UNITED NATIONS ENVIRONMENT PROGRAMME

Ecological interactions between tropical coastal ecosystems

UNEP Regional Seas Reports and Studies No. 73

Prepared in co-operation with

SPC SPEC ESCAP

UNEP 1985

Note: This document has been prepared by Mr. Charles Birkeland and Ms. Deborah Grosenbaugh for the South Pacific Commission (SPC), the South Pacific Bureau for Economic Co-operation (SPEC), the Economic and Social Commission for Asia and the Pacific (ESCAP) and the United Nations Environment Programme (UNEP) under projects FP/5102-82-14 and FP/5102-85-05 as a contribution to the South Pacific Regional Environment Programme.

The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of SPC, SPEC, ESCAP or UNEP concerning the legal status of any State, Territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. The document contains the views expressed by the authors acting in their individual capacities and may not necessarily reflect the views of SPC, SPEC, ESCAP or UNEP.

For bibliographic purposes this document may be cited as:

SPC/SPEC/ESCAP/UNEP: Ecological interactions between tropical coastal ecosystems. UNEP Regional Seas Reports and Studies No. 73. UNEP, 1985.

PREFACE

Thirteen years ago the United Nations Conference on the Human Environment (Stockholm 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" (General Assembly resolution 2997(XXVII) of 15 December 1972). The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing Council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfil its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes eleven regions 1/ and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to combating environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities 2/.

The idea for a regional South Pacific Environment Management Programme came from the South Pacific Commission (SPC) in 1974. Consultations between SPC and UNEP led, in 1975, to the suggestion of organizing a South Pacific Conference on the Human Environment. The South Pacific Bureau for Economic Co-operation (SPEC) and the Economic and Social Commission for Asia and the Pacific (ESCAP) soon joined SPC's initiative and UNEP supported the development of what became known as the South Pacific Regional Environment Programme (SPREP) as part of its Regional Seas Programme.

1/ Mediterranean, Kuwait Action Plan Region, West and Central Africa, Wider Caribbean, East Asian Seas, South-East Pacific, South Pacific, Red Sea and Gulf of Aden, Eastern Africa, South-West Atlantic and South Asian Seas.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

Contents

ECOLOGICAL INTERACTIONS BETWEEN MANGROVES, SEAGRASS BEDS, AND CORAL REEFS

Charles Birkeland

Introduction

Coastal ecosystems have been of particular importance to tropical Pacific islanders because islanders have always depended upon coastal marine resources for at least 90% of their animal protein (Johannes 1977). The rational management of tropical coastal ecosystems should be of worldwide interest because mangroves, seagrass beds, and coral reefs are among the most productive ecosystems, marine or terrestrial (Table 1). In a literature review by Lewis (1977: Table 2), seagrass beds and coral reefs ranked higher in gross primary productivity per m^2 per year than other ecosystems, including sugar cane fields in Java and the nutrient-enriched Peru current. Mangrove ecosystems supplied with allochthonous nutrient input produce comparable levels of gross primary productivity (Lugo and Snedaker 1974; Table 2). These three coastal ecosystems are also of interest because of their geographic prevalence in the Pacific islands. These ecosystems provide or influence the important natural resources for Pacific islanders.

According to Adams et al. (1973), it is generally accepted that 75-90% of marine commercial and sport fish species depend on estuarine habitats during at least part of their life cycle. Even if the availability of estuarine habitats is critical for only one period in the life of an organism, the availability of the habitat is important for the success of the population. Estuarine habitats can be important for fishes and invertebrates either as nurseries for juveniles, as a source of food for adults, or both. Most of the productivity of estuarine habitats is a result of the production of marine vascular plants: mangroves, seagrasses or marsh grasses (Golley et al. 1962; Teal 1962; E.P. Odum 1961, 1971; Lugo et al. 1973a,b; and especially Heald 1971 and W.E. Odum 1971 which were cited in Snedaker and Lugo 1973). Since many commercial and sport fishes are dependent on estuarine habitats and since the major portion of the production of estuarine habitats is from marine vascular plants, one might expect that the primary production of marine vascular plants should be important for fisheries. However, this doesn't necessarily follow. The favorable influence of marine vascular plants on fisheries might not be a direct result of their large primary productivity but instead might be a result of their influences towards stabilizing the physical environment, providing habitat and refuge, contributing to the detrital food chain through bacteria and other microbes, or functioning in a role as substrata for epiphytic algae or bacteria. If this is the case, then the primary productivity possibly could be utilized more efficiently by Pacific islands and this is a major topic that will be addressed in this report.

