Resource Ecology of the Bolinao Coral Reef System

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Association of Southeast Asian Nations/United States
Coastal Resources Management Project
International Center for Living Aquatic Resources Management

Fisheries Stock Assessment-Collaborative Research Support Program
University of Rhode Island
University of the Philippines Marine Science Institute

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Cover: (*Front*) Reef flat including Silaki Island. The spottiness results from patches of coral, sand and seagrass of various densities.
(*Back*) A gillnet against the backdrop of a Bolinao sunset.

All photos by J.W. McManus.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASEAN/US CRMP	Association of Southeast Asian Nations/United States Coastal Resources Management Project
CPUE	catch per unit effort
DA	Department of Agriculture
DAP	Development Academy of the Philippines
DAR	Department of Agrarian Reform
DENR	Department of Environment and Natural Resources
EIA	environmental impact assessment
FSA-CRSP	Fisheries Stock Assessment-Collaborative Research Support Program
GPS	global positioning system
hp	horsepower
MEY	maximum economic yield
MSY	maximum sustainable yield
NGO	nongovernmental organization
SEC	Securities and Exchange Commission
TURF	territorial use rights in fisheries
USAID	United States Agency for International Development

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Rivergold Shellcraft
Adoracion Caalim, Proprietor

Violeta's Shellcraft
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DEDICATION

This book is dedicated to the people of Bolinao. May they have the wisdom to see what must be done, so that their children benefit from the knowledge we have gathered.

FOREWORD

The coastal waters of Southeast Asian countries have some of the world's richest ecosystems characterized by extensive coral reefs and dense mangrove forests. Blessed with warm tropical climate and high rainfall, these waters are further enriched with nutrients from the land which enable them to support a wide diversity of marine life. Because economic benefits could be derived from them, the coastal zones in these countries teem with human settlements. Over 70% of the population in the region lives in coastal areas where resources have been heavily exploited. This situation became apparent between the 1960s and 1970s when socioeconomic pressures increased. Large-scale destruction of the region's valuable resources has caused serious degradation of the environment, thus affecting the economic life of the coastal inhabitants. This lamentable situation is mainly the result of ineffective or poor management of the coastal resources.

Coastal resources are valuable assets that should be utilized on a sustainable basis. Unisectoral overuse of some resources has caused grave problems. Indiscriminate logging and mining in upland areas might have brought large economic benefits to companies undertaking these activities and, to a certain extent, increased government revenues, but could prove detrimental to lowland activities such as fisheries, aquaculture and coastal tourism-dependent industries. Similarly, unregulated fishing effort and the use of destructive fishing methods, such as mechanized push-nets and dynamiting, have seriously destroyed fish habitats and reduced fish stocks. Indiscriminate cutting of mangroves for aquaculture, fuel wood, timber and the like has brought temporary gains in fish production, fuel wood and time supply but losses in nursery areas of commercially important fish and shrimp, coastal erosion and land accretion.

The coastal zones of most nations in ASEAN are subjected to increasing population and economic pressures manifested by a variety of coastal activities, notably, fishing, coastal aquaculture, waste disposal, salt-making, tin mining, oil drilling, tanker traffic, construction and industrialization. This situation is aggravated by the expanding economic activities attempting to uplift the standard of living of coastal people, the majority of whom live below the official poverty line.

Some ASEAN nations have formulated regulatory measures for their coastal resources management (CRM) such as the issuance of permits for fishing, logging, mangrove harvesting, etc. However, most of these measures have not proven effective due partly to enforcement failure and largely to lack of support for the communities concerned.

Experiences in CRM in developed nations suggest the need for an integrated, interdisciplinary and multisectoral approach in developing management plans that will provide a course of action usable for the daily management of the coastal areas.

The ASEAN/US CRMP arose from the existing CRM problems. Its goal is to increase existing capabilities within ASEAN nations for developing and implementing CRM strategies. The project, which is funded by USAID and executed by ICLARM in cooperation with ASEAN institutions, attempts to attain its goals through these activities:

- analyzing, documenting and disseminating information on trends in coastal resources development;
- increasing awareness of the importance of CRM policies and identifying, and where possible, strengthening existing management capabilities;
- providing technical solutions to coastal resource-use conflicts; and
- promoting institutional arrangements that bring multisectoral planning to coastal resources development.

In addition to implementing training and information dissemination programs, CRMP also attempts to develop site-specific CRM plans to formulate integrated strategies that could be implemented in the prevailing conditions in each nation.

The present work, *Resource Ecology of the Bolinao Coral Reef System,* summarizes information gathered during a five-year study of a heavily exploited fringing reef along the western coast of Luzon. The authors have examined the ecology of the fish communities, the dynamics of the fisheries, and a variety of social and economic factors in order to develop a set of specific management recommendations for implementation by the local municipality. Beyond this, however, the study has yielded unprecedented insights into the nature of overfishing under conditions of rapid population growth and growing poverty, a situation known as *Malthusian overfishing.*

Ecologists will find helpful presentations on diversity and abundance patterns of coral reef fishes over time. Sections on yield-effort relationships will be of interest to fisheries scientists and managers. The final two chapters are concerned with the design and implementation of marine reserves and other management measures appropriate to small-scale, open-access coastal fisheries. The book will thus be particularly useful for those engaged in CRM studies in tropical developing countries.

Chua Thia-Eng
Project Coordinator
ASEAN/US CRMP and
Director, Coastal Area
Management Program, ICLARM

ABSTRACT

This book describes an intensive four-year program of monitoring the community ecology and harvest patterns of a large fringing coral reef system in northeastern Philippines. Reef harvest methods included principally gathering, handlining, trapping, gillnetting, seining, corralling and spearfishing, both with and without air compressors. Blast and cyanide fishing have substantially diminished hard coral cover, as have coral-grabbing anchors. Production on the reef flat was approximately 10 t/km^2/year, while that on the reef slope was roughly 3 t/km^2/year. Catch rates on the reef flat were relatively constant, while those on the reef slope varied seasonally. It is shown that 60% effort reduction is a reasonable initial management goal in cases such as this where a fishery subject to Malthusian overfishing produces minimal net profits, and the quantitative nature of the yield-effort relationship is unknown. A simple conceptual framework is provided for analyzing the effects of harvest on diversity.

Visual censusing revealed that the number of adult fish on the reef slope declined substantially during the study period, as did the number of species with individuals reaching maturity. Recruitment on the reef slope occurred in a strong annual pulse around May. Visual and trawl sampling of the reef flat failed to show strong seasonal pulses or interannual declines. Abundances were substantially lower than those reported in some reef areas subject to less harvest pressure. Some dominant species may migrate between seagrass beds and corals seasonally or daily. Total multispecies fish recruitment appeared to be more predictable between years than that of any single species on both the reef slope and reef flat. Invertebrate populations, including commercially important sea urchins (*Tripneustes gratilla*), and gastropods important to the shellcraft industry, alternated in abundance seasonally. Seagrass beds underwent a seasonal thinning in dense areas. Management recommendations include a design for a proposed marine reserve/park and a program for establishing alternative livelihoods to employ at least 60% of the harvest force, including ventures in tourism and mariculture. This book is designed for managers, researchers and students with minimal technical training.

CHAPTER 1
INTRODUCTION

Coral reefs provide food, income and other benefits to millions of people worldwide. Most of the people who depend on reefs survive on marginal incomes, and have few alternative means of survival in the event of a decline in the viability of the reefs. Yet, coral reefs are very vulnerable to problems of excessive siltation, pollution and a myriad of abuses related to the ways in which their resources are exploited. Villagers living alongside reefs tend to have high population growth rates, and reefs in many areas of the world are being subjected to increasing levels of stress related to overharvesting. Because reef access is rarely effectively limited, reefs tend to accumulate increasingly larger dependent human populations as other means of livelihood become less accessible. Human populations are growing at accelerating rates, thus we can expect the status of reefs in many countries to decline at accelerating rates as well.

The coral reef system, which is the subject of this book (Fig. 1.1), is typical of true fringing reefs in the Central Indo-Pacific, i.e., those with a substantial structure typified by a separation into reef flat and reef slope areas by an intertidal reef crest. True fringing reefs tend to be large, covering tens or hundreds of square kilometers. Like many reefs in the Philippines and eastern Indonesia, the Bolinao reef system includes substantial beds of seagrass. The fisheries tend to target seagrass fish as well as coral-dwelling fish. The interdependencies of the two systems are reflected in the daily migrations of fish such as cardinalfish (Apogonidae, *bagsang*) into the seagrass beds for foraging, and the annual migrations of rabbitfish (Siganidae, *barangen*) out of the seagrass beds to breed. Linkages are also reflected in the exploitation system, as a fisher may shift from one ecosystem to the other to catch fish or gather invertebrates.

The Bolinao reef system (Figs. 1.2 and 1.3) provides for 35% of the employment in a municipality of 50,000 people. The proportion of employment in fisheries and gathering is expected to rise sharply as the human population increases in the immediate future because opportunities in farming and industry are limited. Thus, the trends we see today, such as excessive overharvesting, declining stocks and deteriorating environments, may well accelerate in the next few years.

The current study was initiated by the Fisheries Stock Assessment - Collaborative Research Support Program (FSA-CRSP) in order to facilitate the development of new ways to manage complex fisheries. Fieldwork was necessary to generate data for the program because of a worldwide sparsity of long-term data on heavily fished coral reefs. The study evolved gradually, as both the ecosystems and the exploitation systems were extremely complex. Considerable investigation and preliminary sampling were necessary at every stage. The methodology included such approaches as satellite image analysis, surveys from an ultralight aircraft, broad area assessments by towed divers, underwater fish counts, seagrass trawling, mapping of fishing gear use, underwater blast counts, weighing and measuring harvested fish, copying notebooks from fish buyers, distributing questionnaires and specific investigations as questions arose. Some vital

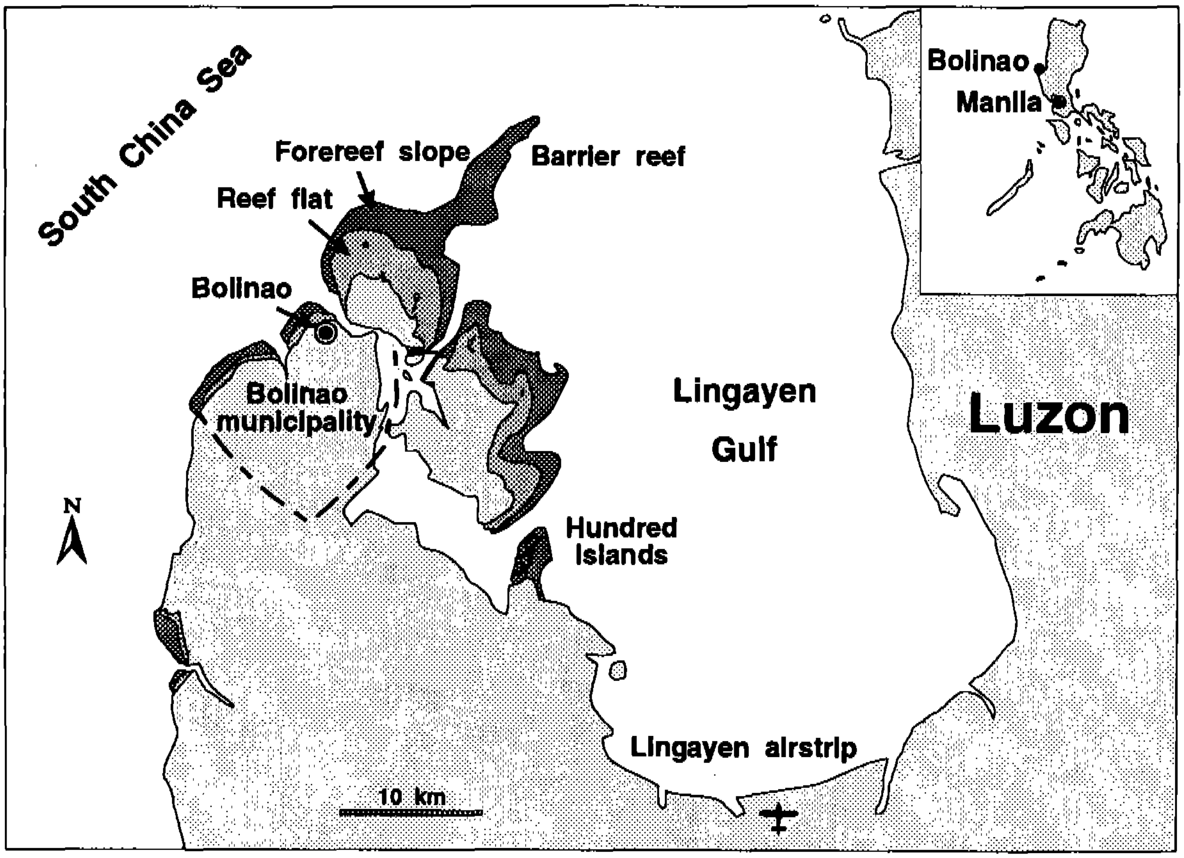


Fig. 1.1. Map showing the extent of the Bolinao municipality and reef system.

data came from students whose Master's work was sponsored by the program. In spite of the diversity of monitoring approaches, there were still important considerations which could not be covered by our small team.

Fortunately, the program coincided with a complementary assessment project, for which Bolinao was a key element. The ASEAN/US CRMP-Philippine component was directed specifically toward obtaining the information necessary for a general management plan, which was to include the Bolinao area. This project included a heavier emphasis on sociological and economic aspects than was possible, given the financial limitations of the FSA-CRSP. Much of this information has been summarized in a book, *The coastal environmental profile of Lingayen Gulf, Philippines* (McManus and Chua 1990), which should serve as a companion volume to the current work. A great deal of information from the CRMP was assessed and evaluated in preparing the management recommendations which provide the focus for this book. Information on problems involving blast fishing was obtained through a grant from the USAID Biodiversity Program. Other information which were considered included the 1990 census of the National Census and Statistics Office, and previous surveys by the Department of Agriculture (DA) and the Department of Agrarian Reform (DAR).

The system of human and ecosystem interaction at Bolinao is extremely complex. We have summarized only the major points. For example, the many harvested and other ecologically important species are recruited at different times of the year. This leads to substantial variations in the effort directed toward each species in any given month (Table 1.1).

The market involves a broad range of species with variable prices (Table 1.2). Murdy (1981) studied the fish sold in the Bolinao market during monthly trips of a few days each for one year, and identified 286 species in 73 families. He classified 209 of these as reef or reef-associated species. The most speciose families, with numbers of species in parentheses, were: Labridae (44), Serranidae (17),

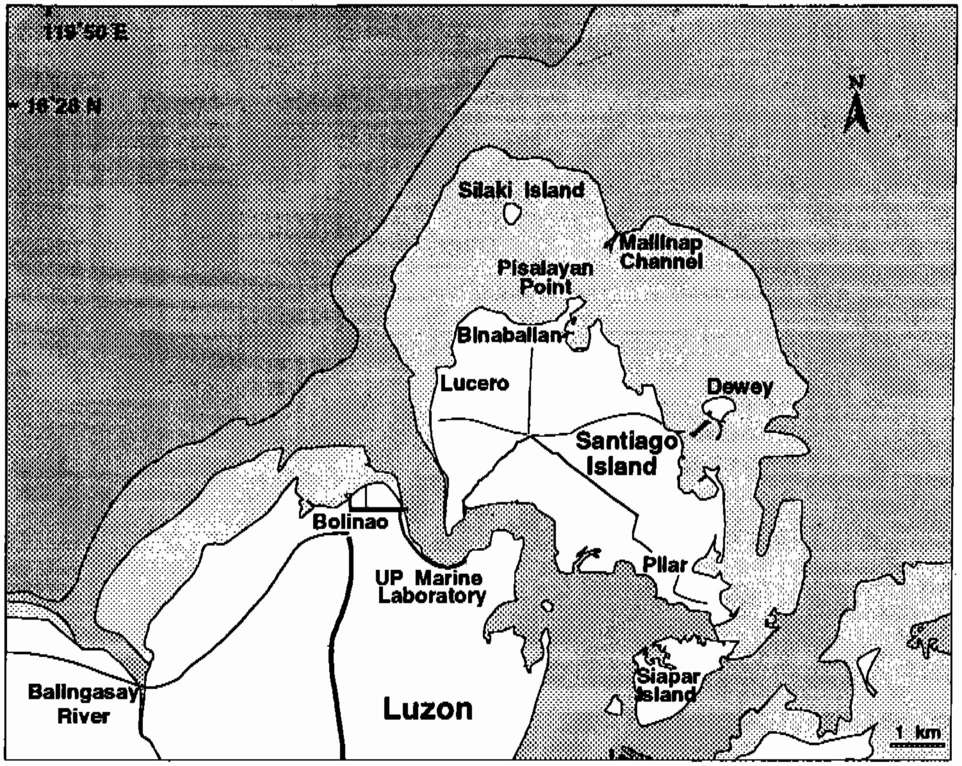


Fig. 1.2. Map of reef areas and adjacent landmarks in Bolinao.

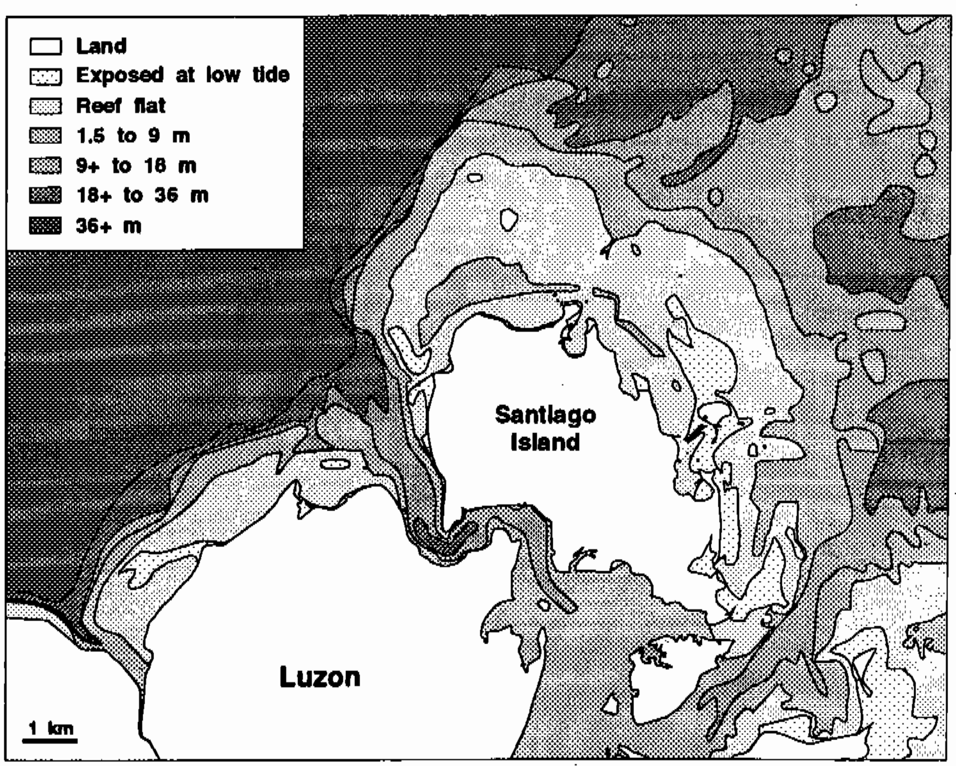
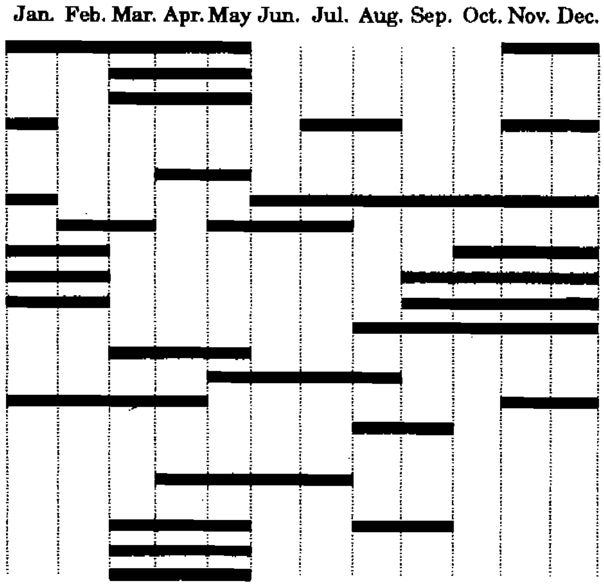


Fig. 1.3. Chart of the subsea topography around Santiago Island.

Table 1.1. Seasonality of selected reef resources. Dates are approximate. Harvestors must often shift between target resources seasonally.

Resource	Source	Events
Seaweeds		
Caulerpa spp. (*arosep*)	1	harvest maxima
Hydroclathrus clathratus	2	biomass maxima
Hydroclathrus tenuis	2	biomass maxima
Sargassum spp.	3	biomass maxima
Invertebrates		
Corals	4	mass spawning
Shells	1	harvest maxima
Strombus luhuanus	5	spawning maxima
Strombus urceus	6	population maxima
Strombus labiatus	6	population maxima
Cypraea annulus	6	population maxima
Cypraea moneta	6	population maxima
Tridacna derasa (giant clam)	7	egg production
Sepioteuthis lessoniana (squid)	8	egg laying
Sea cucumbers	1	harvest maxima
Tripneustes gratilla (sea urchin)	6	population maxima
Fishes		
Reef slope fish (as a community)	9	major recruitment
Migratory rabbitfish (*barangen*)		
Siganus fuscescens	10	migration
Siganus spinus	10	migration
Siganus argenteus	10	migration



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8. Balgos (1990).
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10. Aragones (1987).

Acanthuridae (12), Scaridae (11), Gobiidae (11), Carangidae (11), Lutjanidae (10) and Mullidae (10). Thirty-four families had one species each in the market. As is apparent in Table 1.1, invertebrates, seaweeds and sea turtles are also important components of the market. This does not include the mollusks harvested for the shellcraft industry, the fish landed in other municipalities or sent directly to Manila and the even wider range of organisms eaten at home. In a 1.5-year study of the reef flat of Santiago Island using repetitive quadrat sampling, de Guzman (1990) encountered more than 160 species of macroinvertebrates, of which at least 35 were exploited commercially. The total may be extended to include some rough estimates of marketed lobsters (5?), crabs (5?), shrimps and prawns (7?), cephalopods (5?), seaweeds (6?) and sea turtles (2), some of which are not listed on the official market price board or are found in areas not sampled by de Guzman. We can see that at least 350 species are marketed, of which at least 270 probably come from the reef. These estimates are undoubtedly conservative because of the variety of seasonal or sporadically encountered species which would have been missed in previous sampling efforts.

We cannot possibly account for every factor of interest in managing the reef resource system. Our study has been broad enough that we have adopted the term "resource ecology" in favor of the more traditional "fisheries ecology," which seemed wholly inadequate to describe the range of details necessary to reach even simple, practical conclusions about the system. The current approach could well be a companion to counterpart studies in resource economics, resource sociology and others. A more ideal relationship between these fields is shown in Fig. 1.4.

The data which have been gathered, are those which were believed to be minimally essential to

Table 1.2. Prices of major marine and freshwater commodities set for the Bolinao fish market by the municipal government. Actual prices vary with availability.

English names	Local names	Taxonomic group	Prices (₱) (per kilo)		
			1989	1991	Increase
Seaweeds					
A.	*Arorocep*	*Caulerpa racemosa*	3.50	5.00	1.50
B.	*Culot*	*Acanthophora* spp., others	2.50		
C.	*Puk-puklo*	*Codium edule*	2.50	2.50	0.00
Strawberry/Mauritian conch	*Liswek*	*Strombus luhuanus, S. decorus*	2.00	10.00	8.00
Spider conch	*Bariyawan*	*Lambis lambis*	2.00		
Trapezium horse conch	*Nuga-nuga*	*Fasciolaria trapezium*	2.00		
All other kinds of edible shells			2.00		
Cuttle fish	*Kalanggotan*	*Sepia latimatus*	25.00	35.00	10.00
Squid, white	*Laki*	*Sepiotheutis lessioniana*	40.00	60.00	20.00
Squid, brown	*Ballpen*	*Loligo* spp.	15.00	25.00	10.00
Octopus	*Kurita*	Octopodidae	25.00	27.00	2.00
Shrimps	*Orang, pasayan*	*Metapenaeus* spp., others			
A. Large			60.00	80.00	20.00
B. Medium			40.00	50.00	10.00
C. Small				25.00	
Prawn	*Sugpo, padaw*	*Penaeus* spp.	150.00	160.00	10.00
Rock lobster					
A. Green, spotted white	*Orang kumpasan*	*Panulirus ornatus*	120.00	120.00	0.00
B. Plain green	*Orang kumpasan*	*Panulirus versicolor*	100.00	100.00	0.00
C. Red	*Orang kumpasan*	*Panulirus longipes*	80.00	80.00	0.00
Crabs	*Ayama*	*Scylla serrata*	40.00	50.00	10.00
Blue crabs	*Barisaway*	*Portunus pelagicus*	25.00	30.00	5.00
Shark	*Pating, iyo*	*Carcharhinus* spp.	15.00	20.00	5.00
Ray fish	*Pagui*	*Dasyatis* spp.	15.00	30.00	15.00
Hawaiian ten-pounder	*Bayedbed*	*Elops hawaiiensis*	12.00	20.00	8.00
Milkfish	*Bangus*	*Chanos chanos*	25.00		25.00
A. Large				50.00	
B. Small				30.00	
Indian sardines	*Tamban*	*Sardinella* spp.			
A. Large			15.00	20.00	5.00
B. Small			8.00		
Short-finned gizard	*Cabasi*	*Nematalosa japonica*			
A. Large			25.00	40.00	15.00
B. Small			25.00	30.00	5.00
Eel	*Igat*	*Gymnothorax* spp., others	17.00	25.00	8.00
Sea catfish	*Ito*	*Plotosus* spp.			
A. Large			15.00	25.00	10.00
B. Small				20.00	
Flying fish	*Rayne*	*Cypselurus* spp.	12.00	15.00	3.00
Halfbeak	*Balasot*	*Hemiramphus* spp.	25.00	30.00	5.00
Gar fish	*Layalay*	*Tylosurus* spp., *Strongylura* spp.	20.00	35.00	15.00
Gar fish	*Maulo*	*Tylosurus* spp., *Strongylura* spp.	17.00		
Ember fish	*Baya-baya*	*Myripristis* spp., *Sargocentron* spp.	18.00	20.00	2.00
Grouper (*lapu-lapu*)	*Totokro*	*Epinephelus* spp.			
A. Large			35.00	60.00	25.00
B. Small				25.00	
Red grouper (*lapu-lapu*)	*Totokro*	*Cephalopholis* spp., *Variola* spp.	30.00	45.00	15.00
Glass fish	*Damas, bagsangtaaw*	*Apogon* spp., *Pempheris* spp., others	25.00	50.00	25.00
Large caballa	*Talakitok*	*Carangidae*, others	35.00	60.00	25.00

Continued

Table 1.2 (Continued)

English names	Local names	Taxonomic group	Prices (₱) (per kilo) 1989	1991	Increase
Scad	*Galunggong*	*Decapterus* spp.			
A. Large				35.00	
B. Small				20.00	
Dolphin fish	*Durado*	*Coryphaena hippurus*			
A. Whole			25.00	35.00	10.00
B. Slice				40.00	
C. Head				25.00	
Slip mouth	*Sapsap*	*Leiognathus* spp.			
A. Large			20.00	40.00	20.00
B. Small				30.00	
Red snapper	*Mangngayat*	*Lutjanus argentimaculatus*	35.00	60.00	25.00
Large mouth snapper	*Mara-bituen*	*Lutjanus rivulatus*	30.00	40.00	10.00
Snapper	*Rogso*	*Lutjanus* spp., *Lethrinus* spp.	25.00	40.00	15.00
Spotted pomadasid	*Agu-ot*	*Plectorhynchus* spp.	25.00	35.00	10.00
Fusilier	*Dalagang bukid*	*Caesio* spp.	25.00	30.00	5.00
Bream	*Besugo*	*Nemipterus* spp., *Aphareus* spp.	25.00	30.00	5.00
Threadfin breams	*Manarrat*	*Nemipterus* spp.	25.00	40.00	15.00
Mojarras	*Batuan*	*Gerres abbreviatus*	25.00	30.00	5.00
Goat fish	*Gumian*	*Parupeneus* spp.	25.00	40.00	15.00
Rudder fish	*Ilek*	*Kyphosus vaigiensis*	20.00	35.00	15.00
Mullet	*Burasi*	*Liza* spp.			
A. Large			45.00	65.00	20.00
B. Small			25.00	40.00	15.00
Barracuda	*Tumetyeng*	*Sphyraena barracuda*			
A. Large			20.00	30.00	10.00
B. Small			15.00		
Cichlid	*Tilapia*	*Tilapia*			
A. Large			20.00	30.00	10.00
B. Small			15.00	15.00	0.00
Cigar wrasse	*Sangitan lawin*	*Cheilio inermis*	15.00	20.00	5.00
Parrotfish	*Mulmol tarektek*	*Leptoscarus vaigiensis*			
A. Large			25.00	35.00	10.00
B. Small				25.00	
Parrotfish	*Mulmol tangar*	*Scarus* spp.	15.00	20.00	5.00
Black siganid	*Rorokan*	*Siganus guttatus, S. vermiculatus*	35.00	60.00	25.00
Yellow siganid	*Barangen baka*	*S. virgatus, S. punctatus*	35.00	60.00	25.00
Rabbitfish (*sammaral*)	*Barangen dumadalan*	*Siganus fuscescens*			
A. Large			30.00	50.00	20.00
B. Small			20.00	30.00	10.00
Cutlass fish	*Pinka*	*Trichiurus lepturus*	20.00	25.00	5.00
Yellow and black stripe	*Baliwakwak*	*Acanthurus* spp., *Ctenochaetus* spp.	15.00	25.00	10.00
Surgeon fish	*Sungayan*	*Naso literatus*	15.00	30.00	15.00
Billfish	*Susay*	*Istiophorus platypterus*	20.00	50.00	30.00
Tuna	*Bondying, oreles*	*Thunnus* spp.	20.00	30.00	10.00
Yellow fin tuna	*Oreles*	*Thunnus* spp.	25.00		
Spanish mackerel	*Tanggui-gui*	*Scomberomorus commerson*	35.00	50.00	15.00
Kingfish	*Khaki*	*Seriola* spp.	30.00	50.00	20.00
Spine fish	*Tortongan*	*Diodon* spp.	10.00		
Sea turtle	*Pawikan*	*Eretmochelys imbricata* *Chelonia mydas*	20.00		
		Average increase:			₱11.65
		Average % increase:			43%

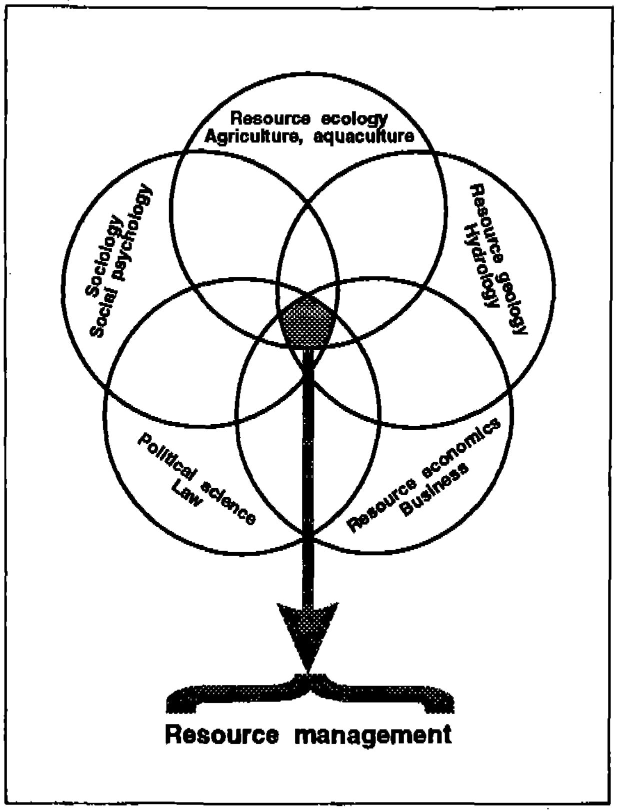


Fig. 1.4. Some fields of study which have direct relevance to CRM. Others which could have been added include public health, nutrition and food science.

understand ecological fundamentals important in the management of the system. The data set is relatively large, encompassing more than 7,000 pages. Future analyses of the data will undoubtedly turn up a smaller set of indicator variables which can be used by future researchers in monitoring other reefs.

The current work will continue for as long as funds are available to support the monitoring. Only through long-term monitoring can we expect to truly understand the dynamics of a system which is driven by annual pulses of juvenile recruitment. Complex statistical analyses have been avoided, so that the book will be useful to both researcher and resource manager alike. Some materials of theoretical interest have been isolated in boxes within the chapters. Supplemental information can be found in the more technical publications stemming from the program (e.g., McManus et al. 1988; del Norte et al. 1989; McManus 1989; del Norte and Pauly 1990; Nañola et al. 1990).

The major recommendations of the project are discussed in the last two chapters. They are summarized here:

1. Establishment of a committee to plan and regulate the development of tourism to ensure that it is directed toward providing employment to fishers and maintaining local natural resources.
2. Development of alternative livelihoods for at least 60% of the existing fishers and gatherers, and all future residents who would otherwise become occupied in harvesting marine resources.
3. Development of nondestructive mariculture activities to provide food, income and livelihood, to alleviate some of the harvest pressures on the natural ecosystem, and to provide a strong incentive for the maintenance of a healthy marine environment. A complementary program of sustainable multicrop agriculture (permiculture) would provide for the optimal use of agricultural lands to further reduce the harvest pressures on marine resources.
4. Establishment of reserve areas to provide undisturbed breeding grounds for reef species and to augment stocks of fish and invertebrates in surrounding areas through larval dispersal and the emigration of adults.
5. Implementation of a program of public education and enforcement to completely eradicate blast and cyanide fishing from the area because of their destructive effects on the organisms, their environments and the potential growth of diving tourism.
6. Banning of compressor diving (hookah) to protect existing deepwater breeding populations from overexploitation and to remove the myriad of occupational hazards associated with this practice.
7. Improvement of fish-handling facilities so as to reduce postharvest losses to spoilage, minimize health hazards from unsanitary conditions, increase local incomes by promoting more local processing, and increase market value upon export by meeting higher quality control standards.
8. Establishment of programs to reduce local human population growth rates so that as total resource levels rise, so will the returns of the individual harvesters.

These recommendations could be critical steps in avoiding a very distressing future scenario for the Bolinao municipality. However, it is hoped that they will also serve as a starting point for the design of assessments on other coral reef systems with similar problems. Finally, we hope that the methods and approaches we have used are evaluated appropriately and serve to guide those who intend to undertake related studies in the future.

Recommended management actions:

1. **Establish a tourism regulatory committee.**
2. **Develop alternative livelihoods.**
3. **Promote mariculture and improved agriculture.**
4. **Establish marine reserves.**
5. **Eradicate blast and cyanide fishing.**
6. **Ban compressor (hookah) diving.**
7. **Improve fish handling facilities.**
8. **Reduce the population growth rate.**

CHAPTER 2
THE HARVEST OF THE REEF

General

Fishery-related occupations currently account for 31% of the employment in Bolinao (Fig. 2.1). However, the population is rising rapidly (Fig. 2.2). Educational achievement is low, with only 7% of the population receiving training beyond high school, and 35% receiving no schooling at all (Fig. 2.1). The farmlands, which currently support 49% of the labor force are already virtually fully occupied. These facts make it very likely that most of the incoming work force in the next few decades will attempt to enter the fishery. Thus, the proportion of fishery-related occupations in Bolinao will probably rise sharply. This will accelerate the decline of the natural resource base, and may leave tens of thousands of people living in deepening levels of poverty. Specific actions which can be taken to avoid this situation are described in the final two chapters of this book.

Fishing already provides the lowest average monthly income of any major occupation locally (Fig. 2.3). The mean monthly income of ₱1,830 is substantially below the estimated poverty level set by the Philippine government of ₱2,650/year. Families of fishers and gatherers generally live in small, one-room nipa huts with floor areas of less than 30 m^2 and an average family size of 5 to 6 persons (McManus and Chua 1990). Because many of the fishing families are not native to Bolinao, having migrated from northern or central Philippines, very few own the land they live on. Houses are often densely packed against the shorelines where they are vulnerable to flooding and severe damage from storm winds. Sanitation is poor, and the implementation of proper sanitary facilities and training is difficult, given the crowding and low-income levels. In many areas, including Silaki Island and parts of Santiago Island, freshwater must be carried over in small boats from the mainland. Most fishing families have no electricity. Remarkably, a few families in each village have television sets, often run on car batteries which are periodically recharged in the main town. Lights are usually kerosene lamps, and cooking fires depend on the locally diminishing supply of small trees.

Monitoring the fishery

Following an extensive program of preliminary investigation, a set of ten fish landing sites were chosen and monitored from July 1988 to June 1991. The daily logbooks of major fish buyers were copied weekly. These books classified fish landed by weight into six broad categories of fish type. Supplemental data were obtained by subsampling each of five gear types at least three times each month for catch composition by weight and abundance at the species level. Inquiries were made routinely concerning the number of boats and fishers per gear and the number of hours and days spent fishing. Much of this data was gathered by research aides who were local fishers themselves, and were therefore trusted by the local villagers and buyers.

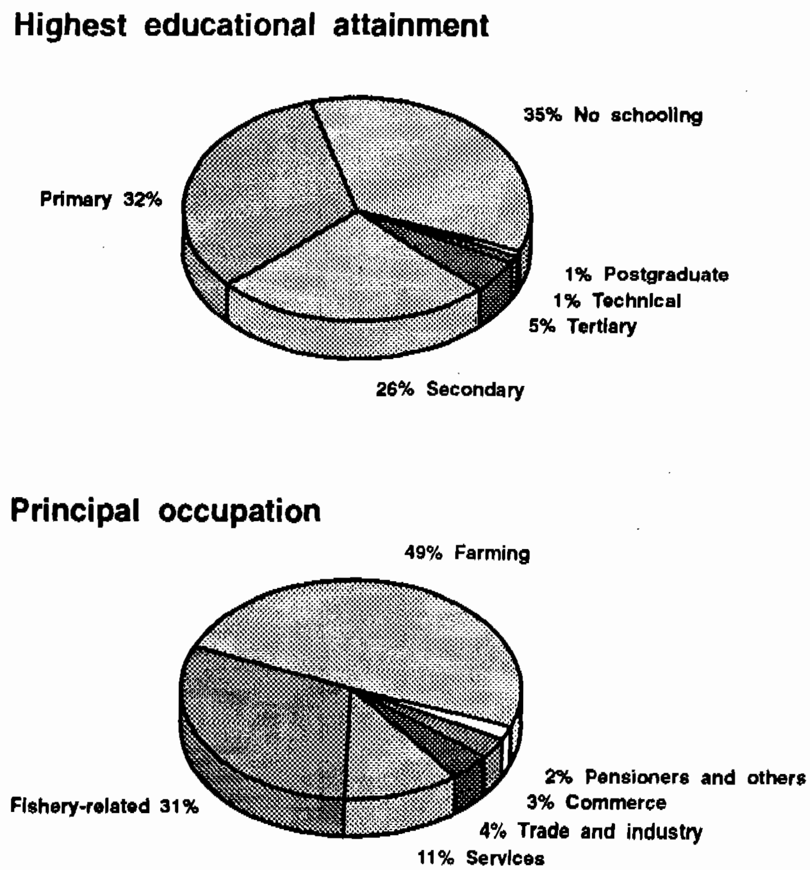


Fig. 2.1. Education and occupation factors affecting development in Bolinao. Data from surveys by DA in 1990 and DAR in 1991.

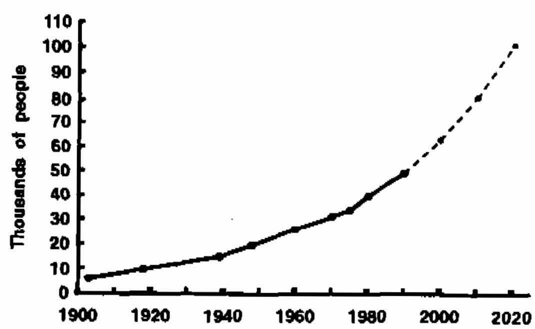


Fig. 2.2. Human population growth in Bolinao based on a log-linear regression of historical levels. Data are from the National Census and Statistics Office.

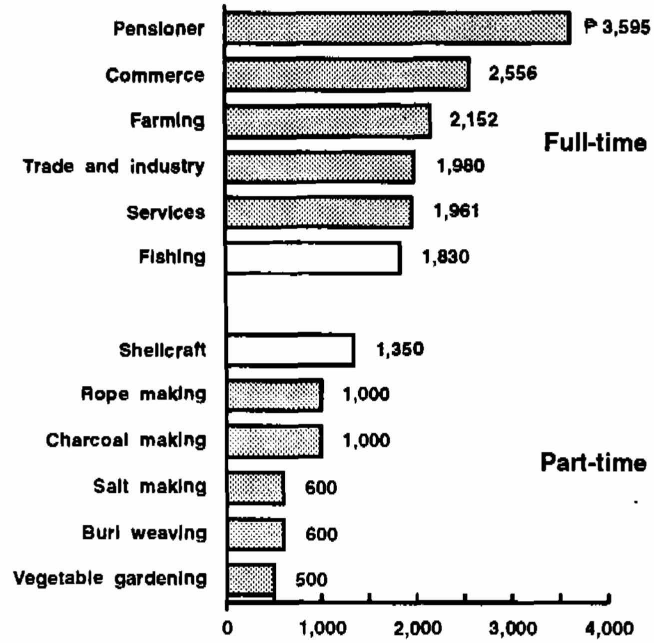


Fig. 2.3. Major full- and part-time occupations in Bolinao. Fishing is the least profitable full-time activity, but shellcraft is the most profitable part-time job. Data are from a survey by DA in 1990.

Boats were mapped on the reef slope on one random day each week. The mapping was done from a research boat using compass triangulation. Generally, the research boat lined up each fishing craft with a landmark and obtained a compass bearing to the landmark. Then the research boat moved to a new location, lined up the same fishing craft with another landmark, and obtained a second bearing. These bearings were back-plotted in the laboratory to obtain precise positions for each craft. In the process, each craft was identified as to the type of gear it supported.

The estimations of catch rate (catch per unit effort [CPUE]), effort and total yield were based primarily on the records of the fish buyers. In almost all cases, the buyers either switched products or became inactive for some portion of the study period. At these times, fish were marketed at unpredictable times and places, often by the wives of the fishers, making yield estimations difficult. The records for each gear include some missing data, usually in groups of months. In order to preserve the effects of seasonality, some records had to be filled in from one year to match months in another year. This could reduce apparent interannual variability somewhat. However, the relative constancy between years has been checked on a gear-by-gear basis with existing data, and appears to be a valid assumption.

Slope fisheries

MAJOR TYPES OF GEAR

Hook and line

People fishing on the reef slope must contend with the wave action of unprotected waters. Some hook and line fishers use moderately sized (often 7 m) double outrigger boats (*bangka*) with small inboard engines (often 16 hp), usually requiring low-octane gasoline. The majority of the boats are smaller and are paddled by hand or use sails. The fishing lines are held by hand without poles. The gear consists of weighted nylon fishing lines of various diameters, with one to three small, single-point hooks usually baited with small shrimps or pieces of squid. The bait is maintained near the bottom. The anchors from these and other boats are constructed from iron-reinforcing rods and are designed to catch corals. They cause substantial damage to the corals and thus reduce the long-term viability of the fish resources. Some research should be initiated to find an alternative low-cost anchoring system.

Squid fishing involves trolling with hand lines pulling surface jigs resembling shrimp. This activity is highly seasonal (Balgos 1990). Octopus fishing (*palaoy*) involves using a small lure of rags shaped like an octopus, which is dragged along the bottom. In these and some other fisheries, series of bamboo rafts are often towed over the reef slope in good weather by motorized *bangka* to provide access for a wider range of fishers. The cephalopod-specific fishery catches have been omitted from the handline fishery calculations.

Drive-in nets

The principal form of drive-in net is the *parisris*. This gear consists of a horizontal scare line of several hundred meters pulled by pairs of *bangka* in U-shape along the surface toward an area in which a floating net is subsequently laid. The net forms a curved wall of a few meters depth and a few tens of meters length. The primary target fish are needlefish (Belonidae, *layalay*) which frequent the surface waters over the reef.

Spearfishing

The local spearfishing gun is carved from wood, and is powered by large rubber strips released with a trigger. The spear is often a metal rod sharpened at one end. The spearfishers use small round goggles made of window glass, wooden frames for each eye and rubber strips. These goggles can cause considerable eye damage when used below a few meters depth because they cannot be equalized through the nose to compensate for rising and falling external pressures. The divers often use a single rigid wooden shield-like paddle attached to one foot to assist them in swimming. Divers traditionally use rocks to assist them in sinking to great depths (30-60 m) rapidly, often resulting in considerable ear damage.

Most spearfishing on the reef slope involves the use of air compressors, such as those used in vulcanizing shops and gasoline stations. The unfiltered air passes a small reserve chamber which provides a final breath of air when motor trouble stops the compressor. The air then passes through a long tube to the diver, who uses the air without a regulator. The divers frequently stay at depths below 30 m for hours at a time, and are frequently crippled or killed by decompression sickness and other diver-related maladies (see Chapter 7).

Blast fishing

A broad variety of blasting devices are used locally to kill fish, ranging from handmade bombs to dynamite. However, the most common device is a bottle filled with layers of sodium nitrate altering with layers of pebbles. The cord-type fuses are usually commercially obtained. Sodium nitrate is sold legally to induce ripening in mangoes, and so is difficult to control. Each blast appears to kill corals within a 2-3 m diameter. Fish kill distances are many times greater than this, especially for fish with swim bladders. The blasts kill all sizes of fish, including juveniles. The fishing is very wasteful because many dead fish living in or falling down among the corals are difficult to see and gather. More importantly, however, blasting reduces coral cover and therefore has long-term effects on fish production.

A common complaint is that the blast fishers come from municipalities outside of Bolinao. However, our studies reveal that a major part of the blasting is by local fishers. A fisher can currently have returns of ten times or more on the investment in the blasting device, and substantially better catches per hour than with traditional gear. However, the gain comes at a substantial loss to other fishers, particularly those of the next generation. It can take several decades for corals to resettle and grow to the states they were in before the blasting.

Blasting rates were high at the start of the study, such that our divers generally heard an average of ten blasts per hour. Beginning in mid-1989, blasting dropped by at least 90%, apparently because of some extremely strict enforcement procedures. However, even the later rate of one blast per hour in a 2 to 3 km listening radius is too high for ecological sustainability and the development of an active tourist trade.

The catch rates from blast fishing are difficult to estimate, and so are omitted in our yield estimations. However, they probably do not exceed 15% of the total catch. The loss of corals undoubtedly leads to the loss of fish yield, but this would not be reflected in short-term estimations.

Fish poisoning

A variety of fish poisons are used in Bolinao, ranging from liquid detergents to natural plant derivatives. However, sodium cyanide is the overwhelmingly dominant poison. It is used on the reef flat both for food and aquarium fish collecting, but on the reef slope it is used more for the latter. It is applied by a skin or compressor diver to fish hiding in corals by squirting as an emulsion from a plastic bottle, or waving the tablet tied to the end of a stick near the fish. The fish are stunned by the poison and captured by hand. However, the fish tend to have a high mortality rate after shipping. Thus, the practice does considerable harm to the international market for Philippine aquarium fish (Albaladejo and Corpuz 1981; Rubec 1986; Hingco and Rivera 1991). It is also harmful to corals and other fish in the vicinity. As a gear which is harmful to the environment of the fish, sodium cyanide fishing should be prevented through management measures.

As with blast fishing, annual yield rates are omitted in total yield estimations. However, they are probably insignificant in the overall mass of fish harvested. The important aspect of the gear that is used is its effect on the corals, and the threat it poses to future yields from the reef.

REEF SLOPE STUDY RESULTS

Fishing on the reef slope was generally uniform, with no particular gear dominating the fishing effort in any given area. Fishing effort was concentrated near the reef crest, with an exponential decline proceeding outward (Figs. 2.4 and 2.5). Throughout the study, 95% of the fishing tended to be within 2.7 km of the shore (Fig. 2.4), indicating that the majority of fishing was confined to approximately 42 km^2 (Fig. 2.6). This limit is related to the cost of gasoline (Fig. 2.7) as well as considerations involving the spoilage of fish and safety from sudden inclement weather events. The monthly production mean of approximately 10 t translates to an annual production of 120 t. About 95% (114 t) of this comes from 42 km^2, for a yield of approximately 2.7 t/km^2/year. We can check this figure by assuming that 50% of the catch comes from within 1 km of the shore (Fig. 2.4), or 22 km^2. Sixty t/year would then come from 22 km^2, or 2.7 t/km^2/year as before. This contrasts sharply with the values ranging as high as 26 t/km^2/year reported for some coralline areas in the Central Philippines (Alcala 1981), and the working value of 15 t/km^2/year summarized from a variety of studies on reefs worldwide (Munro and Williams 1985). However, it is within the general range of 0.5-26 t/km^2/year reported in the same summary.

The present value could be low because:

1. the reef does not support as much fish production as the average reef in previous studies because of factors such as low coral cover;
2. the reef has been fished for so long that gradual declines in production have occurred; and
3. the fishing effort is less than that in the earlier studies.

It is unlikely that increasing fishing effort will yield more fish in the long term. In fact, adult fish appear to be declining and may not be able to

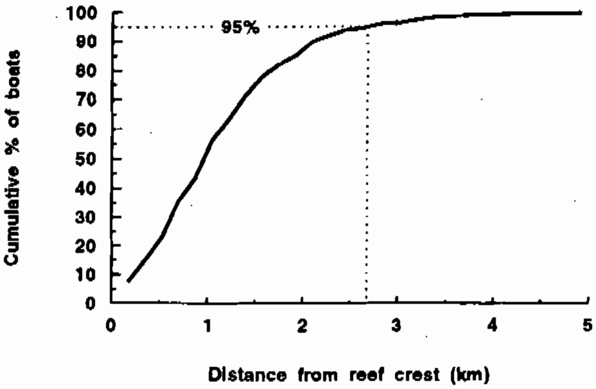


Fig. 2.4. Cumulative percentage of boats found at each distance from the reef crest.

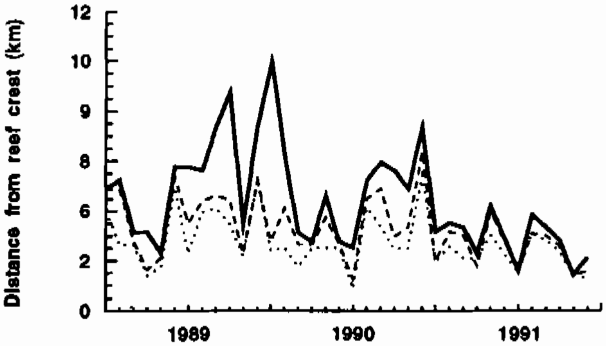


Fig. 2.5. Monthly boat distances from the reef crest.

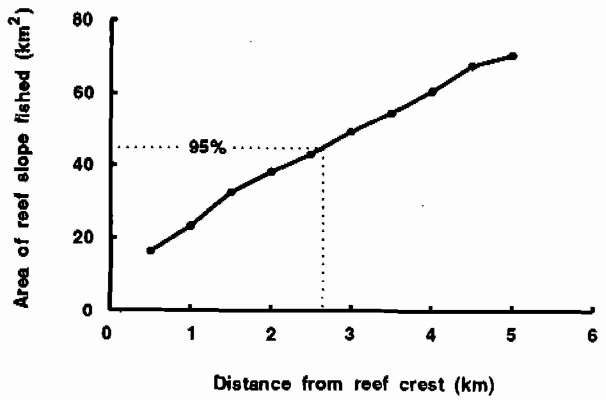


Fig. 2.6. Relationship between the distance from the reef crest and the area of the reef slope. The nearly straight relationship is a result of the trapezoid-like shape of the reef slope.

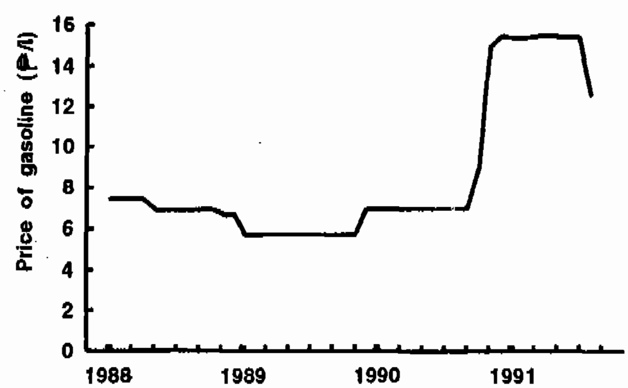


Fig. 2.7. Price of regular gasoline, based on purchases at a local filling station. The sharp rise in price in December 1990 occurred because of government pricing at the time of the Gulf War.

maintain former levels of juvenile recruitment to the slope (see Chapter 3). We must conclude that the low coral cover of the slope, and possibly the long-term effects of high fishing pressure (locally or regionally) combine to give unusually low fishing yields on this reef. The low coral cover could easily be related to the long history of intensive blast fishing in the area.

