine qua non that other workers had assumed.

Several studies have provided clues to the regulation of the community. Collette and Talbot (1972), among others, have examined temporal relationships and found that there is a sharp separation between the nocturnal and diurnal species with a very restricted changeover period. Hobson (1972) noted that predators are especially active during the changeover, which may serve to maintain the distinctness of the two groups, since nonconforming individuals would be subject to more intense predation. This temporal allocation of resources is one of the most obvious mechanisms for allowing more species to use the habitat.

Furthermore, within the reef community there are many symbiotic interactions between species such as inquilinism, parasite picking, crustaceans that feed on fish slime, territory sharing, mixed schooling, and mimicry. The more we look, the more we find, and some of these interactions may represent cybernetic pathways that determine community structure.

Some areas of science deal only with generalities and dismiss ad hoc explanations as trivial. Most natural systems, however, have unique aspects for which only ad hoc explanations exist, mixed with other aspects that are universal. There is no *a priori* way to distinguish the unique from the universal; frequently, phenomena that were at first considered biological curiosities are in fact widespread with considerable importance. Two examples are the occurrence of hermaphroditism among fish and the cleaner organisms, fish and invertebrates, that occur on reefs. Because we cannot make the distinction in advance, our only course is to treat each phenomenon as if it held the key to the universe and to operate on the premise that nothing about the reef is trivial.

## Future Studies

The most pressing needs for reef fish ecology are quantitative studies conducted over long periods of time. We know very little about seasonal changes and almost nothing about annual variations and long-term fluctuations. Our understanding of succession on reefs is based on indirect evidence and studies conducted on different structures that we assume to represent stages in the development of increasingly complex reefs. We also have little autecological data. For example, what are the water chemistry parameters in the reef crevices in which many of the small fish actually live? What are the tolerance limits of the fish themselves? How do unusual weather conditions affect reef organisms? Often we are forced to base our analyses on incomplete or nonexistent data. Our theorizing has gotten unacceptably far ahead of our actual data base, and there is too wide a gap between what we think we know and what we actually know.

To be effective in gathering such data, we need well-equipped laboratories close to coral reefs. First and foremost, these laboratories should be designed from the start for long-term continuous operation over a time frame of decades rather than years. Such laboratories should offer facilities for controlled experiments and the most advanced techniques for long-term, direct, in-situ field studies. Wherever possible, saturation diving techniques should be available for working at greater depths for longer periods.

Perhaps most important of all, we should begin to build a cohesive data base to make information readily available to all workers and managers interested in coral reefs. Such data do not have to be in the form of formal scientific publications, but could be available on tapes or facsimile sheets accessible to the few specialists who have need for them. A single, central data-storage facility should be established to collect and disseminate these data.

## Reef Management

Those of us who find reefs of special scientific interest should not lose sight of the fact that reefs are also a natural resource with commercial and aesthetic as well as scientific importance. As with any management effort, we must recognize certain priorities. First, there is the need for assuring the continued existence of the resource. Second, there is the desirability of using the reef to maximize the economic return from it; commercial fishing and tourism are probably the first priorities, with mineral exploitation possible in some areas. Finally, there is the need for further scientific study. In order to attain these goals, we should classify reef areas and strictly enforce restrictions on the uses permitted in each area.

Although we are still a long way from a cohesive theory of reef fish community structure, we do have enough information to propose a reef conservation program and a basic strategy for reef management. The single most important basic characteristic of reef organisms is that they have planktonic larval stages. Thus, although the reef environment consists of many isolated patches of habitat, these separate patches are not necessarily self-reproducing, and they do not constitute independent units. When an individual dies, its replacement comes from the plankton; the parents may have lived at a great distance from the habitat of the offspring. Therefore, it is extremely important to maintain a source of recruits, and formulation of any conservation plan reduces itself to deciding how best to do this. We should set aside sections of the reef to keep totally undisturbed as protected zones, which will then serve as a source of eggs and larvae for the other areas of the reef. The remaining areas of the reef can then be used for whatever purposes seem appropriate, such as fishing, tourism, or even small amounts of destructive dredging and mining.