Whether nearshore fisheries are mainly influenced by marine vascular plants through primary productivity or by some other factor, the effect is there. Skud and Wilson (1960); Darnell (1958, 1961, 1967); Sykes and Finucane (1966); Smith et al. (1966); Odum and de la Cruz (1967); Wood et al. (1969); Heald and Odum (1970); Cronin and Mansueti (1971); Odum and Heald (1972); Carr and Adams (1973); Snedaker and Lugo (1973); and Heald (1971) and W.E. Odum (1971), both cited in Snedaker and Lugo (1973).

documented the dependency of commercial and sport fisheries on estuarine systems in which the marine vascular plants were the major primary producers. Because of this, the estimates of the monetary value of marine vascular plant habitats are very high. For example, on the west coast of Florida alone, where the commercial fish production is dependent upon the productivity and organic export from mangroves, the wholesale value of commercial fish catches was worth $10.4 million in 1971 (Adams et al. 1973). The estimated value of fisheries is several times greater when secondary economic benefits are taken into account. The mangroves which support the fisheries would therefore be found to have a large economic value if monetary estimates were made. If estimates were made for the potential monetary value of marine vascular plant communities to Pacific island economies, the value would be high in relation to the total economies.

The potential yield by artisanal fisheries of coral reefs and lagoons is of about the same magnitude as is the offshore tuna harvest, at least for Micronesia (Johannes 1977). For example, the potential harvest of reef fish in Palau by artisanal fishermen is between 2,000 and 11,000 tons per year while the commercial skipjack tuna fisheries of Palau harvested between 2,000 and 9,000 tons annually between 1965 and 1974 (Mitchell 1975; Johannes 1977).

There is a tremendous amount of literature on mangroves, seagrass beds, and coral reefs, but there is very little literature on interactions between these three coastal ecosystems. Bibliographies pertaining to mangroves (Thurgood 1968; van Tine and Snedaker 1974; Rollet 1981) include over 6000 references. Kent W. Bridges (Department of Botany, University of Hawaii) has a bibliography for seagrasses with over 2000 references. A comparable bibliography for coral reefs would be much larger. Despite this overwhelming mass of literature on these three ecosystems, nearly all the papers deal with particular ecosystems or with interactions between the particular ecosystem and terrestrial or offshore environments.

Because of the importance of these ecosystems to the peoples of the South Pacific islands as sources of protein and other resources as well as for logistic reasons, human settlement and urban development on islands has generally concentrated in coastal regions, especially in harbors where they exist, and along rivers which drain into coastal areas nearby. So while coastal resources are traditionally the resources most heavily utilized, they are also the areas which most directly and immediately feel the impact of man's developmental activities such as land-clearing and pollution. An understanding of how the coastal ecosystems function and interact with each other and with the abutting terrestrial and offshore areas is of primary importance as a basis on which to make sound rational decisions in developmental and coastal zone resource and land management matters.

McNae (1968) suggests that individual plants or species should be referred to as "mangrove" and the community as a whole should be referred to as the "mangal". This has acquired fairly wide acceptance among plant biogeographers (Mann 1982), but we still do not see it commonly in the transport substantial enough to affect the reef community is provided by Meyer et al. (1983). They measured the growth rates of corals in areas where schools of juvenile haemulid fishes ("grunts") rested during the day, in areas where the haemulids were absent, and in areas in which the haemulids were present during the first year, then experimentally removed for the next eight months. During the first year of the study, two coral heads (*Porites furcata*) near fish aggregations grew significantly faster than did a coral head no more than 25 m away. Water samples were taken within a resting school of haemulids in a coral head and near a head in an adjacent area without the fish aggregation. A significantly greater concentration of ammonium was found in fish aggregations. No differences were found between the two areas in concentrations of molybdate-reactive phosphorous. Sediment traps were also placed under a coral head with an aggregation of fishes and under another head without an aggregation of fishes. A significantly greater quantity of nitrogen and phosphorous in addition to particles with significantly higher percentages of these nutrients were collected from sediment traps under schools of fishes. The results from the first year of the study thus indicated that juvenile carnivorous fishes excrete enough ammonium and defecate enough particles with nitrogen and phosphorous from seagrass beds to significantly affect the coral reef community.