The total effort on the reef slope remained fairly constant during the study (Fig. 2.8). However, the catch rate varied radically between seasons. This indicates its dependence on the annual recruitment pulse of fish in April and May. The uncertainty about catches may also help to limit their entry into the slope fishery. It can be seen in Fig. 2.9 that there are seasons when the catch rate from spearfishing inside the reef flat is higher than that on the reef slope, and for considerably less investment in gasoline and air compressors. The seasonality of the catch rates and the constancy of the effort lead to a seasonality in total catch over the year of a factor of two. Thus, there are times when the reef harvest translates to an annual equivalent of at least 4 t/km^2/year. This may be a further indication that with less fishing, the catch rates could be improved by maintaining the interseasonal populations which are currently being fished to low levels.

The adult fish populations have declined during the study period (Chapter 3), but the time series on fish landings is not long enough to determine for certain if the yield from the reef slope has been declining as well (Fig. 2.8). The fishers have not increased their range of operation to compensate for the sparsity of adult fish (Fig. 2.5) probably because of such factors as the effort needed to paddle the boats of the handliners, the effect of increasing gas prices on the motorized minority, and the increased risks involved in being caught far from shelter during a sudden storm. Instead, it appears that those few boats which once ranged more widely than the others have curtailed their long distance forays. A study of fish sizes caught by handlining (Fig. 2.10) indicates a possible decline in the number of large fish (30 cm) being caught. The long-term decline in fish sizes locally has been common knowledge to the elders in Bolinao. Many people familiar with coral reef fish have commented on the surprisingly small size of the average fish in the markets (generally less than 20 cm). Similar comments are consistently made by experienced coral reef divers visiting the area, who are frequently shocked to see how scarce the fish are underwater, and how small the remaining few appear to be.

Reef flat fishery

MAJOR TYPES OF GEAR

Hook and line

The handlines used on the reef flat are similar to those described for the reef slope. However, the boats on the reef flat do not have to contend with waves because of the protective intertidal reef crest. The *bangka* here tend to be only a few meters long, and powered by paddle and/or sail.

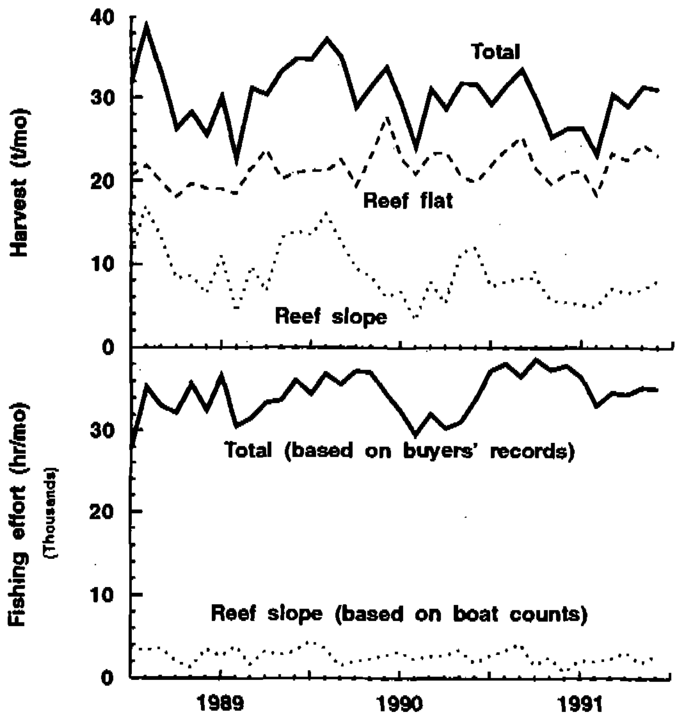


Fig. 2.8. Harvest and fishing effort for the Santiago Island reef flat and lagoon. Effort figures exclude traps and corrals.

Drive-in nets

A reef flat counterpart to the *parisris* gear involves several fishers on rafts slapping the water and converging on a net. The target fish are hemiramphids. The catch is small relative to that of other types of gear and will not be considered further.

Spearfishing

The spear gun and its accessories are similar to those described for the reef slope. Additionally, some fishers use metal rods with rubber strips attached instead of spear guns. Air compressors are unnecessary in the shallow waters of the lagoon and reef flat. Many fishers use kerosene lights mounted on boats or floats to help them spear at night in the seagrass. This is particularly effective for the rabbitfish, *Siganus fuscescens* (*barangen*), which tends to turn sideways to the light, presenting itself as an easy target.

Blasting and poisoning

Blast and cyanide fishing are used widely on the reef flat and do not differ substantially from what has been described for the reef slope. An exception to this is the fact that sodium cyanide is sometimes dispersed from a barrel on a boat in a radius of at least 10 m to capture fish for consumption. The poison is in the form of a slurry or mixed with fish and shrimp bits as "chum" on which the target fish feed. This undoubtedly poses a considerable health risk locally because the poison is very toxic to people. Another health risk involves the practice of biting the tablet of sodium cyanide to facilitate mixing it in plastic bottles for use in the gathering of aquarium fish. More than 60% of the lagoonal corals have been killed by blasting and poisoning, greatly reducing the availability of coral reef fish to the fishery.

Fish traps

The local fish traps are approximately 30 cm in length, and consist of a wicker box with an

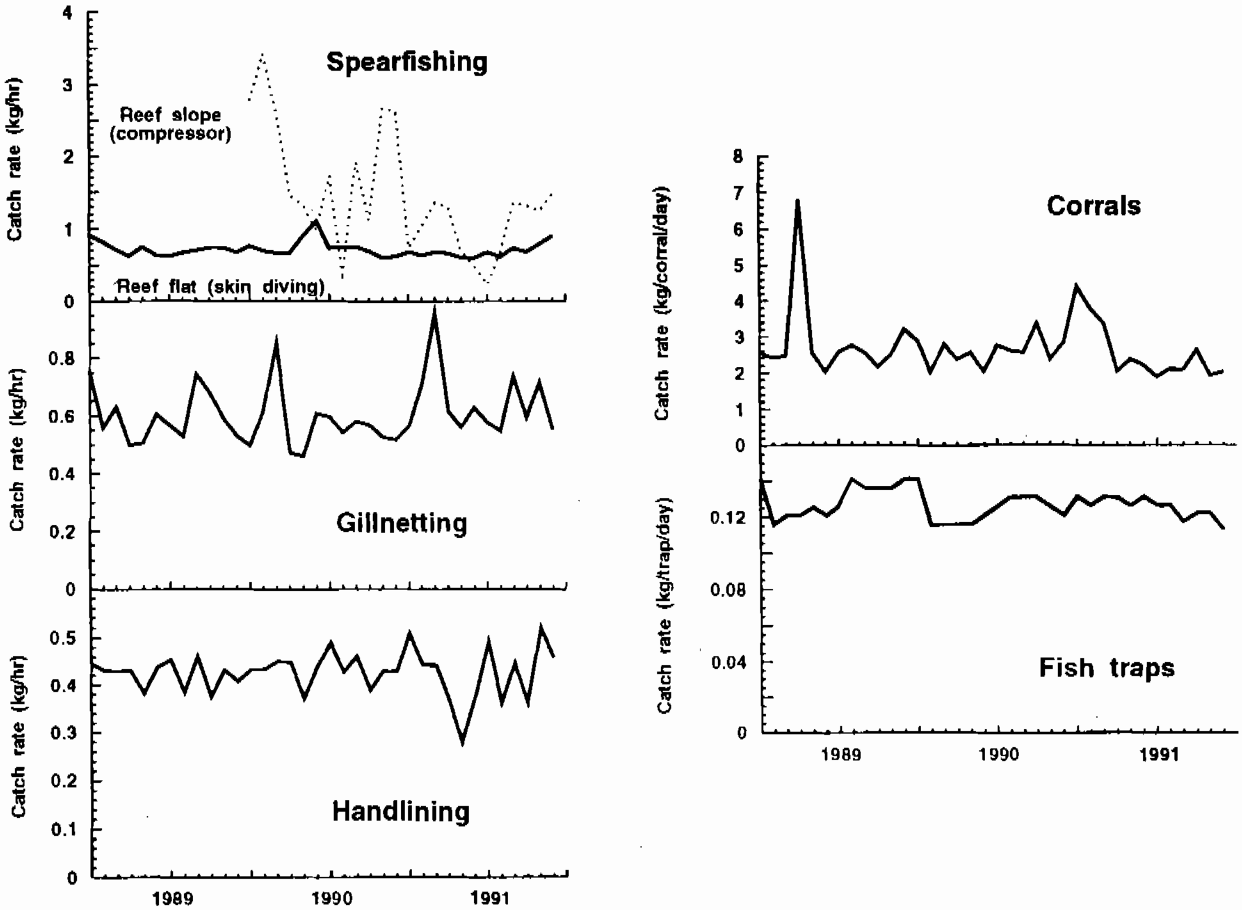


Fig. 2.9. Catch rates (CPUE) of major gear. The most seasonal catches are those from spearfishing on the reef slope. The corral graph omits large catches obtained twice each year during the spawning migrations of *Siganus fuscescens* (rabbitfish, *barangen*).

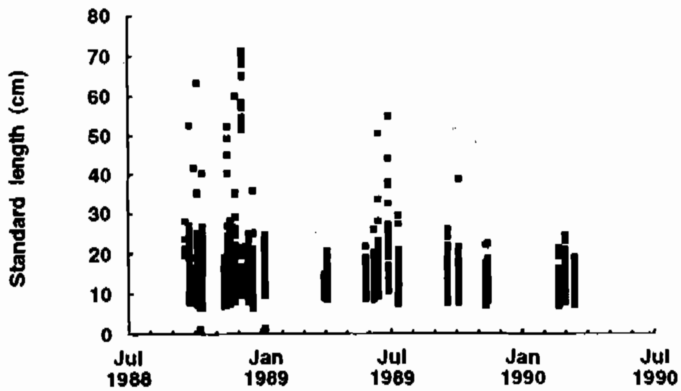


Fig. 2.10. Distribution of fish lengths caught by handliners on the reef slope, indicating a decline in the numbers of fish longer than 30 cm.

entrance cone. These are used without bait in coralline and sandy areas. Fish enter out of curiosity or to seek shelter. Their attempts to escape attract other fish. The traps are generally left overnight and retrieved the following day. The traps are very small compared to those of 2 m or more found on some other Philippine reefs. The traps in Bolinao have become substantially smaller in the last 12 years (J.McManus, personal observations). Because they are made of natural materials, they tend to be torn open by predatory fish if abandoned, and so do not pose serious threats to the fish community. Fish traps are generally size selective and are otherwise favorable from a management standpoint, except when fishers break corals to cover them. However, rocks are used more commonly. Fish traps are not commonly used on the reef slope. The small size and restricted use of the traps contrast markedly with the situation in the Caribbean, where traps are generally larger (122-229 cm) and dominate many coral reef fisheries (Munro and Thompson 1983). The difference in usage and the wide divergence in target species between this and other gear (Table 2.1) call into question the utility of using standard traps to assess coral reef fishery potentials, as is often proposed.

Fish corrals

The fish corrals (*baklad*) of Bolinao are arrow-shaped fence structures whose angled sides, and sometimes the stems, of the arrows extend for several hundred meters. The *baklad* depend on mobile and migrating fish, and are often placed along migration pathways in the seagrass beds. The favored sites are those which intercept the migrating adult rabbitfish, *Siganus fuscescens* (*barangen*), as they leave the reef flat to breed twice each year. The Bolinao municipality leases the area on which the *baklad* are constructed. An investor pays for the lease, and further leases out the rights to establish the *baklad*. The *baklad* at times have virtually closed off large sections of the reef flat to eastward rabbitfish migrations along the reef flat north of Dewey. The *baklad* are usually established by individuals or small consortia with investment capital, and they compete for seagrass fish with smaller-scale users of spears and gillnets.

Karokod seining

The rabbitfish return as juveniles to the reef flat twice each year, and are caught for use as fish

Table 2.1. Catches of major reef flat gear. Numbers represent the percentage of the 1989-1990 catch that each taxon contributed to each gear (+ is < 1%). Species shown are those which ranked in the top five for one or more gear. The table has been extracted from one sorted by reciprocal averaging, so that gear are grouped by similar catches, and species by similar tendencies to be caught by each gear.

Family	Species	Local name	Gear: / Village:	Traps / Goyoden	Corrals / Goyoden	Gillnet / All	Spear / Binabalian
Apogonidae	*Apogon* sp.	*Bagsang*		-	4	-	-
Plotosidae	*Plotosus lineatus*	*Ito*		+	5	-	+
Lethrinidae	*Lethrinus harak*	*Rogso*		2	1	3	2
Scaridae	*Scarus ghobban*	*Molmol*		19	+	+	+
Scaridae	*Scarus rhoduropterus*	*Molmol*		11	3	+	+
Scaridae	*Leptoscarus vaigiensis*	*Molmol tarektek*		2	7	2	2
Labridae	*Choerodon anchorago*	*Molmol mangipen*		23	+	1	1
Scaridae	*Calotomus japonicus*	*Molmol*		11	1	1	+
Siganidae	*Siganus fuscescens*	*Barangen*		+	26	74	60
Loligonidae	*Sepioteuthis lessoniana*	*Pusit*		-	2	1	4
Portunidae	*Portunus pelagicus*	*Barisaway*		+	2	+	4
Plotosidae	*Plotosus canius*	*Ito*		+	18	+	+
Octopodidae	*Octopus*? spp.	*Corita*		-	+	-	5
Gerridae	*Gerres oyena*	*Lumalanang*		-	+	1	+

paste (*bagoong*). One gear designed to capture these juveniles is the *karokod* seine. This is essentially a large plankton seine with a bag end pulled between two sailing bamboo rafts. This gear is believed to be deleterious to the successful recruitment of the rabbitfish, and so has been banned with increasing effectiveness during the final two years of the current study period.

Gillnetting

Local gillnets (*tabar*) usually have stretched mesh sizes that range from 4.5 to 5.4 cm. The nets are found in a variety of sizes and shapes. The usual net is weighted to rest on the bottom, and is approximately 100 m or more in length. The height is usually only approximately 1 m. Gillnetting is a major fishery on the reef flat, but very little occurs on the reef slope.

Gillnets are among the most desirable fishing gear from a management standpoint because each mesh size generally catches only one particular size of each fish species. In many cases, it is possible to regulate the mesh size to target a primary species (e.g., rabbitfish) at a size reached sometime after the age of first reproduction. This gives each fish an opportunity to contribute to the next generation of fish before being harvested. More precise analyses are possible to allow the harvest to be truly optimized through the control of mesh size. The mesh sizes in Bolinao reflect the small sizes of fish which remain on the reef flat under intensive fishing pressure.

Gathering

Gathering invertebrates and seaweeds by hand is probably the most important "fishing" method on the reef flat. Gathered products can match or exceed the total production of reef fish in some places (Savina and White 1986; McManus 1989a). The harvesting usually takes place at low tide. Principal products include sea urchins, sea cucumbers, octopus, some small species of fish, *Caulerpa* seaweed and shells of many kinds. The shells form the basis of the local shellcraft industry, which ranks as the most successful of the local part-time industries (Fig. 2.3). This gathering has enticed the entry of many men into what was formerly a sustenance fishery dominated by women and children. Tools occasionally include push rakes to remove gastropods from the seagrass and bamboo rafts used in deeper waters, especially for sea urchin gathering. The gathering of commercially valuable *Tripneustes gratilla* sea urchins for roe was so intense that by the end of the study period, some gatherers had started using air compressors to provide access to a few deepwater seagrass beds.

The principal gathered species are invertebrates, and their production is omitted in the yield estimations which follow. However, some information is available for the village of Lucero on Santiago Island (de Guzman 1990), which indicates a strong seasonality in the harvests of sea cucumbers and shells (Fig. 2.11).

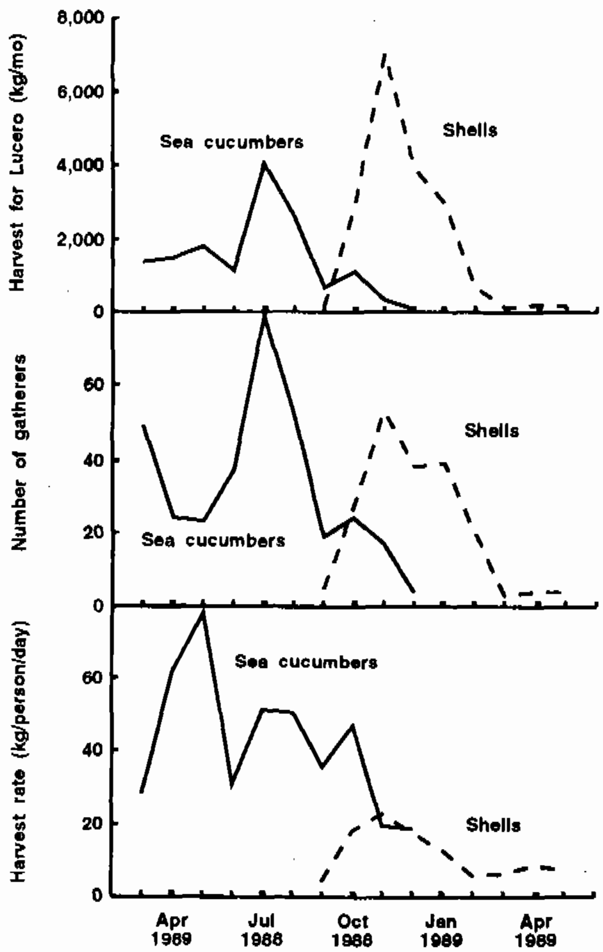


Fig. 2.11. Harvest data on sea cucumbers and shells from Lucero on Santiago Island. The alternation of seasons leads to shifting occupations among some harvestors. Data are from a survey by de Guzman (1990).

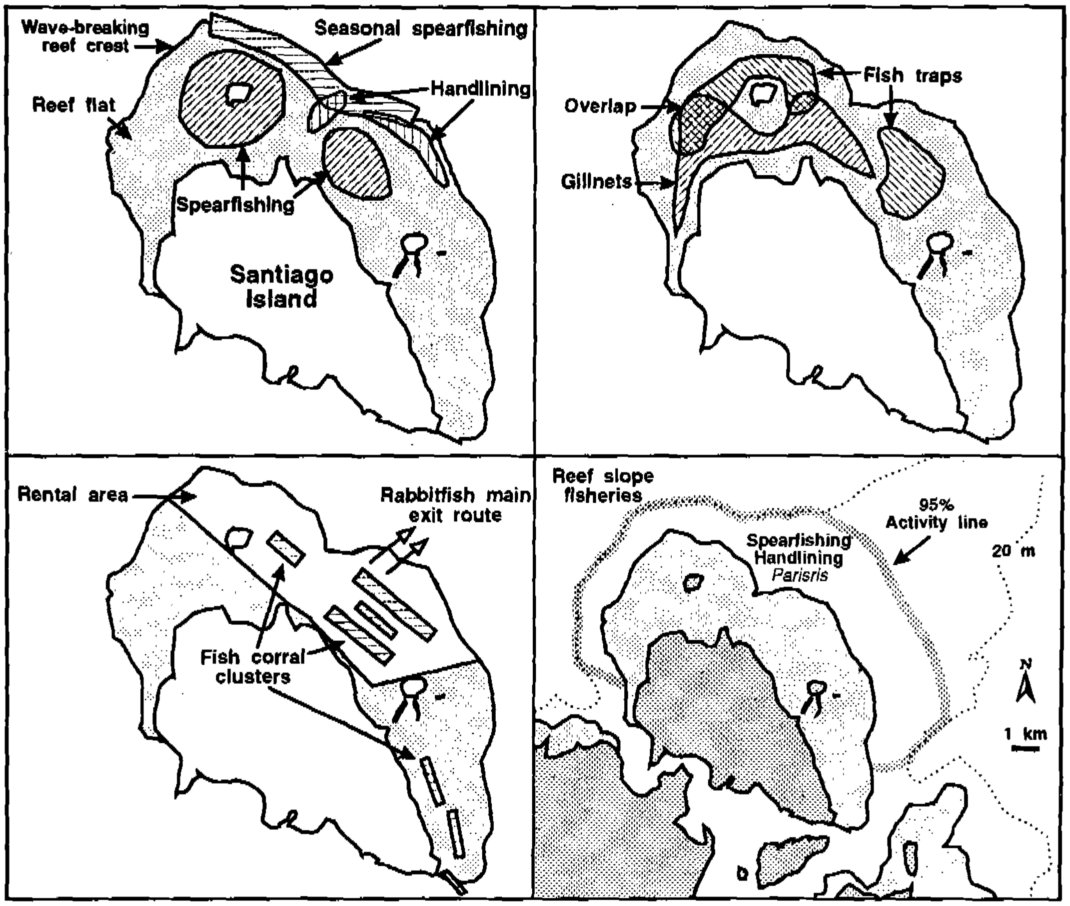


Fig. 2.12. Primary gear use areas on the Santiago Island reef. A large area of the reef flat is rented to fish corral owners by the municipality. During the spawning migrations of *Siganus fuscescens* (*barangen*), other harvest activities in this area are prevented by the corral owners. Fishing gear use on the reef slope is more uniform than on the reef flat, but varies in intensity with distance from the reef crest.

REEF FLAT STUDY RESULTS

Most gear are used in particular portions of the reef flat. Gillnets and fish traps overlap in some areas (Fig. 2.12). However, they tend to target different species. The catch of the gillnets tends to be strongly dominated by rabbitfish (Siganidae), while that of traps is dominated by small wrasses (Labridae) and parrotfish (Scaridae). Spearfishing areas include some seagrass regions and a strip of seasonal grounds along the reef crest (Fig. 2.12). The handlining areas are generally restricted to small areas in the northeastern reef flat and lagoon. However, occasional handlining can occur in other areas. The rental area for *baklad* fish corrals overlaps somewhat with the spearfishing and handlining operating areas. However, the *baklad* owners do not permit other forms of fishing in their areas during the migrations of the rabbitfish (*Siganus fuscescens*) twice each year. Overlaps in species targeted by various gear are illustrated in Table 2.1.

Gathering takes place throughout the non-sandy parts of the reef flat, but different species are harvested in different areas. For example, *Caulerpa* seaweeds are found primarily north of Dewey on the eastern margin of the reef flat, while *Tripneustes* sea urchins are found mainly around Silaki Island and Lucero on the western portions of the flat.

Most of the partitioning of the reef flat is because of the extreme heterogeneity and natural partitioning of the reef flat by the target organisms. Villages tend to specialize strongly in which sets of gear are used, based on such factors as distances to favored fishing grounds and exploitation patterns of other villages. However, none of the gear are exclusive to any village. Instead, each village tends to have a preponderance of one or two types of gear, and a minority of one or two others. This makes sampling difficult because all villages must be surveyed to obtain a reasonable picture of the whole fishery.

The average of approximately 26 t/month translates to approximately 1 t/km^2/month, or 12 t/km^2/year. This is similar to values previously calculated for the present reef flat (del Norte et al. 1989), and is close to the working figure recommended by Munro and Williams (1985) of 14 t/km^2/year. The reef flat production may be kept high by the fact that it is not cost-effective to use blasting devices to capture fish dispersed through the seagrass beds, and the fact that seagrasses tend to recover from various abuses (such as raking for shells) more rapidly than corals do from the stresses they must endure.

There were no obvious long-term trends in either effort, catch rate or total catch (Fig. 2.8). An exception to this is that gillnets tended to have a peak in activity during August 1989 (Fig. 2.9). This peak was not found near Dewey on the eastern reef flat, and is offset from the November-December peaks found in nonreef soft-bottom areas (Fig. 2.13). This type of sporadic variation between years indicates that seagrass fish might be expected to recover in a strong pulse to higher population levels sometime during the few years following the implementation of a marine reserve. Recovery of coral-dwelling fish may be slower because of the longer periods of time necessary to reestablish coral habitats damaged by blast fishing, cyanide fishing and coral-grabbing anchors.

Overall study results

The overall harvest reflects the seasonality of the slope fisheries, which is buffered by the constancy of the reef flat's yields (Fig. 2.8). Analyses of the individual catches illustrate the high degree of uncertainty in the fishery at the species level (Fig. 2.14). The vagaries of irregular recruitment success combine with the multitude of factors affecting the harvest procedures, such as weather and market value, to produce very chaotic-looking patterns. However, the regularity of total recruitment is matched by a regularity in total harvest which is remarkably predictable.

A cursory look at the nonreef longline fishery indicates that harvests may have declined (Fig. 2.15). The time series of data is too short to be certain of the long-term trend. However, there is little hope for finding compensatory harvests in other local ecosystems.

The irregularity of harvests for particular species has some implications for the development of the market system in Bolinao. The buying public

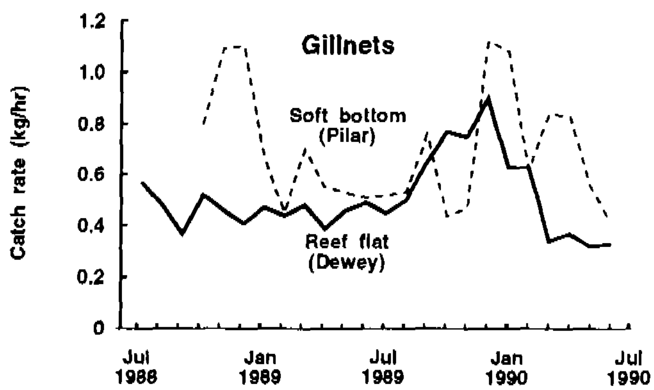


Fig. 2.13. Comparison of seasonality in gillnet harvests in a nonreef soft-bottom area and on the eastern reef flat.

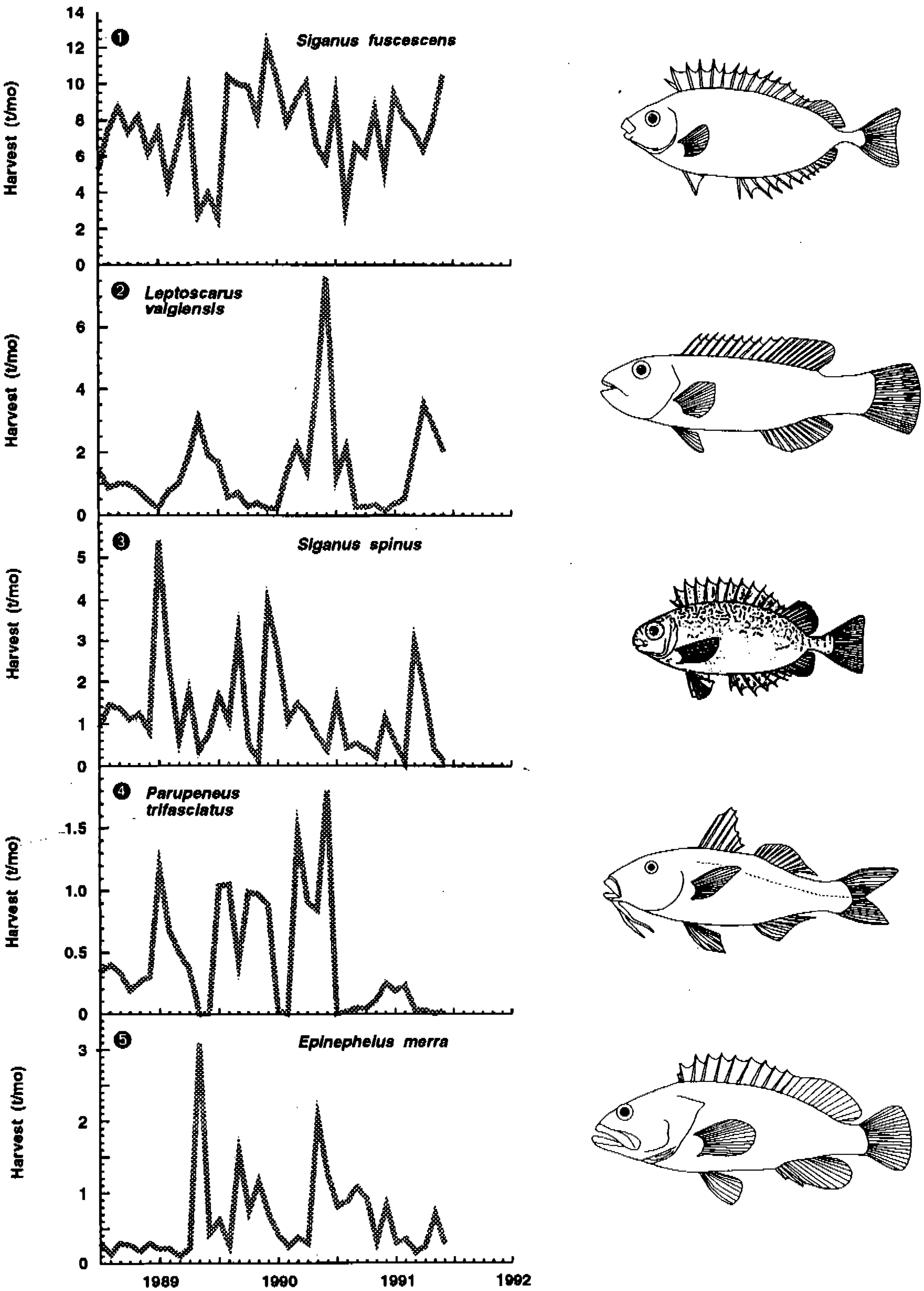


Fig. 2.14. Top species by weight in the shore landings of Bolinao. The irregular patterns are the result of the interplay of factors affecting the fish populations and harvest activities. Fish drawings are by Magnus Olsson-Ringby.

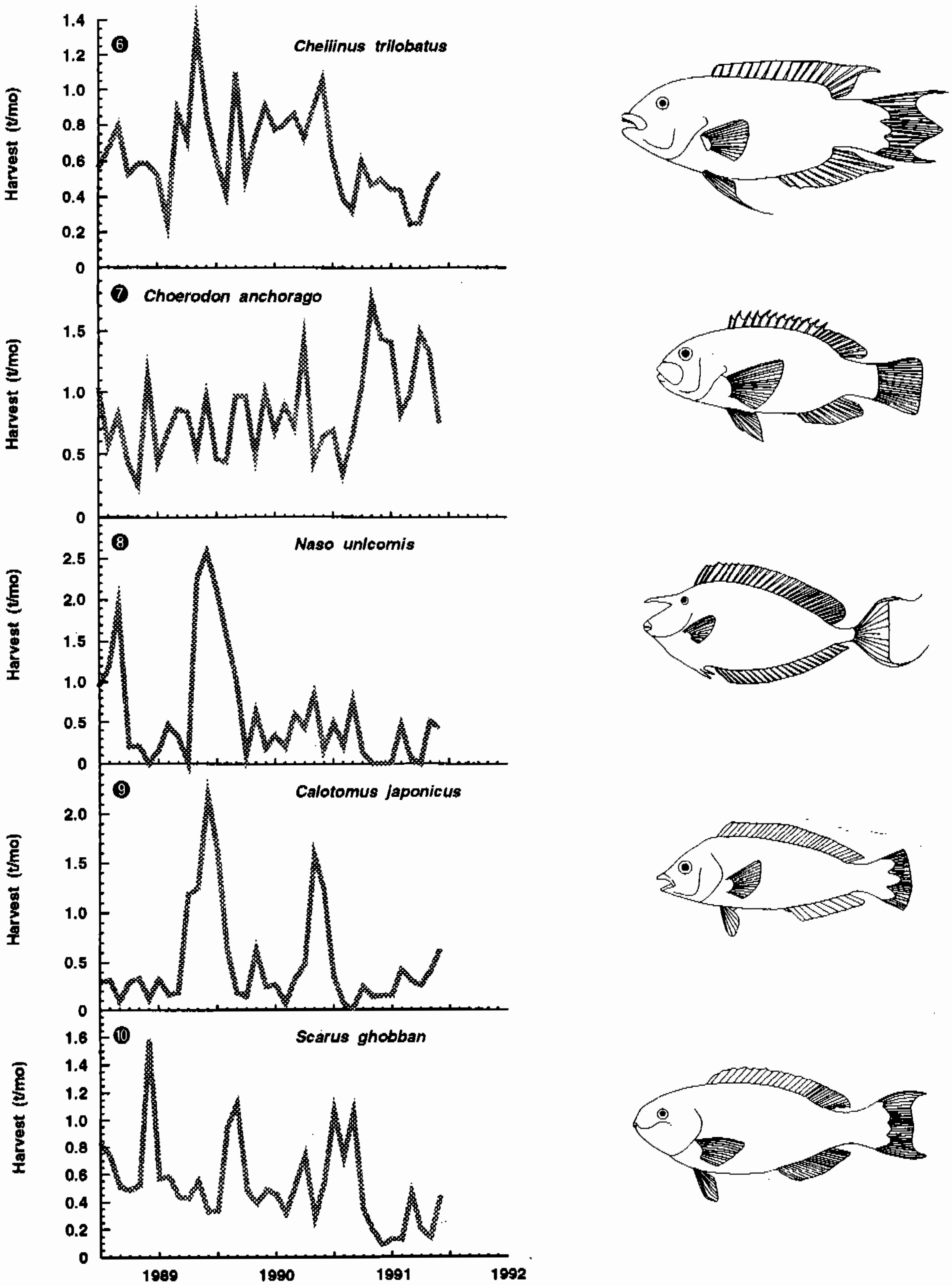


Fig. 2.14 (Continued)

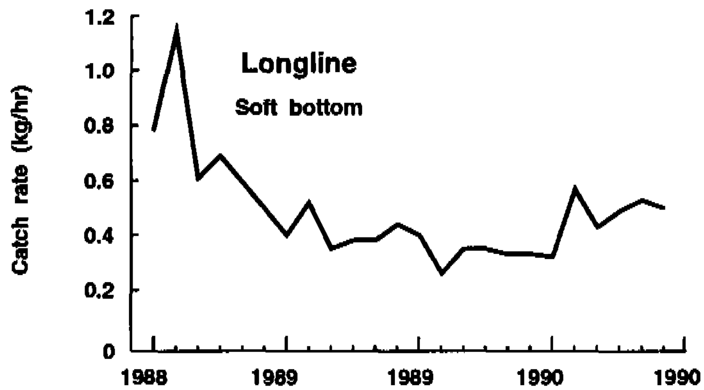


Fig. 2.15. Harvests from a nonreef longline fishery adjacent to Santiago Island.

must be very flexible in order to benefit from the fishery. Export to markets such as Manila may be limited somewhat by the fact that advance orders cannot be filled predictably. This situation may change for some species, such as rabbitfish (*barangen*) and groupers (*lapu-lapu*), if appropriate management measures are instituted, such as the establishment of a marine reserve. The vagaries of the fishery could be avoided far more if a strong shift was made from a dependence on **capturing** organisms to a reliance on **raising** them through mariculture techniques.

CHAPTER 3
REEF SLOPE FISH COMMUNITIES

General

The reef slope is the oceanward extension of the reef which is separated from the reef flat by an intertidal reef crest (Fig. 3.1). The reef slope of Bolinao is very large, extending northeastward into a subsurface barrier for at least 15 km (Fig. 1.1). In general, the slope is gradual down to the edge of a drop-off, which ranges in depth from 10 to 20 m. The bottom of the wall below the drop-off ranges from 20 to 30 m in most areas. Beyond this wall is a gentle talus slope of sand and coral rubble, which extends for several kilometers to the edge of the Luzon shelf. The talus is dotted with large outcrops of limestone substrate covered with corals and other benthic life.

The reef slope is formed from limestone accreted over a base of ancient reef material. The ancient reef had been exposed to the air during the previous ice age from approximately 45,000 to 6,000 years ago, so the reef we see today is no more than about 6,000 years old. The slope is creased with rifts or channels with depths that increase outwardly from the crest. Alternating with these are broad ridges, such that the general morphology resembles the toes of a person's foot. The wall structure is found only on the ridges, with the rifts opening directly into the talus slope. The ridges, rifts and numerous pits of various shapes and sizes on the slope show the combined effects of the weathered ancient limestone and differential modern reef growth.

The coral cover of the reef slope and wall is generally 15-30%, although patches of high density coral cover (100%) exist in some places. The extent of these dense areas has decreased noticeably in the last ten years because of the destructive effects of blast fishing, cyanide fishing and anchor damage. Other organisms covering the slope include sponges, bryozoans, tunicates, hydrozoans, forams and algae, such that very little hard substrate is exposed at any time. There are large areas of sand and rubble in the pits and rifts of the slope, as is the natural case.

The alternating monsoon seasons result locally in a period of dry weather from January to May and rainy weather (with numerous typhoons) from June to December. Slightly out of phase with this is an alternating pattern of temperature which peaks in June and July, and drops to its lowest in January and February (Fig. 3.2). Typhoons rarely hit Bolinao directly, but are turned northward or southward by mountain ranges as they approach Luzon from the east. However, the peripheral winds, rains and wave action do affect the reef substantially, and typhoons have been known to swing back toward Bolinao after arriving in the South China Sea. The storms account for the presence of large boulders of dead corals, sometimes exceeding 2 m in diameter, and shifting sand bars or dunes found on many reef flats.

Our studies of the fish community have revealed that the species are distributed to some degree by depth and by the amount of surface roughness, particularly in the 10-cm range (i.e., small holes and cracks in which the fish and their food organisms can hide). Despite these distributional tendencies, there is very little stratification

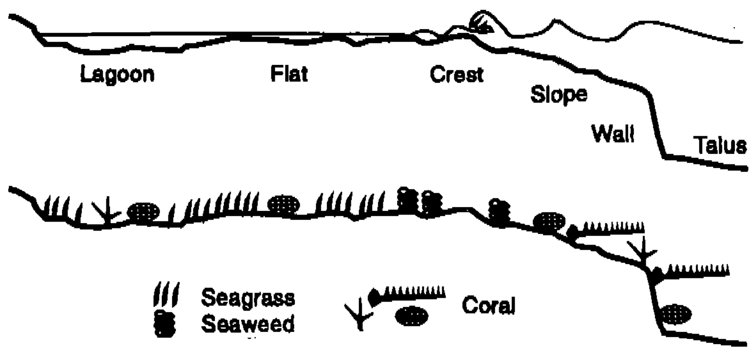


Fig. 3.1. Profile of the Santiago Island reef, showing the flat and slope separated by a wave-breaking intertidal crest. The profile is based on a transect running northwards to the west of Silaki Island (3x vertical exaggeration).

of the fish community into distinct subcommunities. Species abundance peaks are broad and overlap substantially. The assemblages also change significantly over time (Nañola et al. 1990).

Monitoring the reef slope

The reef slope is monitored on alternating months by censusing fish along underwater transects. The divers usually swim in pairs along a transect line, identifying and counting all fish within 5 m to each side and above the line. Fish are classed into life stages corresponding roughly to young juvenile, large recruited juvenile, subadult and adult, based on relative sizes and coloration patterns for each species. It is important to note that the group labeled "recruits" in this book refers to juveniles which are larger than those usually studied in ecological recruitment studies (e.g., Doherty 1988). Our "recruits" are smaller than those generally studied in fisheries studies, in which recruitment is defined in terms of the catchability of a gear (Sparre et al. 1989). A study of recruits focusing on the earliest settling stages would require supplemental sampling from very narrow transects (e.g., 1 m), which was beyond the scope of the current program. Analyses of the abundances of the smaller juveniles have been omitted from this book because of inadequate data.

From August 1987 until June 1990, each site was surveyed based on two transects laid at the time of the dive, each using a 100-m nylon measuring tape on a reel. The depth at each site varied somewhat because of slight inaccuracies in locating the areas between samplings. By July 1990, all 18 sites on the slope had been marked with

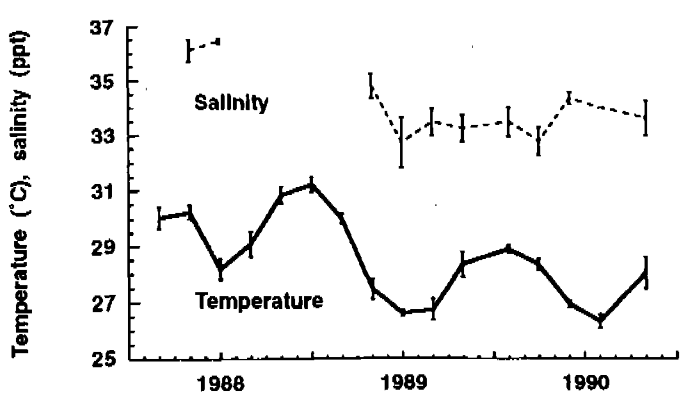


Fig. 3.2. Seasonality in bottom salinity and temperature in 18 reef slope sites. Vertical bars are 95% confidence limits.

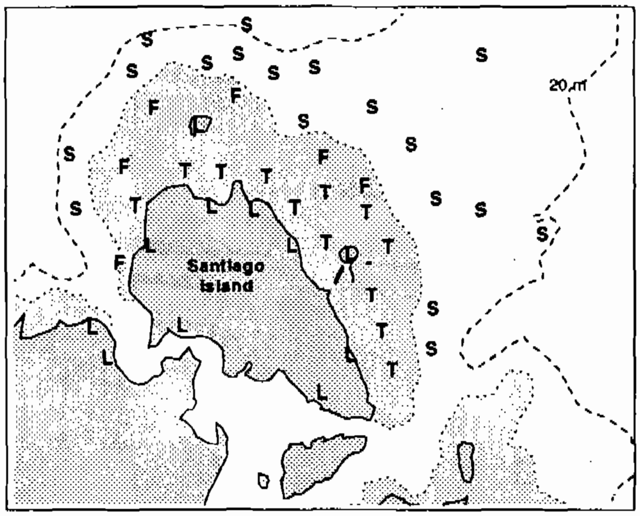


Fig. 3.3. Sampling sites around Santiago Island, Bolinao. S, F = slope and flat visual transect sites, T = trawl sites, L = fish landing sites.

permanent concrete markers anchoring bamboo buoys. Transects were permanently constructed from heavy nylon fishing line anchored with small concrete blocks (Figs. 3.3 and 3.4). The total transect length per site was reduced from 200 m to 100 m because there was less variance between samplings to be accounted for at each site.

The bamboo buoys were designed to tilt over when struck by the horizontal scare line used in some fishing operations. This was intended to reduce damage inflicted by irate fishers. However, some vandalism still existed, resulting in occasionally missed samplings of certain sites at certain times. A global positioning system (GPS) was used to document the coordinates of each site, but relocation often entailed waiting for the proper configuration of satellites to appear within horizon limits. Still, samplings are believed to have

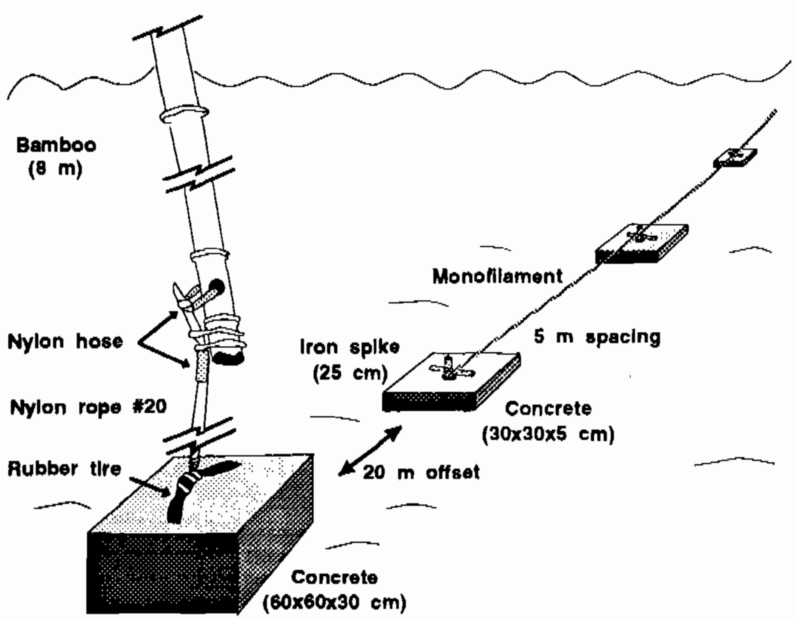


Fig. 3.4. Permanent markings on the reef slope transect sites.

been adequate to represent changes over time in species and abundances on the reef slope.

Temperatures were measured using laboratory-type liquid thermometers, and water samples were taken for salinity analysis using a refractometer. Depths were measured using capillary or Bourdon-tube depth gauges. Surface roughness (heterogeneity) was measured at 1-cm, 10-cm and 1-m scales with the use of a chain with 1-cm links, a pair of 10-cm sticks linked with a string, and a weighted meter stick, respectively. In each case, the number of smaller sticks (links) was counted which, when laid end to end across the substrate, covered a linear distance ten times larger than the stick. The number was divided by ten to give a measure of roughness at that scale. For example, a roughness index of 1.4 at the 1-m scale meant that a meter stick was laid 14 times along a 10-m linear distance, measured with a tape measure held tangentially to the surface. The more rough the surface, the more short sticks or links are required to span the straight distance, and the higher the index. To reduce ambiguity, objects causing a tilt only within the first 20% of the short stick were ignored, and the 10-m distance was measured tangentially to the substrate where it was convex or as a chord where the surface was concave, such that each end was an equal distance vertically above the substrate.

Data calculations

Certain diversity indices are very sensitive to sample size and cannot be scaled up or down without further field sampling (Pielou 1975, 1977; Magurran 1988). This fact contributed to our decision to include for all abundance and diversity analyses only transects (15 of 18) which had been sampled without omission throughout the study dates included. Error bars on graphs based on mean transect abundances and diversities were calculated based on the usual variance estimation procedures. Note that the variance used was that among sites, not based on numbers of individuals among species as is often used for the Shannon-Wiener diversity index (Pielou 1975). The emphasis is therefore on the variability among transects, not on determining the uncertainty associated with applying the index to a sample unit.

The error bars on the diversity measures for *combined* transects were determined by jackknife variance estimation (Tukey 1977; Pauly 1984). The method differed from that described by Zahl (1977) in that the variances were estimated by the successive omission of transects rather than species. As with the analyses of mean transect variances, this was done in order to properly account for the variance among sites, which is conceptually more relevant to our study than a variance based on the way individuals are distributed among species. The estimation of species number variances in this manner is mathematically equivalent to the technique of Heltshe and Forrester (1983). In all cases, erratic results attributable to the sensitivities of the jackknife method to various data characteristics (Wainer and Thissen 1975) prevented the use of the jackknifed diversity index estimators. Thus, the graphs consist of diversities calculated normally, flanked by 95% confidence limits based on jackknifed variances.

Fish abundances

Graphs a and b of Fig. 3.5 show the variations of fish abundances on the reef slope. Every year in April and May, large numbers of juvenile fish are recruited to the slope. A natural decline occurred in the next few months in each case, probably because of the combined effects of losses to predation, harvesting and rapid growth to the subadult stage (Fig. 3.6).

The peaks in subadult abundances follow in July and August, reflecting the rapid growth of most of the fish. The differences between the peaks for juvenile recruits and those for subadults represent primarily losses due to predation because the fishing gear on the reef slope generally target subadult and adult fish. The data series is too short to be certain of any trends in the heights of the peaks of recruitment from year to year.

The adult fish showed only minor seasonality (Fig. 3.7). This might have been expected naturally because there is always a limit on how many fish reach adulthood, at which they achieve a low rate of natural mortality. One reason for this is that the adult fish tend to have well-established and well-defended territories and hiding places. However, there was a decline in the abundances of adults over time, interrupted only briefly by a pulse in June 1991. Fishing pressure gradually reduced the populations of adult fish by approximately 80%. By the end of the study, adult fish

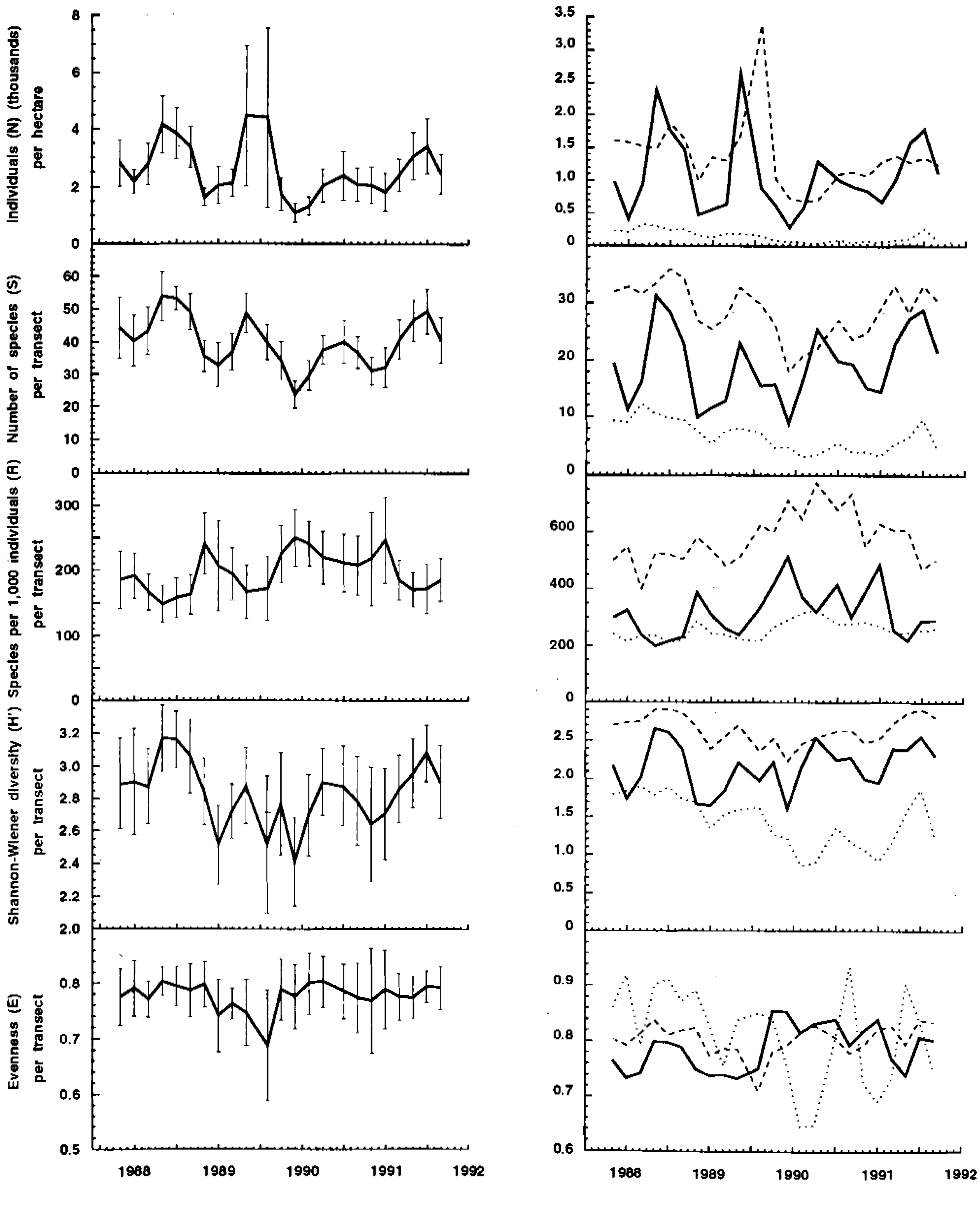


Fig. 3.5. Abundance and diversity by transect on the reef slope. Vertical bars are 95% confidence limits (left: all life stages; right: by life stage where black = recruits, dashed = subadults and dotted = adults).

were so scarce on the reef slope that they were becoming difficult for divers to find. The probability that an adult fish would encounter a hook or spearfisher declines rapidly with low abundances, particularly because they are scattered in essentially two-dimensional space. The one-dimensional search path that a spearfisher would have to take to encounter an adult fish would have to increase exponentially to account for a linearly declining two-dimensional abundance. This may be why the abundance remained fairly constant in the final year of the study.