The most desirable spacing of the refuge areas must be determined, and research directed at this question should have first priority. The following are valid uses of reef environments:

1. Refuge zones -- These are areas that are strictly protected from all visits except for evaluation and protection, and even these inspections should be strictly limited so as to cause the minimum possible disturbance.

2. Tourist zones -- These are sections of the reef set aside for observation visits by divers, snorklers, and glass-bottom boats. Fishing and souvenir collecting should be prohibited, and even feeding of fish discouraged or restricted to limited areas.

3. Research zones -- Because of the desperate need for information about the reef, research should be considered a basic use of the reef, and areas for research should be set aside from the start. It may be desirable to have two types of research areas: one for observation only and one for experimental studies of the effects of harvesting, artificial structures, and the like.

4. Fishing zones -- Coral reefs are a source of human protein food, and this use should be maintained and enhanced where possible. Subsistence fishing on traditional fishing grounds should be given priority. Possible subdivisions are (a) hook-and-line only areas; (b) hook-and-line, nets, and traps; (c) hook-and-line, nets, traps, and spear fishing; (d) a specially designated area (perhaps on a rotating, sustained-yield basis) for harvesting marine curio, corals, shells, aquaria specimens, etc; (e) sport fishing areas; and (f) commercial areas. The need for separate designations for the last two categories would be determined by local conditions and traditions.

5. Mining-dredging zones -- This category includes shoreline and reef-top construction, in fact, any use of the reef that destroys it. An upper limit

should be set (e.g., no more than 5 percent of the reef area when the program becomes effective). Some destructive uses of the reef may allow later recovery; others do not. If the reef does recover, it might be harvested again later on.

The most desirable arrangement would have the protected area upstream in the prevailing current so that larvae will be carried from the refuge to the areas where they will replace individuals lost to fishing or natural mortality. Destructive uses should be downstream, where they will not harm refuge areas (Figure 1, top). In actual practice, however, it will be necessary to consider location with respect to users and tradition, so the arrangement may be more like that depicted in Figure 1, bottom. Each location will have its own special topography, and zoning will be considered accordingly.

Coral reefs are indeed strange worlds where the atmosphere is water, the trees are animals, and many of the stones are plants. But the toy fishes that live there can show us how to preserve environments, ours as well as theirs.

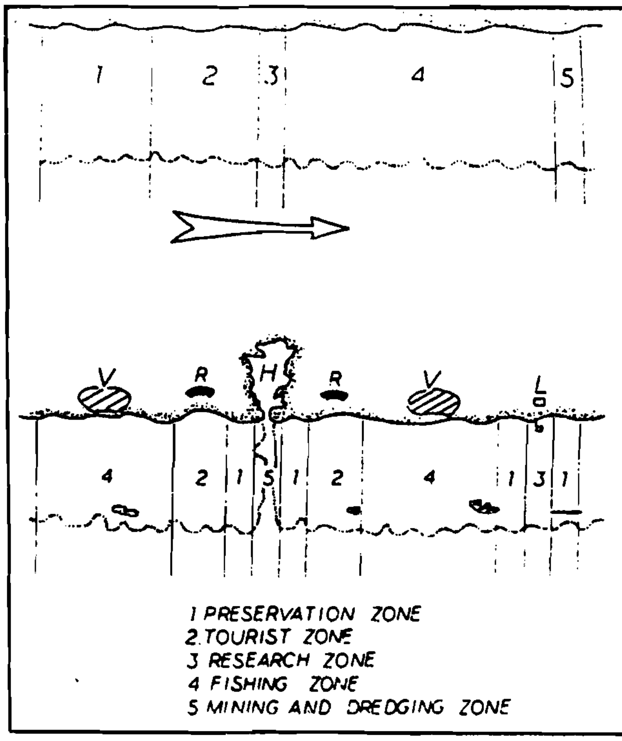


FIGURE 1. Top: The ideal arrangement of zones designated for specific uses takes account of the prevailing currents. Bottom: In a real-life situation the zones may have to be located with reference to tradition and shore features as well as current directions.

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