The conclusions of the first year of the study by Meyer et al. (1983) were based on correlations between the locations of fish aggregations, nutrient contents of water and sediment, and growth rates of coral. An alternative explanation for this correlation could be that fishes aggregated where corals grew faster because the presence of nutrients from some source other than fishes was beneficial to both fishes and corals. To test this alternative hypothesis, the fish aggregation of 304 juveniles was removed from one of the corals with a fish aggregation. Results from this second set of tests did not support their original hypothesis rigorously. There was no significant difference in growth of corals with and without fish aggregations ($t_{[17]} = 1.36$). The authors said this was probably because of a decreased number of grunts (haemulid fishes) over the coral with grunts, more squirrelfish over the coral without grunts, and weather-related factors were obscuring the effect of aggregations of grunts. Whatever the confounding factors were, the experiment did not support conclusively the hypothesis of fish aggregations in influencing the growth of the corals nearby. It would be worthwhile to repeat the experiment in the Caribbean in order to clarify the relative importance of the various factors in influencing the growth of corals.

Assuming that fish which forage over seagrass beds at night and rest over coral heads by day add a substantial input of nutrients to the reef community and can significantly influence the growth of certain coral heads in the Caribbean, we still cannot assume that this same relationship will be found in the Pacific. Initial impressions of fish community structure in the Pacific suggest that the interactions between coral reefs and seagrass beds may be less substantive than in the Caribbean. The aggregations of resting haemulids during the daytime on reefs in the Caribbean are spectacular and appear frequently in travel brochures and photographic books about Caribbean reefs. Although fishes such as *Gnathodentex*, *Monotaxis*, holocentrids and apogonids may forage halos around reefs. In an elegant experiment (i.e., without the use of artificial materials such as cages), Ogden et al. (1973) removed over 7000 urchins from one patch reef and observed the rapid growth of benthic algae on formerly bare substrata on the patch reef. However, Ogden et al. (1973) and Ogden (1976) did comment that herbivorous fishes in the area of their studies were under intense fishing pressure and their abundances may be unnaturally low.

Hay (1981) and Hay et al. (1983) found that over 90% of the material grazed from Thalassia near coral reefs was taken by herbivorous fishes. Urchins removed less than 10%. In further work in widely scattered areas of the Caribbean, Hay (1984a, b) found that urchins were relatively influential on benthic plant communities in areas where fishing pressure by man was intensive and fishes were by far the most influential on benthic plant communities in more pristine or "natural" areas less heavily fished by man. Hay (1984a, b) concluded that much of the research on the influence of herbivores on benthic community structure in the Caribbean was done at marine laboratories in areas in which the resident scientists recognized severe over-fishing was occurring. Hay further warned that since much of the research in the literature on the effects of herbivores on shallow tropical marine communities was done in these overfished areas, we may have a misunderstanding of the functioning of these ecosystems because we assume these studies were done in communities in their near-to-natural states. Hay (1984a, b) conjectures that overfishing probably caused a drastic reduction in the abundances of predators of urchins (e.g., balistids) and so urchins increased in abundance in overfished areas by several orders of magnitude. It is interesting to note the comparative scarcity of urchins in Micronesia as compared to the Caribbean (Table 2). Perhaps Micronesia is still in a relatively natural state as compared to the Caribbean. A multitude of alternative hypotheses could be invoked to explain this difference between oceans in urchin abundances, however, e.g., current patterns, phytoplankton densities, etc.

It is possible that as fishing pressure increases further on coral reef fishes in the Pacific, echinoids will be somewhat released from predation pressure and then become more abundant and influential. One of many alternative possibilities is that the abundances of urchins in the Pacific result from sporadic recruitment success (Ebert 1983) rather than predation pressure on adult urchins.