A major question arises as to whether the recruiting juvenile fish come primarily from the reef itself, from other fringing reefs or from elsewhere, as from the thousands of subsurface reefs of Philippine waters (McManus 1988). Recent studies indicate that most reef fish recruit on a scale of hundreds to thousands of kilometers (e.g., Doherty 1988). Therefore, it is unlikely that the reef is entirely "self-seeding". However, if the timing of reproduction were to be regulated to take advantage of offshore entrainment features, as

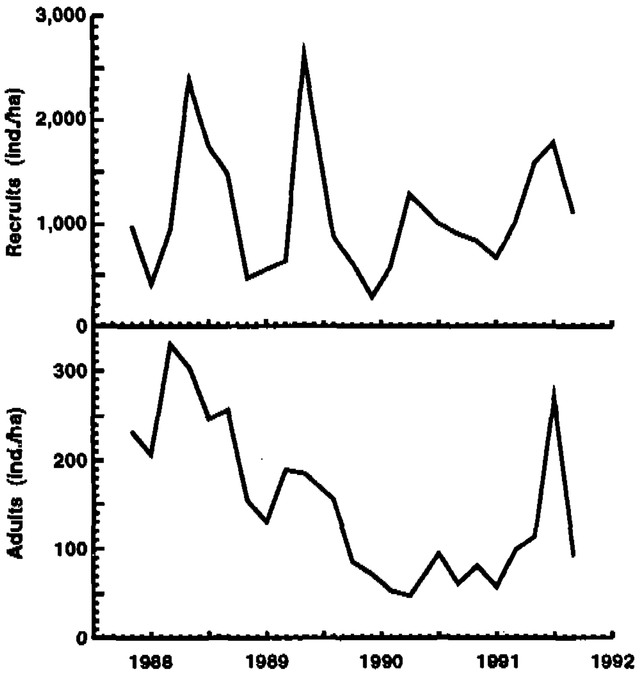
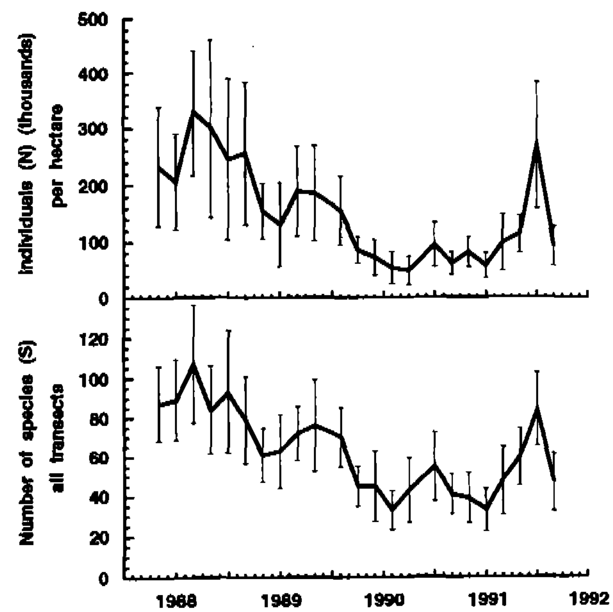


Fig. 3.6. Abundances of fish recruits (top) and adult fish (bottom) on the reef slope. The decline of adults was interrupted only by a temporary pulse in May 1991 which quickly disappeared.



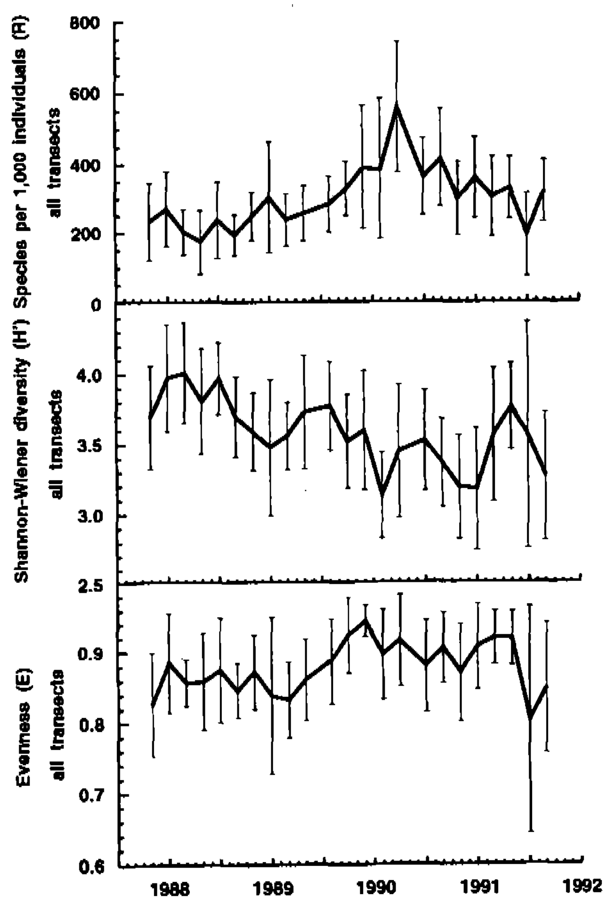


Fig. 3.7. Abundance and diversity of adult fish on the reef slope.

appears to be the case in Hawaii (Lobel and Robinson 1983), then recruitment success may be dependent on adult populations across reefs over a few hundred kilometers of coastline. The reefs of Bolinao may be extensive enough relative to others within such a distance for the local adult populations to directly influence local recruitment. Of more importance and greater likelihood, however, is the limitation in recruitment expected to ensue from the broad-scale overfishing of reefs along much of the southwestern coast of Luzon. May is in the midst of what is considered by local fishers to be the calm period of the year, and falls between monsoon seasons. This could influence the timing of fish reproduction, such that larvae are not broadly dispersed (Pauly and Navaluna 1983; Sinclair 1988). Currents affecting the area during the May recruitment period tend to proceed northwards from the Central Philippines (Wyrtki 1961). The current structure of Lingayen Gulf includes incoming currents from both the north and south, which converge and generally expel to the northwest, away from the Bolinao reef (de las Alas 1986). However, the possibility of recruits arriving from the north on intermittent countercurrents remains.

The data series is too short to determine if the recruitment is clearly decreasing with the decline in local and regional stocks of adult fish. If further studies indicate continued high levels of recruitment despite the increasing levels of coastal exploitation, then recruitment from offshore subsurface reefs may be indicated. There is a need for longer-term transect data, investigations into the genetic structure of the local stocks of coral reef fish, and studies designed to pinpoint the sources of local recruitment.

An analysis of the top ten species by counts (excluding prerecruit juveniles and larvae) shows that no one species accounted for a major part of the seasonal recruitment pattern (Fig. 3.8). Only the goatfish, *Parupeneus trifasciatus,* and the pomacentrid, *Pomachromis richardsoni*, came close to the appropriate pattern. The recruitment appeared to consist of an annual "lottery for living space," with success among individual species varying greatly between years (see also Sale 1978). The total recruitment was fairly predictable, considering the potential effects of variability in larval survival (Beyer 1989). However, the predictability as to *which* species dominated recruitment each year was low. This could be interpreted as indicating that some form of resource limitation is a controlling factor, and that the dominance of these resources is not guaranteed from year to year by any particular species. In any case, it is surprising that the recruitment was so strongly seasonal. It is likely that there was some driving factor, such as favorable current patterns or food availability which made this period particularly successful for new recruits.

Species diversity

The overall mean number of species per transect on the reef slope appears to have dropped temporarily and then recovered. The total number of species in the combined transects known to reach adulthood fell at least 33% (Fig. 3.7). The lack of a similar pattern in the number of species per 1,000 individuals (R) indicates that this drop is related to the general loss of individuals, and not necessarily a more complex ecological change driven by predation and competition.

The Shannon-Wiener diversity is an indication of how likely an individual fish will encounter a high diversity of other species, and accounts for both the number of individuals per species and the evenness with which they are distributed among species. This diversity measure showed little change over time. However, an analysis of the evenness component of that index shows that for a limited period, an increasing evenness balanced out the effect of the overall loss of species. This increase in evenness is to be expected in any situation in which predators, including people, tend to harvest the most abundant species and to switch from one to the other as each becomes scarce (see technical box). The fact that so many species are economically valuable locally tends to favor this process.

The overall annual rise in the number of species in April and May coincided with the annual peaks of recruitment (Figs. 3.5 and 3.9). This confirms that the recruitment tended to involve a multitude of species, approximately 10 to 20 out of roughly 210, or 5 to 10% of the total slope species at the start of the monitoring.

Usually, the total number of species encountered was higher than that found per transect, a result of the restricted ranges of these species. This heterogeneity in composition across the slope would result in an increase in the difficulty that a spearfisher might have in finding a useful target. However, it also indicates that individuals of a

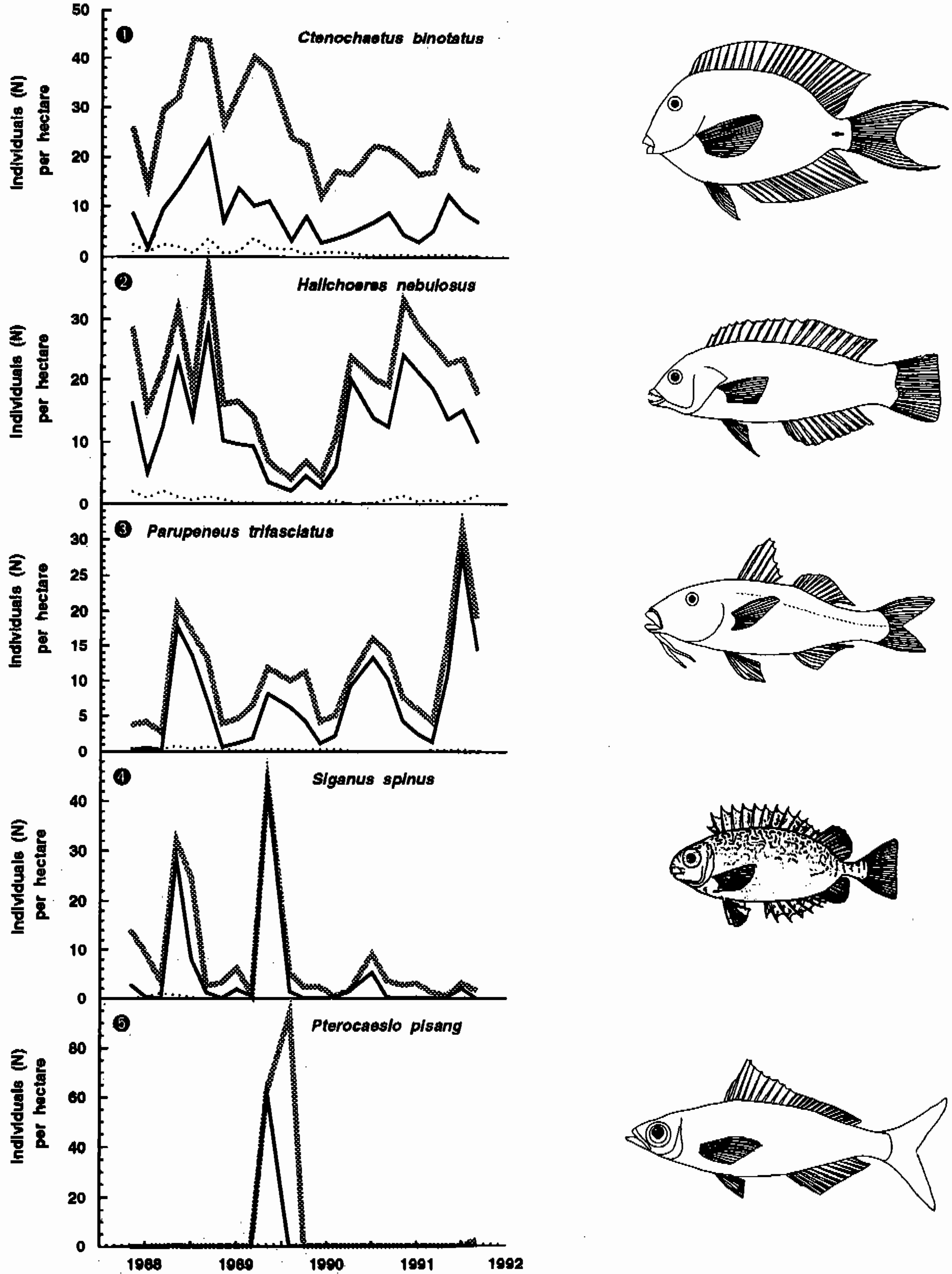


Fig. 3.8. Abundances of the most common species in the reef slope visual censusing (grey = combined sizes, black = recruits, dotted = adults). Fish drawings are by Magnus Olsson-Ringby.

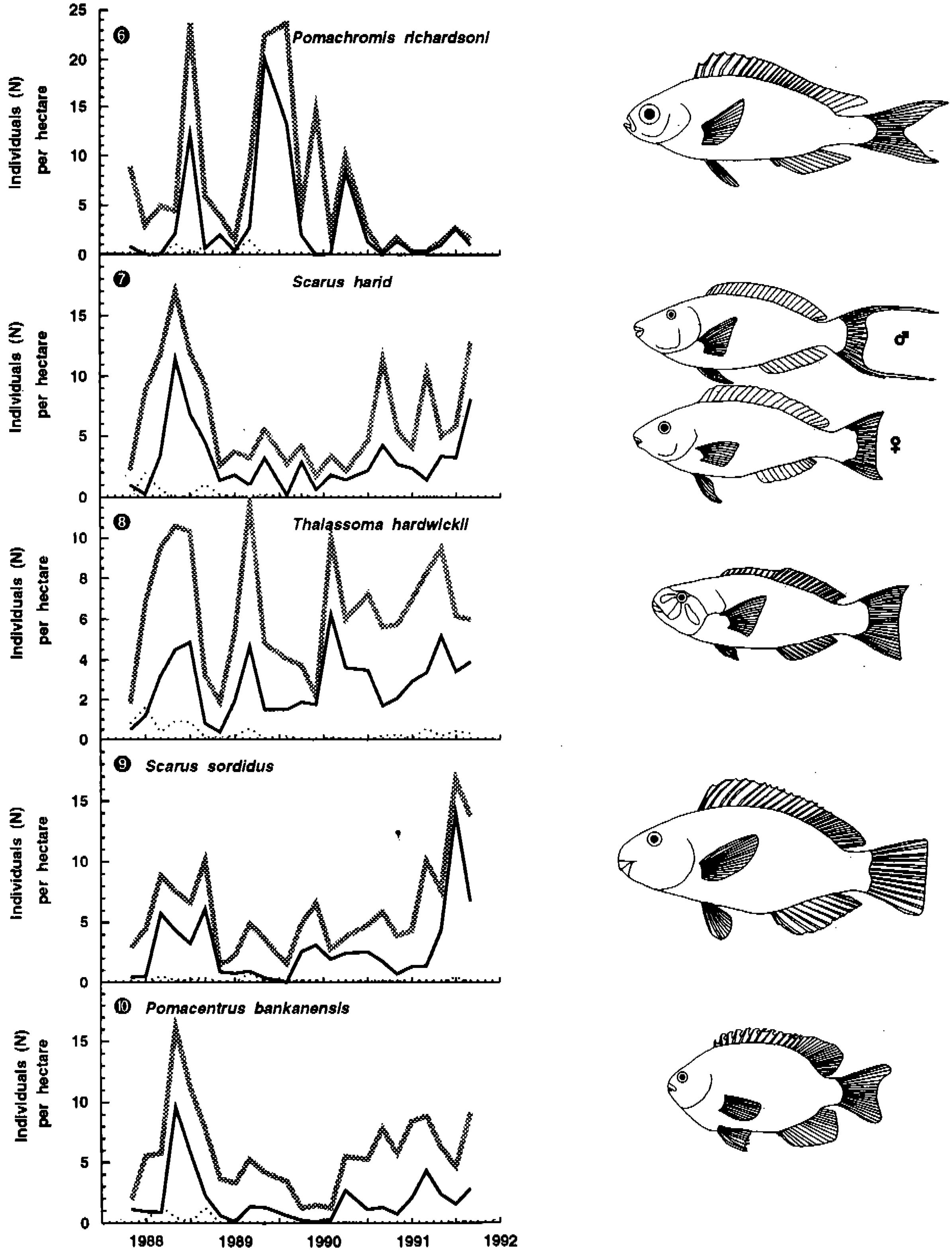


Fig. 3.8 (Continued)

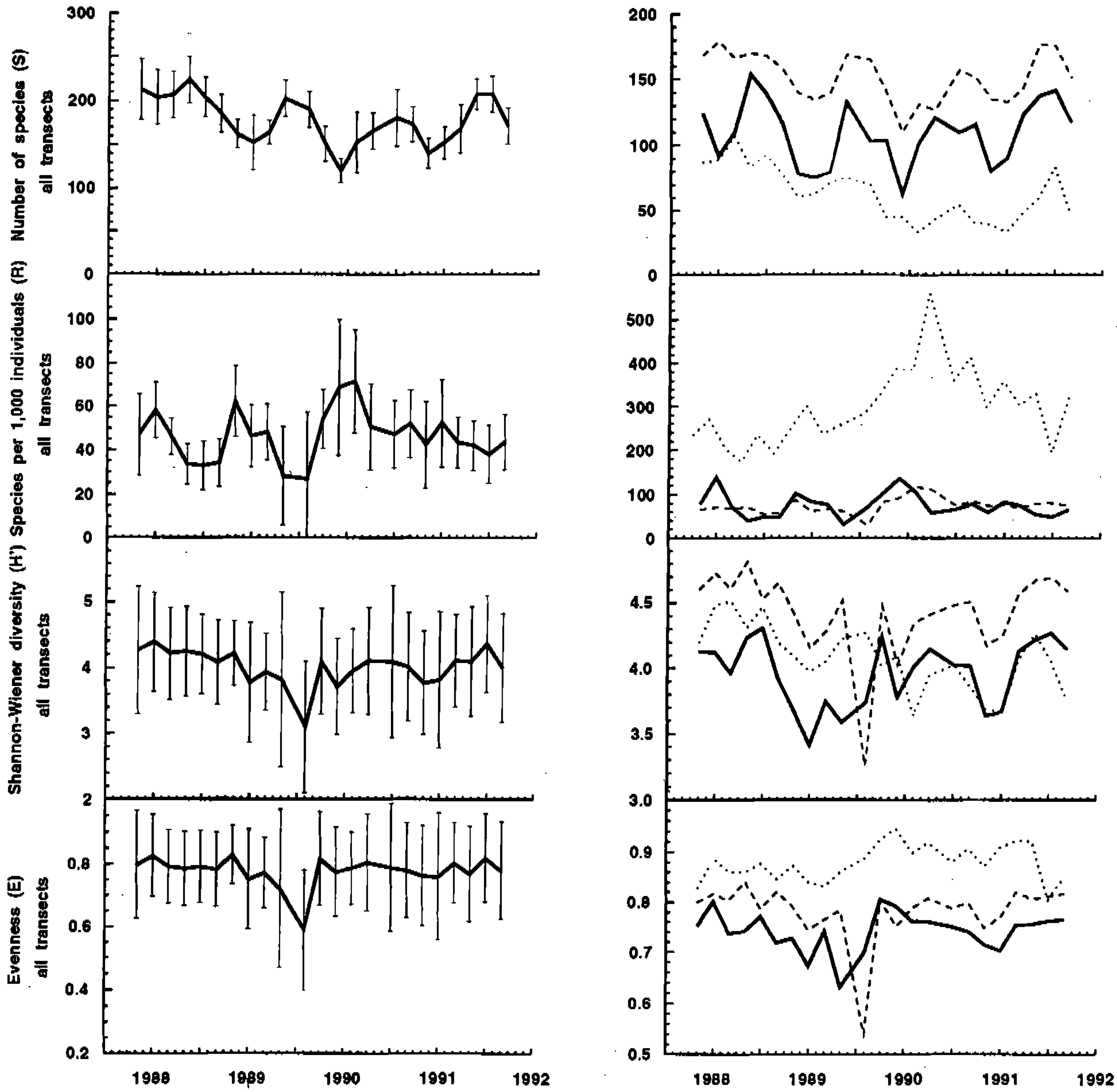


Fig. 3.9. Diversity in combined transects on the reef slope. Vertical bars represent 95% confidence limits determined from variances obtained by jackknifing among sites (left: all life stages; right: by life stage where black = recruits, dashed = subadults and dotted = adults).

species may have difficulties finding mates with which to breed. It is possible that some species have reached or could reach population levels below which reproduction is no longer successful. If this were to occur on a scale large enough to affect entire stocks of the fish, generally hundreds to thousands of kilometers (Sinclair 1988), then this could result in local extinctions, unless at least occasional recruitment from other reef areas replenishes the supply. In areas where all reefs within a wide radius are heavily fished, this could be a problem. The presence of unfished offshore reefs in the Bolinao area makes this unlikely to occur, except possibly for species dependent on shallow-water habitats for survival which are not present on subsurface reefs.

Effects of Harvest on Fish Species Diversity

John W. McManus

GENERAL

In isolating the possible effects of fishing on the diversity of the fish, it is useful to define a set of simple effects which might be seen singly or in concert. Many of the effects of fishing on a fish community known from the literature have been summarized by Russ (1991). I shall present here a classification of some of the possible effects on diversity (Figs. 3.10 and 3.11), and then compare these possibilities with actual data regarding changes in the composition of adult fish on the reef slope.

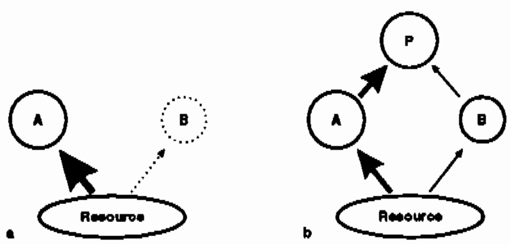


Fig. 3.10. Illustration of predator-mediated coexistence. The predator (P) feeds more on the abundant species (A), preventing it from excluding the weaker competitor (B) by dominating a resource.

HYPOTHETICAL EFFECTS

1. **Fall-off.** The abundance is reduced at many levels including both abundant and rare species, and some of the rare species are reduced to zero abundance. This would only be expected if:
   a. fishing was uniform regardless of the abundance of a species (false in our case), and if many species are involved in the fishery (true).
   b. some of the abundant species normally act as switching predators which prevents competing species from competitive exclusion, i.e., one decimating the other in competition for food or space. This could be happening here (see tilt-off).
2. **Add-on.** Humans remove predators that normally had a fall-off effect. For example, removing most sharks from a reef (essentially true in our case) might cause a general rise in successful recruitment including that of species normally totally incompatible with the predators. This would cause a rise in abundances, species richness and diversity, and have an unpredictable effect on evenness.
3. **Tilt-on.** Humans become switching predators, causing an increase in evenness and freeing niche-space for other species. If the species pool is large, this could conceivably lead to an increase in species richness, simple diversity, Shannon-Wiener diversity, and of course, evenness. Otherwise, only the latter one or two of these would rise and the rest remain unchanged.
4. **Tilt-off.** Humans remove existing switching predators, causing some species to become dominant relative to other competitors. If the switching predators are responsible for maintaining some of the species richness, then their removal might result in losses of richness, diversity and evenness. This effect was widely predicted based on studies of simple systems in which the removal of a predator appeared to have enhanced interspecies competition, as in barnacle communities with predatory snails (Connell 1961), and similar rocky shore assemblages (Paine 1966; Menge and Sutherland 1976). However, the loss of diversity predicted by some to occur with the removal of top predators from a reef fish community has yet to be clearly demonstrated empirically (Bohnsack 1981; Russ 1991). It must be noted that a pulse of successful recruitment of a species in the midst of a fall-off decline process could result in a tilt-off pattern.

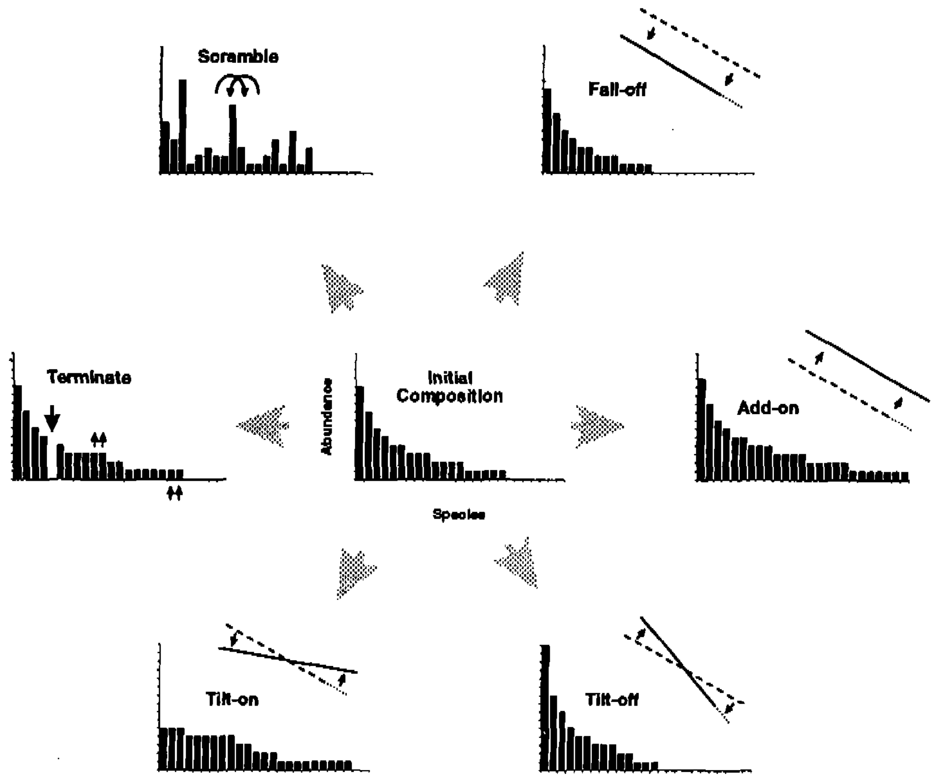


Fig. 3.11. Some possible effects of fishing on a community. Species are represented by bars arranged initially in rank order by abundance. People can act as predators and/or as removers of predators to cause a variety of possible changes.

5. **Terminate.** Humans overexploit selected species to local extinction. This might be true especially when certain species are very valuable, as with certain aquarium species, or if the docile seahorses of the reef flat seagrass beds were to be collected systematically for sale as folk medicine (a realistic danger). The activity would have to occur on a wide enough scale (hundreds to thousands of kilometers of coastline) to impair recruitment processes. We would expect minor drops in richness and diversity, and conceivably a drop in evenness. In all cases, this would hardly be noticeable unless the original number of species was low or the number of selected species was high.

6. **Scramble.** The dominance order of species is merely rearranged, with no substantial net changes in abundance or diversity. This could be the case if recruitment was not strongly limiting and settling space or other resources were.

EMPIRICAL PATTERN

A comparative analysis of diversity profiles from the inter-recruitment months of January-February (Fig. 3.12) highlights the dramatic drop in species encountered from 1988-1991. The number of species per 1,000 individuals increased until 1990, a result of the fact that the number of

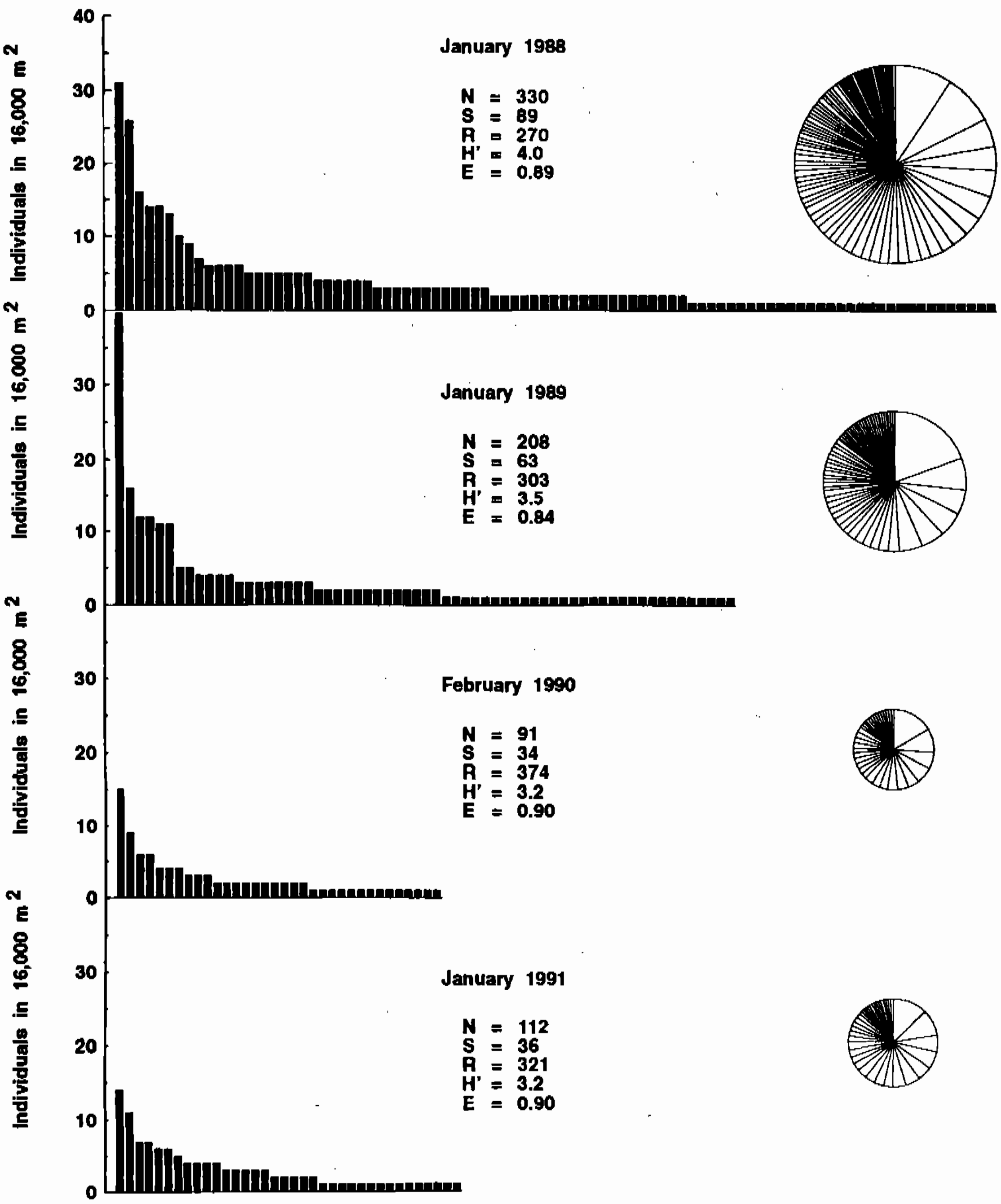


Fig. 3.12. Species abundance profiles of adult reef slope fish from year-end months. Many species appear to have "fallen off" as overall abundances declined.

individuals encountered dropped faster (as percent change per year) than the species number. This pattern reversed slightly in 1991, as the few remaining species reaching adulthood reflected a 10% increase in abundance. The Shannon-Wiener diversity dropped from 4.0 to 3.2 (natural log base). The evenness component of the Shannon-Wiener index dropped somewhat during the 1989 transition period, but returned to near its starting value. This return indicates that the drop in the Shannon-Wiener diversity was more a result of the decrease in the number of species than net changes in the degree of dominance. Considerable "scrambling" took place among dominance ranks, as is apparent from the individual species graphs (Fig. 3.8). However, this could easily be attributable to variability in recruitment success among the years. A possible example of a tilt-off transition from 1988 to 1989, signaled by concurrent drops in diversity, richness and evenness, could be an artifact of recruitment variability in the midst of a general fall-off process. The simplest explanation for the overall loss of species is that they "fell off" as abundances declined.

CHAPTER 4
REEF FLAT FISH COMMUNITIES

General

The reef flat and lagoon are protected from outside waves by the intertidal reef flat. Seasonality is as described for the reef slope (Chapter 3, Fig. 4.1). The substrate throughout is mostly calcareous sand. Encircling the shore and encompassing nearly all the fish ponds is a black, muddy substrate indicative of a time when mangroves were abundant. These are now virtually absent, with the exception of some seedlings recently planted by the Department of Environment and Natural Resources (DENR).

The lagoon consists of what appears to be an ancient riverbed modified by recent reef growth at the ends and sedimentation throughout. The bottom of the lagoon is sand covered with microscopic algae, interrupted in places by patches of coral a few meters across. In 1978, most of these corals were alive and filled with dense schools of coral reef fish. Our survey in 1986 showed that 60% of the coral (in terms of cover) had been killed, primarily by blasting and cyanide fishing. These activities have continued, and coral cover was believed to be far less by 1991. Unlike the case on the reef slope, there were very few newly settled corals to be found in the lagoon and reef flat. The reasons for this are unknown, but possibilities include organic pollution and siltation from coastal villages which may be harmful to planktonic coral larvae or inhibitory to settling.

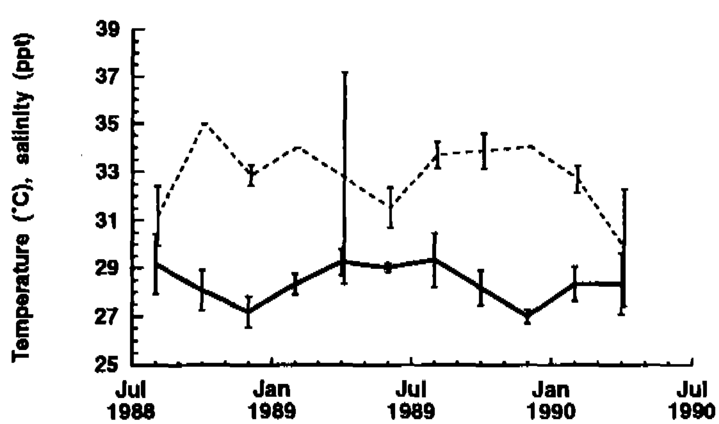


Fig. 4.1. Bottom salinity and temperature measurements from six reef flat sites. Vertical bars are 95% confidence intervals.

The reef flat proper is dominated by seagrass. The beds are found in a variety of densities at various depths, making satellite mapping of the reef flat difficult (McManus 1989). Occasional patches of living coral dot the seagrass beds, but far more patches of dead coral abound. Very few fish inhabit the dead hard coral, even when large abundances of algae and soft coral are present. An exception to this are the dunes of coral rubble near the reef crests, especially north of Dewey, which are inhabited by many herbivorous territorial damselfish (Pomacentridae).

The large sand areas exposed at low tide have little seagrass or algal growth. Seagrass is also absent from the backreef areas behind the reef crest. In some areas, the backreef consists of large solid coral colonies with "bald spots" on top where coral has been killed by exposure to air and freshwater at low tide. These "microatolls" become denser as one approaches the crest, finally coalescing to form the raised crest itself. Other backreef areas contain beds of *Sargassum*, a brown algae which is not exploited locally but has market potential as a source of a variety of products. Proceeding across the crest in these areas, one passes from the wide beds of *Sargassum* into a thin band of club-like *Turbinaria*, another brown algae. Further progress brings one to the intertidal crest itself, which is barren except for grayish-white slippery algal coatings. Beyond the crest, the pattern often reverses, with another shallow-water band of *Turbinaria* algae followed by a wider bed of *Sargassum* leading to the coralline reef slope. In eastern areas of the reef, the crest consists of raised piles of dead coral rubble, often housing the commercially important *Caulerpa* green algae (*arosep*). This algae consists of rhizomes with berry-like projections. The algae is gathered for use in salads, usually eaten with vinegar.

The primary fish species of the seagrass beds is *Siganus fuscescens*, known as "rabbitfish" or "spinefoot" in English and *barangen* (large) or *padas* (juvenile stages) in Bolinao. This rabbitfish migrates out of the reef flat eastwardly, north of Dewey, on 2-4 nights after a new moon twice each year in August-September (major spawning peak) and March-May (minor spawning peak) (Aragones 1987; del Norte et al. 1989; del Norte and Pauly 1990). The fish are assumed to breed on the reef slope, but they have rarely been encountered in the slope monitoring program. The juveniles return to the reef flat within a few weeks, and shift from pelagic to epibenthic within three more weeks (Hasse et al. 1977).

Another group of fish of considerable importance is the cardinalfish, Apogonidae. These fish generally are hidden during the day and disperse at night for feeding (Thresher 1984). Although their hiding places are generally in coral, they are found in large abundances in the seagrass beds at night. This indicates that both types of habitat are essential to the populations. Thus, removal of the coral from the reef flat could adversely affect the fishery potential of the seagrass beds.

Many species of fish in the seagrass beds and remaining coral patches form mixed-species schools which forage widely during the day. The herbivorous feeding activity appears to stir up zooplankton in the substrate which are fed upon by nonherbivores and herbivores alike. These schools of wrasses (Labridae), goatfish (Mullidae), small rabbitfish (Siganidae), small parrotfish (Scaridae) and others also frequent channels where other species lay benthic eggs. Many of these are consumed.

Another common schooling species is the striped catfish, *Plotosus lineatus*. This species forms schools with others of similar species and size, which comb through the seagrass and coral beds in dense masses stirring up demersal zooplankton. These zooplankton, which live in the substrate and migrate daily to and from the water column, are a major source of food in the reef flat, and probably on the reef slope as well. Many fish species are planktivorous throughout their lives (e.g., small sea bass, *Pseudanthias* spp.; fusiliers, Caesionidae). Others are more planktivorous as juveniles and switch to eating seagrass as adults, including some species of rabbitfish (Tsuda and Bryan 1973; Bryan 1975). Studies have demonstrated that live coral tends to support more density of demersal plankton than either coral rubble or sand (Porter and Porter 1977). Thus, damage to the coral beds has a number of deleterious indirect effects on the total fish community of the reef flat, beyond the simple fact that living coral supports greater fish densities than either dead coral or seagrass.

The invertebrate community of the reef flat is divided into species favoring seagrass, sandy, muddy and rocky (coral rubble) areas (de Guzman 1990). The seagrass community is dominated by herbivores, which vary in abundances seasonally. The important commercial sea urchin, *Tripneustes* *gratilla* (*kuden-kuden*), maintains a low abundance throughout most of the year, but peaks in abundance in September and October (Fig. 4.2). This peak occurs just before an annual thinning of the seagrass beds in dense areas (Fig. 4.3), and may be one of the causative factors. The *Tripneustes* peak coincides with a peak in the abundance of *Strombus labiatus*. These are followed by a November peak in the abundance of another gastropod important in the shellcraft industry, *Strombus urceus*. The cowries used in shellcraft are found in rocky areas. *Cypraea annulus*, the ring cowrie, and *Cypraea moneta*, the money cowrie, both have broad peaks, the former being especially abundant in January (Fig. 4.2, data from de Guzman 1990).

Monitoring the reef flat

A set of six transect sites was monitored by visual censusing from August 1988 until July 1991 on alternate months. The techniques and data obtained match those described for the reef slope. Sites were permanently marked as of October 1989; however, the transects were not. There was one transect per site, extending for 100 m, serving as a guideline for a 10-m wide censusing swath. Familiarity with the area gave a high consistency to the process of locating the sites by triangulation and visual cues, so that depth variation was minimal between samplings. Some within-site substrate variability was caused by minor shifts in the transect positioning leading to major shifts in the amount of coral intersected. However, the six sites combined give a fairly representative view of changes over time in the daylight fish community excluding the dense seagrass beds.

The difficulties with visually censusing fish in dense seagrass led to the initiation of a trawl sampling program from August 1988 to July 1991. The trawl had a width of 2 m, a rigid, rectangular opening height of 1 m, and a roller below the mouth to minimize scraping the seagrass and stalling as corals are encountered. Early trials indicated that the escapement rate was unrealistically high during the day, so trawling was scheduled for nights during which the fish cannot see the net until it is upon them. The trawling encompassed 7 sites of 7 minutes trawling time each (approximately 175 m), which are sampled on alternate months. All fish caught were counted, weighed and measured.

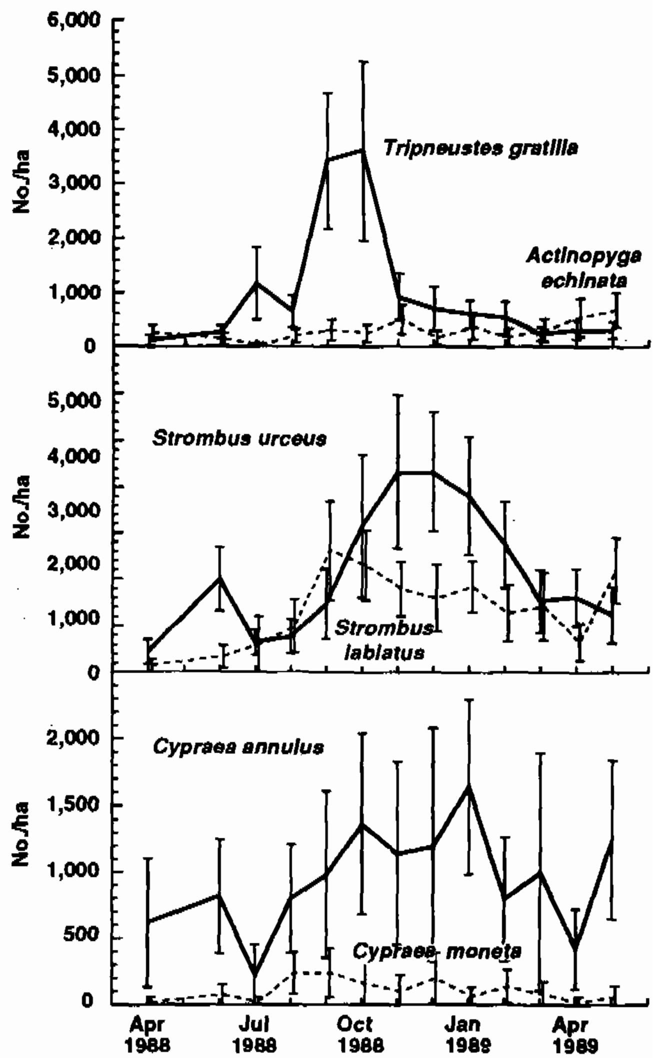


Fig. 4.2. Abundances of selected commercially important invertebrates in 50 quadrats on the reef flat near Lucero. Vertical bars are 95% confidence limits. The graphs are based on unpublished data of A. de Guzman.

Fish abundances

Contrary to the case on the reef slope, the abundances and diversities of reef flat fish show very little consistent seasonality (Figs. 4.4 to 4.7). There is also no particular trend over time. The reef flat has been fished far more intensely than the reef slope for a longer time, and this may be a

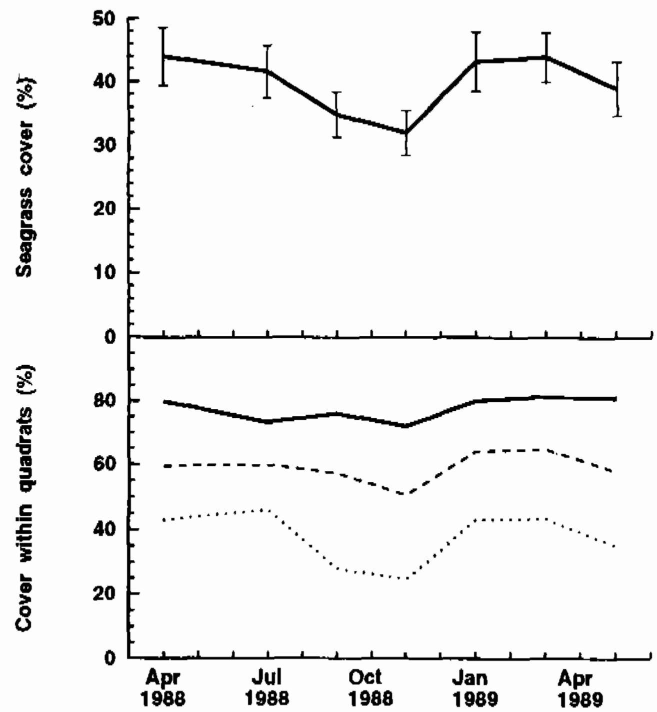


Fig. 4.3. Seasonal variation in seagrass cover on the reef flat. The greatest effect is seen as an annual loss of dense areas, indicating that thinning rather than contraction of seagrass areas explains the annual drop in cover.

factor in the fact that no downward abundance trend is visible. Alternatively, the dominance of the flat by seagrass means that broadly dispersed fish become especially difficult to eradicate below certain levels. Blasting does little damage to seagrass fish populations because they tend to be solitary or form schools which are small. However, the fact that 60% of the coral cover had already been destroyed before the start of the study indicates that the community is far less productive than it should be. In areas of the Philippines where fishing is minimal, densities of coral reef fish generally exceed 10,000/ha (Aliño, pers. comm.). The reef flat abundances here, as on the reef slope, rarely exceed 500/ha.

None of the 10 most abundant fish species in the visual transects and trawl samplings shows very regular seasonality of abundance (Figs. 4.8 and 4.9). Even the regularly migrating *Siganus fuscescens* apparently has difficulty maintaining a regular pattern of successful recruitment (Fig. 4.9). This is not surprising, considering the amount of effort which local exploiters put into harvesting every possible individual (see Chapter 2).

Species diversities

No obvious trends occurred in species richness, diversity or evenness during the study period (Figs. 4.4 to 4.7). Apparently, the reef flat fish community has already long since been reduced to a level of diversity and abundance which has been maintained over the three years of the study. It is difficult to predict how long the current situation can be maintained ecologically with the rapidly growing human population and the systematic destruction of coral by blasting and cyanide fishing. We may expect some further changes in the future as, for example, the amount of coral cover drops below the critical levels necessary to maintain the cardinalfish populations during the day.

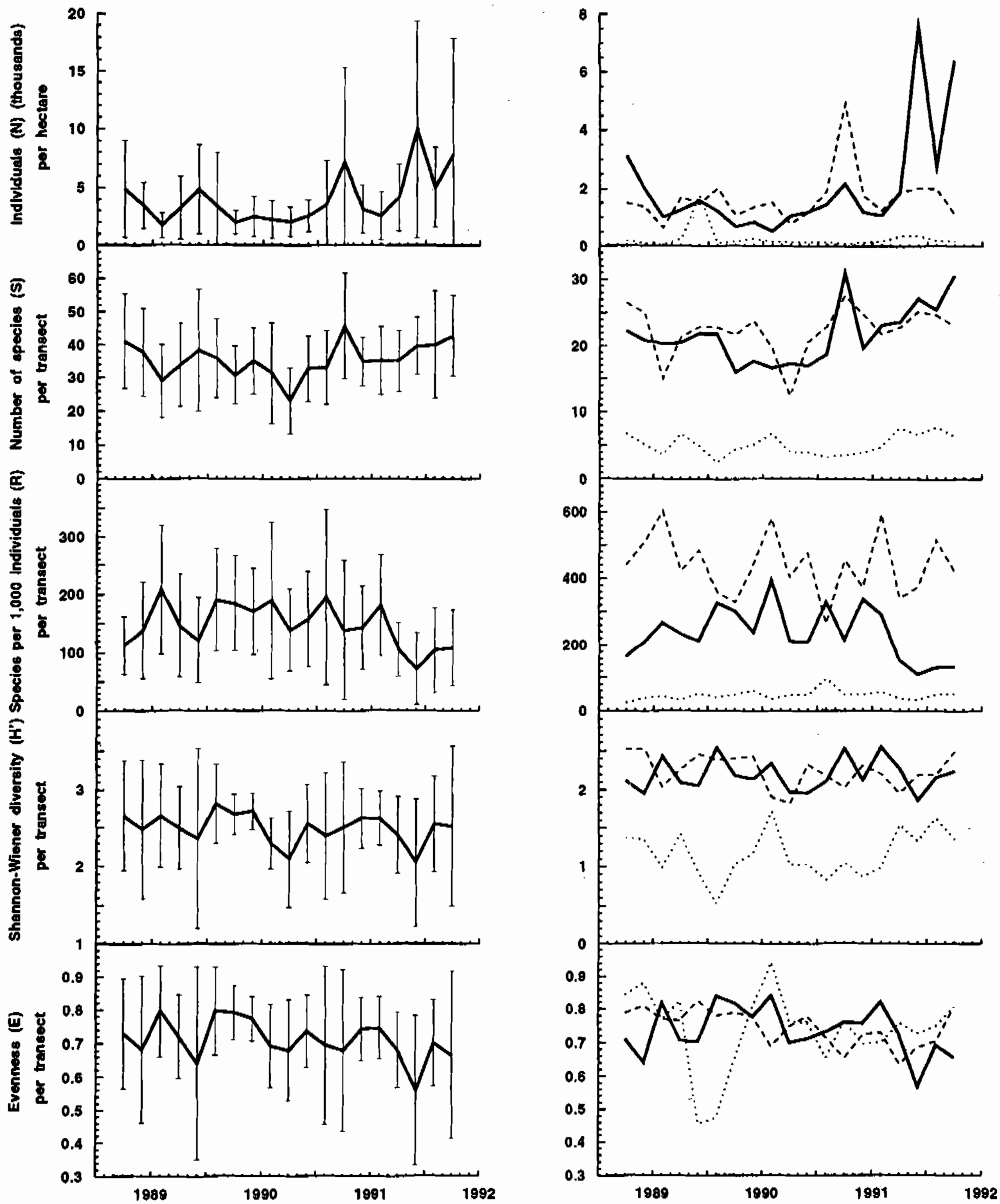


Fig. 4.4. Reef flat fish abundances and diversities by transect from six transect sites. Vertical bars are 95% confidence intervals (left: all life stages; right: by life stage where black = recruits, dashed = subadults and dotted = adults).

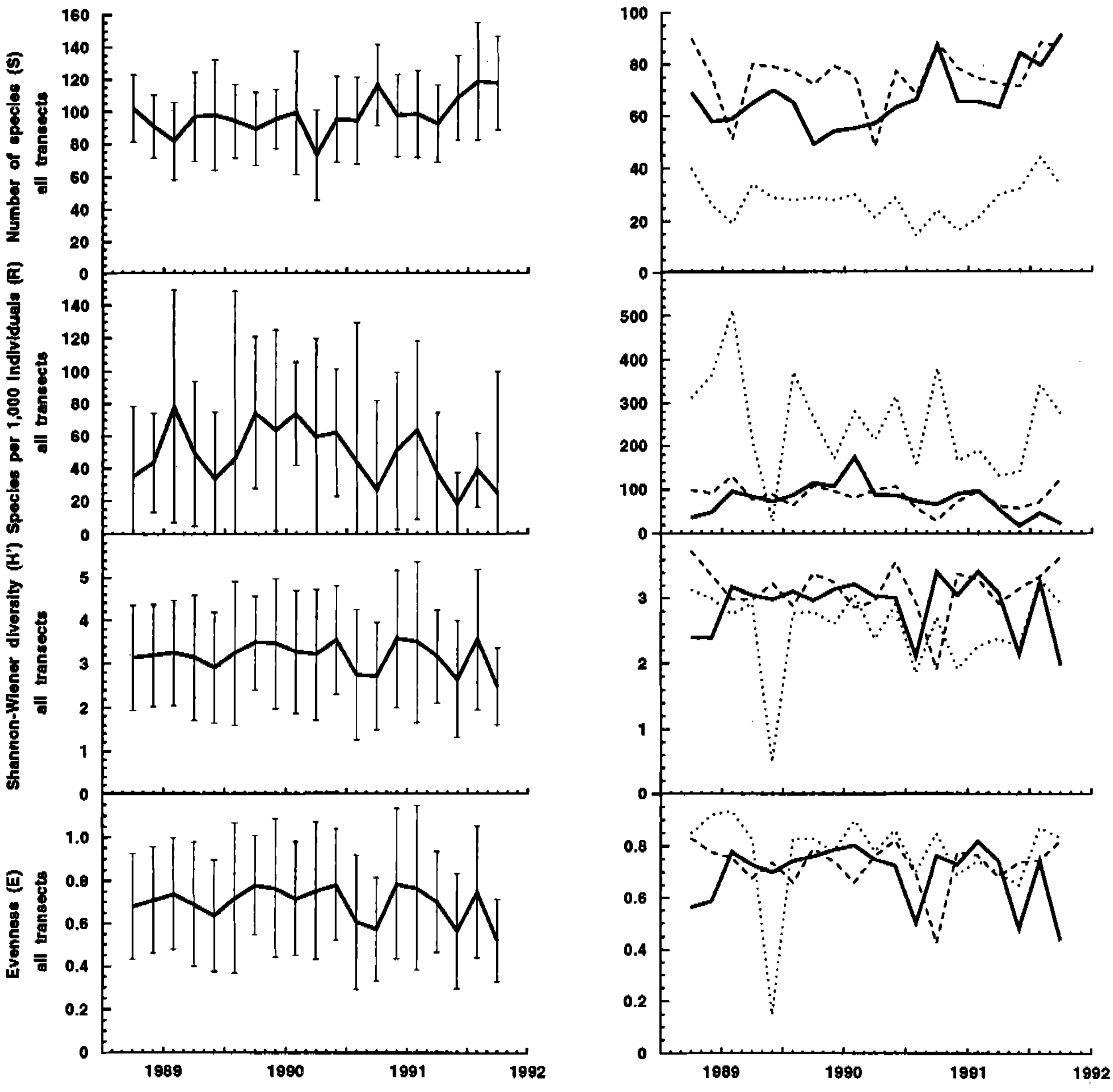


Fig. 4.5. Reef flat fish diversities for combined transects. Vertical bars are 95% confidence limits determined by jackknifing among sites (left: all life stages; right: by life stages where black = recruits, dashed = subadults and dotted = adults).

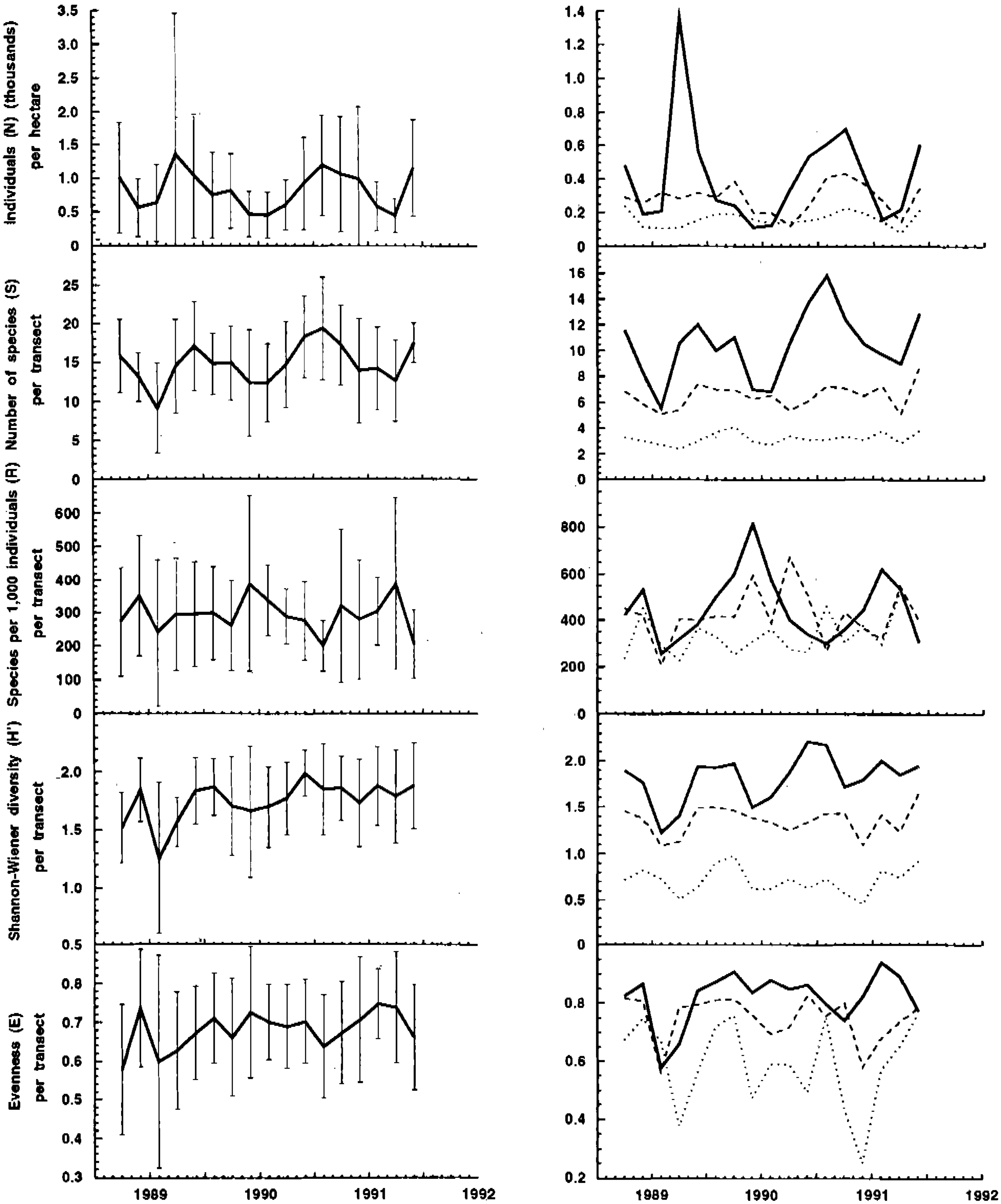


Fig. 4.6. Reef flat fish abundances and diversities by transect from 7 roller trawl sites. Vertical bars are 95% confidence limits computed conventionally (left: all life stages; right: by life stage where black = recruits, dashed = subadults and dotted = adults).

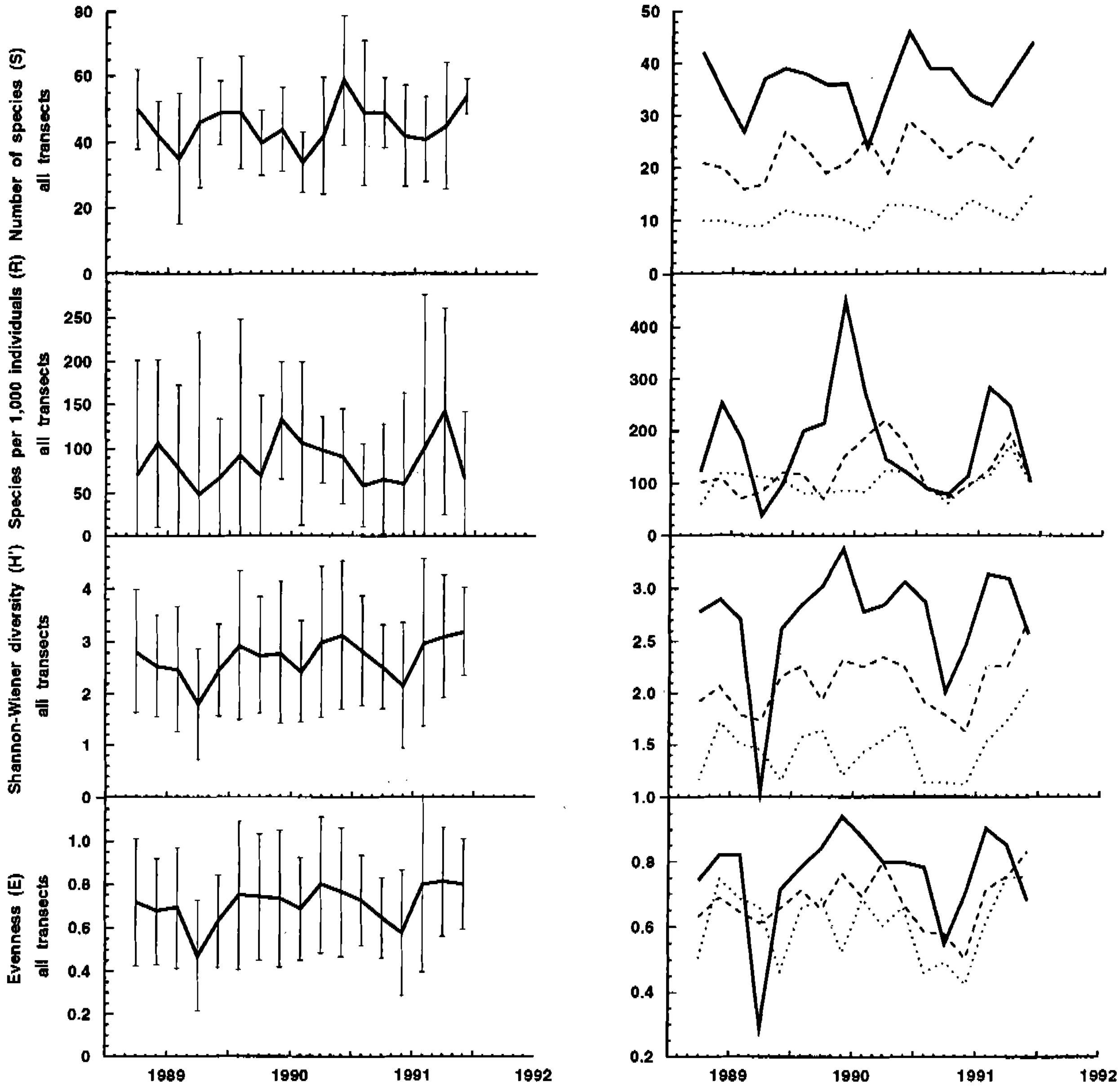


Fig. 4.7. Reef flat fish diversities for combined trawl sites. Vertical bars are 95% confidence limits determined by jackknifing among sites (left: all life stages; right: by life stages where black = recruits, dashed = subadults and dotted = adults).

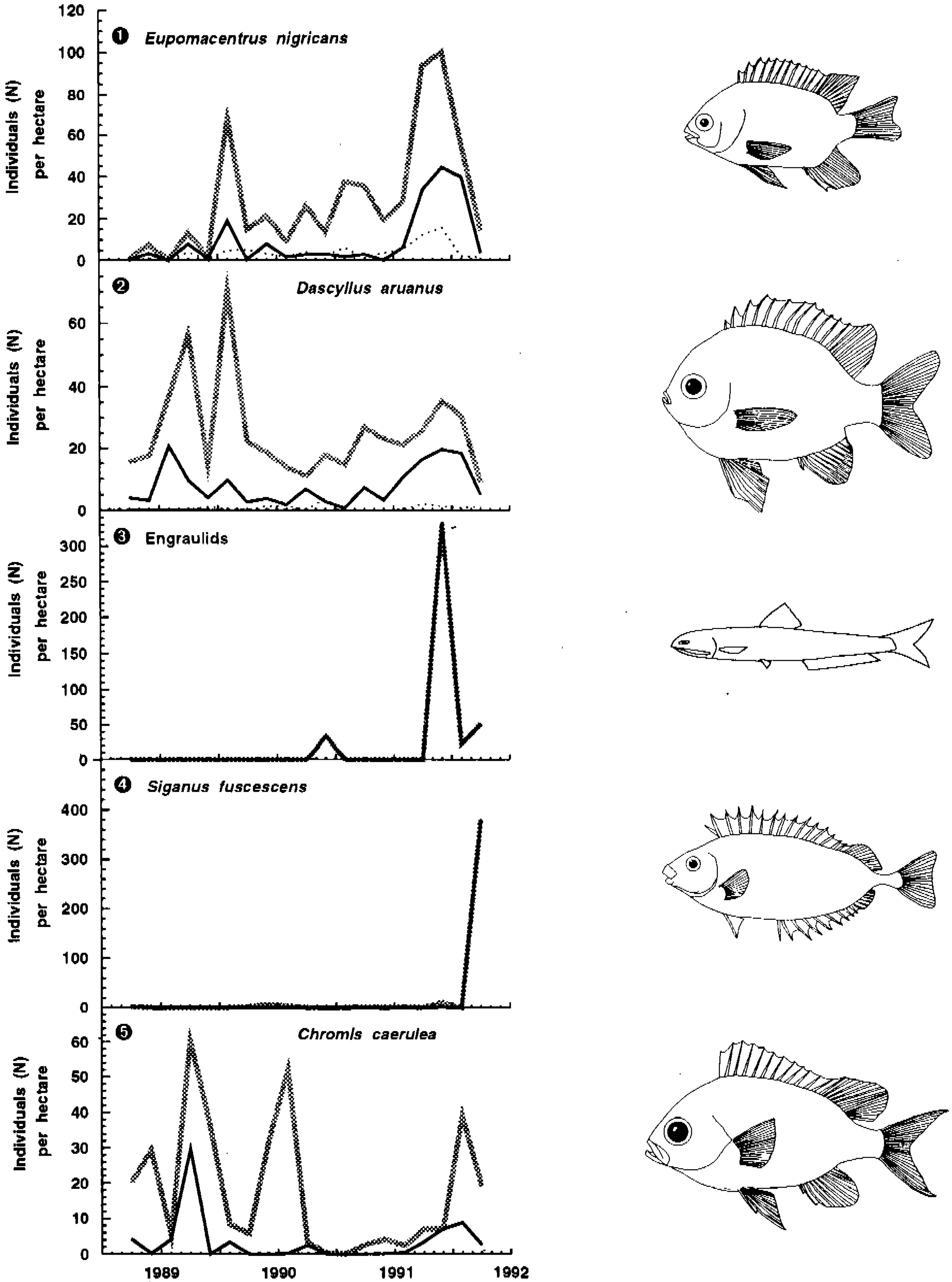


Fig. 4.8. Abundances of top species from the reef flat visual transects conducted during the day (grey = combined sizes, black = recruits, dotted = adults). Fish drawings are by Magnus Olsson-Ringby and J. McManus. Pictures next to unknown species are generalized for the taxa.

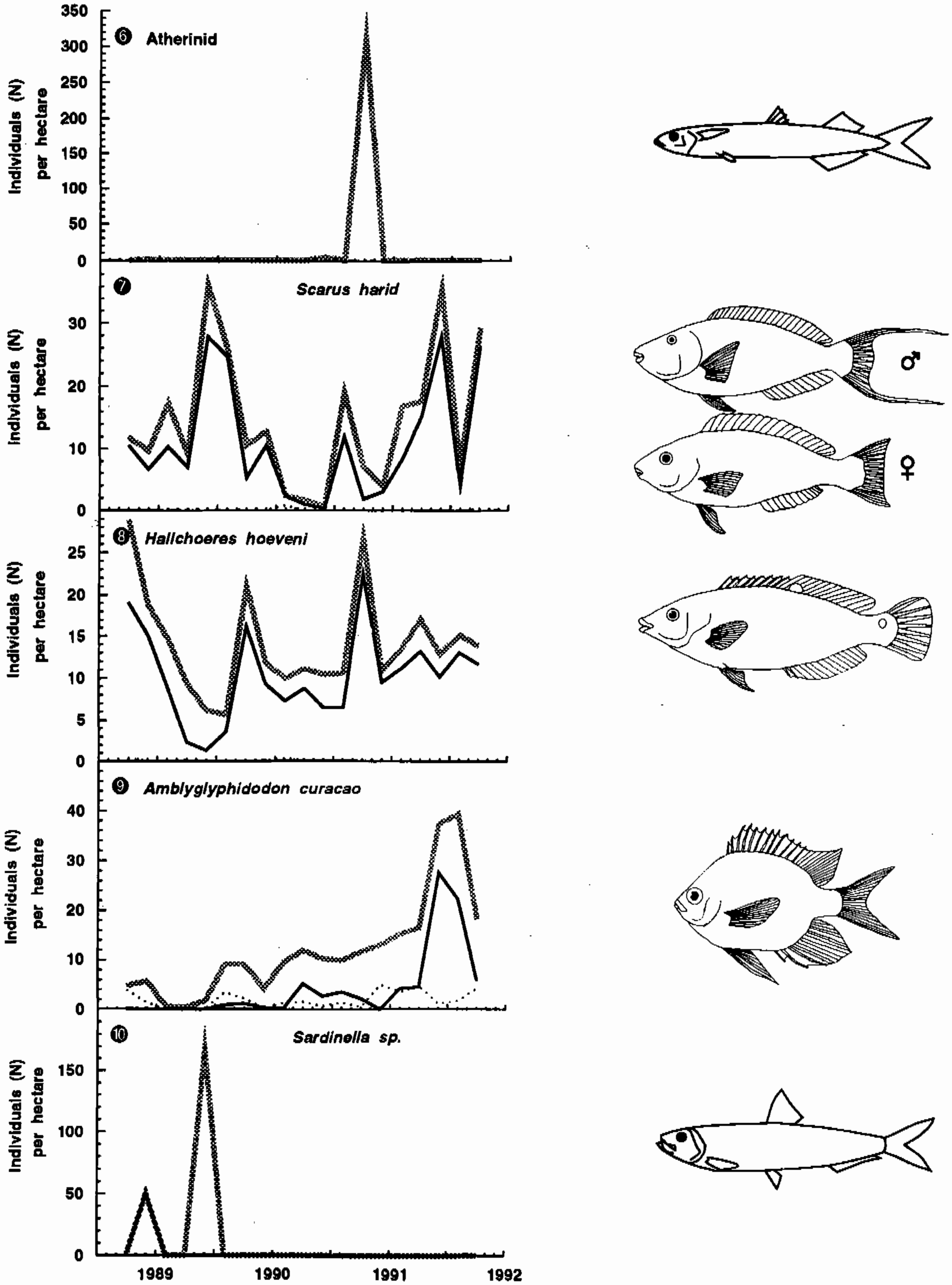


Fig. 4.8 (Continued)

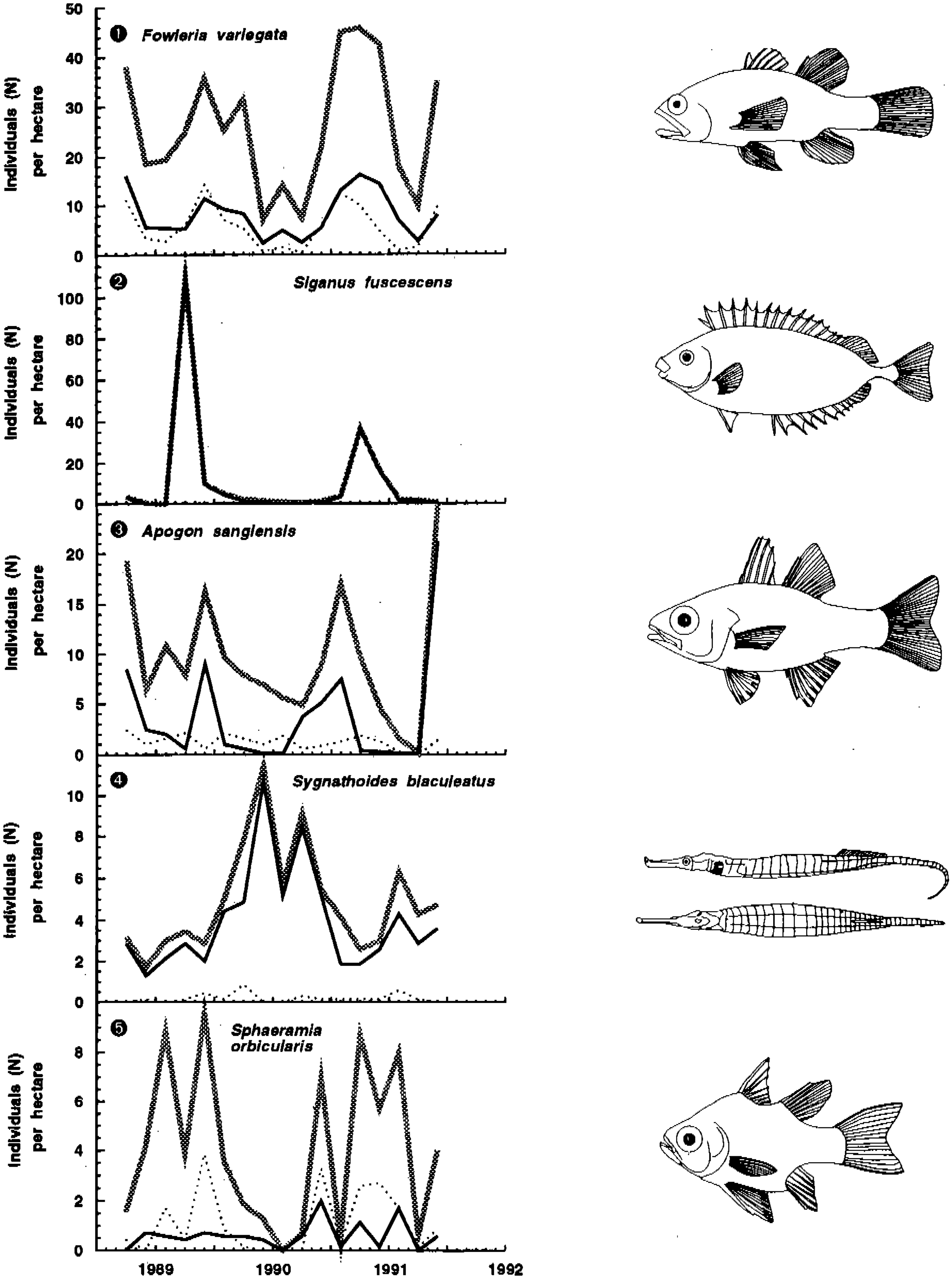


Fig. 4.9. Abundances of top species from the reef flat trawl collections made at night in the seagrass of the reef flat (grey = combined sizes, black = recruits, dotted = adults). Fish drawings are by Magnus Olsson-Ringby and J. McManus. Pictures next to unknown species are generalized for the taxa.

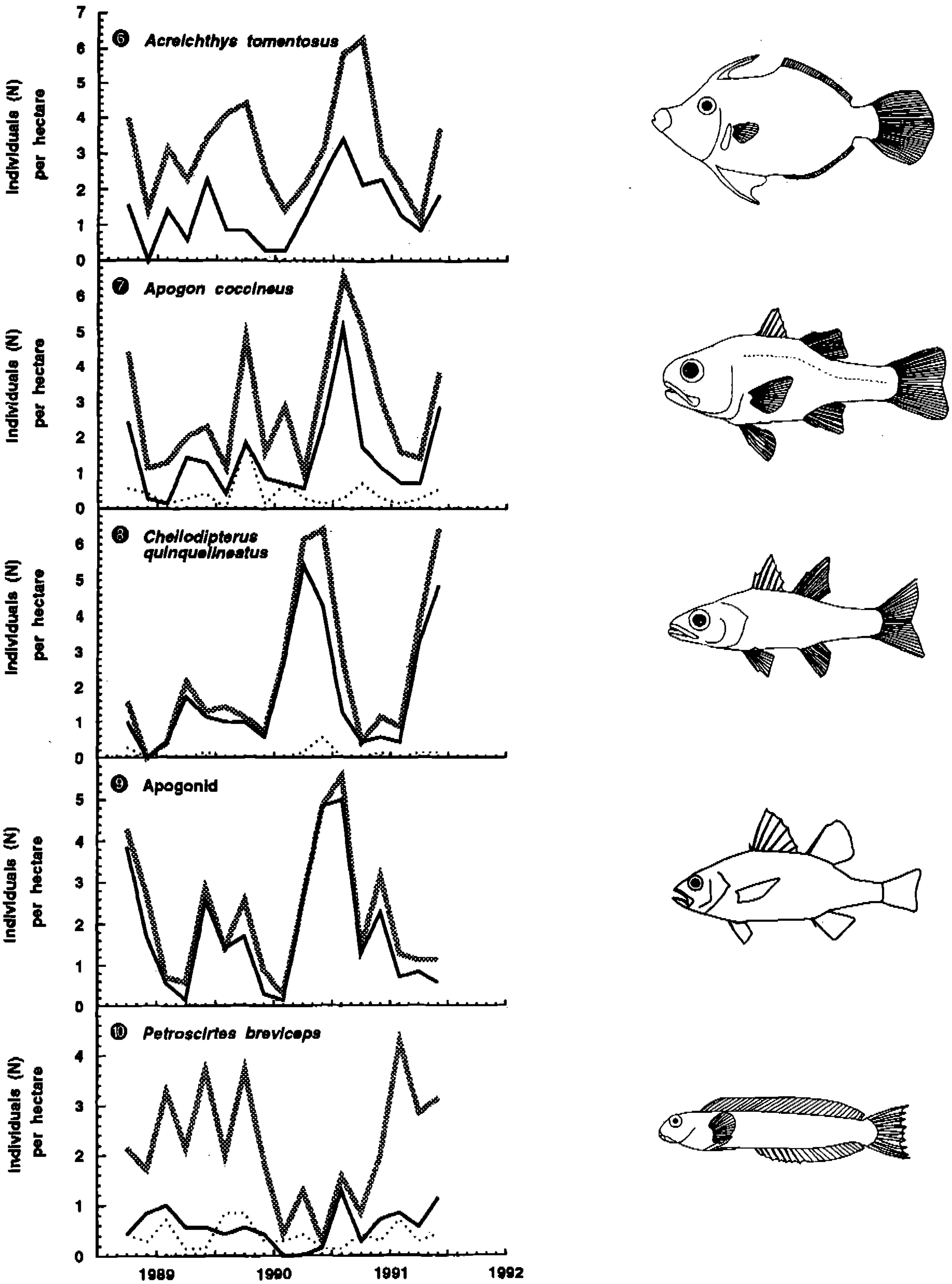


Fig. 4.9 (Continued)

CHAPTER 5
REDUCING THE RATE OF EXPLOITATION

General

In broad terms, the reason for the poverty level among the harvesters of Bolinao is the open-access nature of the fishery combined with a lack of alternative employment (see Smith 1979). This can be summarized simplistically here. In a new fishery, increasing levels of fishing effort yield increasing incomes to a point, beyond which further amounts of fishing result in diminishing total gross returns (Fig. 5.1). If we assume that a constantly rising cost is associated with a rising level

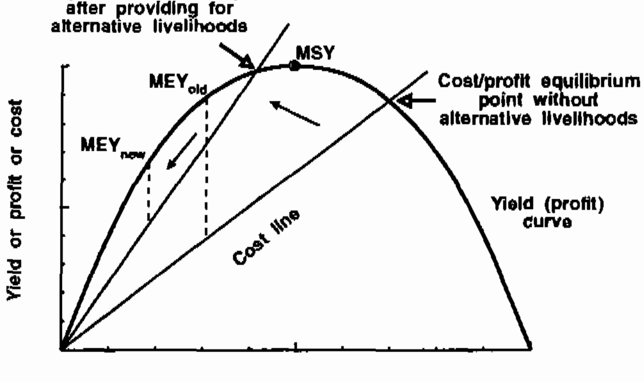


Fig. 5.1. Fixed price model for profit and cost in an open-access fishery. People tend to enter the fishery until profits are reduced to near the cost of fishing. If alternative livelihoods are available, the potential profit creates an additional "opportunity cost" to fishing, and the equilibrium point is pushed back to more desirable levels.

of fishing, then the most desirable fishing level for most situations is that at which net yields (i.e., profit minus cost) are maximized. That point (maximum economic yield -- MEY) usually occurs to the left of the top of the gross profit curve (maximum sustainable yield -- MSY). However, in an open-access fishery where virtually anyone can join in, the number of fishers increases until the average net returns are comparable to those that people could get from other types of employment. In the Philippines, there is very little choice of occupations for those with limited training and investment capital. Unemployment tends to be high, and there is no compensation for the average unemployed laborer. A marginal income is better than no income. There is thus a tendency for increasing numbers of people to enter a fishery until the average person in the fishery is making no more than a marginal income. This is particularly the case in fringing reef systems where a person can harvest with little or no initial investment.

This type of "bionomic equilibrium point" fishery (Smith 1979; Stevenson et al. 1982; Clark 1989) is not ecologically sound because harvests tend to be far beyond those which are sustainable in the long term. Furthermore, the best short-term competitive strategy for the **individual** fisher is often to find ways to cut costs at the expense of the **community** of fishers. For example, the fisher might begin using blasting devices to harvest more fish cheaply. This may improve individual profits until the practice becomes widespread. Then the resources will once again be exploited to the point of minimal returns -- at a new equilibrium point lower on the gross profit curve than before. This practice does considerable harm to the resource itself in the long run.

An alternative way of cutting costs is to give low-interest loans to the fishermen to "improve their gear". This again is a short-term solution (usually with short-term political benefits to those who arranged for the loans). The fishermen generally increase effort again until marginal incomes are the norm. Giving loans to fishers who are in an overfished situation usually makes the situation worse. The net result will actually be *less* catch in the long run, despite increased effective effort. Additionally, the ecosystem may be pushed into a state of less resilience to stresses and perturbations, natural- and human-induced, to which it is periodically subjected.

Reducing fishing effort

There is good reason to believe that fishing effort should be reduced by at least 60% from the current level and maintained that way in the future, i.e., at least 60% of the fishers and gatherers must leave the fishery (see technical box).

In cases such as this, the general solutions to the problem include:

1. offering unemployment compensation to potential fishermen, which is not usually economically feasible in the Philippines;
2. taxing the fishery to raise the cost of fishing, thereby protecting the ecosystem and stabilizing the resource supply -- this would leave many fishermen jobless, and is not a realistic solution for most coastal fisheries;
3. forcing people out of fishing, which would be difficult to achieve, considering that most people locally view fishing as an inalienable human right -- this would also lead to an unacceptably high level of unemployment; and
4. providing viable alternative forms of employment *and* slowing down population growth.

The last solution is the most reasonable. Starting a series of local industries alone would only be a short-term solution. It is unlikely that such industries could keep up with the currently rising population growth rate for long. Efforts must be put into both alternative job development and family planning to change the scenario described above for the immediate future of Bolinao.

The alternative livelihoods would offer profits which the fisher must "pass up" in order to fish. This cost of opportunity lost, "opportunity cost", must be considered by the fisher in deciding whether or not to continue harvesting. The opportunity cost is effectively added on to the cost of fishing. The "absolute cost" of fishing does not change, but the total cost of fishing rises, forcing the equilibrium point back to more desirable levels (Fig. 5.1). Ideally, harvesters would then leave the fishery until the available net profit to be made by each remaining fisher meets or exceeds that which could be made from the alternative livelihood. However, other factors, such as job desirability or the need for training must be accounted for. Furthermore, the alternative livelihoods should be profitable enough that the fisher family could allow children to attend school rather than work. Improvements in local school facilities would also encourage greater attendance, and ultimately improve occupational mobility.

Types of overfishing

At least four types of overfishing have been identified internationally: growth, recruitment, ecosystem and Malthusian overfishing (Pauly et al. 1989). Growth overfishing involves harvesting in such a way that the mean size of the fish captured is suboptimal for providing effective yields from a fishery -- i.e., the *yield per recruit* is not optimal (Beverton and Holt 1957). Recruitment overfishing occurs when the fishing effort is so intense that the process by which the fishery is restocked through reproduction and resettlement is impaired (Ricker 1954, 1975; Schaefer 1954, 1957). Note that this would be most likely to occur when overfishing occurs on such a wide scale (hundreds to thousands of kilometers of coastline) that the "stock" or subpopulation providing the recruits is broadly affected (Sinclair 1988). Ecosystem overfishing causes a shift in community structure from a fishery dominated by valuable species to one dominated by species of less economic value or utility (Pauly 1979).

Malthusian overfishing (Pauly et al. 1989; Pauly 1990) was named after the Rev. I.R. Malthus (1766-1834), who clearly demonstrated that the exponential rise of human populations was a cause for concern. The definition of the overfishing condition is as follows (Pauly et al. 1989):

> *Malthusian overfishing* occurs when poor fishermen, faced with declining catches and lacking any other alternative, initiate wholesale resource destruction in their effort to maintain their incomes. This may involve in order of seriousness, and generally in temporal sequence: (1) use of gears and mesh sizes not sanctioned by the government; (2) use of gears not sanctioned within the fisherfolk communities and/or catching gears that destroy the resource base; and (4) use of "gears" such as dynamite or sodium cyanide that do all of the above and even endanger the fisherfolks themselves.

All forms of overfishing are apparent in the Bolinao fishery. The fish in the markets are generally small subadults. Adult fish are scarce on the reef slope. The fishery produces relatively low yields on the reef slope, and fish populations throughout are far below what would be expected in a natural reef or one in a region fished optimally from a recruitment standpoint. The large schools of milkfish (*bangus*), mullet (Mugilidae) and other valuable species which historically had congregated in the area have nearly disappeared (Quintin Caasi and others, pers. comm.). Finally, the environmentally and self-destructive fishing methods which abound are clearly symptoms of Malthusian overfishing. The strong causal relationship between poverty and this form of overfishing indicates that the most suitable corrective approach is an economically based one. This reinforces the conclusion that the most appropriate means for reducing fishing pressure would be an effective program of alternative livelihood development.

How Much Harvest Effort Should There Be?

John W. McManus

GENERAL

In some studies, it is possible to produce quantitative curves for determining the relationships among yield, cost and effort. Doing this requires that a broad range of information on the relationships is available. This may be obtained by monitoring a fishery from inception to an advanced state. Alternatively, if data on a series of similar reefs are available, including those subject to a broad variety of effort levels, then the curves can be constructed quantitatively (Munro and Thompson 1983). In either case, it is possible to assess the current status of yield, cost and effort, and to estimate the appropriate level of harvest effort (e.g., number of boats per day) necessary to maximize profits and ensure the longevity of the resource.

In cases where this information is lacking, a more indirect route may be necessary. One approach would be to use some methods such as length-frequency analysis on some key species to determine if a system is overfished (Munro 1986). One could then reduce effort arbitrarily to a certain level or to an estimate of the effort which would reduce the ratio of fishing mortality over total mortality to less than 0.5, or a more precisely estimated value based on yield-per-recruit analysis (Gulland 1983; Pauly 1984; Sparre et al. 1989). One could then reassess the situation two or three years later, and readjust effort accordingly. This is feasible because the monthly data on the lengths of 30-50 fish can be gathered by a single worker as part of other duties, such as managing a marine reserve or collecting fishery statistics. No matter what course of management action is taken, it would always be wise to provide some minimal follow-up assessment and to assume from the start that regulations will need readjustments every few years. However, it would be helpful to determine a "rule of thumb" for making an initial assessment of necessary effort adjustments.

YIELD/EFFORT CURVES

There are three fundamental shapes for a yield/effort curve (Pella and Tomlinson 1969; Cushing 1981) which I shall refer to as symmetrical (Fig. 5.2), right-skewed (piled to the left, Fig. 5.3), and left-skewed (piled to the right, Fig. 5.4). The left-skewed curve implies that in the initial fishery, small increases in effort lead to small increases in catch until an optimum is reached, beyond which yield falls off more abruptly. This does not seem to be true of some coral reef fisheries, where initial efforts produce rapidly accelerating yields until a maximum, beyond which yield

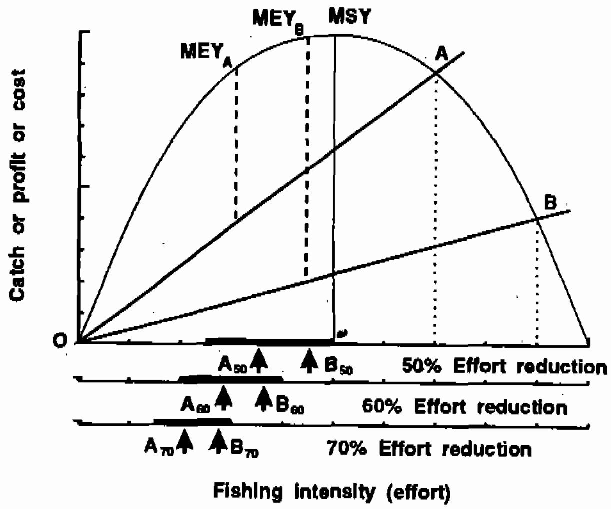


Fig. 5.2. Symmetrical production curve. Bars represent possible ranges for effort reductions; arrows represent reductions from the indicated equilibrium effort levels. An effort reduction of 60% would be appropriate for the low-cost fishery (B) and conservative for the high-cost fishery (A).

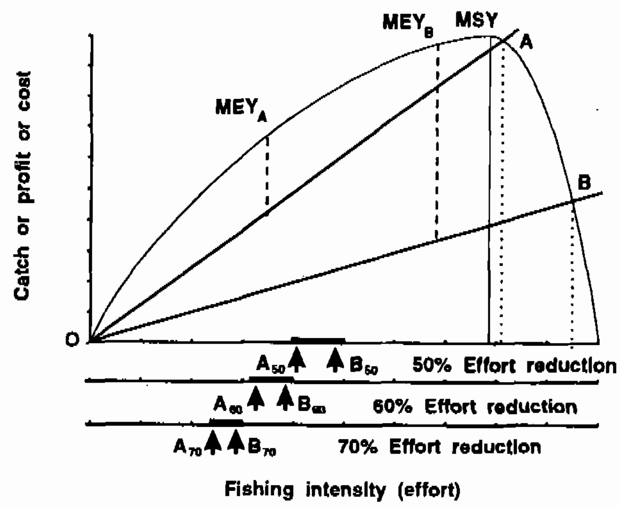


Fig. 5.4. Left-skewed production curve. An effort reduction of 60% is appropriate for the high-cost fishery (A), but is conservative for the low-cost fishery (B). A reduction by 60% in the absence of information on the nature of the curve could serve to help establish the type of curve, permitting more optimal effort levels to be set later.

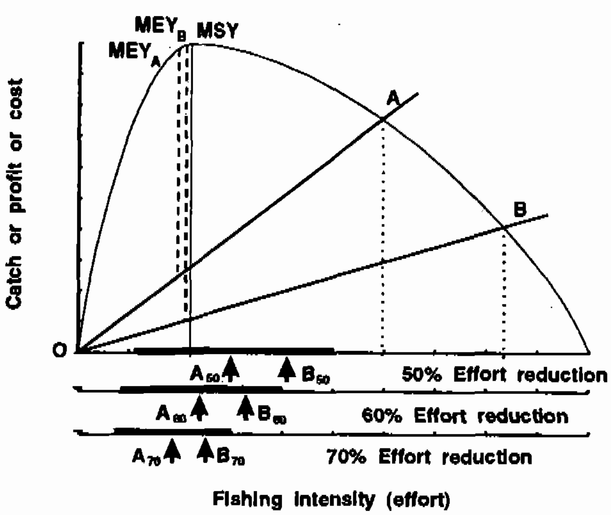


Fig. 5.3. Right-skewed production curve. Cost lines are the same as those in Fig. 5.2. Note that both points A and B fall more than 2.5 times the effort at MSY. A reduction of 70% or more may be optimal in such extreme cases.

appears to taper off slowly, delayed by the fact that species tend to replace each other as they decline in abundance (Figs. 5.5-5.7). This scenario would fit a symmetrical to right-skewed curve.

We now make six assumptions which are valid in our case:

1. The fishery is open-access.
2. An excess, unemployed labor force is willing to enter the fishery as an occupation.
3. There is no formal or informal unemployment compensation which would keep people from wanting to work hard for marginal returns.
4. No noneconomic social force limits entry into the fishery.
5. There is a large demand for fish.
6. The system has been operating under the above factors for a few years.

From this we can conclude that such is an "equilibrium point" fishery operating near the point at which costs are almost equal to yields. This is confirmed in our case by the fact that stocks of fish are declining and incomes are marginal among the harvesters.

Knowing that the equilibrium point generally falls to the right of the top of the curve (MSY), and that the most desirable point for a fishery is somewhere to the left of MSY, we can observe the effect of arbitrarily choosing a reduction of 60% on a variety of curves (Figs. 5.2-5.4, 5.8-5.10). As can be seen, a 60% reduction in effort from an equilibrium point never exceeds MSY unless the yield curve is so strongly skewed to the right and the cost of fishing so low that the initial effort level (at the equilibrium point) is 2.5 times greater than the effort at MSY.

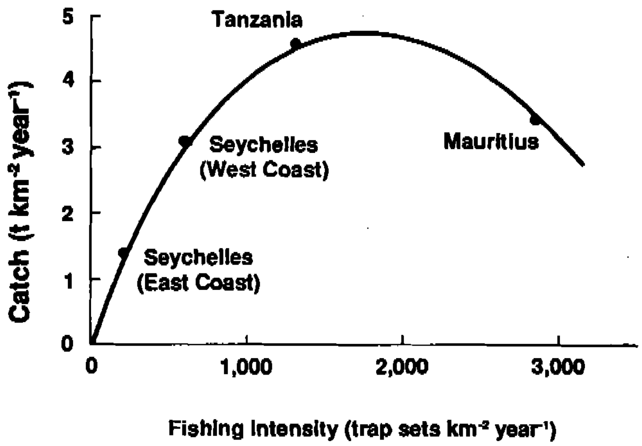


Fig. 5.5. Plot of coral reef fish catch vs. fishing intensity in western Indian Ocean sites (redrawn from Gulland 1979).

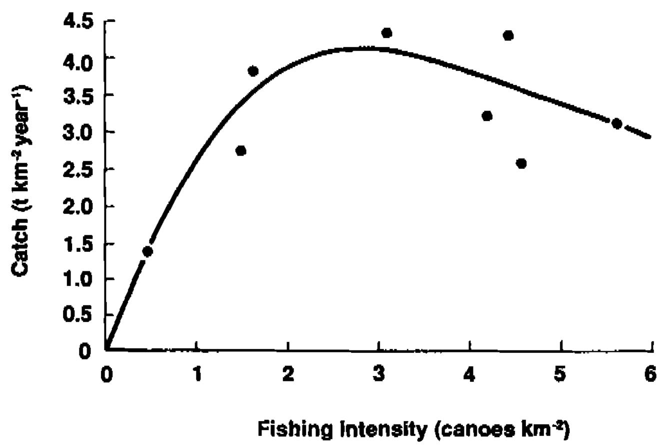


Fig. 5.6. Plot of coral reef fish catch per area vs. fishing intensity for 8 parishes around Jamaica (redrawn from Munro and Thompson 1983).

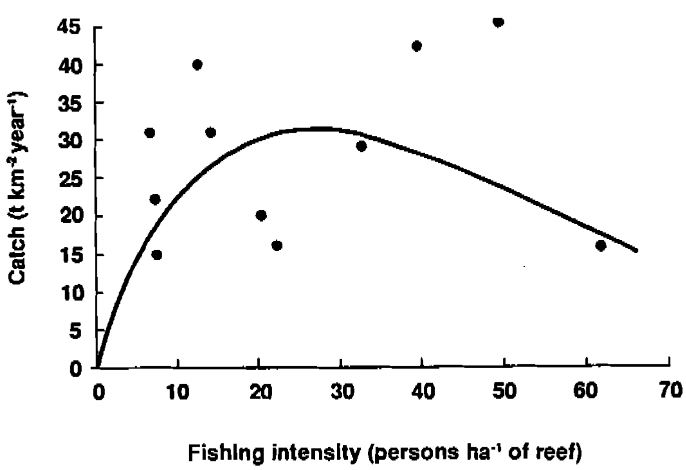


Fig. 5.7. Plot of coral reef fish catch vs. fishing intensity for 11 American Samoa villages (redrawn from Munro and Williams 1985). Note that the shape of the curve cannot be determined from the available data.

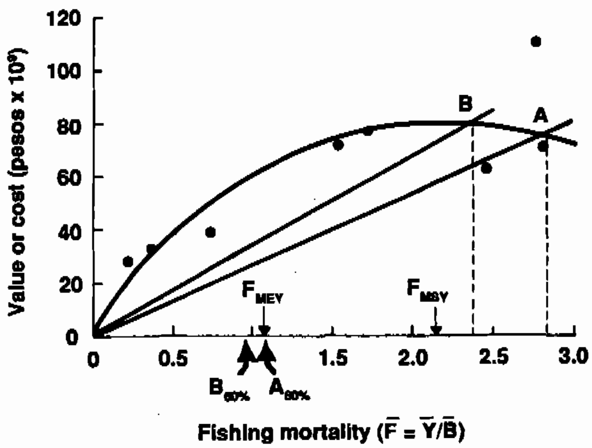


Fig. 5.8. Fixed price model for trawl fishing in Manila Bay. The optimal effort reduction was approximately 60%. Points represent yearly values progressing from left to right (redrawn from Silvestre et al. 1987).

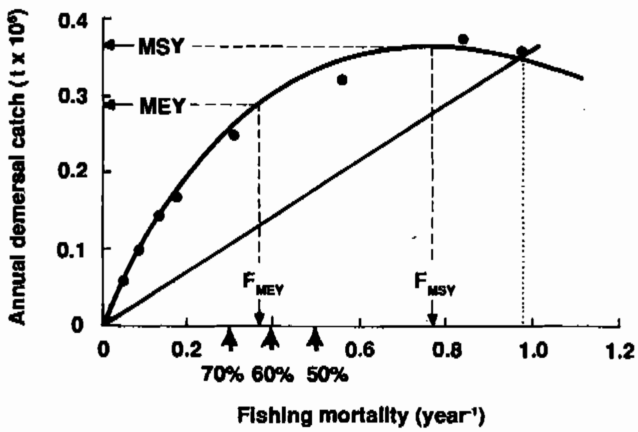


Fig. 5.9. Fixed price model for the overall Philippine demersal fisheries ($t \times 10^6$). The optimal effort reduction was approximately 60%. Points represent groups of annual catches (left to right) from 1946 to 1984 (redrawn from Pauly and Chua 1988).

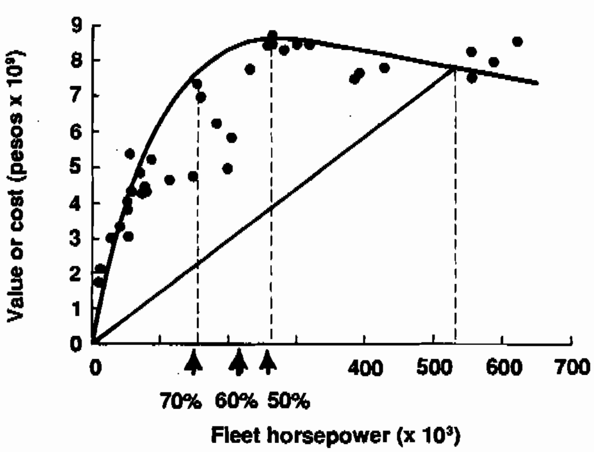


Fig. 5.10. Fixed price model for Philippine pelagic fisheries. The suggested effort reduction was 70%. Data points progress generally from left to right, representing the years 1948 to 1985 (redrawn from Dalzell et al. 1987).

If one chooses a 60% reduction in effort and the unknown curve is:

1. symmetrical -- the estimate will be conservative for a very low-cost fishery (B_{60} in Fig. 5.2), and close to the effort leading to the MEY (E_{MEY}) point otherwise (A_{60} in Fig. 5.2).
2. **right-skewed** (piled to the left) -- the estimate will be close to E_{MEY} for a low-cost fishery as long as the equilibrium effort is less than $2.5*E_{MSY}$. In extreme cases where the effort at equilibrium is greater than $2.5 \bullet E_{MSY}$, a reduction of 70% or more may be optimal (Fig. 5.3).
3. **left-skewed** (piled to the right) -- the estimate will be conservative, i.e., to the left of E_{MEY} and E_{MSY} for a low-cost fishery (B_{60} in Fig. 5.4) and close to E_{MEY} for a high-cost fishery (A_{60} in Fig. 5.4).

Note that the lower the cost of the fishery, the closer MEY approaches MSY. Thus, we must trade off between favoring high net profits and being conservative enough to be certain of being to the left of MSY in case the curve is strongly skewed.

Being conservative is a useful property because:

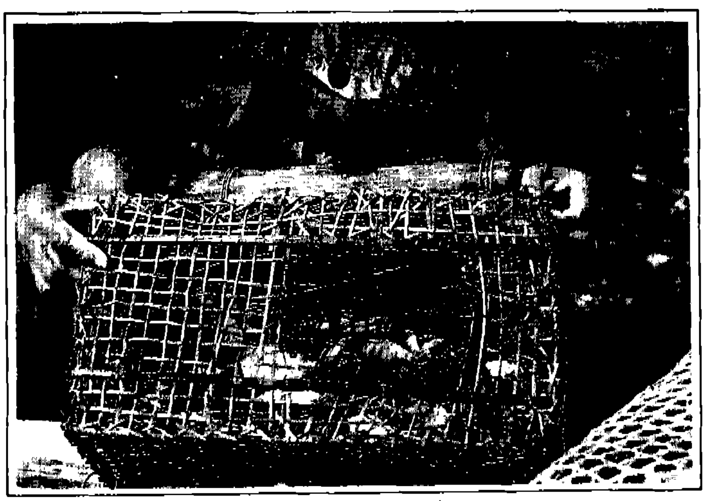
1. schemes to reduce the effort may not work to 100% effectiveness;
2. the total yield may not be precisely optimal, but the catch rate (CPUE) per fisher will be markedly better and this will have a beneficial effect locally;
3. populations tend to rise, and with them, the pressure to find work for more fishers will increase; and
4. having now established an experimental point to the left of the left of MSY, a better estimate of the shape of the curve and appropriate adjustments can be made in subsequent years.

(1) Rake net used to collect shells and small fish from seagrass beds.
(2) Seagrass and branching coral (*Acropora*) on the reef flat.

(3) Sea urchins (*Tripneustes gratilla*) from the reef flat. The gonads are sold as food. A diver's foot paddle is shown on the right.

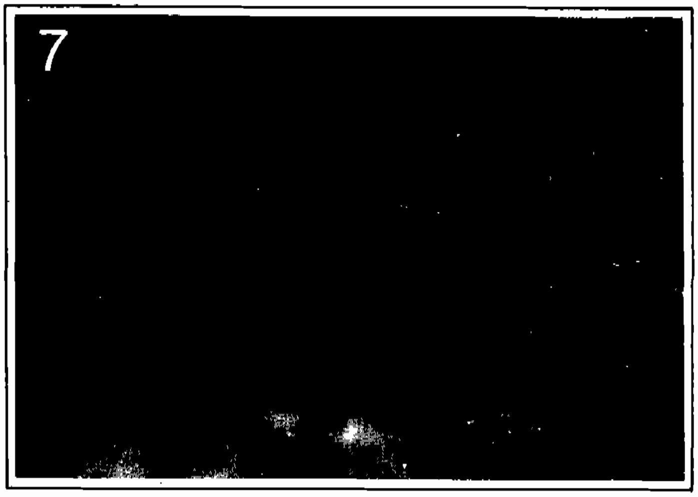
(4) Small fish captured by gillnet on the reef flat. The average size is 10-15 cm. Gillnets are very size-selective and can be designed to catch larger fish if they are abundant.

(5) Fish trap camouflaged with corals. Fish enter through the funnel and have difficulty finding the exit once inside. The wicker construction lowers cost and limits long-term fishing once lost.

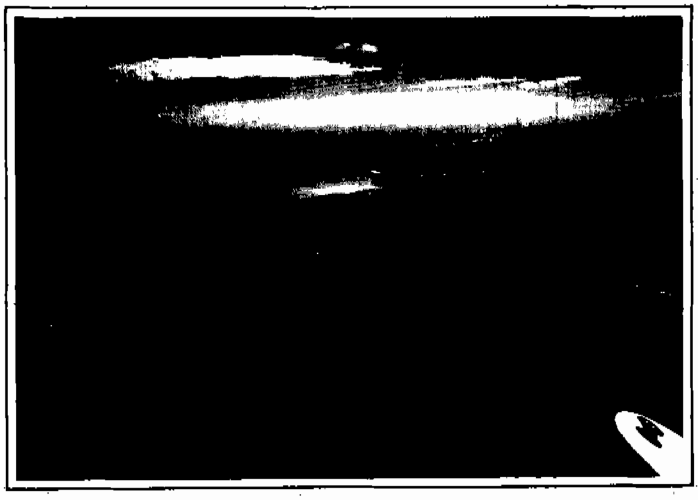


(6) Creel opened to reveal several captured species. The small sizes are typical of local catches.

(7) Anchor designed to catch on corals. Anchor damage can be avoided in a marine reserve/park by establishing permanent moorings.



(8) Research aides Elmer C. Dumaran and Fernando I. Castrence, Jr. measure fish at a landing site. Locally hired personnel are essential to maintaining open lines of communication with villagers.



(9) Portion of reef flat (foreground) recommended for a marine reserve. A reserve would greatly improve local harvests of fish and invertebrates. Sea turtles occasionally migrate through Malilnap Channel on the left to Pisalayan Point on the right.

(10) Spear guns are carved from wood, and are powered by rubber strips. The spear is often a bicycle spoke. (11) Gillnetter slaps the water to frighten fish into the net.

(12) Close-up of a fish corral. Fish become trapped in successively smaller heart-shaped chambers.

CHAPTER 6
A PROPOSED MARINE RESERVE/PARK SYSTEM

General

The most reliable means available for enhancing resource production and sustainability on the reef would be to set aside a substantial portion of the reef system as a nonfishing area (Russ 1985; Alcala 1988). This site would serve as a protected breeding ground, migration route and nursery which would allow fish, invertebrates and seaweeds to maintain natural population levels unperturbed by human activities. The area would permit recruited fish to reach larger sizes before being caught. The migrations and other movements of adult fish out of the reserve area as populations grow should enhance catches by low-investment, size-specific gear such as gillnets, thereby reducing the problem of growth overfishing. Additionally, many species of harvested invertebrates and corals with short plankton stages are likely to be highly dependent on local adult populations for their recruitment, and the young of these species would continually enhance the population levels throughout the reef system. Finally, a system of such reserves along the southwestern coast of Luzon would probably enhance the recruitment of reef fish and invertebrates with long planktonic residence times.

The fact that a marine reserve can substantially enhance fishery yields in adjacent areas has been well demonstrated in a series of studies conducted in the Central Philippines (Alcala 1988; Russ and Alcala 1989; Alcala and Russ 1990). A marine reserve had been established in 1974 for Sumilon Island by the nearby municipality of Oslob, Cebu. The reserve constituted approximately 25% of the coralline areas around the small island. In 1984, a change in local government led to a breakdown of protective management. Fishing was reintroduced to the reserve areas, and the range of gear was extended to include habitat-destructive techniques such as blast fishing and muro-ami. In the latter method, corals are broken by large rocks on lines as fish are driven into nets. Both the total fish production of the island and the daily catch per fisherman dropped by more than 50%. This drop occurred despite the fact that the fishing area increased in size once the reserve was abolished. This clearly shows that a reserve can be an effective way of enhancing fishing yields and individual profits.

Prior experience has shown that the chances for success in the establishment of a marine reserve are greatly enhanced if there is a substantial involvement at the village level in the planning and implementation stages (Casteñeda and Miclat 1981; White 1986; McManus et al. 1988; McManus 1988). There are now more than eight municipal marine reserves and parks in the Philippines (Alcala 1988; Wells 1988). Several of these have been successful enough to foster the reestablishment of dense populations of large reef fish, which have not only increased fishing yield, but also generated substantial municipal income by serving as tourist attractions.

Presented here is a rough outline for a potential marine reserve and park system which is designed to enhance local harvests and incomes from the Bolinao Reef Complex (Fig. 6.1). Many

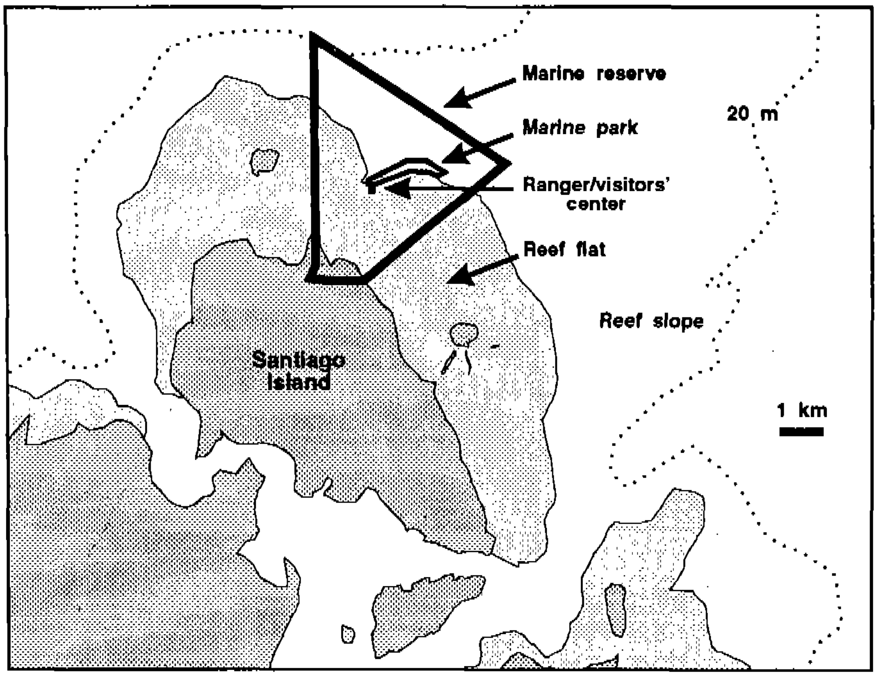


Fig. 6.1. Proposed marine reserve and park system. The area has been chosen to encompass most of the range of habitat types, and is expected to substantially enhance yields of fish and invertebrates throughout the reef. The park would generate income and enhance the tourist trade to provide alternative livelihoods for reef harvesters.

details of management and implementation will depend on future action of the local municipality. The role of the ecologist can include:

1. clearly establishing the fact that the reef resources are being seriously depleted and that timely, effective action is necessary to ensure future sustainability;
2. determining an optimal location, shape and size for the reserve to ensure that all critical habitats and migration routes are included which are necessary in the life cycles of commercially important species, and the associated organisms on which they depend;
3. presenting a general scenario for how such a management scheme could be operated, as a basis for further refinement;
4. presenting the recommendations to the local government for appropriate consideration and action;
5. serving as consultants during the planning and implementation stages to provide ecological analyses of details and modifications to the plan as it develops; and
6. using future ecological and fishery data to evaluate the effectiveness of the plan as it is implemented, and suggest modifications and refinements as it proceeds.

The need for a reserve

The major factors which establish the need for a reserve can be summarized as follows:

1. The densities of fish on the reef are more than one order of magnitude below those found in reefs subject to low fishing pressures.
2. Numbers of adult fish on the reef slope have declined sharply in three years, although fishing pressure was fairly constant. The number of species reaching adulthood has declined by nearly 33%. Fishers are maintaining harvest rates by turning to progressively smaller fish. This practice cannot be expected to be sustained for long.

3. Coral cover in the lagoon is less than 40% of expected levels. An area of protection could be expected to support much higher densities of coral-dependent fish and invertebrates than are currently found. The migratory nature of many species and the dispersion of young fish could ensure a constant supply of both recruiting young fish and harvestable adult fish in other areas.
4. The large fish corrals tend to limit the numbers of migratory fishes which are able to reach sizes suitable for gillnetting and spearfishing. This results in a system which favors the harvest of small fish by sectors capable of higher than average investments. This occurs at the expense of economically restricted smaller-scale fishers whose harvest of adult fish would be more ecologically favorable. A properly located reserve area would ensure a dependable supply of adult fish which would favor the economically disadvantaged fishers.

The reserve/park system

GENERAL

The recommended reserve and park system is mapped in Fig. 6.1. The reserve consists of a four-sided section covering both reef flat and slope areas. The size of the park is limited to that which can be monitored visually on clear days from a small, central tower. A picturesque area near the center of the reserve has been set aside as a marine park, where tourist diving may take place. The rental of permanent mooring sites (and a ban on anchors) would generate income to support a rotating staff of rangers. These would be situated in a small station/information center on stilts at the park center along the exit channel connecting the reef flat and the reef slope. Boats would be permitted to pass through the reserve and park areas along marked channels. However, no anchoring or mobile harvest activities would be allowed anywhere in the reserve or park, except for scientific purposes (by permit) or emergencies. A system of fines and other legal penalties could ensure compliance. Fine collection could be assured by empowering the rangers to confiscate and hold boats or equipment until compliance. Funds collected could further support the ranger team.

SHORE HABITATS

Mangrove forests were once an integral part of the reef ecosystem. A small, uninhabited section of coastline beginning along the eastern side of Pisalayan Point has been set aside for replanting as a mangrove forest. What is illustrated is a very minimal area for this purpose, but it would at least assure a supply of common mangrove-dependent species for other mangrove forests currently being planted in less intensely managed areas nearby.

Pisalayan Point (from the word "egg" in the Bolinao dialect) was until recently a viable breeding ground for sea turtles. The reserve protects what is believed to be the major route of the turtles from the ocean to the beach on the eastern tip of the point. A program of turtle rehabilitation along that beach would be a major asset to the plan.

The eastern side of Pisalayan Point consists of a rough, rocky outcrop (ancient reef limestone) covered with dense brush. Large monitor lizards (*Varanus salvator*) and a variety of birds inhabit the outcrop and a few small rocky islands nearby. The preservation of these habitats would considerably enhance the diversity of protected organisms.

SEAGRASS HABITATS

The areas immediately to the north and east of Pisalayan Point are dominated by seagrass. Seagrass fish tend to be more widely dispersed than coral reef fish, thus maintaining minimal populations may entail setting aside proportionally larger reserve areas. The included areas of reef flat are by no means uniform. The seagrasses vary widely and abruptly in density and species composition. Large and small patches of sand, rock, coral and algae in various combinations are interspersed throughout the reef flat. Each particular combination of these bottom types supports a unique assemblage of fish and invertebrates. The fishery as a whole, and the shellcraft industry in particular, are highly dependent on the availability of a diverse range of species, which must be supported by a correspondingly broad range of habitat types (de Guzman 1990). The site outlined for the reserve includes representative areas of most of the habitats of the reef flat.

SEAWEED HABITATS

Significant stretches of the reef crest in the eastern portions of the reserve are dominated by *Sargassum* brown algae. This algae forms large beds which are scattered throughout the reef complex and support unique biotas. The reserve is designed to permit the enhancement of this type of biota. *Sargassum* is of commercial value, thus stocks of the seaweed may require preservation in the future.

The most important seaweed currently in the markets is *Caulerpa* (*C. racemosa, arosep*, and *C. lentillifera, butones*). This algae consists of berry-like structures on rhizomes, which form patches in areas of moderate wave and current action. Significant patches of this seaweed are included within the reserve area, principally along the north-facing reef crest in the eastern portions.

CORAL HABITATS

The area in the center of the reserve includes a lagoon which supported high densities of coral growth until about 1979 when blasting and cyanide diminished the stocks to a small living fraction. The sides of the lagoon still support a broad variety of lagoonal hard and soft corals and associated invertebrates. The large volume of tidal flushing in the lagoon, the abundance of hard substrate and the presence of seed populations of many coral species immediately beyond the lagoon on the reef slope result in a reasonable probability that rehabilitation will occur.

The lagoon opens into a very heterogeneous reef slope with considerable topographic relief. The walls and channels are covered in places with a high diversity of corals. Damage from blast fishing is particularly noticeable, but small recruiting coral colonies are found in abundance. This area would be a very effective attraction for tourist divers, particularly if feeding stations were established to maintain large, tame fish.

Our research confirms that depth is an important variable in the distribution of fish species (Nañola et al. 1990). The northern corner of the reserve has been extended into depths of over 30 m. The enclosed slope area therefore includes a broad range of depths and a correspondingly wide variety of fish species.

MIGRATION AND REPRODUCTION SITES

The placement of the eastern corner of the reserve is especially critical. The species ***Siganus fuscescens*** constitutes as much as **40%** of the fishery, and is important to the spearfishing, gillnetting and corral industries. The entire northeast sector of the reef flat is currently leased by the town to fish corral operators, and preferential sites are those which intersect the migration routes of this species. Analysis of corral catches indicates that the bulk of the outward migration of adult fish to offshore spawning grounds is through a narrow area along the reef crest. The eastern corner of the reserve has been placed at approximately the center of this area. Thus, the outgoing stocks will be divided into large portions for both potential capture (e.g., by fish corrals) and preservation.

Several studies have indicated that many coral reef fish prefer reef channels and high points of reef structure for reproductive activities (Sale 1980; Johannes 1981; Thresher 1984). The crest regions in the reserve north of the center are cut by several channels in a variety of sizes, and exhibit considerable structural relief. The major channel (Malilnap Channel) in the center of the reserve was known to serve as a major route for the entry and egress of large schools of transient reef species prior to 1980, and continues to be a favored blast fishing site.

Implications for fishery patterns

GENERAL

Important considerations in the construction of the reserve/park system are the existing system of territorial use rights in fisheries (TURFs) (Ferrer 1991), and existing traditional knowledge of fish distributions and behaviors (Lopez 1985). Both of these factors tend to be reflected in the current-day fishing patterns. The proposed reserve park system was developed to account for information on fish abundances and migrations, as indicated by the way particular gear are deployed, as well as to minimize the disruption to be caused by the sudden restriction of the fishing grounds. Further investigations into traditional knowledge and TURFs will be helpful in refining aspects of the design of the reserve/park system, as well as in guiding the approaches toward implementation.

A major advantage of the reserve is that no single major village dominates fishing in the area. Rather, fishers from several villages use the site to supplement fisheries in other parts of the reef. The fact that the area is a desirable fishing ground for a broad variety of gear is indicative of the heterogeneity and productive nature of the area. It is necessary that a reserve support organisms which are desirable to the fishers, otherwise it would not be easily justifiable. Therefore, some conflicts with existing use are inevitable. The important point is that the area should not, and in this case does not, completely monopolize any of the fisheries which it is intended to help sustain.

REEF SLOPE

Fishing along the reef slope is very homogeneous, with no particular gear predominating in any area. Major methods and gear include spearfishing, drive-in nets (*parisris*), handlining, and blast fishing. Approximately 95% of the fishing occurs within 4 km of the reef crest (Fig. 2.4); the intensity drops off sharply beyond that distance. The reserve will cut off only a small portion of that fishery.

REEF FLAT GATHERING

The reserve includes several areas which are subject to harvest by gatherers, particularly in regions east of Silaki Island. The gatherers are currently enticed to travel considerable distances to reach these areas because sites closer to their villages are often too heavily harvested and are depauperate in desirable invertebrates. The patterns of tidal currents on the reef flat indicate that the reserve will bolster the stocks throughout the reef flat as planktonic larvae are dispersed. This will provide increased harvests closer to home for the gatherers. However, the present rate of human population growth and the lack of alternative livelihood will lead to overexploitation of the gathered resources *per gatherer* no matter what level the stocks achieve. The reserve will add to the total harvest, and prevent the complete depletion of most species. A complementary program of introducing alternative livelihood and population control must be implemented before the full effect of improved resource availability will be apparent to the individual gatherer.

REEF FLAT HANDLINING

Approximately one-half of the handlining on the reef flat will be curtailed by the creation of the reserve (Fig. 6.2). This reflects the fact that the area includes some of the few remaining habitats amenable to supporting adult fish under exploitation pressure. We expect that the large fish migrating out of the reserve area once it is operational will favor expansion of the handlining grounds in the future.

REEF FLAT SPEARFISHING

The case with spearfishing will be quite similar to that of handlining (Fig. 6.2). The reserve will cut back primarily on the seasonal spearfishing grounds. The seasonality of the target fish in those areas is indicative of critical life-history events, especially reproduction, which causes them to amass there. The fish are particularly susceptible to overharvesting at that time. Therefore, these areas are particularly desirable for inclusion in the reserve. A major target of the year-round spearfishery is *Siganus fuscescens* (*barangen*), which is expected to flourish with the establishment of the reserve and to migrate outward in mature stages. Therefore, the spearfishing industry can be expected to gain far more than it loses with the establishment of the reserve (Fig. 6.3).

REEF FLAT GILLNETTING

Siganus fuscescens is also a major target of the gillnetting industry, along with a variety of other migratory seagrass species. Gillnetting is very size selective, thus the fishery will adapt to targeting larger individuals as they become abundant. Similar effects will be seen with spearfishing, trapping and, to a lesser degree, handlining. All four of these gear share the characteristics of being low-investment, widely dispersed fisheries with a tendency to target large fish when available, and with sharply declining effectiveness when stocks are reduced. These are all desirable fisheries from a management point of view, which

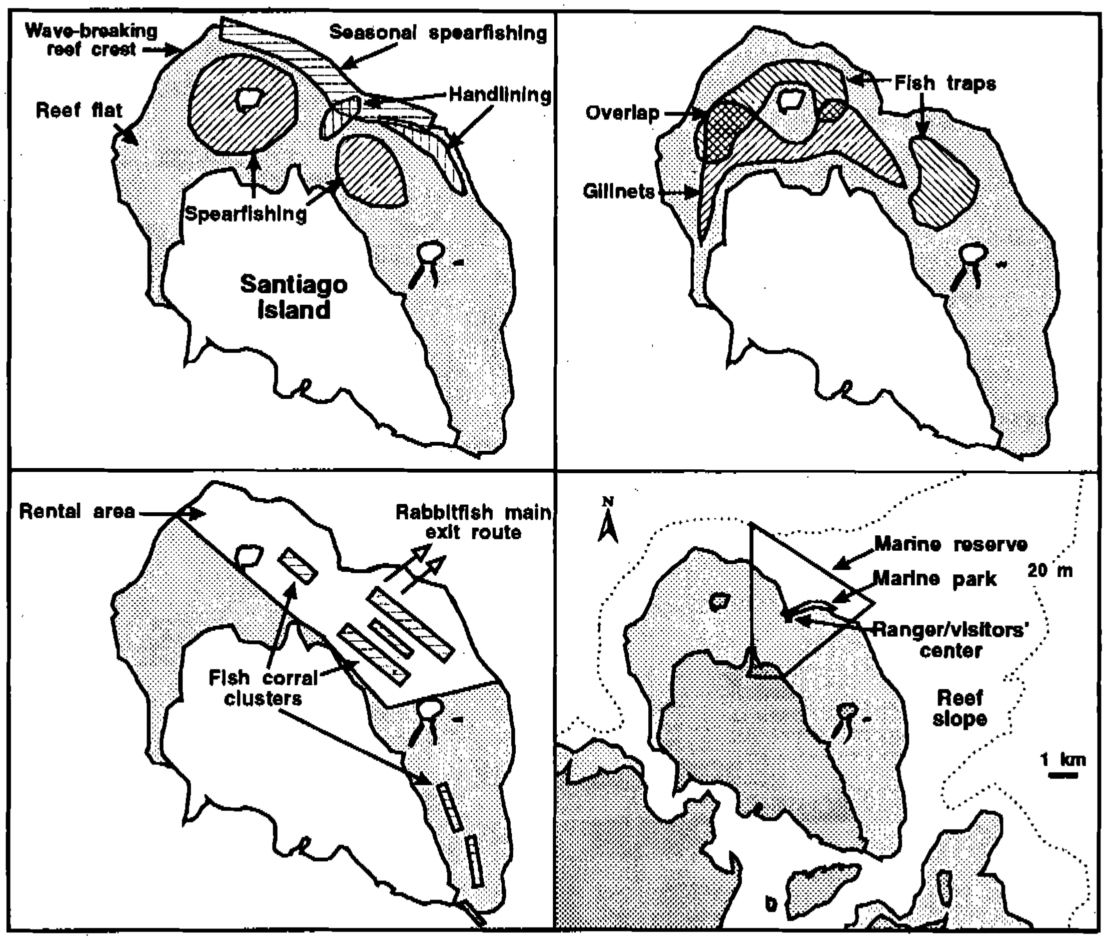


Fig. 6.2. Marine reserve/park system relative to primary reef flat fishing areas. The eastern corner of the reserve would bisect the major migration path for *Siganus fuscescens* (*barangen*), ensuring a supply of adult fish for the gillnetters and spearfishers, and still permitting substantial harvests for the fish corral owners.

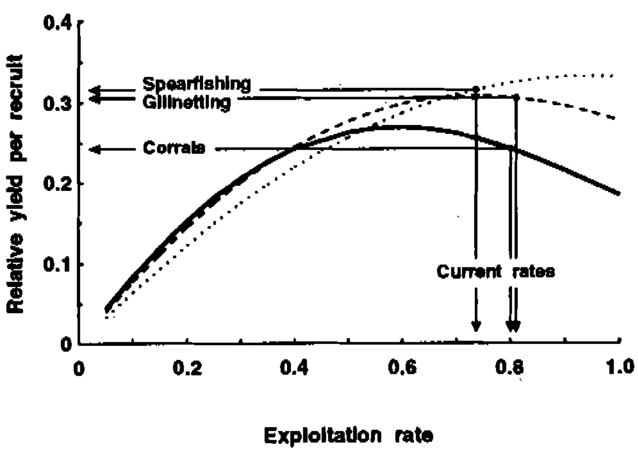


Fig. 6.3. Yield-per-recruit analysis for *Siganus fuscescens (barangen)*. Curves show that the fine-meshed fish corrals induce growth overfishing far more than gillnets and spearfishing as locally utilized. Yields could be improved by favoring spearfishing over fish corrals. This would also improve income distribution because of the labor-intensive nature of spearfishing. Population parameters were based on monthly length histograms per gear weighted by annual catch and combined. Procedures followed those in del Norte and Pauly (1990), but involved an improved data set from mid-1988 to mid-1989 (L_{∞}= 26.0, K = 0.84, M = 1.71). Natural mortality was estimated from the Pauly environmental formula, using T = 30°C. Individual catch curves by gear were used to estimate the length of first capture (L_c) per gear (Gayanilo et al. 1988).

will benefit directly from the reserve. The benefits to gillnetters, in particular, will far outweigh the loss of some fishing areas (Figs. 6.2 and 6.3).

REEF FLAT TRAP FISHING

Trap fishing tends to target coral-dependent fish. There has been a very noticeable drop in the sizes of traps used over the last 12 years as the sizes of the target species have dropped. The reserve actually covers very little of the existing trap fishing grounds (Fig. 6.2). However, the coralline areas protected by the reserve should provide an abundance of large fish which will migrate out to revitalize the trap fishery.

REEF FLAT FISH CORRALS

The reserve will cut back on the area desirable for fish corrals (*baklad*) by about one-half (Fig. 6.2). Fish corrals tend to target fish in the process of migration and to be located along important migratory routes. It is inevitable that an effective reserve would be aimed at protecting those same routes. The southeastern side of the reserve has been located so as to bisect the major migratory route of *Siganus fuscescens*. This will permit the continued harvest by corral owners of some of the stock, while protecting the rest and channeling it toward exploitation by smaller-scale gillnetters and spearfishers. The town currently derives an income from the corral area leasing arrangements. This income may be reduced to some degree initially. However, some expansion of the available stocks due to protection may later increase the desirability of other corral fishing grounds in the future, and the income may then be recovered. Initially, however, the reserve is expected to assist the smaller-scale fishermen by redirecting some of the stock away from the corrals, which tend to benefit a higher economic strata because of their area rental, implementation and maintenance costs.

FISHPONDS

The reserve is anchored along the eastern edge of Binabalian and borders on a significant fishpond area (Fig. 6.4). This area was formerly a very complex mangrove forest. It would be very beneficial to the reserve if the pond could be included and replanted as a mangrove forest. As with the rest of the reserve, it would be important to prevent the harvesting of the forest, so that natural populations could be maintained as a way of reinforcing neighboring mangrove forest populations. There is currently an effective program of replanting mangrove forests throughout the Bolinao area, since many of these areas will be open to the exploitation of the fish, invertebrates and plant products they support. The mangrove areas in the reserve should be set aside and protected from exploitation in order that they may "seed" the biotas of the exploited areas.

Suggested implementation

GENERAL

The major distinction between a "paperwork" reserve and an effective one lies in supervision. The proposed reserve has been designed such that it can be surveyed conveniently from a small tower erected on the reef flat near Malilnap Channel at the center of the reserve. From this point, small boats can be dispatched to investigate possible violations of anchoring or harvesting regulations. The majority of powered boats passing through the reserve will be following the Malilnap Channel, which includes the only useful eastern exit route to the ocean at most tide levels. Therefore, a ranger station located at this point will be very effective in controlling activities by fishers. A small visitors' center could be included in the building complex to provide information on the reserve and on the need for conservation and resource sustainability. The suitability of the site for supporting a building on stilts is demonstrated by the fact that a small shack on stilts at the site (used as a trading station for fishers) has survived for more than two years through several typhoons because of the protection of the reef crest and shallow waters.

MARINE PARK

A small area extending from the ranger station to the reef slope near the mouth of the Malilnap Channel could be set aside as a marine park. As with the reserve, the park area would be protected from all forms of harvest. However, the park

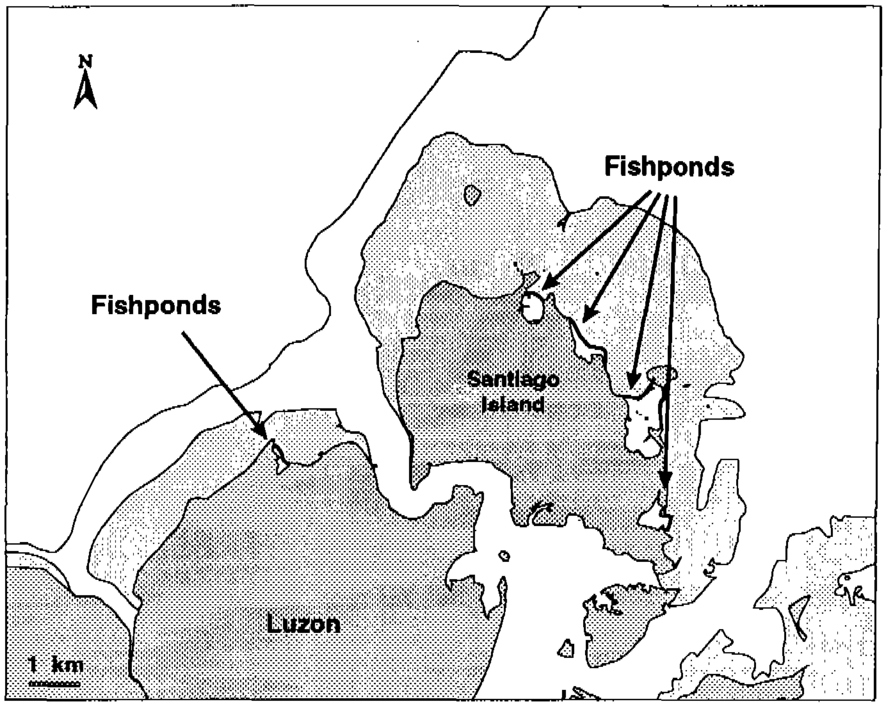


Fig. 6.4. Map of fishpond areas in Bolinao. Most of the ponds have been built on former mangrove forest areas, thereby reducing the potential resources available for small-scale income generation.

would be available for nondestructive recreational diving. A set of permanent mooring buoys could be established, and the use of anchors prohibited so as to protect the corals. A fee could be charged for the use of the buoys, based on tickets dispensed at the ranger station. This income could help maintain the station and support the staff.

A major benefit from establishing a marine park would be the generation of alternative livelihood along the Bolinao coastline. Bolinao has a very high potential for development as a diving tourist area supported by visitors from Manila. The diving population of Manila includes thousands of business employees making repetitive trips to low-cost resort areas. A major diving ground is the Anilao, Batangas area south of Manila. This area requires approximately 2 to 3 hours of travel by road, and has flourished because of the industry. However, diving sites in the area are limited. The divers often travel a total of 3 to 5 hours by road and ferry from Manila to Puerto Galera, and risk becoming stranded when sea conditions become hazardous. Here again, diving sites are limited and degrading because of poor management. Bolinao has an order of magnitude more suitable diving area and site diversity than the entire Batangas-Puerto Galera area combined. Divers would be easily attracted to make the 5-hour trip from Manila to Bolinao if three conditions were met:

1. availability of a diving compressor, preferably operated by a knowledgeable diving expert or instructor;
2. effective curtailment of blast fishing; and
3. abundance of large fish.

The latter two conditions would hold true in the park. If all forms of exploitation were effectively eliminated, especially spearfishing which makes fish avoid divers, then large fish would accumulate within 3-5 years of operation. The process could be greatly enhanced with the establishment of regular feeding stations. A simple routine of feeding by divers on a regular basis at fixed points can rapidly establish a dense population of large fish which can be easily approached and photographed. With this and other enhancements such as underwater trail markers, the park can become a major attraction for tourists in Bolinao.

SHORESIDE PROTECTION

The establishment of mangrove forests along the shore will restrict visibility and make shoreside protection difficult. A substantial security fence would be necessary along the shoreward limit of the reserve. The reserve should extend several hundred meters onto land in order to protect turtle-nesting beaches and shoreside bird, plant and other biota. Therefore, the fence would be mostly on dry ground, which will facilitate maintenance.

MARINE MARKERS

The boundaries of the reserve and park could be marked on the reef flat by permanent structures with warning signs every 100 m or so. In deeper waters, permanent buoys may be necessary, requiring more frequent maintenance. It is essential that everyone entering the reserve know clearly that he or she has done so, and that no anchoring or harvesting be allowed, except for scientific purposes as authorized by carefully controlled permits.

PUBLIC AWARENESS

Management tends to be most effective when violations of regulations are not only illegal, but socially unacceptable as well (McManus et al. 1988). Social unacceptability of an action arises most easily when it is clear to every member of a society that the action is detrimental to the membership as a whole. This clarity is often achieved when the membership itself shares in the responsibility for imposing and arranging for the enforcement of a regulation. This procedure bypasses the common tendency of local groups to increasingly mistrust the motives of progressively higher authoritative bodies over which they exert diminishing levels of control.

There is strong scientific evidence that establishing a marine reserve will provide better harvests from the Bolinao reef system. This information can be simplified and disseminated widely through media such as pamphlets and comic books, school presentations, meetings, public hearings and so forth. However, the material must be presented in appropriate ways. Each person involved will have to be in a position to use the evidence to convince herself or himself that previously held concepts are wrong; e.g., that larger fishing grounds and more fishing effort yield more fish.

The decision to set aside some areas to increase yields in others will be a difficult one, involving *cognitive dissonance* (Festinger 1972), i.e., a challenge to existing value systems. Most people tend to avoid cognitive dissonance, particularly when the avoidance is reinforced by short-term rewards such as the immediate benefits of daily harvest activities in the proposed reserve area. Changes in value systems can often be effected through societal interactions which direct peer pressure toward convincing individuals to realize the need to change them (Asch 1972). Carefully guided discussion groups can be effective in this manner (Ferrer 1989; Ortigas 1991). Follow-up information campaigns and public activities can be equally important, as it is necessary to reinforce changes in value systems in order to stabilize them (Cabanban and White 1981). The reserve/park system must incorporate a continual information dissemination effort to remind the public of the need to maintain the system. It must inform them of the benefits attributable to the reserve/park as data become available on such matters as increased harvests or job opportunities. It is important to avoid *ningas kogon* (literally, grass fire), or the tendency to act with enthusiasm in the short term, but lose interest over time. In order to be effective, the plan for the reserve/park system must be thoroughly integrated into the long-term planning and governance of the municipality.

CHAPTER 7
RECOMMENDATIONS FOR MANAGEMENT ACTION

Overview

The management of the coral reef resources of Bolinao can be improved with the following specific actions:

1. Establish a tourism regulatory committee.
2. Develop alternative livelihoods.
3. Promote mariculture and improved agriculture activities.
4. Establish marine reserves.
5. Eradicate blast and cyanide fishing.
6. Ban compressor (hookah) diving.
7. Improve fish-handling facilities.

Regulating tourism

The Bolinao area has a very high potential for tourism development. The area includes nearly 200 km^2 of coral reef, 17 km of sandy beaches, large sheltered harbor areas, several underwater shipwrecks, two scenic lighthouses, an early 17th century church, and numerous caves and waterfalls (Fig. 7.1). The town is approximately 5 hours of driving time from Manila, roughly the same amount of time necessary to reach popular tourist sites to the south such as Puerto Galera.

Some major factors which currently limit diving activities include the lack of an air compressor, the abundance of blast fishing, and the scarcity of fish. These constraints can be eliminated through proper investment and management. An air compressor can represent a liability to a resort operator lacking expertise in diving. However, there are several diving instructors in Manila who earn salaries on an unpredictable basis, who might be attracted to more stable job opportunities associated with resort operations. An interim solution to the problem of eliminating blast fishing and attracting fish would be the creation of a marine reserve and park (see Chapter 6). This would provide a safe area for divers, and could serve as a focal point for attracting tourists to Bolinao.

Once Bolinao gains a reputation as a safe, attractive diving area, one can expect a rapid period of increased tourism, as was seen in the early 1980s in Anilao, Batangas and Puerto Galera, Mindoro. However, both of these areas suffered from a lack of regulation in the development of the industry, particularly with respect to the preservation of the marine and shoreside environments. For example, the many isolated, remote beaches in Puerto Galera adjacent to small patches of coral were rapidly crowded with dense, unsanitary living and eating facilities. The corals were substantially damaged through associated siltation, gathering and breakage from boat anchors. This type of difficulty arises because of the tendency of many investors to favor quick profits from short-term investments in the face of unregulated competition.

A much different problem has arisen with some tourist developments in Bohol, Cebu and elsewhere. Large areas which were previously a source of livelihood to economically disadvantaged

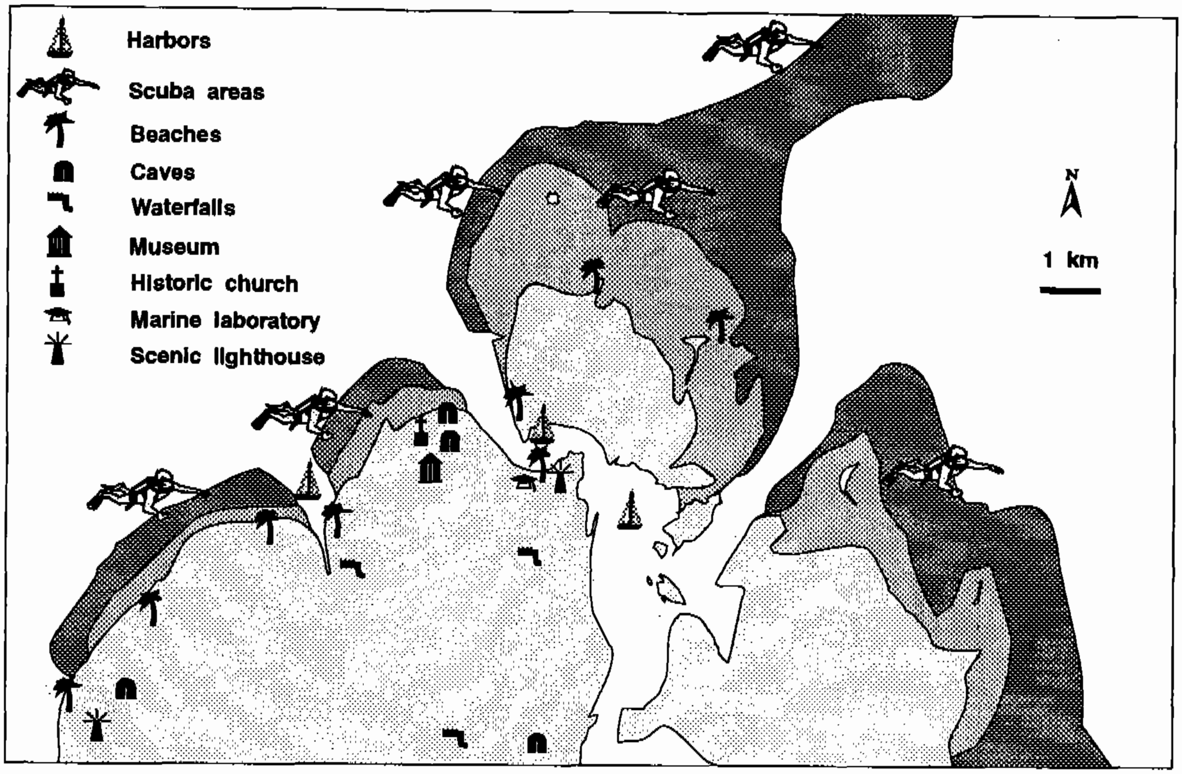


Fig. 7.1 Tourist attractions in the Bolinao area. Tourism could be greatly enhanced with the provision of a scuba compressor, establishment of a marine park, and elimination of blast and cyanide fishing.

people have been purchased for expensive resort hotel operations, sometimes with the aid of political pressure. In many cases, profits are tightly restricted to the outside investors, who provide monopolized transportation to the resort, and all the boats, food and services needed by the tourists. The resorts tend to hire well-trained staff members from Manila and elsewhere, and employment of local labor is very minimal. In these cases, there is very little benefit to the local populace. For this reason, it may be best to discourage development aimed at attracting high-income overseas tourists, and to concentrate instead on carefully controlled developments aimed at attracting visitors from Manila.

There is also a suitable target group of international tourists, such as many of those already visiting Bolinao regularly, who prefer economical tourist facilities. There are areas in the Caribbean and elsewhere where small-scale tourist facilities ("ecotourism") are highly successful (Boo 1990). For example, a coastal dweller who owns one house for his or her family may build a second house nearby for rental to tourists. Some factors which would ensure the success of such an investment include access to sanitary, fresh food; the certainty that the quarters are clean, screened and vermin-free; and the provision of running water and clean toilet facilities. These conditions are rarely met in a village nipa hut in the Bolinao area. However, collaborative investment among neighbors or relatives could produce indigenously designed cottages incorporating the necessary levels of convenience and sanitation. Electricity may be helpful, but is by no means essential provided that an adequate variety of fresh food is available and kerosene or gas lamps and stoves are available. Some tourists prefer to "rough it", but are rarely willing to forfeit accustomed levels of sanitation to do so. The important point is that the accommodations are not misrepresented when advertised. A few cases of misrepresentation and poor quality control in the Bolinao area would do considerable damage to the industry. It would be desirable to form cooperatives for the purposes of quality control and advertising both nationally and internationally. These cooperatives could be regulated and assisted by the town government.

In order to ensure the longevity of the local resources and optimal benefit to the town and the majority of its people, it will be necessary to regulate development along the coast. This can be achieved through methods such as zoning, selective licensing, provision of economic incentives, and strict requirements for and evaluation of environmental impact assessments (EIAs) for all proposed construction. This type of planning and control could be vested in a small committee empowered appropriately by the local government. It would be important that the committee adequately represent the views of both local merchants and economically disadvantaged fishers who must profit from the development in order to justify it. One or more scientists from the Bolinao Marine Laboratory could be involved to help ensure that natural resources are enhanced rather than degraded by proposed activities.

An appropriately directed tourism program would allow the present fishers to use their boats to support recreational diving rather than for fishing. In Anilao, Batangas, small boat owners were able to earn a gross income of ₱800/day when diving tourism began to grow in the early 1980s. This was at a time when the peso was worth more than twice its current value in spending power. Boat owners in Bolinao today rarely earn that much for rentals. The prices in Anilao fluctuated under the competing forces of local inflation, which was discouraging many potential tourists, and price war declines, which threatened incomes. The prices were eventually stabilized by a local boat owners association.

Developing alternative livelihoods

Even if blast and cyanide fishing were to be completely curtailed, the reef environment would continue to be degraded because of anchor damage, and the fish and invertebrate stocks would continue to decline because of overexploitation. There are too many fishers in Bolinao.

The families dependent on harvesting reef organisms tend to live on marginal and unpredictable incomes. Fishing ranks the lowest in annual incomes of the major occupations in Bolinao (Fig. 2.3). The willingness of many to shift occupations has been well illustrated by the fact that often more than 50 men abandon fishing to seek work whenever a new phase of construction is initiated at the Bolinao Marine Laboratory. Thus, nearly any environmentally sound industry which provides higher salaries and more stable incomes than fishing is likely to have a positive effect on the resource ecology of the reefs.

The major natural resource of the municipality is its 200-km^2 coral reef. This could be used effectively to build a viable tourism industry, as discussed above, especially if a marine park were to be implemented (Chapter 6).

Aside from tourism based on living reefs, Bolinao has a potential for limestone production, based on fossil reefs. At the time of this writing, there is an ongoing survey which may lead to the development of an open pit mine immediately south of the Bolinao Marine Station. The proposed mine, which will be financed principally by investors from Taiwan, would cover an area of several tens of square kilometers. A thorough study would be necessary to ensure that any silt which leaks from the operation areas will not remain in suspension until it is carried over the reef slopes. Siltation can block the light needed by the algae living in coral tissues, thereby hindering the growth of the corals (Johannes 1975; Yap and Gomez 1985). Silt which settles out of the water column too quickly to be removed by the mucous and polyp actions of the corals can kill the coral colonies (Aliño 1983). Losses in coral cover can lead directly to loss in harvestable fishes and invertebrates.

Of equal concern is the effect of the mine on the land biota. The Bolinao area supports a rich plant and animal biota. The area under consideration supports a broad variety of birds and populations of the endangered monkey (*Macaca*). Many of the plants are valuable sources of natural medicinal drugs. An adequate environmental impact study should involve surveys by knowledgeable botanists and zoologists before the project is approved. Additionally, the possibility that the town subterranean water supplies might be adversely affected should be investigated by a competent hydrologist.

On the positive side, the mine would provide a few years of employment to many hundreds of workers. Should the mine be implemented, it would be important that steps be taken to ensure that local labor is employed wherever possible. Otherwise, the mine will serve to draw immigrants from other areas into the Bolinao municipality. This would exacerbate the current resource problems, especially after the mine closes down again and ceases to be a source of employment.

It is important to emphasize that the purpose of an EIA is not to hinder development, but rather to enhance long-term, rational development. The assessment provides access to several sides of the total development picture, so that optimal decisions may be made. Without environmental assessments, the interests of a minority, usually an economically advantaged group, are facilitated at the expense of the environment, which inevitably adversely affects the economically disadvantaged. This would be particularly true in Bolinao, where fishers and farmers, who depend directly on the maintenance of a healthy environment, constitute 80% of the human population (Fig. 2.1).

Another potential source of employment would be to expand various cottage industries. Currently, the most profitable part-time cottage industry is shellcraft (Fig. 2.3). This industry is probably operating near the limit of the available resource supply, and could not be extended further until total shell production is enhanced by such means as the establishment of a marine reserve. The shellcraft industry has the desirable characteristic of maintaining local workers in producing a refined end product. In this way, the town benefits optimally from a limited resource. If the product was to be exported in its raw state, much of the profit to be made would be lost to the town. The fact that end products are completed locally also makes this industry complementary to the development of tourism.

Another industry of high potential involves seaweed gathering and processing. More than 15 km of reef slope in the southwestern portions of the municipality are highly dominated by *Sargassum* seaweed (*aragan*). This algae can be used for a broad variety of purposes ranging from feeding cows to the production of medicines. The addition of the seaweed to chicken feed can replace the expensive beta carotene often added to enhance yolk production. However, it would be desirable to initiate an industry requiring local processing to produce a widely saleable product. One such industry would be liquid fertilizer. The seaweed can be cooked and filtered to produce a concentrate. When mixed with water and sprayed on plants twice monthly, it can reduce dehydration and insect damage, induce budding and fruiting, and reduce the need for commercial fertilizers, especially when cooked with a source of calcium such as ash from burned coconut fronds (Dr. Nemesio Montaño, pers. comm.) This type of backyard industry would involve little capital investment, and a demand might be generated at progressively larger scales to national or international levels. Once established, the industry might move onward to mariculture activities and the production of more refined products such as medicinal chemicals. A similar industrial potential may exist in the form of jellyfish, which abound locally and can be processed initially for sale to Chinese and Japanese communities for food. Jellyfish such as seawasps produce biochemicals associated with stinging cells which may eventually prove to be of considerable medicinal value (Walker 1988).

The current program of planting mangroves throughout the Bolinao coastline could lead to a broad variety of cottage industries. The range of products available from mangroves is broad (Table 7.1) (Saenger et al. 1983; Salm and Clark 1984). However, an effective industry based on gathered mangrove products would require organizational efforts, such that the products of individual collectors are amassed and delivered to appropriate processing facilities and markets. This would be especially true for wood products such as shipbuilding materials. A high demand for firewood for the salt making industry in adjacent municipalities brings an immediate danger of overexploitation of the planted mangroves. This must be acted upon immediately through controls such as restrictive regulation and licensing. Additionally, the provision of a marine reserve incorporating mangrove areas would provide for renewed populations of mangrove species on a continual basis.

Educational achievement is limited in the municipality, where more than one-third receive no education (Fig. 2.1). However, a substantial number of people maintain skills useful in the development of small-scale industries (Table 7.2). Some of these skills are passed on locally, while others are acquired during periods of employment in Manila or overseas, including training in the Philippine or U.S. military, and work experience on Saudi Arabian oil fields.

Occupational mobility could be enhanced considerably by improving local schools to encourage attendance. Most of the schools are greatly in need of repairs, new desks and chairs, books and sanitary plumbing. Funds for such improvements could be solicited from various sources, including international sources targeting nongovernmental organizations (NGOs) and various civic groups in developed countries. In some circumstances, a local parent-teacher organization might qualify to acquire the necessary funds. In others, it may be

Table 7.1. Potential products from mangrove forests (Saenger et al. 1983; Salm and Clark 1984).

Mangrove plant products

Food, drugs and beverages
- Sugar
- Alcohol
- Cooking oil
- Vinegar
- Tea substitute
- Fermented drinks
- Dessert topping
- Condiments from bark
- Sweetmeats from propagules
- Vegetables from propagules, fruits or leaves
- Cigar substitute

Textiles and leather
- Synthetic fibers (e.g., rayon)
- Dye for cloth
- Tannins for leather preservation

Agriculture
- Fodder, green manure

Construction materials
- Timber, scaffolds
- Heavy construction timber
- Railroad ties
- Mining pit props
- Boatbuilding materials
- Dock pilings
- Beams and poles for buildings
- Flooring
- Paneling, clapboard
- Thatch or matting
- Fence posts, water pipes, chipboards, glues

Fuel
- Firewood for cooking, heating
- Charcoal
- Alcohol

Paper products
- Paper of various kinds

Fishing equipment
- Poles for fish traps
- Fishing floats
- Fuel for smoking fish
- Tannins for net and line preservation
- Wood for fish drying or smoking racks

Household items
- Furniture
- Glue
- Hairdressing oil
- Tool handles
- Mortars and pestles
- Toys
- Matchsticks
- Incense

Other products
- Packing boxes
- Wood for smoking sheet rubber
- Wood for firing bricks
- Medicine from bark, leaves and fruits

Mangrove wildlife products

Fish	Oysters	Insects	Birds
Crabs	Mussels	Honey	Mammals
Shrimp	Shells	Wax	Reptiles and reptile skins

possible to create an appropriate NGO by compliance with the regulations of the Philippine Securities and Exchange Commission (SEC). A further step toward improving school enrollment would be to ensure that alternative livelihoods provide harvesters with adequate incomes to make it unnecessary for a family to employ its children to acquire food or income. Currently, children represent a major workforce in the communities, and this works against the long-term improvement of local life-styles.

It is likely that an effective alternative livelihood program would require the active development of markets for existing or proposed products (DAP 1978; Kotler and Armstrong 1989). Products such as shellcraft creations sell widely not because they are outstandingly useful, but because they have public appeal. Public opinion is often strongly influenced by advertising. The success or failure of a cottage industry may depend less on the need for the product than on the effectiveness with which local producers are able to interact with marketing agencies and companies with advertising and outlet distribution capabilities. Many potential industries, such as clothes or shoe manufacture, would be better supported if an organized effort was put into the development of shipping arrangements for raw materials and end products. The excellent harbor behind Santiago Island could facilitate this. A major renovation of the portside facilities has recently been completed. Some additional modifications may be necessary, however, because the current dock is located in water too shallow for any reasonable ocean-going vessel.

A major portion of the fishing population lives on Santiago Island. This island has electricity only in the southeastern corner, and this is very sporadic because of the exposure of the lines to weather as they cross wide channels to and from Siapar Island. There are many areas which have no fresh water during the dry months from February to May. Many people bring in water from the mainland in small containers by boat. There is no bridge connecting the island to the mainland. Thus, it would greatly improve the chances of success in a program of alternative livelihood development if a bridge could be constructed to the

Table 7.2. Skilled labor available in the Bolinao municipality. A variety of human resources could be tapped for small-scale industry. Data are from a survey by DAR in 1991.

Type of skill	Skilled individuals	Barangays involved
Factory/industrial	441	10
Shellcraft	380	12
Construction	311	25
Ropemaking	254	1
Charcoalmaking	205	8
Matweaving	123	5
Copra	52	1
Bamboocraft	52	5
Drivers	10	1
Total	1,828	

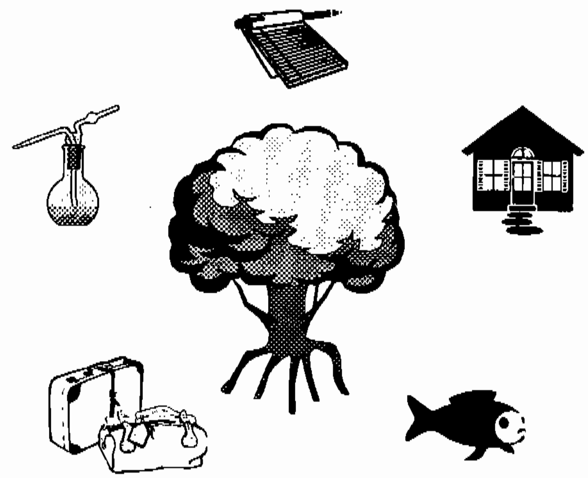


Fig. 7.2. Selected products from a well-managed mangrove forest.

island, bringing water pipes, electrical lines, and ready transportation to and from the mainland.

A meaningful effort in developing alternative livelihoods must involve a strong effort in market analysis in Manila and overseas. It will also be necessary to invest in efforts to advertise existing products and to attract investors for others. A number of bilateral aid agencies could be tapped for funds to assist in these areas, particularly with the current emphasis on supporting privatization (e.g., Australia) and NGOs (e.g., United States).

Mariculture and agriculture

Marine and brackishwater aquaculture which involves the destruction of productive marine habitats, such as mangrove forests and estuaries, are referred to as "destructive mariculture activities". For example, nearly all of the formerly extensive mangrove forests in the Bolinao area have been displaced by ponds for growing milkfish (*bangus*) and prawns. This has severely reduced the availability of a myriad of plant and animal products which would otherwise be available for harvest by local villagers (Table 7.2, Fig. 7.2). Instead, the profits from the enclosed areas now go directly to large-scale pond owners with very little diversion to laborers such as guards and occasional maintenance people.

There are many mariculture techniques which cause minimal disruption of natural ecosystems. Many of these involve very little investment, and are suitable for implementation by villagers. Examples include maintaining pens for crabs, lobsters, conchs, sea urchins, sea cucumbers and giant clams; stick culture of oysters and mussels; rack culture of seaweeds; and cage culture of fishes. It is conceivable that most of the gastropods and bivalves involved in the shellcraft industry could be maintained in some form of controlled enclosures and fed for optimal growth.

Potentially, at least 30 km^2 of reef flat and a few square kilometers of protected harbor waters could be used in one way or another for mariculture. Potential problems from mariculture include disruption of local currents and localized pollution, especially where feeding is necessary (e.g., grouper culture). However, these problems could be monitored as the industry grows and development altered as necessary. A major benefit from having efforts directed toward mariculture by a large segment of the population is that strong incentives will be developed to maintain a healthy environment and to prevent disruptions from blast and cyanide fishing. A further benefit of considerable consequence is that more food will become available, leading to reduced health problems and absorbing some of the demand for reef fish.

A major research thrust of the Bolinao Marine Laboratory of the Marine Science Institute of the University of the Philippines is in the area of small-scale mariculture. Some potential mariculture organisms which have been investigated include giant clams (*Tridacna* spp., *Hippopus* spp., *taklobo*), sea urchins (*Tripneustes gratilla*, *kuden-kuden*), sea scallops (*Amusium pleuronectes*, *kapis*), abalone (*Haliotus asina*), lobsters (*Panulirus* spp., *kising-kising*), rabbitfish (*Siganus fuscescens*, *barangen*) and seaweed (especially *Eucheuma alverasi*, *tomsao*). Currently, programs are underway to encourage local small-scale mariculture of giant clams and *Eucheuma* through training programs and the provision of spat or propagules. Similar programs for other species are expected to follow, which could help considerably in efforts to promote local mariculture.

As with other forms of alternative livelihood, success in mariculture depends on the provision of an adequate market and product transportation. The latter is particularly complex in some cases, such as the supply of live groupers to restaurants in Manila. In other cases, an emphasis on local processing, such as canning, could help to reduce postharvest losses and internalize economic returns within the municipality. The development of markets and advertising campaigns would require funding and could be facilitated through the formation of cooperatives and assistance and action by the local government. Additionally, educational programs would be necessary to encourage fishers to become mariculturists and to broaden the diets of the local populace to absorb the new products and promote better health.

A further step toward alleviating harvest pressure from the marine environment would be an intensive program to improve the use of local agricultural lands. For example, many hectares of land are currently devoted to growing *maguey*, a plant used to provide fibers for constructing inexpensive ropes. The market for this fiber has been poor recently, but local farmers have been slow to refocus on more profitable crops.

In economic settings such as Bolinao, it is a questionable practice for a low-income family to devote available lands to producing single crops, such as rice, maguey or coconuts. A substantial proportion of the money gained from such production goes toward buying other foods necessary to sustain the family. The sporadic and risky nature of the incomes leads to periods when purchases of fruits and vegetables are minimized, leading to malnutrition. In many cases, it would be better for the family to concentrate on growing a variety of food crops for consumption by the family, and then to sell the excess production. Intensive multispecies gardens can be designed in such a way that they require decreasing levels of maintenance over time -- a major goal of the internationally growing practice of *permaculture* (Mollison and Slay 1991). Fertilizer costs can be eliminated through the use of mulch and seaweed products. Appropriate technologies and crop choices can eliminate the need for expensive fertilizers. A concentration on perennial rather than annual crops can lead to reduced maintenance efforts and a constant supply of a variety of food products. The street market system of Bolinao consists of small stalls selling overlapping varieties of crops. This system lends itself well to the sale of small quantities of various fruits and vegetables produced in small family plots.

Complementary agricultural approaches include the small-scale crop-livestock-aquaculture techniques developed at ICLARM and elsewhere for use in tropical areas (Edwards et al. 1988). Possibilities include integrated rice-fish, livestock/poultry-fish, vegetable-fish, and all combinations of these (Pullin 1989). As with permaculture, the general goal is to minimize investments and waste by producing groups of complementary products. These systems could provide for better nutrition and incomes from agricultural lands, and reduce the pressure to exploit the marine environment.

Establishing marine reserves

Marine reserves could potentially improve the local fisheries and provide for a continually high diversity of harvestable species. A sample plan for a marine reserve centered on Malilnap Channel has been outlined in Chapter 6. Once this system has demonstrated its merits, it may be useful to establish others. One excellent site which has been proposed elsewhere (McManus 1989b) would be Cangaluyan Island, an area which would support reefs in both the Bolinao and Anda municipalities. The island falls under the latter's jurisdiction. Other potential sites include an area along the reef crest northwest of Lucero, an offshore reef several kilometers east of Silaki, and selected areas both east and west of the Balingasay River. However, as considerable educational and political effort is required for each reserve area, it may be desirable to finish establishing the primary reserve at the Malilnap Channel prior to undertaking new programs. This area is ecologically and oceanographically the most suitable of the potential sites in the Bolinao municipality.

Blast and cyanide fishing

Blast and cyanide fishing are both nonselective, environmentally damaging fishing methods. The explosions and poisons kill all life history stages of the target species and most other organisms nearby. The corals, which form the basis for the ecological habitats of the species, are also destroyed (Talbot and Goldman 1972; Carpenter et al. 1981; McManus et al. 1981; Nañola et al. 1990). Corals are very slow at recolonization and growth, and complete recovery may take several decades (Johannes 1975; Yap and Gomez 1985). The living coral cover in the reef flat and lagoonal areas has been reduced by 60% because of these fishing methods. The methods compete directly with the use of more desirable gear such as gillnets, traps, hook and line, and spearfishing.

Ultimately, however, blast and cyanide fishing should be completely eradicated because of their effects on tourism. The tourist industry holds the greatest promise for providing alternative employment and removing harvesters from the reef. Theoretically, a frequency of about one blast per week might have very little direct ecological effect on the reef system as a whole. However, tourism is built on reputation and expectation. If a diver from Manila hears a single blast during his limited stay in Bolinao, the chances are great that news of the event will spread throughout the diving clubs of Manila within a few weeks. A similar effect would arise from a tourist diver encountering a fisher squirting cyanide underwater to catch aquarium fish. Tourists are not usually concerned with the statistical adequacy of the sampling of an event. Rather, they tend to react to signs that previously held beliefs are valid. It has become common knowledge that some divers in the last few years have been seriously injured and killed by blast fishing in the Philippines. Fear of the danger of being injured or killed by blast fishing or by ingesting poisoned water is prevalent. Thus, a few unfavorable anecdotes could seriously damage the diving tourist industry in Bolinao.

The eradication of these destructive fishing methods must involve both public education and publicly acceptable forms of enforcement. A reduction in blasting by 90% during the study period is largely attributable to fears generated by the rumor that five people involved in blast fishing or transporting blasted fish were summarily executed by unknown parties. This form of extreme enforcement is not likely to endear the people to promoters of resource management programs. A much prefered approach would be one of community organization and public information involving publications (in the Bolinao and Ilocano dialects), village meetings and school assemblies (Cabanban and White 1981; Ferrer 1989, 1991). Blasting is not commonly viewed with the level of seriousness necessary to prevent its open use in the villages (Galvez 1989), and efforts must be directed toward making it not only illegal, but *socially unacceptable* as well (McManus et al. 1988).

Banning compressor diving

A growing number of fishers use air compressors with long hoses to facilitate underwater harvesting. The most prominent uses are for spearfishing, lobster gathering, aquarium fish catching, and recently, for sea urchin gathering. The air compressors are of the type commonly used for filling tires at gasoline stations.

International scuba diving norms dictate that a compressor should involve an air intake extending several meters upwind of the compressor and a series of filters to remove particles from the air. These precautions are necessary because concentrations of gases such as carbon monoxide and carbon dioxide which have negligible effects at sea level, can become fatal if inhaled under pressure during a dive. Both gases are produced by the compressor itself, as well as by boat engines and tobacco smoke. They cannot be filtered out of the air under most conditions, and must be carefully avoided. Oils which enter the compressor can cause lipo-pneumonia as they accumulate in the lungs.

International standards dictate that diver ascents and descents must be carefully regulated to avoid ear and sinus damage, and similar injuries. Nitrogen narcosis often leads to diving accidents, particularly in waters below 30 m, because the euphoric feelings it induces cause judgement to be altered. The use of medical drugs, alcohol or tobacco smoke in the 12 hours prior to a dive can lead to difficulties during the dive. Medical conditions must be checked frequently to avoid heart attacks and other heavy work or pressure-related injuries. Underwater times, depths and rates of ascents must be strictly limited to prevent decompression sickness, which often leads to paralysis or death. Frequency of diving is limited to avoid degradation of the bone marrow. Training is particularly concentrated on reducing the likelihood of a diver holding his or her breath during emergency ascents, which often leads to lung bursts, producing emphysema and air embolisms, the latter of which is a frequent cause of death. Underwater asthma attacks are yet another cause of air embolisms and death.

The compressor divers of Bolinao often dive in depths of 30 to 60 m for a few hours at a time. They are susceptible to all of the above-mentioned diving hazards. The most commonly known problem is death or paralysis from decompression sickness, which is locally called *kuriente*. The local name refers to the fact that the divers associate it with electrocution, and often believe that it is caused directly by temperature changes in the water. Actually, it is common because the divers routinely exceed the so-called "no decompression" limits used by knowledgeable divers (Fig. 7.3). The air from the compressors is laden with oils and dangerous gases. The lack of a regulator at the diver's end of the air hose invites problems of panic and associated air embolism.

There is no practical way for Bolinao fishers to be properly trained and equipped for commercial diving. The only feasible means of avoiding the overwhelming number of safety and health hazards associated with compressor diving is to ban it entirely.

Banning compressor diving would have a beneficial effect on fisheries ecology in the Bolinao area. There is currently a rapid decline in the number and diversity of fishes reaching adult sizes on the reef slope. This decrease includes a 50% drop in species richness and an 80% drop in abundance in three years. A ban on compressor diving would serve to curtail this decline and help safeguard the breeding populations which help to supply the coastal reefs along Western Luzon with annual recruits. Thus, a ban on compressor diving would be beneficial for both resource management and humanitarian reasons. Such a ban should be considered for implementation at a national scale as well.

Improving fish-handling facilities

A substantial portion of the catch in Bolinao is lost to spoilage. Conditions in the fish landing sites are unsanitary, and a significant public health risk exists. This is a common situation throughout the Philippines (Santos 1988).

The fishers on the reef generally fish approximately 6 hours each day. Those involved in spearfishing and hook-and-line fishing often carry boxes of ice, especially during the day. However, upon arrival at the landing site, the fish are often laid on top of the ice rather than properly buried and interspersed with the ice. Ice is ground or chopped under unsanitary conditions. Most fishers who use other gear do not carry ice.

In the main fish market in Bolinao, many fish are spread on table tops with no ice, and are exposed to flies. Those in boxes or washtubs of ice

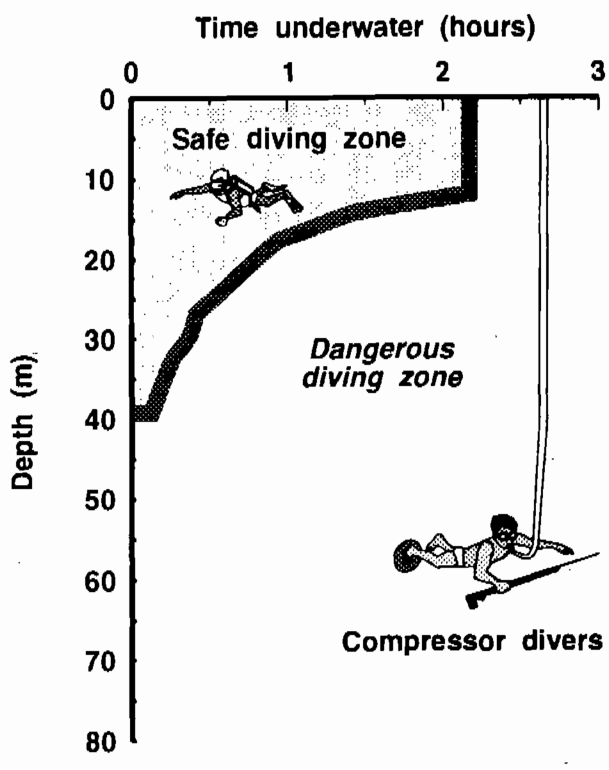


Fig. 7.3. Many compressor (hookah) divers dive too deep for too long and acquire decompression sickness and other maladies. Paralysis and death are common.

are not usually interspersed. The floors are invariably slippery with material dripping from the tables. Fish are handled without protection and no sanitary facilities are available. There is a faucet with running water, but no hose is available for washing the floors. Fish which are purchased for Manila are usually shipped in ice trucks. Local fish processing is limited and generally involves open air drying and/or salting.

The fish market should be reconstructed to include raised water taps and sinks, and properly drained floors. Tables should be designed to facilitate holding trays of ice to preserve fish on display. A single full-time employee could periodically clean the floors, provide soap for the sinks, and generally maintain sanitary conditions. Inexpensive ice should be made available and its use required in the market. It may also be possible to provide disposable plastic gloves and bags with heat sealers to minimize spoilage and health hazards upon purchase. These changes might entail raising the current fee for market usage by a small amount to finance the maintenance of the facilities. However, funding for the initial construction could be sought from bilateral aid agencies.

Ice may become more readily and inexpensively available in the future because of the recent construction of a new ice plant. An information campaign about the use of ice and the need to maintain sanitary conditions in the market could be implemented, including posters and school presentations. Training in sanitary fish-handling methods could be requested from the Bureau of Fisheries and Aquatic Resources, the Home Economics Department of the University of the Philippines, or the University of the Philippines in the Visayas College of Fisheries, all of which maintain appropriate specialty staff members. A local investment in fish processing, such as canning, might help internalize economic returns from the resource within Bolinao.

Reducing human population growth rates

The human population of Bolinao is rising at an accelerating rate (Fig. 2.2). The current population is approximately 50,000, of whom 31% are involved in fishery-related employment, and 49% in farming. The population is expected to reach 100,000 in 30 years. Farm land is limited, and forms a natural limit on the number of people who can be employed in farming. With the current scarcity of alternative employment, most of the incoming labor is expected to seek employment in fishing. There are already roughly twice as many fishers on the reef as the system can sustain in the long term. Doubling this again will cause a very rapid decline of the major resource of the municipality. Those already dependent on the reef will be left with diminishing catches and incomes as more competitors join the fishery work force. A great deal of conflict and difficulty is expected to result in the next few decades.

Conceivably, the Philippines could enter into a period of rapid economic growth and jobs could become available in cities which will draw people out of Bolinao. However, the growth rate in Bolinao is matched by an equally high rate throughout the country. A disproportionately large amount of the incoming national labor force is expected to migrate to cities. Therefore, it is unlikely that even a very high rate of economic growth nationally will result in enough job opportunities in cities to alleviate the population problem in Bolinao.

In addition to creating alternative sources of employment locally and restricting the entry of laborers to indigenous people, steps can be taken to encourage birth control. The national program of family planning has had little impact locally. Occasional attempts at developing educational programs and distributing birth control devices have been short-lived and on too small a scale to substantially change traditional social values. The average resident still depends on having a large number of grateful children as a way of ensuring a source of income in retirement. It is felt that it is far more fruitful to invest in progeny than in savings accounts and other economic investments. A strong educational campaign would be necessary to convince young couples that investing more in fewer children and in personal economic growth is a rational strategy for success in later years. Other programs aimed at avoiding teenage pregnancies would be helpful as well.

It is widely believed that the birth rate will decline as the local economy grows. This could very well be the case. Unfortunately, the population growth rate is being matched by a rapid decline in available resources. An active program of alternative livelihood generation and the establishment of marine reserves and parks could conceivably slow the decline in resources. However, it is not likely that such programs would compensate for the accelerating population growth rate. Even with a general strengthening of the local economy, it is unlikely that the average life-style will change significantly under current circumstances. An active program of encouraging birth control would increase the likelihood that average personal incomes would rise, and thus that population growth rates might diminish more passively in the future.

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APPENDICES: FISH SPECIES ABUNDANCES

Appendix 1. Combined list of all species sorted alphabetically. Abundances are in ind./1,000 m². Weights are in g/1,000 m². Most identifications were based on Allen 1975; Rau and Rau 1980; Schroeder 1980; Masuda et al. 1984; Randall et al. 1990; and Myers 1991. (* denotes uncertain identification).

			By frequency						By weight	
			Rank			Ind./transect				
No.	Species	Family	Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
1	*Abudefduf coelestinus*	Pomacentridae	175	59	-	0.06	0.98	-	-	-
2	**Abudefduf leucozonus*	Pomacentridae	-	311	-	-	<0.01	-	-	-
3	*Abudefduf saxatilis*	Pomacentridae	167	66	155	0.07	0.78	0.01	180	0.01
4	*Abudefduf septemfasciatus*	Pomacentridae	-	143	-	-	0.10	-	-	-
5	Acanthurid	Acanthuridae	-	-	135	-	-	0.02	173	0.02
6	Acanthurid sp.1	Acanthuridae	-	211	-	-	0.03	-	-	-
7	Acanthurid sp.5	Acanthuridae	301	-	-	0.01	-	-	-	-
8	Acanthurid sp.6	Acanthuridae	267	246	-	0.02	0.01	-	-	-
9	Acanthurid sp.9	Acanthuridae	-	291	-	-	0.01	-	-	-
10	*Acanthurus bariene*	Acanthuridae	-	310	-	-	<0.01	-	-	-
11	*Acanthurus dussumieri*	Acanthuridae	-	231	-	-	0.02	-	-	-
12	*Acanthurus gahhm*	Acanthuridae	61	98	186	0.46	0.31	0.01	159	0.05
13	**Acanthurus glaucopareius*	Acanthuridae	160	318	-	0.08	<0.01	-	-	-
14	**Acanthurus japonicus*	Acanthuridae	95	257	-	0.26	0.01	-	-	-
15	*Acanthurus lineatus*	Acanthuridae	135	162	-	0.14	0.07	-	-	-
16	*Acanthurus mata*	Acanthuridae	257	176	-	0.02	0.05	-	-	-
17	*Acanthurus nigrofuscus*	Acanthuridae	171	-	-	0.06	-	-	-	-
18	*Acanthurus olivaceus*	Acanthuridae	104	-	-	0.21	-	-	-	-
19	*Acanthurus pyroferus*	Acanthuridae	130	-	-	0.15	-	-	-	-
20	*Acanthurus* sp.1	Acanthuridae	-	292	-	-	0.01	-	-	-
21	*Acanthurus triostegus*	Acanthuridae	265	252	-	0.02	0.01	-	-	-
22	**Acanthurus xanthopterus*	Acanthuridae	333	-	-	0.01	-	-	-	-
23	*Acreichthys tomentosus*	Monacanthidae	-	105	7	-	0.24	8.61	7	47.67
24	*Aeoliscus strigatus*	Centriscidae	217	109	34	0.03	0.22	0.95	76	0.79
25	*Aesopia cornuta*	Soleidae	-	-	166	-	-	0.01	128	0.14
26	*Aluteres scriptus*	Monacanthidae	-	-	81	-	-	0.08	63	1.53
27	*Amblyapistus taenianotus*	Congiopodidae	-	-	59	-	-	0.22	51	2.88
28	**Amblyeleotris fasciata*	Gobiidae	192	332	-	0.04	<0.01	-	-	-
29	**Amblyeleotris japonica*	Gobiidae	323	270	-	0.01	0.01	-	-	-
30	*Amblyglyphidodon aureus*	Pomacentridae	-	295	-	-	0.01	-	-	-
31	*Amblyglyphidodon curacao*	Pomacentridae	113	15	-	0.19	8.39	-	-	-
32	*Amblyglyphidodon leucogaster*	Pomacentridae	165	243	-	0.08	0.02	-	-	-
33	*Amblygobius albimaculatus*	Gobiidae	269	142	63	0.02	0.10	0.19	68	1.33
34	*Amblygobius phalaena*	Gobiidae	-	250	185	-	0.01	0.01	141	0.11
35	*Amblygobius* sp.	Gobiidae	-	-	167	-	-	0.01	136	0.12
36	*Amphiprion clarkii*	Pomacentridae	40	111	-	0.70	0.20	-	-	-
37	*Amphiprion frenatus*	Pomacentridae	344	-	-	0.01	-	-	-	-
38	*Amphiprion ocellaris*	Pomacentridae	118	94	-	0.18	0.36	-	-	-
39	*Amphiprion perideraion*	Pomacentridae	283	-	-	0.01	-	-	-	-
40	*Amphiprion sandaracinos*	Pomacentridae	295	-	-	0.01	-	-	-	-
41	*Anampses caeruleopunctatus*	Labridae	92	282	-	0.28	0.01	-	-	-
42	*Anampses geographicus*	Labridae	71	127	-	0.38	0.11	-	-	-
43	*Anampses meleagrides*	Labridae	256	-	-	0.02	-	-	-	-
44	*Anampses twistii*	Labridae	146	-	-	0.11	-	-	-	-
45	*Antennarius moluccensis*	Antennariidae	-	-	129	-	-	0.03	114	0.24
46	*Antennarius nummifer*	Antennariidae	-	-	109	-	-	0.04	118	0.21
47	*Antennarius* sp.1	Antennariidae	-	-	157	-	-	0.01	130	0.13
48	*Anthias* sp.	Serranidae	310	-	-	0.01	-	-	-	-
49	*Apogon amboinensis*	Apogonidae	-	-	28	-	-	1.22	39	4.95
50	*Apogon bandanensis*	Apogonidae	277	54	25	0.01	1.21	1.53	34	6.75
51	*Apogon coccineus*	Apogonidae	-	215	8	-	0.03	6.03	14	19.92
52	*Apogon compressus*	Apogonidae	-	169	-	-	0.06	-	-	-
53	*Apogon cyanosoma*	Apogonidae	154	34	36	0.09	3.56	0.92	56	2.23

Continued

Appendix 1 (Continued)

			By frequency						By weight	
			Rank			Ind./transect				
No.	Species	Family	Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
54	*Apogon novemfasciatus*	Apogonidae	191	38	35	0.05	2.38	0.94	53	2.73
55	*Apogon sangiensis*	Apogonidae	-	-	3	-	-	25.89	3	80.94
56	*Apogon* sp.	Apogonidae	29	35	123	1.12	2.83	0.03	168	0.03
57	*Apogon* sp.1 (Schroeder 1980)	Apogonidae	-	214	-	-	0.03	-	-	-
58	*Apogon* sp.5 (Schroeder 1980)	Apogonidae	30	18	37	1.04	8.01	0.91	52	2.77
59	*Apogon* sp.8 (Schroeder 1980)	Apogonidae	-	-	121	-	-	0.03	108	0.29
60	Apogonid	Apogonidae	15	79	151	1.97	0.57	0.01	181	0.01
61	Apogonid sp.10	Apogonidae	-	-	127	-	-	0.03	170	0.03
62	Apogonid sp.11	Apogonidae	-	-	106	-	-	0.04	131	0.13
63	Apogonid sp.2	Apogonidae	-	170	53	-	0.06	0.33	95	0.37
64	Apogonid sp.3	Apogonidae	-	221	-	-	0.02	-	-	-
65	Apogonid sp.4	Apogonidae	-	198	-	-	0.03	-	-	-
66	Apogonid sp.5	Apogonidae	232	21	12	0.03	7.74	4.69	29	7.89
67	Apogonid sp.6	Apogonidae	-	238	-	-	0.02	-	-	-
68	Apogonid sp.7	Apogonidae	-	-	89	-	-	0.07	97	0.35
69	Apogonid sp.8	Apogonidae	-	235	-	-	0.02	-	-	-
70	*Archamia lineolata*	Apogonidae	-	-	68	-	-	0.17	79	0.68
71	*Ariosoma anagoides*	Colocongridae	-	-	56	-	-	0.30	49	3.09
72	*Arothron hispidus*	Tetraodontidae	373	283	44	<0.01	0.01	0.57	8	35.76
73	*Arothron immaculatus*	Tetraodontidae	-	147	16	-	0.09	2.93	2	97.57
74	*Arothron mappa*	Tetraodontidae	-	-	161	-	-	0.01	100	0.33
75	*Arothron nigropunctatus*	Tetraodontidae	123	140	125	0.17	0.10	0.03	57	2.12
76	*Arothron* sp.	Tetraodontidae	-	287	-	-	0.01	-	-	-
77	*Arothron* sp.2	Tetraodontidae	-	-	153	-	-	0.01	158	0.05
78	*Arothron stellatus*	Tetraodontidae	224	197	133	0.03	0.03	0.03	46	3.21
79	*Aspidontus taeniatus*	Blenniidae	302	249	-	0.01	0.01	-	-	-
80	* *Asterropteryx semipunctatus*	Gobiidae	313	-	54	0.01	-	0.33	55	2.42
81	Atherinid	Atherinidae	68	5	-	0.42	16.98	-	-	-
82	*Atule mate*	Carangidae	356	-	-	<0.01	-	-	-	-
83	*Aulostomus chinensis*	Aulostomidae	249	179	108	0.02	0.05	0.04	78	0.75
84	*Balistapus undulatus*	Balistidae	103	-	-	0.21	-	-	-	-
85	Balistid	Balistidae	246	-	141	0.02	-	0.02	164	0.05
86	Balistid sp.1	Balistidae	190	-	-	0.05	-	-	-	-
87	Balistid sp.4	Balistidae	352	-	-	<0.01	-	-	-	-
88	Balistid sp.6	Balistidae	276	-	-	0.01	-	-	-	-
89	Blenny	Blenniidae	145	236	-	0.11	0.02	-	-	-
90	Blenny sp.2	Blenniidae	362	-	-	<0.01	-	-	-	-
91	Blenny sp.7	Blenniidae	309	-	-	0.01	-	-	-	-
92	*Bodianus axillaris*	Labridae	287	-	-	0.01	-	-	-	-
93	*Bodianus bilunulatus*	Labridae	264	-	-	0.02	-	-	-	-
94	*Bodianus hirsutus*	Labridae	239	-	-	0.02	-	-	-	-
95	*Bodianus mesothorax*	Labridae	139	144	-	0.14	0.10	-	-	-
96	*Bodianus* sp.	Labridae	289	-	-	0.01	-	-	-	-
97	*Bolbometopon bicolor*	Scaridae	189	189	-	0.05	0.04	-	-	-
98	*Bothus pantherinus*	Bothidae	-	-	160	-	-	0.01	129	0.13
99	*Caesio caerulaurea*	Lutjanidae	64	-	-	0.45	-	-	-	-
100	*Caesio erythrogaster*	Lutjanidae	82	201	177	0.33	0.03	0.01	160	0.05
101	*Caesio* sp.	Lutjanidae	297	-	-	0.01	-	-	-	-
102	*Caesio tile*	Lutjanidae	129	84	-	0.15	0.49	-	-	-
103	*Calloplesiops altivelis*	Plesiopidae	345	-	-	0.01	-	-	-	-
104	*Calotomus carolinus*	Scaridae	254	-	-	0.02	-	-	-	-
105	*Calotomus japonicus*	Scaridae	32	27	42	1.02	5.14	0.59	25	9.98
106	*Calotomus* sp.	Scaridae	179	-	-	0.05	-	-	-	-
107	*Cantherhines dumerilii*	Monacanthidae	359	-	-	<0.01	-	-	-	-
108	*Cantherhines pardalis*	Monacanthidae	157	233	-	0.09	0.02	-	-	-

Continued

Appendix 1 (Continued)

			By frequency						By weight	
			Rank			Ind./transect				
No.	Species	Family	Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
109	*Canthigaster bennetti*	Tetraodontidae	127	154	64	0.15	0.08	0.17	66	1.35
110	*Canthigaster compressa*	Tetraodontidae	338	-	-	0.01	-	-	-	-
111	*Canthigaster coronata*	Tetraodontidae	322	-	-	0.01	-	-	-	-
112	*Canthigaster janthinoptera*	Tetraodontidae	-	253	-	-	0.01	-	-	-
113	* *Canthigaster solandri*	Tetraodontidae	374	279	-	<0.01	0.01	-	-	-
114	*Canthigaster valentini*	Tetraodontidae	49	76	88	0.56	0.60	0.07	101	0.32
115	Carangid	Carangidae	369	-	-	<0.01	-	-	-	-
116	*Carangoides fulvoguttatus*	Carangidae	348	-	-	<0.01	-	-	-	-
117	*Caranx melampygus*	Carangidae	332	-	-	0.01	-	-	-	-
118	*Centrogenys vaigiensis*	Percichthyidae	202	294	17	0.04	0.01	2.55	9	28.63
119	*Centropyge bicolor*	Pomacanthidae	237	-	-	0.02	-	-	-	-
120	*Centropyge bispinosus*	Pomacanthidae	112	-	-	0.19	-	-	-	-
121	*Centropyge heraldi*	Pomacanthidae	94	212	-	0.26	0.03	-	-	-
122	*Centropyge tibicen*	Pomacanthidae	161	260	-	0.08	0.01	-	-	-
123	*Centropyge vrolicki*	Pomacanthidae	99	-	-	0.24	-	-	-	-
124	*Cephalopholis argus*	Serranidae	207	-	-	0.03	-	-	-	-
125	* *Cephalopholis boenack*	Serranidae	336	-	-	0.01	-	-	-	-
126	*Cephalopholis miniata*	Serranidae	308	-	-	0.01	-	-	-	-
127	*Cephalopholis pachycentron*	Serranidae	196	-	-	0.04	-	-	-	-
128	*Cephalopholis* sp.	Serranidae	325	-	-	0.01	-	-	-	-
129	*Cephalopholis urodela*	Serranidae	45	-	-	0.59	-	-	-	-
130	* *Chaetodon adiergastos*	Chaetodontidae	-	182	-	-	0.05	-	-	-
131	*Chaetodon auriga*	Chaetodontidae	147	74	78	0.11	0.64	0.11	115	0.23
132	*Chaetodon baronessa*	Chaetodontidae	306	278	-	0.01	0.01	-	-	-
133	*Chaetodon bennetti*	Chaetodontidae	-	316	-	-	<0.01	-	-	-
134	*Chaetodon citrinellus*	Chaetodontidae	121	92	-	0.17	0.36	-	-	-
135	*Chaetodon ephippium*	Chaetodontidae	-	219	-	-	0.03	-	-	-
136	*Chaetodon kleinii*	Chaetodontidae	20	90	-	1.49	0.41	-	-	-
137	*Chaetodon lineolatus*	Chaetodontidae	-	264	-	-	0.01	-	-	-
138	*Chaetodon lunula*	Chaetodontidae	260	193	140	0.02	0.04	0.02	177	0.02
139	*Chaetodon melannotus*	Chaetodontidae	128	68	104	0.15	0.75	0.04	116	0.22
140	*Chaetodon mertensii*	Chaetodontidae	22	104	-	1.39	0.25	-	-	-
141	*Chaetodon octofasciatus*	Chaetodontidae	115	-	-	0.19	-	-	-	-
142	*Chaetodon ornatissimus*	Chaetodontidae	193	-	-	0.04	-	-	-	-
143	*Chaetodon punctatofasciatus*	Chaetodontidae	62	227	-	0.45	0.02	-	-	-
144	*Chaetodon rafflesi*	Chaetodontidae	-	263	-	-	0.01	-	-	-
145	*Chaetodon* sp.	Chaetodontidae	303	-	-	0.01	-	-	-	-
146	*Chaetodon trifascialis*	Chaetodontidae	227	-	-	0.03	-	-	-	-
147	*Chaetodon trifasciatus*	Chaetodontidae	131	60	163	0.14	0.91	0.01	183	0.01
148	*Chaetodon ulietensis*	Chaetodontidae	294	226	-	0.01	0.02	-	-	-
149	*Chaetodon unimaculatus*	Chaetodontidae	178	314	-	0.05	<0.01	-	-	-
150	*Chaetodon vagabundus*	Chaetodontidae	97	99	-	0.25	0.30	-	-	-
151	*Chaetodon xanthurus*	Chaetodontidae	134	122	-	0.14	0.12	-	-	-
152	*Cheilinus bimaculatus*	Labridae	57	165	95	0.49	0.07	0.06	125	0.15
153	* *Cheilinus celebicus*	Labridae	63	234	-	0.45	0.02	-	-	-
154	*Cheilinus diagrammus*	Labridae	73	245	-	0.37	0.02	-	-	-
155	*Cheilinus fasciatus*	Labridae	173	220	169	0.06	0.03	0.01	154	0.06
156	*Cheilinus rhodochrous*	Labridae	349	-	-	<0.01	-	-	-	-
157	*Cheilinus* sp.	Labridae	315	-	-	0.01	-	-	-	-
158	*Cheilinus trilobatus*	Labridae	12	39	39	2.33	2.36	0.74	41	4.37
159	*Cheilinus undulatus*	Labridae	271	-	-	0.02	-	-	-	-
160	*Cheilio inermis*	Labridae	93	71	62	0.27	0.69	0.20	44	3.34
161	*Cheilodipterus macrodon*	Apogonidae	152	72	60	0.09	0.69	0.21	111	0.28
162	*Cheilodipterus quinquelineatus*	Apogonidae	19	19	9	1.57	7.95	5.19	24	10.68
163	*Chelonodon patoca*	Tetraodontidae	-	-	74	-	-	0.13	33	6.91

Continued

Appendix 1 (Continued)

No.	Species	Family	By frequency Rank Slope	Flat	Trawl	Ind./transect Slope	Flat	Trawl	By weight Rank	Trawl
164	*Choerodon anchorago*	Labridae	125	45	27	0.16	1.77	1.34	23	11.53
165 *	*Choerodon shoenleinii*	Labridae	-	-	173	-	-	0.01	163	0.05
166	*Chromis caerulea*	Pomacentridae	144	6	-	0.11	16.76	-	-	-
167	*Chromis lepidolepis*	Pomacentridae	311	-	-	0.01	-	-	-	-
168	*Chromis margaritifer*	Pomacentridae	47	299	-	0.57	0.01	-	-	-
169	*Chromis* sp.	Pomacentridae	234	-	-	0.03	-	-	-	-
170	*Chromis weberi*	Pomacentridae	38	200	-	0.75	0.03	-	-	-
171	*Chromis xanthura*	Pomacentridae	107	184	-	0.20	0.05	-	-	-
172	*Chrysiptera leucopoma*	Pomacentridae	229	-	-	0.03	-	-	-	-
173	*Cirrhilabrus cyanopleura*	Labridae	23	281	-	1.34	0.01	-	-	-
174 *	*Cirrhilabrus polyzona*	Labridae	288	-	-	0.01	-	-	-	-
175	*Cirrhitichthys aprinus*	Cirrhitidae	225	-	-	0.03	-	-	-	-
176	*Cirrhitichthys falco*	Cirrhitidae	58	-	-	0.48	-	-	-	-
177	*Cirrhitichthys serratus*	Cirrhitidae	290	-	-	0.01	-	-	-	-
178	*Cirrhitops hubbardi*	Cirrhitidae	305	-	-	0.01	-	-	-	-
179	*Cirripectes polyzona*	Blenniidae	304	-	-	0.01	-	-	-	-
180 *	*Cirripectes variolosus*	Blenniidae	138	93	-	0.14	0.36	-	-	-
181	Clupeid	Clupeidae	35	9	117	0.83	15.28	0.03	176	0.02
182	*Conger cinereus*	Congridae	-	-	80	-	-	0.11	32	6.93
183	*Conger* sp.	Congridae	-	-	144	-	-	0.02	140	0.11
184	*Coris aygula*	Labridae	350	-	-	<0.01	-	-	-	-
185	*Coris dorsumacula*	Labridae	280	-	-	0.01	-	-	-	-
186	*Coris gaimardi*	Labridae	84	113	-	0.30	0.18	-	-	-
187	*Coris variegata*	Labridae	50	40	-	0.56	2.34	-	-	-
188	*Corythoichthys haematopterus*	Syngnathidae	-	117	46	-	0.15	0.52	69	1.15
189 *	*Corythoichthys schultzi*	Syngnathidae	-	284	126	-	0.01	0.03	157	0.05
190	*Ctenochaetus binotatus*	Acanthuridae	2	42	175	11.04	1.98	0.01	166	0.03
191	*Ctenochaetus striatus*	Acanthuridae	11	56	-	2.54	1.13	-	-	-
192	*Dampieria cyclophthalma*	Pseudochromidae	34	83	58	0.89	0.49	0.23	72	1.06
193	*Dampieria* sp.	Pseudochromidae	-	187	-	-	0.05	-	-	-
194	*Dascyllus aruanus*	Pomacentridae	253	4	-	0.02	28.46	-	-	-
195	*Dascyllus melanurus*	Pomacentridae	-	132	-	-	0.11	-	-	-
196	*Dascyllus reticulatus*	Pomacentridae	88	85	-	0.29	0.48	-	-	-
197	*Dascyllus trimaculatus*	Pomacentridae	66	82	-	0.43	0.50	-	-	-
198	*Decapterus* sp.	Carangidae	353	-	-	<0.01	-	-	-	-
199	*Dendrochirus zebra*	Scorpaenidae	162	228	148	0.08	0.02	0.01	81	0.66
200	*Diodon hystrix*	Diodontidae	312	334	164	0.01	<0.01	0.01	36	5.48
201	*Diploprion bifasciatus*	Grammistidae	186	241	-	0.05	0.02	-	-	-
202	*Dischistodus chrysopoecilus*	Pomacentridae	126	20	94	0.16	7.80	0.06	104	0.30
203	*Dischistodus notopthalmus*	Pomacentridae	-	69	150	-	0.72	0.01	152	0.07
204	*Dischistodus perspicillatus*	Pomacentridae	-	216	-	-	0.03	-	-	-
205	*Dischistodus prosopotaenia*	Pomacentridae	182	57	-	0.05	1.07	-	-	-
206 *	*Dischistodus pseudochrysopoecilus*	Pomacentridae	-	137	-	-	0.10	-	-	-
207	*Drepane longimana*	Ephippidae	-	-	165	-	-	0.01	155	0.06
208	*Dunckerocampus dactyliophorus*	Syngnathidae	-	-	70	-	-	0.15	85	0.54
209	*Echidna nebulosa*	Muraenidae	-	181	-	-	0.05	-	-	-
210 *	*Eleotris fusca*	Gobiidae	-	-	134	-	-	0.02	143	0.10
211	*Encheiliophis vermicularis*	Carapidae	-	-	97	-	-	0.05	91	0.46
212	Engraulid	Engraulididae	-	2	-	-	33.26	-	-	-
213	*Epibulus insidiator*	Labridae	116	114	-	0.18	0.18	-	-	-
214	*Epinephelus fasciatus*	Serranidae	53	205	-	0.53	0.03	-	-	-
215	*Epinephelus fuscoguttatus*	Serranidae	-	-	183	-	-	0.01	87	0.50
216	*Epinephelus hexagonatus*	Serranidae	-	288	-	-	0.01	-	-	-
217	*Epinephelus macrospilus*	Serranidae	-	302	-	-	0.01	-	-	-
218	*Epinephelus maculatus*	Serranidae	-	335	-	-	<0.01	-	-	-

Continued

Appendix 1 (Continued)

			By frequency						By weight	
			Rank			Ind./transect				
No.	Species	Family	Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
219	*Epinephelus megachir*	Serranidae	-	305	-	-	0.01	-	-	-
220	*Epinephelus merra*	Serranidae	42	29	31	0.62	4.84	1.07	20	13.24
221	*Epinephelus ongus*	Serranidae	-	120	38	-	0.13	0.80	26	9.27
222	*Epinephelus sexfasciatus*	Serranidae	282	-	-	0.01	-	-	-	-
223	*Epinephelus* sp.	Serranidae	275	-	-	0.01	-	-	-	-
224	*Epinephelus tauvina*	Serranidae	-	-	146	-	-	0.01	132	0.13
225	*Escualosa thoracata*	Clupeidae	-	91	69	-	0.39	0.17	123	0.16
226	*Eupomacentrus lividus*	Pomacentridae	140	13	168	0.12	11.74	0.01	147	0.08
227	*Eupomacentrus nigricans*	Pomacentridae	164	1	130	0.08	35.52	0.03	153	0.07
228	*Exallias brevis*	Blenniidae	166	247	-	0.07	0.01	-	-	-
229	*Exyrias bellissimus*	Gobiidae	-	-	96	-	-	0.05	88	0.49
230	*Exyrias puntang*	Gobiidae	-	224	66	-	0.02	0.17	58	2.06
231	*Fistularia petimba*	Fistulariidae	240	159	113	0.02	0.08	0.04	144	0.10
232	*Forcipiger flavissimus*	Chaetodontidae	142	-	-	0.12	-	-	-	-
233	*Fowleria variegata*	Apogonidae	-	-	2	-	-	58.02	1	303.10
234 *	*Gerres acinaces*	Gerreidae	-	327	-	-	<0.01	-	-	-
235	*Gerres oyena*	Gerreidae	-	315	49	-	<0.01	0.39	71	1.07
236	*Glossogobius olivaceous*	Gobiidae	-	-	152	-	-	0.01	120	0.20
237	*Glyphidodontops biocellatus*	Pomacentridae	-	123	-	-	0.12	-	-	-
238	*Glyphidodontops cyaneus*	Pomacanthidae	357	100	-	<0.01	0.28	-	-	-
239	*Glyphidodontops hemicyaneus*	Pomacentridae	-	199	-	-	0.03	-	-	-
240	*Glyphidodontops leucopomus*	Pomacanthidae	263	267	-	0.02	0.01	-	-	-
241	*Glyphidodontops rollandi*	Pomacanthidae	343	155	-	0.01	0.08	-	-	-
242 *	*Glyphidodontops starcki*	Pomacentridae	-	261	-	-	0.01	-	-	-
243	*Gnathodentex aureolineatus*	Lethrinidae	65	46	-	0.44	1.75	-	-	-
244	Goby	Gobiidae	181	135	86	0.05	0.10	0.07	86	0.51
245	Goby sp.	Gobiidae	-	290	-	-	0.01	-	-	-
246	Goby sp.11	Gobiidae	-	-	67	-	-	0.17	106	0.30
247	Goby sp.12	Gobiidae	296	-	-	0.01	-	-	-	-
248	Goby sp.4	Gobiidae	-	317	-	-	<0.01	-	-	-
249	Goby sp.5	Gobiidae	-	329	-	-	<0.01	-	-	-
250	Goby sp.6	Gobiidae	-	286	-	-	0.01	-	-	-
251	Goby sp.7	Gobiidae	370	-	-	<0.01	-	-	-	-
252	Goby sp.8	Gobiidae	-	-	118	-	-	0.03	90	0.48
253	Goby sp.9	Gobiidae	-	-	99	-	-	0.05	134	0.13
254	*Gomphosus varius*	Labridae	44	81	-	0.62	0.52	-	-	-
255	*Grammistes sexlineatus*	Grammistidae	238	138	116	0.02	0.10	0.03	83	0.59
256	*Gymnomuraena zebra*	Muraenidae	268	297	-	0.02	0.01	-	-	-
257	*Gymnothorax fimbriatus*	Muraenidae	335	190	-	0.01	0.04	-	-	-
258	*Gymnothorax meleagris*	Muraenidae	368	-	-	<0.01	-	-	-	-
259	*Gymnothorax pictus*	Muraenidae	222	158	32	0.03	0.08	1.02	11	25.67
260	*Halicamphus dunckeri*	Syngnathidae	-	-	85	-	-	0.07	127	0.14
261	*Halichoeres biocellatus*	Labridae	101	196	-	0.23	0.04	-	-	-
262	*Halichoeres hortulanus*	Labridae	69	62	-	0.41	0.88	-	-	-
263	*Halichoeres margaritaceus*	Labridae	215	166	-	0.03	0.06	-	-	-
264	*Halichoeres marginatus*	Labridae	67	67	-	0.42	0.77	-	-	-
265	*Halichoeres melanochir*	Labridae	31	218	-	1.03	0.03	-	-	-
266	*Halichoeres melanurus*	Labridae	17	7	-	1.89	16.17	-	-	-
267	*Halichoeres nebulosus*	Labridae	1	63	-	14.88	0.83	-	-	-
268	*Halichoeres poecilopterus*	Labridae	76	89	-	0.35	0.43	-	-	-
269	*Halichoeres prosopeion*	Labridae	172	161	-	0.06	0.07	-	-	-
270	*Halichoeres scapularis*	Labridae	360	32	-	<0.01	4.33	-	-	-
271	*Halichoeres* sp.	Labridae	361	124	-	<0.01	0.11	-	-	-
272	*Halichoeres* sp.2 (Schroeder 1980)	Labridae	-	225	-	-	0.02	-	-	-
273	*Halichoeres* sp.3	Labridae	-	239	-	-	0.02	-	-	-

Continued

Appendix 1 (Continued)

No.	Species	Family	By frequency: Rank Slope	Rank Flat	Rank Trawl	Ind./transect Slope	Ind./transect Flat	Ind./transect Trawl	By weight: Rank	By weight: Trawl
274	*Halichoeres trimaculatus*	Labridae	158	26	-	0.08	5.23	-	-	-
275	*Hemiglyphidodon plagiometopon*	Pomacentridae	231	131	-	0.03	0.11	-	-	-
276	*Hemigymnus fasciatus*	Labridae	281	145	-	0.01	0.10	-	-	-
277	*Hemigymnus melapterus*	Labridae	75	58	-	0.36	1.06	-	-	-
278	*Hemipteronotus taeniurus*	Labridae	-	265	-	-	0.01	-	-	-
279	*Heniochus chrysostomus*	Chaetodontidae	184	178	-	0.05	0.05	-	-	-
280	*Heniochus varius*	Chaetodontidae	220	177	-	0.03	0.05	-	-	-
281	*Hippichthys spicifer*	Syngnathidae	-	-	142	-	-	0.02	179	0.02
282	*Hippocampus histrix*	Syngnathidae	-	-	93	-	-	0.06	99	0.34
283	*Hippocampus kuda*	Syngnathidae	-	-	107	-	-	0.04	94	0.38
284	*Hippocampus* sp.	Syngnathidae	-	326	-	-	<0.01	-	-	-
285	*Histrio histrio*	Antennariidae	-	-	128	-	-	0.03	117	0.21
286	*Hologymnosus annulatus*	Labridae	119	-	-	0.18	-	-	-	-
287	*Hologymnosus doliatus*	Labridae	261	-	-	0.02	-	-	-	-
288	*Hologymnosus* sp.	Labridae	314	-	-	0.01	-	-	-	-
289	*Hypoatherina bleekeri*	Atherinidae	-	10	26	-	15.13	1.43	45	3.33
290	*Hypodytes rubripinnis*	Congiopodidae	-	-	98	-	-	0.05	77	0.77
291	*Istigobius ornatus*	Gobiidae	242	-	-	0.02	-	-	-	-
292	*Labrichthys unilineatus*	Labridae	90	186	-	0.29	0.05	-	-	-
293	Labrid	Labridae	86	168	139	0.30	0.06	0.02	186	0.01
294	Labrid sp.17	Labridae	-	275	-	-	0.01	-	-	-
295	*Labroides bicolor*	Labridae	-	324	-	-	<0.01	-	-	-
296	*Labroides dimidiatus*	Labridae	27	37	-	1.15	2.44	-	-	-
297	*Labropsis manabei*	Labridae	341	-	-	0.01	-	-	-	-
298	*Lactoria cornuta*	Ostraciidae	-	-	91	-	-	0.06	59	1.96
299	*Leptoscarus vaigiensis*	Scaridae	-	248	57	-	0.01	0.24	65	1.42
300	Lethrinid	Lethrinidae	340	-	-	0.01	-	-	-	-
301	* *Lethrinus haematopterus*	Lethrinidae	-	271	-	-	0.01	-	-	-
302	*Lethrinus harak*	Lethrinidae	262	101	13	0.02	0.27	4.30	10	27.12
303	*Lethrinus lentjan*	Lethrinidae	-	331	55	-	<0.01	0.31	60	1.89
304	*Lethrinus mahsena*	Lethrinidae	278	152	52	0.01	0.08	0.34	75	0.91
305	* *Lethrinus nebulosus*	Lethrinidae	-	-	176	-	-	0.01	167	0.03
306	* *Lethrinus nematacanthus*	Lethrinidae	-	254	110	-	0.01	0.04	126	0.15
307	* *Lethrinus obsoletus*	Lethrinidae	-	259	21	-	0.01	2.07	31	7.00
308	*Lethrinus ornatus*	Lethrinidae	364	96	18	<0.01	0.33	2.52	35	5.62
309	* *Lethrinus reticulatus*	Lethrinidae	-	337	23	-	<0.01	1.83	28	8.55
310	*Lethrinus* sp.	Lethrinidae	-	-	181	-	-	0.01	184	0.01
311	* *Lethrinus variegatus*	Lethrinidae	-	-	120	-	-	0.03	96	0.37
312	Lutjanid	Lutjanidae	243	-	-	0.02	-	-	-	-
313	*Lutjanus biguttatus*	Lutjanidae	-	209	-	-	0.03	-	-	-
314	*Lutjanus bohar*	Lutjanidae	-	280	-	-	0.01	-	-	-
315	*Lutjanus decussatus*	Lutjanidae	206	172	114	0.03	0.06	0.04	121	0.19
316	*Lutjanus fulviflamma*	Lutjanidae	208	229	50	0.03	0.02	0.37	47	3.17
317	*Lutjanus fulvus*	Lutjanidae	-	130	-	-	0.11	-	-	-
318	*Lutjanus gibbus*	Lutjanidae	273	223	162	0.01	0.02	0.01	151	0.07
319	*Lutjanus kasmira*	Lutjanidae	-	-	182	-	-	0.01	124	0.15
320	*Lutjanus lineolatus*	Lutjanidae	328	273	115	0.01	0.01	0.03	165	0.04
321	*Lutjanus lutjanus*	Lutjanidae	327	-	-	0.01	-	-	-	-
322	*Lutjanus monostigma*	Lutjanidae	-	210	-	-	0.03	-	-	-
323	*Lutjanus russellii*	Lutjanidae	-	330	-	-	<0.01	-	-	-
324	*Lutjanus* sp.	Lutjanidae	307	-	-	0.01	-	-	-	-
325	*Lutjanus vitta*	Lutjanidae	300	-	-	0.01	-	-	-	-
326	*Macolor niger*	Lutjanidae	244	-	-	0.02	-	-	-	-
327	*Macropharyngodon meleagris*	Labridae	25	148	-	1.24	0.09	-	-	-
328	*Macropharyngodon negrosensis*	Labridae	170	-	-	0.06	-	-	-	-

Continued

Appendix 1 (Continued)

No.	Species	Family	By frequency: Rank Slope	Rank Flat	Rank Trawl	Ind./transect Slope	Ind./transect Flat	Ind./transect Trawl	By weight: Rank	Trawl
329	*Malacanthus brevirostris*	Malacanthidae	250	-	-	0.02	-	-	-	-
330	*Meiacanthus grammistes*	Blenniidae	55	107	-	0.50	0.23	-	-	-
331	*Melichthys vidua*	Balistidae	150	-	-	0.10	-	-	-	-
332	Monacanthid sp.1	Monacanthidae	274	-	-	0.01	-	-	-	-
333	*Monotaxis grandoculis*	Lethrinidae	236	125	-	0.02	0.11	-	-	-
334	*Mulloidichthys flavolineatus*	Mullidae	209	202	83	0.03	0.03	0.08	145	0.10
335	*Myrichthys aki*	Ophichthidae	-	303	143	-	0.01	0.02	148	0.08
336	*Myripristis berndti*	Holocentridae	258	262	-	0.02	0.01	-	-	-
337	*Myripristis murdjan*	Holocentridae	102	118	-	0.22	0.13	-	-	-
338	*Myripristis* sp.1	Holocentridae	324	-	-	0.01	-	-	-	-
339	*Naso brevirostris*	Acanthuridae	331	-	-	0.01	-	-	-	-
340	*Naso lituratus*	Acanthuridae	105	163	184	0.20	0.07	0.01	133	0.13
341	*Naso* sp.	Acanthuridae	226	213	102	0.03	0.03	0.04	149	0.07
342	*Naso unicornis*	Acanthuridae	159	188	111	0.08	0.05	0.04	103	0.31
343	*Nemateleotris magnifica*	Gobiidae	41	-	-	0.70	-	-	-	-
344	*Neoniphon sammara*	Holocentridae	330	75	-	0.01	0.60	-	-	-
345	*Novaculichthys macrolepidotus*	Labridae	320	-	-	0.01	-	-	-	-
346	*Novaculichthys taeniurus*	Labridae	187	167	-	0.05	0.06	-	-	-
347	*Oostethus brachyurus*	Syngnathidae	-	-	136	-	-	0.02	172	0.02
348	*Ophichthus* sp.	Ophichthidae	-	-	156	-	-	0.01	93	0.40
349	*Ophichthus urolophus*	Ophichthidae	-	306	-	-	0.01	-	-	-
350	*Ostracion cubicus*	Ostraciidae	141	141	92	0.12	0.10	0.06	112	0.28
351	*Ostracion meleagris*	Ostraciidae	122	244	-	0.17	0.02	-	-	-
352	*Paracirrhites arcatus*	Cirrhitidae	24	272	-	1.30	0.01	-	-	-
353	*Paracirrhites forsteri*	Cirrhitidae	168	-	-	0.07	-	-	-	-
354	*Paraglyphidodon behni*	Pomacentridae	106	128	-	0.20	0.11	-	-	-
355 *	*Paraglyphidodon carlsoni*	Pomacentridae	205	126	-	0.04	0.11	-	-	-
356	*Paraglyphidodon melas*	Pomacentridae	43	43	-	0.62	1.89	-	-	-
357	*Paraglyphidodon nigroris*	Pomacentridae	143	110	-	0.11	0.20	-	-	-
358 •	*Paraglyphidodon polyacanthus*	Pomacentridae	-	208	-	-	0.03	-	-	-
359 *	*Paraglyphidodon thoracotaeniatus*	Pomacentridae	219	269	-	0.03	0.01	-	-	-
360	*Parapercis cephalopunctata*	Mugiloididae	79	-	-	0.34	-	-	-	-
361	*Parapercis clathrata*	Mugiloididae	39	116	-	0.72	0.15	-	-	-
362	*Parapercis cylindrica*	Mugiloididae	120	23	30	0.18	5.75	1.12	22	11.78
363	*Parapercis polyophthalma*	Mugiloididae	83	206	-	0.32	0.03	-	-	-
364	*Parapercis* sp.	Mugiloididae	285	-	-	0.01	-	-	-	-
365	*Parapercis tetracantha*	Mugiloididae	286	-	-	0.01	-	-	-	-
366	*Pardachirus pavoninus*	Soleidae	-	321	47	-	<0.01	0.41	27	8.57
367	*Parupeneus barberinoides*	Mullidae	247	87	48	0.02	0.46	0.40	61	1.82
368	*Parupeneus barberinus*	Mullidae	100	95	14	0.23	0.33	4.01	19	13.35
369	*Parupeneus bifasciatus*	Mullidae	177	149	-	0.06	0.09	-	-	-
370	*Parupeneus cyclostomus*	Mullidae	124	230	-	0.16	0.02	-	-	-
371	*Parupeneus heptacanthus*	Mullidae	316	309	124	0.01	<0.01	0.03	150	0.07
372	*Parupeneus indicus*	Mullidae	329	-	71	0.01	-	0.14	64	1.44
373	*Parupeneus pleurostigma*	Mullidae	200	-	-	0.04	-	-	-	-
374	*Parupeneus trifasciatus*	Mullidae	3	25	41	4.87	5.25	0.59	54	2.45
375	*Pelatus quadrilineatus*	Teraponidae	-	-	43	-	-	0.58	62	1.69
376	*Pempheris oualensis*	Pempherididae	-	-	159	-	-	0.01	171	0.03
377	*Pentapodus macrurus*	Nemipteridae	223	-	158	0.03	-	0.01	138	0.12
378	*Pervagor aspricaudus*	Monacanthidae	133	-	-	0.14	-	-	-	-
379	*Pervagor janthinosoma*	Monacanthidae	96	276	-	0.25	0.01	-	-	-
380	*Petroscirtes breviceps*	Blenniidae	-	320	11	-	<0.01	4.86	17	15.55
381	*Petroscirtes* sp.	Blenniidae	-	232	-	-	0.02	-	-	-
382	*Plagiotremus rhinorhynchos*	Blenniidae	108	173	-	0.20	0.06	-	-	-
383	*Plagiotremus tapeinosoma*	Blenniidae	148	285	-	0.10	0.01	-	-	-

Continued

Appendix 1 (Continued)

No.	Species	Family	By frequency						By weight	
			Rank			Ind /transect				
			Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
384	*Platax orbicularis*	Ephippidae	-	-	131	-	-	0.03	135	0.12
385	*Platax pinnatus*	Ephippidae	-	304	-	-	0.01	-	-	-
386	*Platycephalus indicus*	Platycephalidae	-	-	84	-	-	0.08	42	4.21
387	*Plectorhynchus chaetodontoides*	Haemulidae	367	195	132	<0.01	0.04	0.03	113	0.26
388	*Plectorhynchus diagrammus*	Haemulidae	163	121	-	0.08	0.13	-	-	-
389	*Plectorhynchus goldmanni*	Haemulidae	346	240	-	<0.01	0.02	-	-	-
390	*Plectorhynchus lineatus*	Haemulidae	153	136	103	0.09	0.10	0.04	82	0.64
391	*Plectorhynchus* sp.	Haemulidae	354	-	149	<0.01	-	0.01	182	0.01
392	*Plectroglyphidodon dickii*	Pomacentridae	98	175	-	0.25	0.06	-	-	-
393	*Plectroglyphidodon lacrymatus*	Pomacentridae	52	44	-	0.55	1.83	-	-	-
394 *	*Plectroglyphidodon leucozona*	Pomacentridae	-	115	-	-	0.16	-	-	-
395	*Plectropomus leopardus*	Serranidae	155	-	-	0.09	-	-	-	-
396	*Plotosus canius*	Plotosidae	-	-	77	-	-	0.12	50	2.90
397	*Plotosus lineatus*	Plotosidae	4	12	4	4.06	12.14	25.64	18	15.35
398	*Pomacanthus imperator*	Pomacanthidae	339	-	-	0.01	-	-	-	-
399	*Pomacanthus semicirculatus*	Pomacanthidae	292	-	-	0.01	-	-	-	-
400	Pomacentrid	Pomacentridae	199	289	-	0.04	0.01	-	-	-
401	Pomacentrid sp.1	Pomacentridae	183	312	-	0.05	<0.01	-	-	-
402	Pomacentrid sp.10	Pomacentridae	-	256	-	-	0.01	-	-	-
403	Pomacentrid sp.11	Pomacentridae	372	-	-	<0.01	-	-	-	-
404	Pomacentrid sp.12	Pomacentridae	284	-	-	0.01	-	-	-	-
405	Pomacentrid sp.2	Pomacentridae	321	-	-	0.01	-	-	-	-
406	Pomacentrid sp.4	Pomacentridae	89	-	-	0.29	-	-	-	-
407	*Pomacentrus amboinensis*	Pomacentridae	211	103	-	0.03	0.25	-	-	-
408	*Pomacentrus bankanensis*	Pomacentridae	14	33	-	2.15	3.77	-	-	-
409	*Pomacentrus coelestis*	Pomacentridae	8	80	-	2.98	0.53	-	-	-
410	*Pomacentrus flavicauda*	Pomacentridae	36	11	-	0.82	13.31	-	-	-
411	*Pomacentrus grammorhynchus*	Pomacentridae	366	31	-	<0.01	4.49	-	-	-
412	*Pomacentrus labiatus*	Pomacentridae	-	129	-	-	0.11	-	-	-
413	*Pomacentrus lepidogenys*	Pomacentridae	74	194	-	0.36	0.04	-	-	-
414	*Pomacentrus melanopterus*	Pomacentridae	-	139	-	-	0.10	-	-	-
415	*Pomacentrus moluccensis*	Pomacentridae	77	53	-	0.35	1.29	-	-	-
416	*Pomacentrus nagasakiensis*	Pomacentridae	319	-	-	0.01	-	-	-	-
417	*Pomacentrus philippinus*	Pomacentridae	81	88	-	0.33	0.43	-	-	-
418	*Pomacentrus smithi*	Pomacentridae	70	133	-	0.40	0.10	-	-	-
419	*Pomacentrus* sp.	Pomacentridae	201	106	-	0.04	0.24	-	-	-
420	*Pomacentrus taeniometopon**	Pomacentridae	114	49	-	0.19	1.57	-	-	-
421	*Pomacentrus trimaculatus*	Pomacentridae	204	102	-	0.04	0.26	-	-	-
422	*Pomacentrus tripunctatus*	Pomacentridae	291	41	179	0.01	2.22	0.01	139	0.12
423	*Pomacentrus vaiuli*	Pomacentridae	7	112	-	3.02	0.19	-	-	-
424	*Pomachromis richardsoni*	Pomacentridae	9	70	-	2.82	0.71	-	-	-
425	*Priacanthus macracanthus*	Priacanthidae	188	-	-	0.05	-	-	-	-
426	*Pseudanthias squamipinnis*	Serranidae	233	-	-	0.03	-	-	-	-
427	*Pseudobalistes flavimarginatus*	Balistidae	255	322	154	0.02	<0.01	0.01	146	0.09
428	*Pseudobalistes fuscus*	Balistidae	371	-	105	<0.01	-	0.04	107	0.29
429	*Pseudocheilinus evanidus*	Labridae	214	-	-	0.03	-	-	-	-
430	*Pseudocheilinus hexataenia*	Labridae	28	77	-	1.14	0.58	-	-	-
431	*Pseudocheilinus octotaenia*	Labridae	245	-	-	0.02	-	-	-	-
432	Pseudochromid sp.2	Pseudochromidae	-	301	-	-	0.01	-	-	-
433	*Pseudochromis* sp.	Pseudochromidae	-	307	-	-	0.01	-	-	-
434	*Pseudojuloides cerasinus*	Labridae	221	-	-	0.03	-	-	-	-
435	*Pseudomonacanthus macrurus*	Monacanthidae	-	328	180	-	<0.01	0.01	161	0.05
436	*Ptereleotris evides*	Gobiidae	78	-	-	0.35	-	-	-	-
437	*Pterocaesio chrysozona*	Lutjanidae	136	51	-	0.14	1.39	-	-	-
438	*Pterocaesio pisang*	Lutjanidae	151	-	-	0.09	-	-	-	-

Continued

Appendix 1 (Continued)

			By frequency						By weight	
			Rank			Ind./transect				
No.	Species	Family	Slope	Flat	Trawl	Slope	Flat	Trawl	Rank	Trawl
439	*Pterois volitans*	Scorpaenidae	363	174	112	<0.01	0.06	0.04	119	0.21
440	*Rhinecanthus aculeatus*	Balistidae	176	151	-	0.06	0.09	-	-	-
441	*Rhinecanthus rectangulus*	Balistidae	318	-	-	0.01	-	-	-	-
442	*Rhinecanthus* sp.	Balistidae	-	300	-	-	0.01	-	-	-
443	*Rhinecanthus verrucosus*	Balistidae	180	242	-	0.05	0.02	-	-	-
444	*Salarias fasciatus*	Blenniidae	60	47	-	0.47	1.67	-	-	-
445	*Salarias* sp.	Blenniidae	230	-	-	0.03	-	-	-	-
446	*Sardinella* sp.	Clupeidae	-	3	61	-	31.34	0.21	122	0.19
447	*Sargocentron caudimaculatum*	Holocentridae	-	251	-	-	0.01	-	-	-
448	*Sargocentron diadema*	Holocentridae	259	222	-	0.02	0.02	-	-	-
449	*Sargocentron ittodai*	Holocentridae	-	204	-	-	0.03	-	-	-
450	*Sargocentron rubrum*	Holocentridae	210	217	-	0.03	0.03	-	-	-
451	*Sargocentron* sp.	Holocentridae	365	-	-	<0.01	-	-	-	-
452	*Sargocentron* sp.3	Holocentridae	-	296	-	-	0.01	-	-	-
453	*Saurida gracilis*	Synodontidae	185	164	20	0.05	0.07	2.13	13	22.37
454	*Saurida* sp.	Synodontidae	-	-	137	-	-	0.02	174	0.02
455	Scarid	Scaridae	37	16	119	0.78	8.25	0.03	178	0.02
456	Scarid sp.10	Scaridae	-	323	-	-	<0.01	-	-	-
457	Scarid sp.15	Scaridae	-	266	-	-	0.01	-	-	-
458	Scarid sp.18	Scaridae	-	108	-	-	0.22	-	-	-
459	Scarid sp.2	Scaridae	-	183	-	-	0.05	-	-	-
460	Scarid sp.7	Scaridae	-	146	-	-	0.09	-	-	-
461	*Scarus bowersi*	Scaridae	109	-	-	0.20	-	-	-	-
462	*Scarus chlorodon*	Scaridae	149	-	-	0.10	-	-	-	-
463	*Scarus dimidiatus*	Scaridae	228	73	-	0.03	0.65	-	-	-
464	*Scarus fasciatus*	Scaridae	198	160	-	0.04	0.07	-	-	-
465	*Scarus forsteni*	Scaridae	203	-	-	0.04	-	-	-	-
466	*Scarus ghobban*	Scaridae	110	185	24	0.19	0.05	1.58	16	16.77
467	*Scarus gibbus*	Scaridae	342	-	-	0.01	-	-	-	-
468	*Scarus globiceps*	Scaridae	347	-	-	<0.01	-	-	-	-
469	*Scarus harid*	Scaridae	13	8	-	2.29	15.45	-	-	-
470	*Scarus lepidus*	Scaridae	197	-	-	0.04	-	-	-	-
471	*Scarus longiceps*	Scaridae	72	207	29	0.38	0.03	1.19	40	4.42
472	*Scarus ovifrons*	Scaridae	137	55	147	0.14	1.21	0.01	169	0.03
473	*Scarus prasiognathus*	Scaridae	-	180	73	-	0.05	0.13	84	0.58
474	*Scarus psittacus*	Scaridae	218	-	-	0.03	-	-	-	-
475	*Scarus quoyi*	Scaridae	195	-	-	0.04	-	-	-	-
476	*Scarus rhoduropterus*	Scaridae	10	14	19	2.76	8.42	2.18	21	11.85
477	*Scarus rubroviolaceus*	Scaridae	279	-	-	0.01	-	-	-	-
478	*Scarus schlegeli*	Scaridae	132	78	178	0.14	0.57	0.01	175	0.02
479	*Scarus sordidus*	Scaridae	6	28	-	3.35	5.01	-	-	-
480	*Scarus* sp.	Scaridae	117	61	-	0.18	0.91	-	-	-
481	*Scarus* sp.2	Scaridae	91	97	-	0.29	0.32	-	-	-
482	*Scarus* sp.3	Scaridae	213	-	-	0.03	-	-	-	-
483	* *Scarus tricolor*	Scaridae	252	-	-	0.02	-	-	-	-
484	*Scolopsis bilineatus*	Nemipteridae	59	48	65	0.48	1.64	0.17	110	0.28
485	*Scolopsis cancellatus*	Nemipteridae	-	119	87	-	0.13	0.07	156	0.06
486	*Scolopsis ciliatus*	Nemipteridae	111	-	75	0.19	-	0.12	89	0.49
487	*Scolopsis* sp.	Nemipteridae	326	-	-	0.01	-	-	-	-
488	*Scolopsis* sp.2	Nemipteridae	-	274	-	-	0.01	-	-	-
489	*Scolopsis* sp.3	Nemipteridae	-	325	-	-	<0.01	-	-	-
490	*Scorpaena* sp.	Scorpaenidae	-	-	76	-	-	0.12	70	1.10
491	*Scorpaena* sp.1	Scorpaenidae	-	-	170	-	-	0.01	137	0.12
492	Scorpaenid	Scorpaenidae	337	-	145	0.01	-	0.01	102	0.32
493	* *Scorpaenopsis cirrhosa*	Scorpaenidae	355	237	101	<0.01	0.02	0.04	74	0.94

Continued

Appendix 1 (Continued)

No.	Species	Family	By frequency: Rank Slope	Rank Flat	Rank Trawl	Ind./transect Slope	Ind./transect Flat	Ind./transect Trawl	By weight: Rank	By weight: Trawl
494	*Scorpaenopsis* sp.	Scorpaenidae	-	333	-	-	<0.01	-	-	-
495	*Selar crumenophthalmus*	Carangidae	235	-	-	0.03	-	-	-	-
496	Serranid	Serranidae	251	-	-	0.02	-	-	-	-
497	Serranid sp.4	Serranidae	-	336	-	-	<0.01	-	-	-
498	Serranid sp.5	Serranidae	334	-	-	0.01	-	-	-	-
499	Siganid	Siganidae	-	-	138	-	-	0.02	185	0.01
500	*Siganus argenteus*	Siganidae	85	153	22	0.30	0.08	1.86	38	4.97
501	*Siganus fuscescens*	Siganidae	194	50	1	0.04	1.41	89.08	4	80.29
502	*Siganus guttatus*	Siganidae	-	-	90	-	-	0.06	37	5.30
503	*Siganus puellus*	Siganidae	-	-	174	-	-	0.01	162	0.05
504	*Siganus punctatus*	Siganidae	-	-	45	-	-	0.56	30	7.53
505	*Siganus spinus*	Siganidae	16	30	15	1.91	4.77	3.61	15	19.58
506	*Siganus virgatus*	Siganidae	212	203	10	0.03	0.03	5.10	12	23.96
507	*Siganus vulpinus*	Siganidae	241	-	-	0.02	-	-	-	-
508	*Solenostomus paradoxus*	Solenomostidae	-	308	-	-	<0.01	-	-	-
509	*Sphaeramia nematoptera*	Apogonidae	-	-	51	-	-	0.36	80	0.68
510	*Sphaeramia orbicularis*	Apogonidae	-	-	6	-	-	9.06	5	55.19
511	*Sphyraena barracuda*	Sphyraenidae	-	-	122	-	-	0.03	142	0.10
512	*Sphyraena jello*	Sphyraenidae	-	-	79	-	-	0.11	98	0.35
513	*Stenogobius* sp.	Gobiidae	358	-	-	<0.01	-	-	-	-
514	*Stephanolepis tomentosus*	Monacanthidae	272	-	-	0.02	-	-	-	-
515	*Stethojulis bandanensis*	Labridae	51	52	-	0.56	1.32	-	-	-
516	*Stethojulis* sp.	Labridae	317	157	-	0.01	0.08	-	-	-
517	*Stethojulis* sp.5	Labridae	298	-	-	0.01	-	-	-	-
518	*Stethojulis strigiventer*	Labridae	87	24	40	0.29	5.49	0.60	67	1.33
519	*Stethojulis trilineata*	Labridae	33	36	-	0.93	2.57	-	-	-
520	*Stolephorus indicus*	Engraulididae	-	17	-	-	8.09	-	-	-
521	*Sufflamen bursa*	Balistidae	270	-	-	0.02	-	-	-	-
522	*Sufflamen chrysopterus*	Balistidae	18	192	-	1.58	0.04	-	-	-
523	*Sufflamen fraenatus*	Balistidae	351	-	-	<0.01	-	-	-	-
524	*Synaptura marginata*	Soleidae	-	-	72	-	-	0.14	43	3.69
525	*Syngnathoides biaculeatus*	Syngnathidae	-	319	5	-	<0.01	9.92	6	49.21
526	*Synodus variegatus*	Synodontidae	156	156	82	0.09	0.08	0.08	73	1.06
527	*Takifugu rubripes*	Tetraodontidae	-	-	172	-	-	0.01	109	0.29
528	Tetraodontid sp.2	Tetraodontidae	-	-	171	-	-	0.01	105	0.30
529	*Thalassoma amblycephalum*	Labridae	21	171	-	1.40	0.06	-	-	-
530	*Thalassoma hardwickii*	Labridae	5	22	-	3.89	6.10	-	-	-
531	*Thalassoma janseni*	Labridae	54	-	-	0.52	-	-	-	-
532	*Thalassoma lunare*	Labridae	46	64	-	0.58	0.79	-	-	-
533	*Thalassoma lutescens*	Labridae	169	313	-	0.07	<0.01	-	-	-
534 *	*Thalassoma purpureum*	Labridae	248	-	-	0.02	-	-	-	-
535	*Thalassoma quinquevittatum*	Labridae	26	191	-	1.23	0.04	-	-	-
536	*Thalassoma* sp.	Labridae	216	-	-	0.03	-	-	-	-
537	*Tylosurus acus melanotus*	Belonidae	-	150	-	-	0.09	-	-	-
538	*Upeneus tragula*	Mullidae	299	277	33	0.01	0.01	0.97	48	3.12
539 *	*Valenciennea longispinnis*	Gobiidae	-	258	-	-	0.01	-	-	-
540	*Valenciennea strigata*	Gobiidae	80	268	-	0.33	0.01	-	-	-
541	*Valenciennea wardi*	Gobiidae	266	298	-	0.02	0.01	-	-	-
542	*Yongeichthys criniger*	Gobiidae	-	255	100	-	0.01	0.05	92	0.42
543	*Zanclus cornutus*	Zanclidae	48	65	-	0.56	0.79	-	-	-
544	*Zebrasoma scopas*	Acanthuridae	56	86	-	0.49	0.47	-	-	-
545	*Zebrasoma veliferum*	Acanthuridae	174	134	-	0.06	0.10	-	-	-
	Totals					132.30	467.89	314.34		1,247.48
	Total no. of species		373	336	186				186	
	Total no. of families		41	45	48				48	

Appendix 2. Reef slope fish recorded from visual census from October 1989 to June 1991 and sorted by frequency of occurrence (ind./1,000 m^2). (* denotes uncertain identification).

						Slope			Overlap	
Rank	Species	Family	Cum%	%	Total	Upper 1-5 m	Mid 5-16 m	Lower 16-26 m	Flat Total	Trawl Total
1	*Halichoeres nebulosus*	Labridae	11.25	11.25	44.65	36.70	7.40	0.55	3.32	-
2	*Ctenochaetus binotatus*	Acanthuridae	19.59	8.34	33.12	10.93	7.19	15.00	7.93	0.04
3	*Parupeneus trifasciatus*	Mullidae	23.28	3.68	14.61	4.70	7.31	2.60	21.00	2.37
4	*Plotosus lineatus*	Plotosidae	26.34	3.07	12.18	-	8.76	3.42	48.54	102.55
5	*Thalassoma hardwickii*	Labridae	29.29	2.94	11.68	10.93	0.75	-	24.40	-
6	*Scarus sordidus*	Scaridae	31.82	2.53	10.05	7.78	0.69	1.58	20.06	-
7	*Pomacentrus vaiuli*	Pomacentridae	34.10	2.28	9.05	0.58	2.05	6.42	0.76	-
8	*Pomacentrus coelestis*	Pomacentridae	36.35	2.25	8.93	5.58	3.25	0.10	2.11	-
9	*Pomachromis richardsoni*	Pomacentridae	38.48	2.13	8.45	1.53	6.58	0.35	2.83	-
10	*Scarus rhoduropterus*	Scaridae	40.56	2.09	8.28	6.55	0.95	0.78	33.67	8.73
11	*Ctenochaetus striatus*	Acanthuridae	42.48	1.92	7.61	4.88	1.26	1.47	4.51	-
12	*Cheilinus trilobatus*	Labridae	44.24	1.76	7.00	2.15	2.98	1.87	9.43	2.95
13	*Scarus harid*	Scaridae	45.97	1.73	6.87	5.50	0.84	0.54	61.81	-
14	*Pomacentrus bankanensis*	Pomacentridae	47.60	1.63	6.45	5.03	1.23	0.20	15.10	-
15	Apogonid	Apogonidae	49.09	1.49	5.90	5.78	0.04	0.09	2.28	0.05
16	*Siganus spinus*	Siganidae	50.53	1.44	5.73	2.25	2.66	0.82	19.10	14.43
17	*Halichoeres hoeveni*	Labridae	51.96	1.43	5.68	4.23	1.24	0.22	64.68	-
18	*Sufflamen chrysopterus*	Balistidae	53.16	1.20	4.75	0.80	2.66	1.28	0.15	-
19	*Cheilodipterus quinquelineatus*	Apogonidae	54.34	1.18	4.70	2.98	0.35	1.37	31.82	20.78
20	*Chaetodon kleinii*	Chaetodontidae	55.47	1.12	4.46	1.08	2.20	1.19	1.65	-
21	*Thalassoma amblycephalum*	Labridae	56.53	1.06	4.21	0.20	3.91	0.10	0.24	-
22	*Chaetodon mertensii*	Chaetodontidae	57.58	1.05	4.17	0.70	1.06	2.40	0.99	-
23	*Cirrhilabrus cyanopleura*	Labridae	58.59	1.01	4.01	-	2.36	1.65	0.03	-
24	*Paracirrhites arcatus*	Cirrhitidae	59.57	0.99	3.91	1.13	1.64	1.15	0.03	-
25	*Macropharyngodon meleagris*	Labridae	60.51	0.93	3.71	0.33	3.23	0.16	0.36	-
26	*Thalassoma quinquevittatum*	Labridae	61.44	0.93	3.70	1.75	1.81	0.13	0.15	-
27	*Labroides dimidiatus*	Labridae	62.31	0.87	3.46	1.70	1.30	0.46	9.75	-
28	*Pseudocheilinus hexataenia*	Labridae	63.17	0.86	3.43	1.53	1.46	0.44	2.33	-
29	*Apogon* sp.	Apogonidae	64.02	0.85	3.36	1.63	0.01	1.72	11.32	0.12
30	*Apogon* sp.5 (Schroeder 1980)	Apogonidae	64.81	0.79	3.13	2.18	0.95	-	32.03	3.64
31	*Halichoeres melanochir*	Labridae	65.59	0.78	3.09	0.28	1.19	1.62	0.11	-
32	*Calotomus japonicus*	Scaridae	66.36	0.77	3.07	1.93	0.85	0.29	20.56	2.36
33	*Stethojulis trilineata*	Labridae	67.06	0.70	2.79	2.18	0.48	0.14	10.28	-
34	*Dampieria cyclophthalma*	Pseudochromidae	67.73	0.67	2.66	0.45	0.90	1.31	1.97	0.93
35	Clupeid	Clupeidae	68.36	0.63	2.50	-	2.50	-	61.14	0.13
36	*Pomacentrus flavicauda*	Pomacentridae	68.98	0.62	2.48	1.45	1.03	-	53.25	-
37	Scarid	Scaridae	69.58	0.59	2.35	1.58	0.49	0.29	33.01	0.13
38	*Chromis weberi*	Pomacentridae	70.14	0.57	2.24	0.58	1.36	0.31	0.14	-
39	*Parapercis clathrata*	Mugiloididae	70.68	0.54	2.15	0.45	1.01	0.68	0.61	-
40	*Amphiprion clarkii*	Pomacentridae	71.21	0.53	2.11	0.33	1.63	0.16	0.79	-
41	*Nemateleotris magnifica*	Gobiidae	71.74	0.53	2.09	0.05	1.05	0.99	-	-
42	*Epinephelus merra*	Serranidae	72.21	0.47	1.87	1.40	0.11	0.36	19.36	4.28
43	*Gomphosus varius*	Labridae	72.68	0.47	1.87	1.65	0.16	0.05	2.08	-
44	*Paraglyphidodon melas*	Pomacentridae	73.15	0.47	1.87	1.58	0.14	0.15	7.57	-
45	*Cephalopholis urodela*	Serranidae	73.59	0.44	1.76	0.28	0.70	0.78	-	-
46	*Thalassoma lunare*	Labridae	74.03	0.43	1.73	1.60	0.13	-	3.15	-
47	*Chromis margaritifer*	Pomacentridae	74.46	0.43	1.70	0.40	1.21	0.09	0.03	-
48	*Zanclus cornutus*	Zanclidae	74.88	0.43	1.69	0.43	0.63	0.64	3.15	-
49	*Canthigaster valentini*	Tetraodontidae	75.31	0.43	1.69	-	0.64	1.05	2.39	0.28
50	*Coris variegata*	Labridae	75.73	0.42	1.68	0.58	0.96	0.15	9.36	-
51	*Stethojulis bandanensis*	Labridae	76.16	0.42	1.68	1.20	0.36	0.12	5.28	-
52	*Plectroglyphidodon lacrymatus*	Pomacentridae	76.58	0.42	1.66	1.20	0.36	0.10	7.32	-
53	*Epinephelus fasciatus*	Serranidae	76.98	0.40	1.60	0.45	0.60	0.55	0.13	-
54	*Thalassoma janseni*	Labridae	77.37	0.39	1.56	0.10	1.36	0.10	-	-

Continued

Appendix 2 (Continued)

Rank	Species	Family	Cum%	%	Total	Slope Upper 1-5 m	Slope Mid 5-16 m	Slope Lower 16-26 m	Overlap Flat Total	Overlap Trawl Total
55	*Meiacanthus grammistes*	Blenniidae	77.75	0.38	1.51	0.40	0.44	0.67	0.93	-
56	*Zebrasoma scopas*	Acanthuridae	78.13	0.37	1.48	0.98	0.29	0.22	1.86	-
57	*Cheilinus bimaculatus*	Labridae	78.50	0.37	1.48	0.28	0.83	0.38	0.26	0.22
58	*Cirrhitichthys falco*	Cirrhitidae	78.86	0.37	1.45	-	1.04	0.42	-	-
59	*Scolopsis bilineatus*	Nemipteridae	79.23	0.36	1.44	0.78	0.28	0.39	6.57	0.69
60	*Salarias fasciatus*	Blenniidae	79.58	0.35	1.41	1.15	0.15	0.11	6.68	-
61	*Acanthurus gahhm*	Acanthuridae	79.93	0.35	1.39	0.68	0.31	0.40	1.25	0.04
62	*Chaetodon punctatofasciatus*	Chaetodontidae	80.27	0.34	1.36	0.20	0.33	0.84	0.10	-
63 *	*Cheilinus celebicus*	Labridae	80.61	0.34	1.35	0.18	0.93	0.25	0.08	-
64	*Caesio caerulaurea*	Lutjanidae	80.95	0.34	1.35	-	0.01	1.33	-	-
65	*Gnathodentex aureolineatus*	Lethrinidae	81.28	0.33	1.32	0.88	0.04	0.40	7.00	-
66	*Dascyllus trimaculatus*	Pomacentridae	81.61	0.32	1.29	0.15	0.34	0.80	1.99	-
67	*Halichoeres marginatus*	Labridae	81.93	0.32	1.26	1.03	0.16	0.07	3.07	-
68	Atherinid	Atherinidae	82.24	0.31	1.25	1.25	-	-	67.90	-
69	*Halichoeres hortulanus*	Labridae	82.55	0.31	1.22	0.85	0.24	0.13	3.51	-
70	*Pomacentrus smithi*	Pomacentridae	82.85	0.30	1.21	0.78	0.40	0.03	0.42	-
71	*Anampses geographicus*	Labridae	83.14	0.29	1.14	0.80	0.19	0.16	0.46	-
72	*Scarus longiceps*	Scaridae	83.43	0.29	1.14	0.68	0.06	0.40	0.13	4.76
73	*Cheilinus diagrammus*	Labridae	83.71	0.28	1.11	0.08	0.19	0.85	0.07	-
74	*Pomacentrus lepidogenys*	Pomacentridae	83.98	0.27	1.09	0.63	0.38	0.09	0.15	-
75	*Hemigymnus melapterus*	Labridae	84.25	0.27	1.07	1.00	0.04	0.03	4.22	-
76	*Halichoeres poecilopterus*	Labridae	84.52	0.27	1.06	0.50	0.51	0.05	1.71	-
77	*Pomacentrus moluccensis*	Pomacentridae	84.79	0.27	1.06	0.55	0.29	0.22	5.15	-
78	*Ptereleotris evides*	Gobiidae	85.05	0.26	1.04	0.90	0.14	-	-	-
79	*Parapercis cephalopunctata*	Mugiloididae	85.31	0.26	1.03	0.05	0.53	0.45	-	-
80	*Valenciennea strigata*	Gobiidae	85.56	0.25	1.00	0.43	0.56	0.02	0.04	-
81	*Pomacentrus philippinus*	Pomacentridae	85.81	0.25	1.00	0.10	0.53	0.38	1.71	-
82	*Caesio erythrogaster*	Lutjanidae	86.06	0.25	0.98	0.10	0.33	0.55	0.14	0.04
83	*Parapercis polyophthalma*	Mugiloididae	86.30	0.24	0.96	0.05	0.44	0.47	0.13	-
84	*Coris gaimardi*	Labridae	86.53	0.23	0.91	0.35	0.56	-	0.74	-
85	*Siganus argenteus*	Siganidae	86.76	0.23	0.90	0.28	0.59	0.04	0.32	7.44
86	Labrid	Labridae	86.98	0.22	0.89	0.78	0.11	-	0.25	0.08
87	*Stethojulis strigiventer*	Labridae	87.20	0.22	0.88	0.60	0.20	0.08	21.94	2.39
88	*Dascyllus reticulatus*	Pomacentridae	87.43	0.22	0.88	0.03	0.34	0.52	1.90	-
89	Pomacentrid sp.4	Pomacentridae	87.65	0.22	0.88	-	0.06	0.82	-	-
90	*Labrichthys unilineatus*	Labridae	87.87	0.22	0.86	0.75	0.08	0.04	0.18	-
91	*Scarus* sp.2	Scaridae	88.08	0.22	0.86	0.23	0.41	0.22	1.29	-
92	*Anampses caeruleopunctatus*	Labridae	88.29	0.21	0.83	0.40	0.34	0.09	0.03	-
93	*Cheilio inermis*	Labridae	88.49	0.20	0.80	0.75	0.05	-	2.76	0.79
94	*Centropyge heraldi*	Pomacanthidae	88.69	0.20	0.78	0.15	0.06	0.57	0.11	-
95 *	*Acanthurus japonicus*	Acanthuridae	88.88	0.19	0.77	0.05	0.40	0.32	0.06	-
96	*Pervagor janthinosoma*	Monacanthidae	89.07	0.19	0.76	-	0.39	0.37	0.03	-
97	*Chaetodon vagabundus*	Chaetodontidae	89.26	0.19	0.75	0.38	0.28	0.10	1.21	-
98	*Plectroglyphidodon dickii*	Pomacentridae	89.45	0.19	0.75	0.68	0.04	0.03	0.22	-
99	*Centropyge vrolicki*	Pomacanthidae	89.63	0.18	0.72	0.05	0.30	0.37	-	-
100	*Parupeneus barberinus*	Mullidae	89.81	0.17	0.69	0.13	0.06	0.50	1.33	16.03
101	*Halichoeres melanurus*	Labridae	89.98	0.17	0.68	-	0.41	0.26	0.15	-
102	*Myripristis murdjan*	Holocentridae	90.14	0.16	0.65	0.08	0.05	0.52	0.53	-
103	*Balistapus undulatus*	Balistidae	90.30	0.16	0.62	0.05	0.23	0.34	-	-
104	*Acanthurus olivaceus*	Acanthuridae	90.45	0.15	0.62	0.33	0.20	0.09	-	-
105	*Naso lituratus*	Acanthuridae	90.61	0.15	0.61	0.08	0.18	0.36	0.26	0.04
106	*Paraglyphidodon behni*	Pomacentridae	90.76	0.15	0.61	0.13	0.04	0.45	0.44	-
107	*Chromis xanthura*	Pomacentridae	90.91	0.15	0.61	0.08	0.40	0.14	0.19	-
108	*Plagiotremus rhinorhynchos*	Blenniidae	91.06	0.15	0.60	0.45	0.15	-	0.24	-
109	*Scarus bowersi*	Scaridae	91.21	0.15	0.60	0.03	-	0.57	-	-

Continued

Appendix 2 (Continued)

						Slope			Overlap	
Rank	Species	Family	Cum%	%	Total	Upper 1-5 m	Mid 5-16 m	Lower 16-26 m	Flat Total	Trawl Total
110	*Scarus ghobban*	Scaridae	91.36	0.15	0.58	0.43	0.03	0.13	0.18	6.31
111	*Scolopsis ciliatus*	Nemipteridae	91.51	0.15	0.58	-	-	0.58	-	0.48
112	*Centropyge bispinosus*	Pomacanthidae	91.65	0.15	0.58	-	0.05	0.53	-	-
113	*Amblyglyphidodon curacao*	Pomacentridae	91.80	0.14	0.58	0.45	0.08	0.05	33.54	-
114	*Pomacentrus taeniometopon*	Pomacentridae	91.94	0.14	0.57	0.55	-	0.02	6.29	-
115	*Chaetodon octofasciatus*	Chaetodontidae	92.08	0.14	0.57	0.08	0.03	0.47	-	-
116	*Epibulus insidiator*	Labridae	92.22	0.14	0.55	0.05	0.10	0.40	0.74	-
117	*Scarus* sp.	Scaridae	92.36	0.14	0.55	0.13	0.25	0.17	3.63	-
118	*Amphiprion ocellaris*	Pomacentridae	92.50	0.14	0.54	-	0.04	0.50	1.43	-
119	*Hologymnosus annulatus*	Labridae	92.63	0.13	0.53	0.08	0.38	0.08	-	-
120	*Parapercis cylindrica*	Mugiloididae	92.76	0.13	0.53	-	0.38	0.15	22.99	4.47
121	*Chaetodon citrinellus*	Chaetodontidae	92.89	0.13	0.52	0.45	0.05	0.02	1.44	-
122	*Ostracion meleagris*	Ostraciidae	93.02	0.13	0.51	0.20	0.19	0.12	0.07	-
123	*Arothron nigropunctatus*	Tetraodontidae	93.15	0.13	0.50	0.15	0.19	0.16	0.39	0.11
124	*Parupeneus cyclostomus*	Mullidae	93.27	0.12	0.49	0.28	0.16	0.05	0.08	-
125	*Choerodon anchorago*	Labridae	93.39	0.12	0.49	0.48	0.01	-	7.07	5.34
126	*Dischistodus chrysopoecilus*	Pomacentridae	93.51	0.12	0.48	0.45	0.01	0.02	31.19	0.22
127	*Canthigaster bennetti*	Tetraodontidae	93.63	0.12	0.46	0.10	0.14	0.22	0.32	0.69
128	*Chaetodon melannotus*	Chaetodontidae	93.74	0.11	0.45	0.28	0.09	0.09	2.99	0.17
129	*Caesio tile*	Lutjanidae	93.86	0.11	0.44	-	0.38	0.07	1.94	-
130	*Acanthurus pyroferus*	Acanthuridae	93.97	0.11	0.44	0.05	0.10	0.29	-	-
131	*Chaetodon trifasciatus*	Chaetodontidae	94.07	0.11	0.43	0.18	0.09	0.17	3.65	0.05
132	*Scarus schlegeli*	Scaridae	94.18	0.11	0.43	0.05	0.18	0.20	2.29	0.04
133	*Pervagor aspricaudus*	Monacanthidae	94.29	0.11	0.42	-	0.23	0.19	-	-
134	*Scarus ovifrons*	Scaridae	94.39	0.10	0.42	0.28	0.13	0.02	4.83	0.05
135	*Pterocaesio chrysozona*	Lutjanidae	94.50	0.10	0.42	-	-	0.42	5.56	-
136	*Acanthurus lineatus*	Acanthuridae	94.60	0.10	0.42	0.40	-	0.02	0.26	-
137	*Chaetodon xanthurus*	Chaetodontidae	94.71	0.10	0.42	0.03	0.13	0.27	0.47	-
138	* *Cirripectes variolosus*	Blenniidae	94.81	0.10	0.41	0.40	0.01	-	1.44	-
139	*Bodianus mesothorax*	Labridae	94.91	0.10	0.41	0.10	0.03	0.28	0.39	-
140	*Eupomacentrus lividus*	Pomacentridae	95.00	0.09	0.36	0.30	0.06	-	46.94	0.05
141	*Ostracion cubicus*	Ostraciidae	95.10	0.09	0.36	0.30	0.03	0.04	0.39	0.24
142	*Forcipiger flavissimus*	Chaetodontidae	95.18	0.09	0.35	-	-	0.35	-	-
143	*Paraglyphidodon nigroris*	Pomacentridae	95.27	0.09	0.34	0.23	-	0.11	0.79	-
144	*Chromis caerulea*	Pomacentridae	95.35	0.09	0.34	0.03	0.31	-	67.04	-
145	Blenny	Blenniidae	95.44	0.08	0.33	0.30	0.03	-	0.08	-
146	*Anampses twistii*	Labridae	95.52	0.08	0.32	0.10	0.09	0.13	-	-
147	*Chaetodon auriga*	Chaetodontidae	95.60	0.08	0.32	0.23	0.08	0.02	2.54	0.45
148	*Plagiotremus tapeinosoma*	Blenniidae	95.68	0.08	0.31	0.18	0.14	-	0.03	-
149	*Scarus prasiognathus*	Scaridae	95.75	0.08	0.30	0.15	0.14	0.02	0.19	0.54
150	*Melichthys vidua*	Balistidae	95.83	0.07	0.30	0.03	0.24	0.03	-	-
151	*Pterocaesio pisang*	Lutjanidae	95.90	0.07	0.28	-	-	0.28	-	-
152	*Cheilodipterus macrodon*	Apogonidae	95.97	0.07	0.28	0.25	0.01	0.02	2.75	0.83
153	*Plectorhynchus lineatus*	Haemulidae	96.04	0.07	0.28	0.25	0.03	-	0.40	0.17
154	*Apogon cyanosoma*	Apogonidae	96.11	0.07	0.28	-	0.03	0.25	14.24	3.69
155	*Plectropomus leopardus*	Serranidae	96.17	0.07	0.27	0.03	-	0.24	-	-
156	*Synodus variegatus*	Synodontidae	96.24	0.07	0.26	0.08	0.14	0.05	0.31	0.32
157	*Cantherhines pardalis*	Monacanthidae	96.31	0.06	0.26	0.03	0.13	0.11	0.08	-
158	*Halichoeres trimaculatus*	Labridae	96.37	0.06	0.25	-	0.03	0.23	20.92	-
159	*Naso unicornis*	Acanthuridae	96.43	0.06	0.25	0.05	0.15	0.05	0.18	0.16
160	* *Acanthurus glaucopareius*	Acanthuridae	96.49	0.06	0.25	-	0.06	0.18	0.01	-
161	*Centropyge tibicen*	Pomacanthidae	96.55	0.06	0.24	-	0.19	0.05	0.06	-
162	*Dendrochirus zebra*	Scorpaenidae	96.61	0.06	0.24	-	0.18	0.06	0.10	0.05
163	*Plectorhynchus diagrammus*	Haemulidae	96.67	0.06	0.23	0.15	0.05	0.03	0.50	-
164	*Eupomacentrus nigricans*	Pomacentridae	96.73	0.06	0.23	0.10	0.08	0.05	142.10	0.10

Continued

Appendix 2 (Continued)

Rank	Species	Family	Cum%	%	Total	Slope Upper 1-5 m	Slope Mid 5-16 m	Slope Lower 16-26 m	Overlap Flat Total	Overlap Trawl Total
165	*Amblyglyphidodon leucogaster*	Pomacentridae	96.79	0.06	0.23	0.23	-	-	0.07	-
166	*Exallias brevis*	Blenniidae	96.84	0.05	0.21	0.20	0.01	-	0.06	-
167	*Paracirrhites forsteri*	Cirrhitidae	96.89	0.05	0.20	0.20	-	-	-	-
168	*Abudefduf saxatilis*	Pomacentridae	96.94	0.05	0.20	0.20	-	-	3.13	0.05
169	*Thalassoma lutescens*	Labridae	96.99	0.05	0.20	0.13	0.08	-	0.01	-
170	*Macropharyngodon negrosensis*	Labridae	97.04	0.05	0.19	-	0.14	0.05	-	-
171	*Acanthurus nigrofuscus*	Acanthuridae	97.09	0.05	0.19	-	-	0.19	-	-
172	*Halichoeres prosopeion*	Labridae	97.13	0.05	0.18	-	0.08	0.11	0.28	-
173	*Cheilinus fasciatus*	Labridae	97.18	0.04	0.18	0.03	0.01	0.14	0.11	0.05
174	*Abudefduf coelestinus*	Pomacentridae	97.22	0.04	0.18	0.18	-	-	3.93	-
175	*Zebrasoma veliferum*	Acanthuridae	97.26	0.04	0.18	0.18	-	-	0.42	-
176	*Rhinecanthus aculeatus*	Balistidae	97.31	0.04	0.17	0.15	-	0.02	0.35	-
177	*Parupeneus bifasciatus*	Mullidae	97.35	0.04	0.17	0.10	0.01	0.05	0.36	-
178	*Chaetodon unimaculatus*	Chaetodontidae	97.39	0.04	0.16	0.03	0.05	0.08	0.01	-
179	*Calotomus* sp.	Scaridae	97.43	0.04	0.15	0.03	0.11	0.02	-	-
180	*Rhinecanthus verrucosus*	Balistidae	97.47	0.04	0.15	0.10	0.01	0.04	0.07	-
181	Goby	Gobiidae	97.50	0.04	0.15	0.10	0.05	-	0.42	0.28
182	Pomacentrid sp.1	Pomacentridae	97.54	0.04	0.15	-	-	0.15	0.01	-
183	*Dischistodus prosopotaenia*	Pomacentridae	97.58	0.04	0.15	0.15	-	-	4.29	-
184	*Heniochus chrysostomus*	Chaetodontidae	97.62	0.04	0.15	0.15	-	-	0.21	-
185	*Saurida gracilis*	Synodontidae	97.65	0.04	0.15	0.08	0.04	0.03	0.26	8.52
186	*Diploprion bifasciatus*	Grammistidae	97.69	0.04	0.15	0.03	-	0.12	0.07	-
187	*Novaculichthys taeniurus*	Labridae	97.73	0.04	0.14	0.08	0.05	0.02	0.25	-
188	*Bolbometopon bicolor*	Scaridae	97.76	0.04	0.14	-	-	0.14	0.17	-
189	*Priacanthus macracanthus*	Priacanthidae	97.80	0.04	0.14	-	-	0.14	-	-
190	*Apogon novemfasciatus*	Apogonidae	97.83	0.03	0.14	0.13	0.01	-	9.50	3.77
191	Balistid sp.1	Balistidae	97.87	0.03	0.14	-	0.09	0.05	-	-
192	* *Amblyeleotris fasciata*	Gobiidae	97.90	0.03	0.13	-	0.11	0.02	0.01	-
193	*Chaetodon ornatissimus*	Chaetodontidae	97.93	0.03	0.13	0.08	0.01	0.04	-	-
194	*Siganus fuscescens*	Siganidae	97.96	0.03	0.13	0.08	0.05	-	5.63	356.32
195	*Scarus quoyi*	Scaridae	97.99	0.03	0.12	-	0.04	0.09	-	-
196	*Cephalopholis pachycentron*	Serranidae	98.02	0.03	0.12	-	-	0.12	-	-
197	*Scarus lepidus*	Scaridae	98.05	0.03	0.12	0.05	0.04	0.03	-	-
198	*Parupeneus pleurostigma*	Mullidae	98.08	0.03	0.12	0.08	0.03	0.02	-	-
199	*Scarus fasciatus*	Scaridae	98.11	0.03	0.12	0.08	0.03	0.02	0.29	-
200	Pomacentrid	Pomacentridae	98.14	0.03	0.12	0.08	0.03	0.02	0.03	-
201	*Pomacentrus trimaculatus*	Pomacentridae	98.17	0.03	0.11	0.10	0.01	-	1.04	-
202	*Pomacentrus* sp.	Pomacentridae	98.20	0.03	0.11	0.10	0.01	-	0.94	-
203	*Centrogenys vaigiensis*	Percichthyidae	98.23	0.03	0.11	0.10	0.01	-	0.03	10.20
204	*Scarus forsteni*	Scaridae	98.26	0.03	0.11	0.05	0.06	-	-	-
205	* *Paraglyphidodon carlson*	Pomacentridae	98.28	0.03	0.11	0.03	0.09	-	0.46	-
206	*Lutjanus decussatus*	Lutjanidae	98.31	0.03	0.10	0.10	-	-	0.24	0.15
207	*Cephalopholis argus*	Serranidae	98.33	0.03	0.10	-	-	0.10	-	-
208	*Sargocentron rubrum*	Holocentridae	98.36	0.03	0.10	-	-	0.10	0.11	-
209	*Lutjanus fulviflamma*	Lutjanidae	98.38	0.03	0.10	0.10	-	-	0.10	1.49
210	*Mulloidichthys flavolineatus*	Mullidae	98.41	0.03	0.10	-	-	0.10	0.13	0.30
211	*Pomacentrus amboinensis*	Pomacentridae	98.43	0.02	0.10	-	0.06	0.03	0.99	-
212	*Siganus virgatus*	Siganidae	98.46	0.02	0.09	0.03	0.01	0.06	0.13	20.39
213	*Scarus* sp.3	Scaridae	98.48	0.02	0.09	-	0.03	0.07	-	-
214	*Pseudocheilinus evanidus*	Labridae	98.50	0.02	0.09	0.03	0.01	0.05	-	-
215	*Aeoliscus strigatus*	Centriscidae	98.53	0.02	0.09	0.08	0.01	-	0.89	3.81
216	*Thalassoma* sp.	Labridae	98.55	0.02	0.09	-	0.09	-	-	-
217	*Halichoeres margaritaceus*	Labridae	98.57	0.02	0.09	0.08	0.01	-	0.25	-
218	* *Paraglyphidodon thoracotaeniatus*	Pomacentridae	98.59	0.02	0.08	-	-	0.08	0.03	-
219	*Scarus psittacus*	Scaridae	98.61	0.02	0.08	0.03	0.03	0.03	-	-

Continued

Appendix 2 (Continued)

Rank	Species	Family	Cum%	%	Total	Slope Upper 1-5 m	Slope Mid 5-16 m	Slope Lower 16-26 m	Overlap Flat Total	Overlap Trawl Total
220	*Heniochus varius*	Chaetodontidae	98.63	0.02	0.08	-	0.01	0.07	0.21	-
221	*Pseudojuloides cerasinus*	Labridae	98.65	0.02	0.08	0.05	0.01	0.02	-	-
222	*Gymnothorax pictus*	Muraenidae	98.67	0.02	0.08	0.03	0.01	0.04	0.31	4.06
223	*Pentapodus macrurus*	Nemipteridae	98.69	0.02	0.08	-	-	0.08	-	0.05
224	*Chaetodon trifascialis*	Chaetodontidae	98.71	0.02	0.08	0.05	0.03	-	-	-
225	*Cirrhitichthys aprinus*	Cirrhitidae	98.73	0.02	0.08	0.05	0.03	-	-	-
226	*Arothron stellatus*	Tetraodontidae	98.75	0.02	0.08	0.05	0.03	-	0.14	0.10
227	*Scarus dimidiatus*	Scaridae	98.77	0.02	0.08	0.05	0.03	-	2.60	-
228	*Naso* sp.	Acanthuridae	98.79	0.02	0.08	0.03	0.05	-	0.11	0.18
229	*Hemiglyphidodon plagiometopon*	Pomacentridae	98.80	0.02	0.08	0.08	-	-	0.43	-
230	*Salarias* sp.	Blenniidae	98.82	0.02	0.08	0.08	-	-	-	-
231	Apogonid sp.5	Apogonidae	98.84	0.02	0.08	0.08	-	-	30.96	18.77
232	*Pseudanthias squamipinnis*	Serranidae	98.86	0.02	0.08	0.08	-	-	-	-
233	*Chrysiptera leucopoma*	Pomacentridae	98.88	0.02	0.08	0.08	-	-	-	-
234	*Chromis* sp.	Pomacentridae	98.90	0.02	0.08	0.08	-	-	-	-
235	*Selar crumenophthalmus*	Carangidae	98.92	0.02	0.08	0.08	-	-	-	-
236	*Monotaxis grandoculis*	Lethrinidae	98.94	0.02	0.07	-	0.04	0.04	0.46	-
237	*Centropyge bicolor*	Pomacanthidae	98.95	0.02	0.07	-	0.04	0.03	-	-
238	*Grammistes sexlineatus*	Grammistidae	98.97	0.02	0.07	-	0.05	0.02	0.40	0.13
239	Lutjanid	Lutjanidae	98.99	0.02	0.07	0.05	-	0.02	-	-
240	*Istigobius ornatus*	Gobiidae	99.01	0.02	0.07	0.05	-	0.02	-	-
241	*Siganus vulpinus*	Siganidae	99.02	0.02	0.07	-	-	0.07	-	-
242	*Fistularia petimba*	Fistulariidae	99.04	0.02	0.07	0.05	-	0.02	0.31	0.15
243	*Bodianus hirsutus*	Labridae	99.06	0.02	0.07	-	0.05	0.02	-	-
244	*Macolor niger*	Lutjanidae	99.07	0.02	0.07	-	0.03	0.04	-	-
245	*Pseudocheilinus octotaenia*	Labridae	99.09	0.02	0.06	0.03	0.04	-	-	-
246	*Malacanthus brevirostris*	Malacanthidae	99.10	0.02	0.06	-	0.06	-	-	-
247	*Parupeneus barberinoides*	Mullidae	99.12	0.02	0.06	-	0.01	0.05	1.85	1.61
248	Balistid	Balistidae	99.14	0.02	0.06	0.05	0.01	-	-	0.06
249	*Aulostomus chinensis*	Aulostomidae	99.15	0.02	0.06	0.03	0.04	-	0.21	0.16
250	* *Thalassoma purpureum*	Labridae	99.17	0.02	0.06	-	0.06	-	-	-
251	* *Scarus tricolor*	Scaridae	99.18	0.02	0.06	-	-	0.06	-	-
252	Serranid	Serranidae	99.20	0.02	0.06	-	-	0.06	-	-
253	*Dascyllus aruanus*	Pomacentridae	99.21	0.01	0.06	-	0.03	0.03	113.83	-
254	*Calotomus carolinus*	Scaridae	99.23	0.01	0.06	-	0.03	0.03	-	-
255	*Pseudobalistes flavimarginatus*	Balistidae	99.24	0.01	0.06	-	0.03	0.03	0.01	0.05
256	*Anampses meleagrides*	Labridae	99.26	0.01	0.06	-	0.04	0.02	-	-
257	*Acanthurus mata*	Acanthuridae	99.27	0.01	0.05	0.03	0.01	0.02	0.21	-
258	*Hologymnosus doliatus*	Labridae	99.28	0.01	0.05	-	0.05	-	-	-
259	*Acanthurus triostegus*	Acanthuridae	99.29	0.01	0.05	0.05	-	-	0.06	-
260	*Amblygobius albimaculatus*	Gobiidae	99.31	0.01	0.05	0.03	0.03	-	0.39	0.75
261	Acanthurid sp.6	Acanthuridae	99.32	0.01	0.05	0.05	-	-	0.06	-
262	*Lethrinus harak*	Lethrinidae	99.33	0.01	0.05	0.03	0.03	-	1.10	17.21
263	*Sargocentron diadema*	Holocentridae	99.34	0.01	0.05	-	-	0.05	0.10	-
264	*Gymnomuraena zebra*	Muraenidae	99.36	0.01	0.05	0.05	-	-	0.03	-
265	*Glyphidodontops leucopomus*	Pomacanthidae	99.37	0.01	0.05	0.05	-	-	0.04	-
266	*Chaetodon lunula*	Chaetodontidae	99.38	0.01	0.05	0.05	-	-	0.15	0.06
267	*Valenciennea wardi*	Gobiidae	99.40	0.01	0.05	-	0.05	-	0.03	-
268	*Bodianus bilunulatus*	Labridae	99.41	0.01	0.05	-	0.05	-	-	-
269	*Myripristis berndti*	Holocentridae	99.42	0.01	0.05	-	-	0.05	0.06	-
270	*Sufflamen bursa*	Balistidae	99.43	0.01	0.05	-	0.01	0.04	-	-
271	*Stephanolepis tomentosus*	Monacanthidae	99.44	0.01	0.05	-	0.01	0.03	-	-
272	*Cheilinus undulatus*	Labridae	99.46	0.01	0.05	-	0.01	0.03	-	-
273	Monacanthid sp.1	Monacanthidae	99.47	0.01	0.04	-	0.03	0.02	-	-
274	*Epinephelus* sp.	Serranidae	99.48	0.01	0.04	0.03	-	0.02	-	-

Continued

Appendix 2 (Continued)

Rank	Species	Family	Cum%	%	Total	Slope			Overlap	
						Upper 1-5 m	Mid 5-16 m	Lower 16-26 m	Flat Total	Trawl Total
275	*Lutjanus gibbus*	Lutjanidae	99.49	0.01	0.04	0.03	-	0.02	0.10	0.05
276	Balistid sp.6	Balistidae	99.50	0.01	0.04	-	-	0.04	-	-
277	*Apogon bandanensis*	Apogonidae	99.51	0.01	0.04	0.03	0.01	-	4.85	6.13
278	*Coris dorsumacula*	Labridae	99.52	0.01	0.04	-	0.04	-	-	-
279	*Lethrinus mahsena*	Lethrinidae	99.53	0.01	0.04	-	0.04	-	0.33	1.37
280	*Scarus rubroviolaceus*	Scaridae	99.54	0.01	0.04	-	0.04	-	-	-
281	*Hemigymnus fasciatus*	Labridae	99.54	0.01	0.04	-	-	0.04	0.39	-
282	*Epinephelus sexfasciatus*	Serranidae	99.55	0.01	0.03	-	-	0.03	-	-
283	Pomacentrid sp.12	Pomacentridae	99.56	0.01	0.03	-	-	0.03	-	-
284	*Amphiprion perideraion*	Pomacentridae	99.57	0.01	0.03	-	-	0.03	-	-
285	*Bodianus axillaris*	Labridae	99.58	0.01	0.03	-	0.01	0.02	-	-
286	*Parapercis tetracantha*	Mugiloididae	99.58	0.01	0.03	-	0.01	0.02	-	-
287	*Parapercis* sp.	Mugiloididae	99.59	0.01	0.03	-	0.01	0.02	-	-
288	*Bodianus* sp.	Labridae	99.60	0.01	0.03	-	0.03	-	-	-
289	*Chaetodon ulietensis*	Chaetodontidae	99.60	0.01	0.03	0.03	-	-	0.10	-
290	Blenny sp.7	Blenniidae	99.61	0.01	0.03	0.03	-	-	-	-
291	*Diodon hystrix*	Diodontidae	99.62	0.01	0.03	0.03	-	-	0.01	0.05
292	*Lutjanus vitta*	Lutjanidae	99.62	0.01	0.03	-	0.03	-	-	-
293	*Amphiprion sandaracinos*	Pomacentridae	99.63	0.01	0.03	-	0.03	-	-	-
294	*Rhinecanthus rectangulus*	Balistidae	99.64	0.01	0.03	0.03	-	-	-	-
295	* *Cirrhitichthys serratus*	Cirrhitidae	99.64	0.01	0.03	-	0.03	-	-	-
296	*Pomacanthus semicirculatus*	Pomacanthidae	99.65	0.01	0.03	0.03	-	-	-	-
297	*Parupeneus heptacanthus*	Mullidae	99.65	0.01	0.03	0.03	-	-	0.01	0.11
298	*Anthias* sp.	Serranidae	99.66	0.01	0.03	0.03	-	-	-	-
299	Acanthurid sp.5	Acanthuridae	99.67	0.01	0.03	0.03	-	-	-	-
300	*Cephalopholis miniata*	Serranidae	99.67	0.01	0.03	0.03	-	-	-	-
301	*Stethojulis* sp.	Labridae	99.68	0.01	0.03	0.03	-	-	0.31	-
302	* *Amblyeleotris japonica*	Gobiidae	99.69	0.01	0.03	-	0.03	-	0.03	-
303	*Chaetodon baronessa*	Chaetodontidae	99.69	0.01	0.03	0.03	-	-	0.03	-
304	*Pomacentrus tripunctatus*	Pomacentridae	99.70	0.01	0.03	0.03	-	-	8.86	0.04
305	Pomacentrid sp.2	Pomacentridae	99.70	0.01	0.03	0.03	-	-	-	-
306	*Caesio* sp.	Lutjanidae	99.71	0.01	0.03	0.03	-	-	-	-
307	*Chaetodon* sp.	Chaetodontidae	99.72	0.01	0.03	0.03	-	-	-	-
308	*Canthigaster coronata*	Tetraodontidae	99.72	0.01	0.03	-	0.03	-	-	-
309	* *Asterropteryx semipunctatus*	Gobiidae	99.73	0.01	0.03	0.03	-	-	-	1.31
310	*Cirripectes polyzona*	Blenniidae	99.74	0.01	0.03	0.03	-	-	-	-
311	*Cheilinus* sp.	Labridae	99.74	0.01	0.03	-	0.03	-	-	-
312	Goby sp.12	Gobiidae	99.75	0.01	0.03	0.03	-	-	-	-
313	* *Cirrhilabrus polyzona*	Labridae	99.76	0.01	0.03	0.03	-	-	-	-
314	*Pomacentrus nagasakiensis*	Pomacentridae	99.76	0.01	0.03	-	0.03	-	-	-
315	*Hologymnosus* sp.	Labridae	99.77	0.01	0.03	-	0.03	-	-	-
316	*Aspidontus taeniatus*	Blenniidae	99.77	0.01	0.03	0.03	-	-	0.06	-
317	*Novaculichthys macrolepidotus*	Labridae	99.78	0.01	0.03	0.03	-	-	-	-
318	*Cirrhitops hubbardi*	Cirrhitidae	99.79	0.01	0.03	0.03	-	-	-	-
319	*Stethojulis* sp.5	Labridae	99.79	0.01	0.03	0.03	-	-	-	-
320	*Chromis lepidolepis*	Pomacentridae	99.80	0.01	0.03	0.03	-	-	-	-
321	*Upeneus tragula*	Mullidae	99.81	0.01	0.03	0.03	-	-	0.03	3.87
322	*Lutjanus* sp.	Lutjanidae	99.81	0.01	0.03	0.03	-	-	-	-
323	*Lutjanus lutjanus*	Lutjanidae	99.82	0.01	0.02	-	-	0.02	-	-
324	*Scolopsis* sp.	Nemipteridae	99.82	0.01	0.02	-	-	0.02	-	-
325	*Cephalopholis* sp.	Serranidae	99.83	0.01	0.02	-	-	0.02	-	-
326	*Myripristis* sp.1	Holocentridae	99.83	0.01	0.02	-	-	0.02	-	-
327	*Lutjanus lineolatus*	Lutjanidae	99.84	0.01	0.02	-	-	0.02	0.03	0.13
328	* *Acanthurus xanthopterus*	Acanthuridae	99.84	<0.01	0.02	-	-	0.02	-	-
329	*Canthigaster compressa*	Tetraodontidae	99.85	<0.01	0.02	-	-	0.02	-	-

Continued

Appendix 2 (Continued)

Rank	Species	Family	Cum%	%	Total	Slope Upper 1-5 m	Slope Mid 5-16 m	Slope Lower 16-26 m	Overlap Flat Total	Overlap Trawl Total
330	Scorpaenid	Scorpaenidae	99.85	<0.01	0.02	-	-	0.02	-	0.05
331	*Amphiprion frenatus*	Pomacentridae	99.85	<0.01	0.02	-	-	0.02	-	-
332	*Glyphidodontops rollandi*	Pomacanthidae	99.86	<0.01	0.02	-	-	0.02	0.31	-
333	* *Cephalopholis boenack*	Serranidae	99.86	<0.01	0.02	-	-	0.02	-	-
334	*Calloplesiops altivelis*	Plesiopidae	99.87	<0.01	0.02	-	-	0.02	-	-
335	*Scarus gibbus*	Scaridae	99.87	<0.01	0.02	-	-	0.02	-	-
336	*Neoniphon sammara*	Holocentridae	99.88	<0.01	0.02	-	-	0.02	2.42	-
337	*Parupeneus indicus*	Mullidae	99.88	<0.01	0.02	-	-	0.02	-	0.57
338	Serranid sp.5	Serranidae	99.88	<0.01	0.02	-	-	0.02	-	-
339	*Pomacanthus imperator*	Pomacanthidae	99.89	<0.01	0.02	-	-	0.02	-	-
340	*Gymnothorax fimbriatus*	Muraenidae	99.89	<0.01	0.02	-	-	0.02	0.17	-
341	*Naso brevirostris*	Acanthuridae	99.90	<0.01	0.02	-	-	0.02	-	-
342	*Labropsis manabei*	Labridae	99.90	<0.01	0.02	-	-	0.02	-	-
343	*Caranx melampygus*	Carangidae	99.90	<0.01	0.02	-	-	0.02	-	-
344	Lethrinid	Lethrinidae	99.91	<0.01	0.02	-	-	0.02	-	-
345	*Pseudobalistes fuscus*	Balistidae	99.91	<0.01	0.01	-	0.01	-	-	0.16
346	* *Scorpaenopsis cirrhosa*	Scorpaenidae	99.91	<0.01	0.01	-	0.01	-	0.08	0.18
347	*Lethrinus ornatus*	Lethrinidae	99.92	<0.01	0.01	-	0.01	-	1.31	10.06
348	*Pterois volitans*	Scorpaenidae	99.92	<0.01	0.01	-	0.01	-	0.24	0.16
349	*Arothron hispidus*	Tetraodontidae	99.92	<0.01	0.01	-	0.01	-	0.03	2.30
350	*Plectorhynchus chaetodontoides*	Haemulidae	99.93	<0.01	0.01	-	0.01	-	0.15	0.10
351	*Atule mate*	Carangidae	99.93	<0.01	0.01	-	0.01	-	-	-
352	*Cantherhines dumerilii*	Monacanthidae	99.93	<0.01	0.01	-	0.01	-	-	-
353	Blenny sp.2	Blenniidae	99.94	<0.01	0.01	-	0.01	-	-	-
354	*Decapterus* sp.	Carangidae	99.94	<0.01	0.01	-	0.01	-	-	-
355	*Stenogobius* sp.	Gobiidae	99.94	<0.01	0.01	-	0.01	-	-	-
356	Pomacentrid sp.11	Pomacentridae	99.95	<0.01	0.01	-	0.01	-	-	-
357	*Halichoeres* sp.	Labridae	99.95	<0.01	0.01	-	0.01	-	0.46	-
358	*Glyphidodontops cyaneus*	Pomacanthidae	99.95	<0.01	0.01	-	0.01	-	1.13	-
359	*Halichoeres scapularis*	Labridae	99.96	<0.01	0.01	-	0.01	-	17.33	-
360	*Carangoides fulvoguttatus*	Carangidae	99.96	<0.01	0.01	-	0.01	-	-	-
361	*Pomacentrus grammorhynchus*	Pomacentridae	99.96	<0.01	0.01	-	0.01	-	17.94	-
362	Balistid sp.4	Balistidae	99.97	<0.01	0.01	-	0.01	-	-	-
363	*Coris aygula*	Labridae	99.97	<0.01	0.01	-	0.01	-	-	-
364	* *Canthigaster solandri*	Tetraodontidae	99.97	<0.01	0.01	-	0.01	-	0.03	-
365	*Sargocentron* sp.	Holocentridae	99.97	<0.01	0.01	-	0.01	-	-	-
366	*Plectorhynchus* sp.	Haemulidae	99.98	<0.01	0.01	-	0.01	-	-	0.05
367	Goby sp.7	Gobiidae	99.98	<0.01	0.01	-	0.01	-	-	-
368	*Cheilinus rhodochrous*	Labridae	99.98	<0.01	0.01	-	0.01	-	-	-
369	*Plectorhynchus goldmanni*	Haemulidae	99.99	<0.01	0.01	-	0.01	-	0.07	-
370	Carangid	Carangidae	99.99	<0.01	0.01	-	0.01	-	-	-
371	*Gymnothorax meleagris*	Muraenidae	99.99	<0.01	0.01	-	0.01	-	-	-
372	* *Scarus globiceps*	Scaridae	99.99	<0.01	0.01	-	0.01	-	-	-
373	*Sufflamen fraenatus*	Balistidae	100.00	<0.01	0.01	-	0.01	-	-	-
	Others			-	-	-	-	-	368.88	561.19
	Totals			100.00	396.89	187.43	122.59	86.88	1,871.55	1,257.38

Appendix 3. Reef slope fish families recorded from visual census from October 1989 to June 1991 and sorted by frequency of occurrence (ind./1,000 m²).

Rank	Family	Cum%	%	Total	Upper 1-5 m	Mid 5-16 m	Lower 16-26 m
1	Labridae	31.74	31.74	125.97	76.70	37.48	11.80
2	Pomacentridae	46.81	15.07	59.80	24.78	22.50	12.52
3	Acanthuridae	58.80	11.99	47.59	18.75	10.20	18.64
4	Scaridae	68.04	9.25	36.70	25.55	5.43	5.72
5	Apogonidae	72.55	4.51	17.89	13.03	1.41	3.45
6	Mullidae	76.66	4.11	16.31	5.33	7.59	3.39
7	Chaetodontidae	80.31	3.65	14.51	4.00	4.41	6.09
8	Plotosidae	83.38	3.07	12.18	-	8.76	3.42
9	Siganidae	85.12	1.74	6.92	2.63	3.31	0.98
10	Balistidae	86.73	1.61	6.39	1.20	3.31	1.88
11	Serranidae	88.25	1.52	6.03	2.30	1.41	2.32
12	Cirrhitidae	89.69	1.43	5.69	1.40	2.73	1.57
13	Blenniidae	90.93	1.24	4.94	3.23	0.94	0.78
14	Mugiloididae	92.12	1.19	4.72	0.55	2.38	1.79
15	Gobiidae	93.30	1.18	4.67	1.60	2.04	1.04
16	Lutjanidae	94.30	1.00	3.95	0.43	0.76	2.76
17	Tetraodontidae	95.00	0.70	2.79	0.30	1.04	1.45
18	Pseudochromidae	95.67	0.67	2.66	0.45	0.90	1.31
19	Pomacanthidae	96.30	0.63	2.51	0.28	0.65	1.59
20	Clupeidae	96.93	0.63	2.50	-	2.50	-
21	Nemipteridae	97.46	0.53	2.12	0.78	0.28	1.07
22	Zanclidae	97.89	0.43	1.69	0.43	0.63	0.64
23	Monacanthidae	98.28	0.39	1.54	0.03	0.79	0.72
24	Lethrinidae	98.66	0.38	1.51	0.90	0.15	0.46
25	Atherinidae	98.97	0.31	1.25	1.25	-	-
26	Holocentridae	99.20	0.23	0.89	0.08	0.06	0.76
27	Ostraciidae	99.42	0.22	0.87	0.50	0.21	0.16
28	Haemulidae	99.55	0.14	0.55	0.40	0.11	0.03
29	Synodontidae	99.66	0.10	0.41	0.15	0.18	0.08
30	Scorpaenidae	99.73	0.07	0.28	0.00	0.20	0.08
31	Grammistidae	99.78	0.05	0.22	0.03	0.05	0.14
32	Muraenidae	99.82	0.04	0.16	0.08	0.03	0.06
33	Carangidae	99.86	0.04	0.14	0.08	0.05	0.02
34	Priacanthidae	99.89	0.04	0.14	-	-	0.14
35	Percichthyidae	99.92	0.03	0.11	0.10	0.01	-
36	Centriscidae	99.94	0.02	0.09	0.08	0.01	-
37	Fistulariidae	99.96	0.02	0.07	0.05	-	0.02
38	Malacanthidae	99.97	0.02	0.06	-	0.06	-
39	Aulostomidae	99.99	0.02	0.06	0.03	0.04	-
40	Diodontidae	99.99	0.01	0.03	0.03	-	-
41	Plesiopidae	100.00	<0.01	0.02	-	-	0.02
	Totals		100.00	396.89	187.43	122.59	86.88

Appendix 4. Reef flat fish recorded from visual census from August 1988 to June 1991 and sorted by frequency of occurrence (ind./1,000 m^2). Bottom cover, A = corals and sand, B = corals and seagrass, C = seagrass and D = *Sargassum* spp. (* denotes uncertain identification).

						Flat				Overlap	
Rank	Species	Family	Cum%	%	Total	A	B	C	D	Slope Total	Trawl Total
1	*Eupomacentrus nigricans*	Pomacentridae	7.59	7.59	142.10	3.22	136.00	2.24	0.64	0.23	0.10
2	Engraulid	Engraulididae	14.70	7.11	133.06	34.72	-	42.78	55.56	-	-
3	*Sardinella* sp.	Clupeidae	21.40	6.70	125.38	2.36	72.22	50.79	-	-	0.83
4	*Dascyllus aruanus*	Pomacentridae	27.48	6.08	113.83	9.86	93.44	8.53	2.00	0.06	-
5	Atherinid	Atherinidae	31.11	3.63	67.90	50.00	13.89	4.01	-	1.25	-
6	*Chromis caerulea*	Pomacentridae	34.69	3.58	67.04	32.44	20.75	3.82	10.03	0.34	-
7	*Halichoeres hoeveni*	Labridae	38.15	3.46	64.68	14.79	5.00	13.03	31.86	5.68	-
8	*Scarus harid*	Scaridae	41.45	3.30	61.81	18.71	19.61	14.49	9.00	6.87	-
9	Clupeid	Clupeidae	44.72	3.27	61.14	-	-	5.58	55.56	2.50	0.13
10	*Hypoatherina bleekeri*	Atherinidae	47.95	3.23	60.50	2.08	3.94	54.47	-	-	5.72
11	*Pomacentrus flavicauda*	Pomacentridae	50.80	2.85	53.25	10.15	4.64	2.49	35.97	2.48	-
12	*Plotosus lineatus*	Plotosidae	53.39	2.59	48.54	27.78	5.56	15.21	-	12.18	102.55
13	*Eupomacentrus lividus*	Pomacentridae	55.90	2.51	46.94	6.71	38.94	1.10	0.19	0.36	0.05
14	*Scarus rhoduropterus*	Scaridae	57.70	1.80	33.67	7.33	16.36	3.28	6.69	8.28	8.73
15	*Amblyglyphidodon curacao*	Pomacentridae	59.49	1.79	33.54	22.76	6.97	0.89	2.92	0.58	-
16	Scarid	Scaridae	61.25	1.76	33.01	2.90	17.14	9.31	3.67	2.35	0.13
17	*Stolephorus indicus*	Engraulididae	62.98	1.73	32.36	1.81	-	30.56	-	-	-
18	*Apogon* sp.5 (Schroeder 1980)	Apogonidae	64.69	1.71	32.03	5.57	0.36	0.49	25.61	3.13	3.64
19	*Cheilodipterus quinquelineatus*	Apogonidae	66.39	1.70	31.82	5.38	7.03	14.19	5.22	4.70	20.78
20	*Dischistodus chrysopoecilus*	Pomacentridae	68.06	1.67	31.19	4.63	18.44	8.04	0.08	0.48	0.22
21	Apogonid sp.5	Apogonidae	69.71	1.65	30.96	6.07	-	24.89	-	0.08	18.77
22	*Thalassoma hardwickii*	Labridae	71.02	1.30	24.40	8.81	10.28	2.35	2.97	11.68	-
23	*Parapercis cylindrica*	Mugiloididae	72.25	1.23	22.99	7.75	2.17	10.57	2.50	0.53	4.47
24	*Stethojulis strigiventer*	Labridae	73.42	1.17	21.94	2.67	1.08	5.86	12.33	0.88	2.39
25	*Parupeneus trifasciatus*	Mullidae	74.54	1.12	21.00	5.18	1.72	3.99	10.11	14.61	2.37
26	*Halichoeres trimaculatus*	Labridae	75.66	1.12	20.92	5.82	10.11	2.76	2.22	0.25	-
27	*Calotomus japonicus*	Scaridae	76.76	1.10	20.56	1.86	7.11	9.17	2.42	3.07	2.36
28	*Scarus sordidus*	Scaridae	77.83	1.07	20.06	5.42	10.53	2.56	1.56	10.05	-
29	*Epinephelus merra*	Serranidae	78.86	1.03	19.36	2.57	11.64	3.79	1.36	1.87	4.28
30	*Siganus spinus*	Siganidae	79.88	1.02	19.10	3.75	2.17	4.90	8.28	5.73	14.43
31	*Pomacentrus grammorhynchus*	Pomacentridae	80.84	0.96	17.94	0.81	17.11	0.03	-	0.01	-
32	*Halichoeres scapularis*	Labridae	81.77	0.93	17.33	8.04	4.47	1.74	3.08	0.01	-
33	*Pomacentrus bankanensis*	Pomacentridae	82.58	0.81	15.10	4.54	3.31	1.89	5.36	6.45	-
34	*Apogon cyanosoma*	Apogonidae	83.34	0.76	14.24	2.35	1.14	1.33	9.42	0.28	3.69
35	*Apogon* sp.	Apogonidae	83.94	0.60	11.32	2.71	0.06	3.78	4.78	3.36	0.12
36	*Stethojulis trilineata*	Labridae	84.49	0.55	10.28	1.58	1.89	1.19	5.61	2.79	-
37	*Labroides dimidiatus*	Labridae	85.01	0.52	9.75	2.17	2.00	1.61	3.97	3.46	-
38	*Apogon novemfasciatus*	Apogonidae	85.52	0.51	9.50	2.64	0.33	0.94	5.58	0.14	3.77
39	*Cheilinus trilobatus*	Labridae	86.02	0.50	9.43	2.03	1.94	1.85	3.61	7.00	2.95
40	*Coris variegata*	Labridae	86.52	0.50	9.36	3.61	1.22	0.28	4.25	1.68	-
41	*Pomacentrus tripunctatus*	Pomacentridae	87.00	0.47	8.86	0.65	7.92	0.29	-	0.03	0.04
42	*Ctenochaetus binotatus*	Acanthuridae	87.42	0.42	7.93	1.36	4.53	1.32	0.72	33.12	0.04
43	*Paraglyphidodon melas*	Pomacentridae	87.82	0.40	7.57	3.36	2.61	0.38	1.22	1.87	-
44	*Plectroglyphidodon lacrymatus*	Pomacentridae	88.22	0.39	7.32	4.38	2.75	0.08	0.11	1.66	-
45	*Choerodon anchorago*	Labridae	88.59	0.38	7.07	0.89	2.78	2.79	0.61	0.49	5.34
46	*Gnathodentex aureolineatus*	Lethrinidae	88.97	0.37	7.00	0.31	0.19	0.03	6.47	1.32	-
47	*Salarias fasciatus*	Blenniidae	89.32	0.36	6.68	2.53	0.64	2.26	1.25	1.41	-
48	*Scolopsis bilineatus*	Nemipteridae	89.68	0.35	6.57	1.51	1.33	1.61	2.11	1.44	0.69
49	*Pomacentrus taeniometopon*	Pomacentridae	90.01	0.34	6.29	2.92	2.67	0.15	0.56	0.57	-
50	*Siganus fuscescens*	Siganidae	90.31	0.30	5.63	0.94	0.06	2.99	1.64	0.13	356.32
51	*Pterocaesio chrysozona*	Lutjanidae	90.61	0.30	5.56	-	5.56	-	-	0.42	-
52	*Stethojulis bandanensis*	Labridae	90.89	0.28	5.28	1.57	0.53	0.26	2.92	1.68	-
53	*Pomacentrus moluccensis*	Pomacentridae	91.17	0.28	5.15	0.63	2.72	1.58	0.22	1.06	-

Continued

Appendix 4 (Continued)

Rank	Species	Family	Cum%	%	Total	Flat A	Flat B	Flat C	Flat D	Overlap Slope Total	Overlap Trawl Total
54	*Apogon bandanensis*	Apogonidae	91.42	0.26	4.85	0.33	0.08	1.35	3.08	0.04	6.13
55	*Scarus ovifrons*	Scaridae	91.68	0.26	4.83	1.72	1.61	0.78	0.72	0.42	0.05
56	*Ctenochaetus striatus*	Acanthuridae	91.92	0.24	4.51	1.11	2.50	0.26	0.64	7.61	-
57	*Dischistodus prosopotaenia*	Pomacentridae	92.15	0.23	4.29	1.26	1.36	1.53	0.14	0.15	-
58	*Hemigymnus melapterus*	Labridae	92.38	0.23	4.22	0.51	3.14	0.57	-	1.07	-
59	*Abudefduf coelestinus*	Pomacentridae	92.59	0.21	3.93	1.43	0.25	0.42	1.83	0.18	-
60	*Chaetodon trifasciatus*	Chaetodontidae	92.78	0.20	3.65	0.03	3.58	0.04	-	0.43	0.05
61	*Scarus* sp.	Scaridae	92.98	0.19	3.63	0.61	0.83	2.18	-	0.55	-
62	*Halichoeres hortulanus*	Labridae	93.17	0.19	3.51	1.28	0.47	0.21	1.56	1.22	-
63	*Halichoeres nebulosus*	Labridae	93.34	0.18	3.32	0.42	0.06	0.04	2.81	44.65	-
64	*Zanclus cornutus*	Zanclidae	93.51	0.17	3.15	1.28	0.44	0.32	1.11	1.69	-
65	*Thalassoma lunare*	Labridae	93.68	0.17	3.15	0.82	1.19	0.58	0.56	1.73	-
66	*Abudefduf saxatilis*	Pomacentridae	93.85	0.17	3.13	0.81	0.83	0.18	1.31	0.20	0.05
67	*Halichoeres marginatus*	Labridae	94.01	0.16	3.07	0.75	0.28	0.32	1.72	1.26	-
68	*Chaetodon melannotus*	Chaetodontidae	94.17	0.16	2.99	0.11	2.42	0.35	0.11	0.45	0.17
69	*Dischistodus notopthalmus*	Pomacentridae	94.32	0.15	2.86	1.40	0.56	0.82	0.08	-	0.05
70	*Pomachromis richardsoni*	Pomacentridae	94.48	0.15	2.83	1.39	1.42	-	0.03	8.45	-
71	*Cheilio inermis*	Labridae	94.62	0.15	2.76	0.35	0.39	0.39	1.64	0.80	0.79
72	*Cheilodipterus macrodon*	Apogonidae	94.77	0.15	2.75	0.07	0.06	0.18	2.44	0.28	0.83
73	*Scarus dimidiatus*	Scaridae	94.91	0.14	2.60	0.46	1.89	0.25	-	0.08	-
74	*Chaetodon auriga*	Chaetodontidae	95.04	0.14	2.54	0.33	0.72	0.49	1.00	0.32	0.45
75	*Neoniphon sammara*	Holocentridae	95.17	0.13	2.42	0.14	2.14	0.06	0.08	0.02	-
76	*Canthigaster valentini*	Tetraodontidae	95.30	0.13	2.39	1.19	0.75	0.36	0.08	1.69	0.28
77	*Pseudocheilinus hexataenia*	Labridae	95.43	0.12	2.33	0.65	1.11	0.13	0.44	3.43	-
78	*Scarus schlegeli*	Scaridae	95.55	0.12	2.29	0.24	2.06	-	-	0.43	0.04
79	Apogonid	Apogonidae	95.67	0.12	2.28	0.83	-	0.06	1.39	5.90	0.05
80	*Pomacentrus coelestis*	Pomacentridae	95.78	0.11	2.11	1.08	0.14	0.17	0.72	8.93	-
81	*Gomphosus varius*	Labridae	95.89	0.11	2.08	0.40	0.86	0.35	0.47	1.87	-
82	*Dascyllus trimaculatus*	Pomacentridae	96.00	0.11	1.99	1.06	0.28	0.13	0.53	1.29	-
83	*Dampieria cyclophthalma*	Pseudochromidae	96.11	0.11	1.97	0.18	1.33	0.26	0.19	2.66	0.93
84	*Caesio tile*	Lutjanidae	96.21	0.10	1.94	-	1.94	-	-	0.44	-
85	*Dascyllus reticulatus*	Pomacentridae	96.31	0.10	1.90	0.43	0.97	0.31	0.19	0.88	-
86	*Zebrasoma scopas*	Acanthuridae	96.41	0.10	1.86	0.03	1.44	0.22	0.17	1.48	-
87	*Parupeneus barberinoides*	Mullidae	96.51	0.10	1.85	0.01	-	0.06	1.78	0.06	1.61
88	*Halichoeres poecilopterus*	Labridae	96.60	0.09	1.71	0.42	0.11	0.24	0.94	1.06	-
89	*Pomacentrus philippinus*	Pomacentridae	96.69	0.09	1.71	0.47	0.89	0.07	0.28	1.00	-
90	*Chaetodon kleinii*	Chaetodontidae	96.78	0.09	1.65	0.50	0.08	0.04	1.03	4.46	-
91	*Escualosa thoracata*	Clupeidae	96.86	0.08	1.57	-	-	1.57	-	-	0.66
92*	*Cirripectes variolosus*	Blenniidae	96.94	0.08	1.44	0.06	1.17	0.06	0.17	0.41	-
93	*Chaetodon citrinellus*	Chaetodontidae	97.02	0.08	1.44	0.29	0.36	0.10	0.69	0.52	-
94	*Amphiprion ocellaris*	Pomacentridae	97.09	0.08	1.43	0.15	-	0.06	1.22	0.54	-
95	*Parupeneus barberinus*	Mullidae	97.17	0.07	1.33	0.56	0.17	0.22	0.39	0.69	16.03
96	*Lethrinus ornatus*	Lethrinidae	97.24	0.07	1.31	-	-	0.22	1.08	0.01	10.06
97	*Scarus* sp.2	Scaridae	97.30	0.07	1.29	0.43	0.42	0.44	-	0.86	-
98	*Acanthurus gahhm*	Acanthuridae	97.37	0.07	1.25	0.32	0.75	0.01	0.17	1.39	0.04
99	*Chaetodon vagabundus*	Chaetodontidae	97.44	0.06	1.21	0.36	0.36	0.29	0.19	0.75	-
100	*Glyphidodontops cyaneus*	Pomacanthidae	97.50	0.06	1.13	0.33	0.75	0.01	0.03	0.01	-
101	*Lethrinus harak*	Lethrinidae	97.55	0.06	1.10	0.50	0.03	0.54	0.03	0.05	17.21
102	*Pomacentrus trimaculatus*	Pomacentridae	97.61	0.06	1.04	0.69	0.33	0.01	-	0.11	-
103	*Pomacentrus amboinensis*	Pomacentridae	97.66	0.05	0.99	0.10	0.78	0.11	-	0.10	-
104	*Chaetodon mertensii*	Chaetodontidae	97.72	0.05	0.99	0.49	-	0.03	0.47	4.17	-
105	*Acreichthys tomentosus*	Monacanthidae	97.77	0.05	0.97	0.42	0.17	0.11	0.28	-	34.43
106	*Pomacentrus* sp.	Pomacentridae	97.82	0.05	0.94	0.42	0.33	0.08	0.11	0.11	-
107	*Meiacanthus grammistes*	Blenniidae	97.87	0.05	0.93	0.31	0.42	0.04	0.17	1.51	-
108	Scarid sp.18	Scaridae	97.92	0.05	0.89	-	-	0.89	-	-	-

Continued

Appendix 4 (Continued)

Rank	Species	Family	Cum%	%	Total	Flat A	Flat B	Flat C	Flat D	Overlap Slope Total	Overlap Trawl Total
109	*Aeoliscus strigatus*	Centriscidae	97.96	0.05	0.89	0.47	0.36	0.06	-	0.09	3.81
110	*Amphiprion clarkii*	Pomacentridae	98.01	0.04	0.79	0.15	0.08	0.11	0.44	2.11	-
111	*Paraglyphidodon nigroris*	Pomacentridae	98.05	0.04	0.79	0.21	0.42	0.17	-	0.34	-
112	*Pomacentrus vaiuli*	Pomacentridae	98.09	0.04	0.76	0.19	0.28	0.04	0.25	9.05	-
113	*Epibulus insidiator*	Labridae	98.13	0.04	0.74	0.18	0.47	-	0.08	0.55	-
114	*Coris gaimardi*	Labridae	98.17	0.04	0.74	0.21	0.33	0.08	0.11	0.91	-
115*	*Plectroglyphidodon leucozona*	Pomacentridae	98.20	0.03	0.64	0.03	0.44	0.17	-	-	-
116	*Parapercis clathrata*	Mugiloididae	98.23	0.03	0.61	0.15	0.17	0.26	0.03	2.15	-
117	*Corythoichthys haematopterus*	Syngnathidae	98.27	0.03	0.60	0.49	-	0.06	0.06	-	2.07
118	*Myripristis murdjan*	Holocentridae	98.29	0.03	0.53	0.11	0.08	0.06	0.28	0.65	-
119	*Scolopsis cancellatus*	Nemipteridae	98.32	0.03	0.53	0.03	0.14	0.19	0.17		0.28
120	*Epinephelus ongus*	Serranidae	98.35	0.03	0.51	0.01	0.50	-	-	-	3.21
121	*Plectorhynchus diagrammus*	Haemulidae	98.38	0.03	0.50	0.07	0.08	0.04	0.31	0.23	-
122	*Chaetodon xanthurus*	Chaetodontidae	98.40	0.03	0.47	0.08	-	-	0.39	0.42	-
123	*Glyphidodontops biocellatus*	Pomacentridae	98.43	0.03	0.47	0.03	-	0.44	-	-	-
124	*Anampses geographicus*	Labridae	98.45	0.02	0.46	0.15	0.19	-	0.11	1.14	-
125	*Halichoeres* sp.	Labridae	98.48	0.02	0.46	0.07	0.06	0.33	-	0.01	-
126	*Paraglyphidodon carlsoni*	Pomacentridae	98.50	0.02	0.46	0.19	0.17	0.10	-	0.11	-
127	*Monotaxis grandoculis*	Lethrinidae	98.52	0.02	0.46	0.24	0.14	-	0.08	0.07	-
128	*Paraglyphidodon behni*	Pomacentridae	98.55	0.02	0.44	0.14	0.31	-	-	0.61	-
129	*Lutjanus fulvus*	Lutjanidae	98.57	0.02	0.44	0.28	-	-	0.17	-	-
130	*Pomacentrus labiatus*	Pomacentridae	98.60	0.02	0.44	-	0.44	-	-	-	-
131	*Hemiglyphidodon plagiometopon*	Pomacentridae	98.62	0.02	0.43	0.22	0.19	0.01	-	0.08	-
132	*Dascyllus melanurus*	Pomacentridae	98.64	0.02	0.43	0.15	0.28	-	-	-	-
133	*Pomacentrus smithi*	Pomacentridae	98.66	0.02	0.42	-	0.25	0.11	0.06	1.21	-
134	Goby	Gobiidae	98.69	0.02	0.42	0.22	0.17	0.03	-	0.15	0.28
135	*Zebrasoma veliferum*	Acanthuridae	98.71	0.02	0.42	0.03	0.25	0.06	0.08	0.18	-
136	*Grammistes sexlineatus*	Grammistidae	98.73	0.02	0.40	0.11	0.17	0.13	-	0.07	0.13
137	*Plectorhynchus lineatus*	Haemulidae	98.75	0.02	0.40	0.08	0.06	0.07	0.19	0.28	0.17
138*	*Dischistodus pseudochrysopoecilus*	Pomacentridae	98.77	0.02	0.40	0.13	0.03	0.25	-	-	-
139	*Pomacentrus melanopterus*	Pomacentridae	98.79	0.02	0.40	0.39	-	0.01	-	-	-
140	*Arothron nigropunctatus*	Tetraodontidae	98.82	0.02	0.39	0.13	0.06	0.07	0.14	0.50	0.11
141	*Bodianus mesothorax*	Labridae	98.84	0.02	0.39	0.14	0.17	0.08	-	0.41	-
142	*Hemigymnus fasciatus*	Labridae	98.86	0.02	0.39	0.01	0.25	0.13	-	0.04	-
143	*Abudefduf septemfasciatus*	Pomacentridae	98.88	0.02	0.39	-	0.11	-	0.28	-	-
144	*Amblygobius albimaculatus*	Gobiidae	98.90	0.02	0.39	0.18	-	0.15	0.06	0.05	0.75
145	*Ostracion cubicus*	Ostraciidae	98.92	0.02	0.39	0.11	0.06	0.14	0.08	0.36	0.24
146	Scarid sp.7	Scaridae	98.94	0.02	0.38	0.24	-	-	0.14	-	-
147	*Arothron immaculatus*	Tetraodontidae	98.96	0.02	0.38	0.01	0.17	0.17	0.03	-	11.71
148	*Tylosurus acus melanotus*	Belonidae	98.98	0.02	0.36	0.03	0.33	-	-	-	-
149	*Macropharyngodon meleagris*	Labridae	99.00	0.02	0.36	0.08	-	-	0.28	3.71	-
150	*Parupeneus bifasciatus*	Mullidae	99.02	0.02	0.36	0.11	0.14	-	0.11	0.17	-
151	*Rhinecanthus aculeatus*	Balistidae	99.04	0.02	0.35	0.10	0.03	0.06	0.17	0.17	-
152	*Lethrinus mahsena*	Lethrinidae	99.05	0.02	0.33	-	0.06	-	0.28	0.04	1.37
153	*Siganus argenteus*	Siganidae	99.07	0.02	0.32	0.26	-	-	0.06	0.90	7.44
154	*Canthigaster bennetti*	Tetraodontidae	99.09	0.02	0.32	0.24	-	-	0.08	0.46	0.69
155	*Fistularia petimba*	Fistulariidae	99.10	0.02	0.31	0.04	0.19	0.04	0.03	0.07	0.15
156	*Gymnothorax pictus*	Muraenidae	99.12	0.02	0.31	0.13	0.06	0.13	-	0.08	4.06
157	*Synodus variegatus*	Synodontidae	99.14	0.02	0.31	0.18	-	0.07	0.06	0.26	0.32
158	*Glyphidodontops rollandi*	Pomacanthidae	99.15	0.02	0.31	0.04	0.19	0.04	0.03	0.02	-
159	*Stethojulis* sp.	Labridae	99.17	0.02	0.31	-	-	-	0.31	0.03	-
160	*Scarus fasciatus*	Scaridae	99.19	0.02	0.29	0.14	-	0.15	-	0.12	-
161	*Halichoeres prosopeion*	Labridae	99.20	0.01	0.28	0.15	0.06	0.04	0.03	0.18	-
162	*Naso lituratus*	Acanthuridae	99.21	0.01	0.26	0.07	0.17	-	0.03	0.61	0.04
163	*Cheilinus bimaculatus*	Labridae	99.23	0.01	0.26	0.01	0.11	0.06	0.08	1.48	0.22

Continued

Appendix 4 (Continued)

						Flat				Overlap	
Rank	Species	Family	Cum%	%	Total	A	B	C	D	Slope Total	Trawl Total
164	*Saurida gracilis*	Synodontidae	99.24	0.01	0.26	0.18	-	-	0.08	0.15	8.52
165	*Acanthurus lineatus*	Acanthuridae	99.26	0.01	0.26	0.24	-	-	0.03	0.42	-
166	Labrid	Labridae	99.27	0.01	0.25	-	-	0.03	0.22	0.89	0.08
167	Apogonid sp.2	Apogonidae	99.28	0.01	0.25	-	-	-	0.25	-	1.32
168	*Halichoeres margaritaceus*	Labridae	99.30	0.01	0.25	0.17	-	-	0.08	0.09	-
169	*Apogon compressus*	Apogonidae	99.31	0.01	0.25	0.08	0.06	0.06	0.06	-	-
170	*Novaculichthys taeniurus*	Labridae	99.32	0.01	0.25	0.06	-	-	0.19	0.14	-
171	*Plagiotremus rhinorhynchos*	Blenniidae	99.34	0.01	0.24	0.04	0.03	-	0.17	0.60	-
172	*Thalassoma amblycephalum*	Labridae	99.35	0.01	0.24	-	0.22	0.01	-	4.21	-
173	*Pterois volitans*	Scorpaenidae	99.36	0.01	0.24	0.08	0.06	0.04	0.06	0.01	0.16
174	*Lutjanus decussatus*	Lutjanidae	99.37	0.01	0.24	0.07	0.17	-	-	0.10	0.15
175	*Plectroglyphidodon dickii*	Pomacentridae	99.39	0.01	0.22	0.07	0.08	0.01	0.06	0.75	-
176	*Heniochus varius*	Chaetodontidae	99.40	0.01	0.21	0.06	0.08	0.01	0.06	0.08	-
177	*Aulostomus chinensis*	Aulostomidae	99.41	0.01	0.21	0.13	0.06	0.03	-	0.06	0.16
178	*Heniochus chrysostomus*	Chaetodontidae	99.42	0.01	0.21	0.03	0.11	0.04	0.03	0.15	-
179	*Acanthurus mata*	Acanthuridae	99.43	0.01	0.21	0.13	0.06	-	0.03	0.05	-
180	*Scarus prasiognathus*	Scaridae	99.44	0.01	0.19	0.04	-	0.04	0.11	0.30	0.54
181*	*Chaetodon adiergastos*	Chaetodontidae	99.45	0.01	0.19	0.03	0.14	0.03	-	-	-
182	Scarid sp.2	Scaridae	99.46	0.01	0.19	0.03	0.17	-	-	-	-
183	*Chromis xanthura*	Pomacentridae	99.47	0.01	0.19	0.03	0.06	-	0.11	0.61	-
184	*Echidna nebulosa*	Muraenidae	99.48	0.01	0.19	0.08	0.06	0.03	0.03	-	-
185	*Naso unicornis*	Acanthuridae	99.49	0.01	0.18	0.14	0.03	0.01	-	0.25	0.16
186	*Dampieria* sp.	Pseudochromidae	99.50	0.01	0.18	-	0.17	0.01	-	-	-
187	*Labrichthys unilineatus*	Labridae	99.51	0.01	0.18	0.01	0.17	-	-	0.86	-
188	*Scarus ghobban*	Scaridae	99.52	0.01	0.18	0.13	-	0.03	0.03	0.58	6.31
189	*Gymnothorax fimbriatus*	Muraenidae	99.53	0.01	0.17	0.06	-	0.06	0.06	0.02	-
190	*Bolbometopon bicolor*	Scaridae	99.54	0.01	0.17	-	0.06	0.03	0.08	0.14	-
191	*Pomacentrus lepidogenys*	Pomacentridae	99.55	0.01	0.15	0.01	0.14	-	-	1.09	-
192	*Chaetodon lunula*	Chaetodontidae	99.55	0.01	0.15	0.04	0.03	0.08	-	0.05	0.06
193	*Sufflamen chrysopterus*	Balistidae	99.56	0.01	0.15	0.10	-	-	0.06	4.75	-
194	*Halichoeres melanurus*	Labridae	99.57	0.01	0.15	0.01	0.03	0.06	0.06	0.68	-
195	*Thalassoma quinquevittatum*	Labridae	99.58	0.01	0.15	0.01	0.06	0.03	0.06	3.70	-
196	*Plectorhynchus chaetodontoides*	Haemulidae	99.59	0.01	0.15	0.01	-	0.14	-	0.01	0.10
197	*Caesio erythrogaster*	Lutjanidae	99.59	0.01	0.14	0.03	-	-	0.11	0.98	0.04
198	*Glyphidodontops hemicyaneus*	Pomacentridae	99.60	0.01	0.14	-	0.11	0.03	-	-	-
199	Apogonid sp.4	Apogonidae	99.61	0.01	0.14	-	-	0.14	-	-	-
200	*Arothron stellatus*	Tetraodontidae	99.62	0.01	0.14	0.08	-	-	0.06	0.08	0.10
201	*Chromis weberi*	Pomacentridae	99.62	0.01	0.14	-	-	-	0.14	2.24	-
202	*Siganus virgatus*	Siganidae	99.63	0.01	0.13	-	0.06	0.07	-	0.09	20.39
203	*Epinephelus fasciatus*	Serranidae	99.64	0.01	0.13	0.06	-	0.01	0.06	1.60	-
204	*Parapercis polyophthalma*	Mugiloididae	99.64	0.01	0.13	0.13	-	-	-	0.96	-
205	*Mulloidichthys flavolineatus*	Mullidae	99.65	0.01	0.13	-	0.08	0.04	-	0.10	0.30
206*	*Paraglyphidodon polyacanthus*	Pomacentridae	99.66	0.01	0.13	0.01	-	0.11	-	-	-
207	*Scarus longiceps*	Scaridae	99.66	0.01	0.13	0.04	0.03	0.03	0.03	1.14	4.76
208	*Sargocentron ittodai*	Holocentridae	99.67	0.01	0.13	0.01	-	-	0.11	-	-
209	*Apogon* sp.1 (Schroeder 1980)	Apogonidae	99.68	0.01	0.11	-	0.08	0.03	-	-	-
210	*Lutjanus monostigma*	Lutjanidae	99.68	0.01	0.11	0.01	-	0.01	0.08	-	-
211	*Lutjanus biguttatus*	Lutjanidae	99.69	0.01	0.11	-	0.11	-	-	-	-
212	*Centropyge heraldi*	Pomacanthidae	99.69	0.01	0.11	-	0.11	-	-	0.78	-
213	*Cheilinus fasciatus*	Labridae	99.70	0.01	0.11	0.06	-	0.03	0.03	0.18	0.05
214	*Sargocentron rubrum*	Holocentridae	99.71	0.01	0.11	0.03	-	0.08	-	0.10	-
215	*Halichoeres melanochir*	Labridae	99.71	0.01	0.11	-	-	-	0.11	3.09	-
216	*Dischistodus perspicillatus*	Pomacentridae	99.72	0.01	0.11	0.03	0.06	0.03	-	-	-
217	Acanthurid sp.1	Acanthuridae	99.72	0.01	0.11	0.01	0.06	0.01	0.03	-	-
218	*Naso* sp.1	Acanthuridae	99.73	0.01	0.11	0.08	-	-	0.03	0.08	0.18

Continued

Appendix 4 (Continued)

Rank	Species	Family	Cum%	%	Total	Flat A	Flat B	Flat C	Flat D	Overlap Slope Total	Overlap Trawl Total
219	*Chaetodon ephippium*	Chaetodontidae	99.74	0.01	0.11	-	0.03	0.03	0.06	-	-
220	*Apogon coccineus*	Apogonidae	99.74	0.01	0.11	0.01	-	0.10	-	-	24.12
221	*Chaetodon ulietensis*	Chaetodontidae	99.75	0.01	0.10	-	0.08	0.01	-	0.03	-
222	Apogonid sp.3	Apogonidae	99.75	0.01	0.10	0.01	-	-	0.08	-	-
223	*Sargocentron diadema*	Holocentridae	99.76	0.01	0.10	0.04	0.06	-	-	0.05	-
224	*Halichoeres* sp.2 (Schroeder 1980)	Labridae	99.76	0.01	0.10	0.01	-	0.08	-	-	-
225	*Exyrias puntang*	Gobiidae	99.77	0.01	0.10	0.01	0.08	-	-	-	0.69
226	*Lutjanus fulviflamma*	Lutjanidae	99.77	0.01	0.10	0.04	-	0.03	0.03	0.10	1.49
227	*Dendrochirus zebra*	Scorpaenidae	99.78	0.01	0.10	0.07	0.03	-	-	0.24	0.05
228	*Lutjanus gibbus*	Lutjanidae	99.78	0.01	0.10	0.07	-	-	0.03	0.04	0.05
229	*Chaetodon punctatofasciatus*	Chaetodontidae	99.79	0.01	0.10	-	0.03	0.04	0.03	1.36	-
230	*Parupeneus cyclostomus*	Mullidae	99.79	<0.01	0.08	0.03	0.03	-	0.03	0.49	-
231	Apogonid sp.8	Apogonidae	99.80	<0.01	0.08	-	0.08	-	-	-	-
232	Petroscirtes sp.	Blenniidae	99.80	<0.01	0.08	-	-	0.08	-	-	-
233	Apogonid sp.6	Apogonidae	99.81	<0.01	0.08	-	-	0.08	-	-	-
234	*Acanthurus dussumieri*	Acanthuridae	99.81	<0.01	0.08	0.03	0.06	-	-	-	-
235	*Halichoeres* sp.3	Labridae	99.82	<0.01	0.08	0.06	-	-	0.03	-	-
236	Blenny	Blenniidae	99.82	<0.01	0.08	0.03	0.03	-	0.03	0.33	-
237	*Cantherhines pardalis*	Monacanthidae	99.82	<0.01	0.08	0.03	-	-	0.06	0.26	-
238*	*Scorpaenopsis cirrhosa*	Scorpaenidae	99.83	<0.01	0.08	0.06	-	0.03	-	0.01	0.18
239	*Cheilinus celebicus*	Labridae	99.83	<0.01	0.08	-	-	-	0.08	1.35	-
240	*Rhinecanthus verrucosus*	Balistidae	99.84	<0.01	0.07	0.03	-	0.01	0.03	0.15	-
241	*Amblyglyphidodon leucogaster*	Pomacentridae	99.84	<0.01	0.07	0.04	0.03	-	-	0.23	-
242	*Cheilinus diagrammus*	Labridae	99.84	<0.01	0.07	0.04	0.03	-	-	1.11	-
243	*Plectorhynchus goldmanni*	Haemulidae	99.85	<0.01	0.07	0.01	0.03	0.03	-	0.01	-
244	*Ostracion meleagris*	Ostraciidae	99.85	<0.01	0.07	0.01	0.06	-	-	0.51	-
245	*Diploprion bifasciatus*	Grammistidae	99.86	<0.01	0.07	0.04	-	-	0.03	0.15	-
246*	*Glyphidodontops starcki*	Pomacentridae	99.86	<0.01	0.06	-	0.06	-	-	-	-
247	*Yongeichthys criniger*	Gobiidae	99.86	<0.01	0.06	0.06	-	-	-	-	0.19
248*	*Lethrinus nematacanthus*	Lethrinidae	99.86	<0.01	0.06	-	-	-	0.06	-	0.16
249	*Centropyge tibicen*	Pomacanthidae	99.87	<0.01	0.06	-	-	-	0.06	0.24	-
250	*Acanthurus triostegus*	Acanthuridae	99.87	<0.01	0.06	0.06	-	-	-	0.05	-
251*	*Lethrinus obsoletus*	Lethrinidae	99.87	<0.01	0.06	0.03	-	0.03	-	-	8.28
252	*Myripristis berndti*	Holocentridae	99.88	<0.01	0.06	-	-	-	0.06	0.05	-
253	Acanthurid sp.6	Acanthuridae	99.88	<0.01	0.06	0.04	-	0.01	-	0.05	-
254	*Leptoscarus vaigiensis*	Scaridae	99.88	<0.01	0.06	-	-	-	0.06	-	0.94
255	*Exallias brevis*	Blenniidae	99.89	<0.01	0.06	-	0.06	-	-	0.21	-
256	*Aspidontus taeniatus*	Blenniidae	99.89	<0.01	0.06	-	0.06	-	-	0.03	-
257	Pomacentrid sp.10	Pomacentridae	99.89	<0.01	0.06	-	0.06	-	-	-	-
258	*Canthigaster janthinoptera*	Tetraodontidae	99.89	<0.01	0.06	-	-	0.06	-	-	-
259	*Chaetodon lineolatus*	Chaetodontidae	99.90	<0.01	0.06	-	0.06	-	-	-	-
260*	*Valenciennea longispinnis*	Gobiidae	99.90	<0.01	0.06	-	-	-	0.06	-	-
261*	*Acanthurus japonicus*	Acanthuridae	99.90	<0.01	0.06	-	0.06	-	-	0.77	-
262	*Chaetodon rafflesi*	Chaetodontidae	99.91	<0.01	0.06	-	-	0.06	-	-	-
263	*Sargocentron caudimaculatum*	Holocentridae	99.91	<0.01	0.06	-	-	-	0.06	-	-
264	*Amblygobius phalaena*	Gobiidae	99.91	<0.01	0.06	0.03	-	0.03	-	-	0.04
265	*Glyphidodontops leucopomus*	Pomacanthidae	99.91	<0.01	0.04	0.01	-	0.03	-	0.05	-
266	*Valenciennea strigata*	Gobiidae	99.92	<0.01	0.04	-	-	0.01	0.03	1.00	-
267	*Hemipteronotus taeniurus*	Labridae	99.92	<0.01	0.04	-	-	0.01	0.03	-	-
268	Scarid sp.15	Scaridae	99.92	<0.01	0.04	-	-	0.04	-	-	-
269	*Lethrinus haematopterus*	Lethrinidae	99.92	<0.01	0.03	-	-	-	0.03	-	-
270	*Gymnomuraena zebra*	Muraenidae	99.92	<0.01	0.03	-	-	0.03	-	0.05	-
271	Pseudochromid sp.2	Pseudochromidae	99.93	<0.01	0.03	0.03	-	-	-	-	-
272	*Paraglyglyphidodon thoracotaeniatus*	Pomacentridae	99.93	<0.01	0.03	-	0.03	-	-	0.08	-
273	*Valenciennea wardi*	Gobiidae	99.93	<0.01	0.03	-	-	-	0.03	0.05	-

Continued

Appendix 4 (Continued)

Rank	Species	Family	Cum%	%	Total	Flat A	Flat B	Flat C	Flat D	Overlap Slope Total	Overlap Trawl Total
274	*Myrichthys aki*	Ophichthidae	99.93	<0.01	0.03	-	-	-	0.03	-	0.06
275	Acanthurid sp.9	Acanthuridae	99.93	<0.01	0.03	0.03	-	-	-	-	-
276*	*Canthigaster solandri*	Tetraodontidae	99.93	<0.01	0.03	0.03	-	-	-	0.01	-
277	Goby sp.6	Gobiidae	99.93	<0.01	0.03	-	-	0.03	-	-	-
278*	*Corythoichthys schultzi*	Syngnathidae	99.94	<0.01	0.03	0.03	-	-	-	-	0.11
279	*Lutjanus lineolatus*	Lutjanidae	99.94	<0.01	0.03	-	-	-	0.03	0.02	0.13
280	*Lutjanus bohar*	Lutjanidae	99.94	<0.01	0.03	-	0.03	-	-	-	-
281	*Chaetodon baronessa*	Chaetodontidae	99.94	<0.01	0.03	-	-	-	0.03	0.03	-
282	*Acanthurus* sp.1	Acanthuridae	99.94	<0.01	0.03	-	0.03	-	-	-	-
283	*Scolopsis* sp.2	Nemipteridae	99.94	<0.01	0.03	0.03	-	-	-	-	-
284*	*Amblyeleotris japonica*	Gobiidae	99.95	<0.01	0.03	0.03	-	-	-	0.03	-
285	*Pseudochromis* sp.	Pseudochromidae	99.95	<0.01	0.03	-	0.03	-	-	-	-
286	*Ophichthus urolophus*	Ophichthidae	99.95	<0.01	0.03	0.03	-	-	-	-	-
287	*Epinephelus hexagonatus*	Serranidae	99.95	<0.01	0.03	0.01	-	0.01	-	-	-
288	*Plagiotremus tapeinosoma*	Blenniidae	99.95	<0.01	0.03	-	-	-	0.03	0.31	-
289	*Arothron* sp.	Tetraodontidae	99.95	<0.01	0.03	-	-	0.03	-	-	-
290	Pomacentrid	Pomacentridae	99.95	<0.01	0.03	0.03	-	-	-	0.12	-
291	Goby sp.	Gobiidae	99.96	<0.01	0.03	0.03	-	-	-	-	-
292	*Anampses caeruleopunctatus*	Labridae	99.96	<0.01	0.03	-	-	0.03	-	0.83	-
293	*Paracirrhites arcatus*	Cirrhitidae	99.96	<0.01	0.03	0.03	-	-	-	3.91	-
294	*Chromis margaritifer*	Pomacentridae	99.96	<0.01	0.03	-	-	-	0.03	1.70	-
295	*Pervagor janthinosoma*	Monacanthidae	99.96	<0.01	0.03	-	0.03	-	-	0.76	-
296	*Cirrhilabrus cyanopleura*	Labridae	99.96	<0.01	0.03	0.03	-	-	-	4.01	-
297	*Rhinecanthus* sp.	Balistidae	99.96	<0.01	0.03	0.03	-	-	-	-	-
298	Labrid sp.17	Labridae	99.97	<0.01	0.03	-	-	0.03	-	-	-
299	*Epinephelus megachir*	Serranidae	99.97	<0.01	0.03	-	-	0.03	-	-	-
300	*Arothron hispidus*	Tetraodontidae	99.97	<0.01	0.03	0.01	-	0.01	-	0.01	2.30
301	*Epinephelus macrospilus*	Serranidae	99.97	<0.01	0.03	-	-	-	0.03	-	-
302	*Platax pinnatus*	Ephippidae	99.97	<0.01	0.03	0.03	-	-	-	-	-
303	*Centrogenys vaigiensis*	Percichthyidae	99.97	<0.01	0.03	-	-	-	0.03	0.11	10.20
304	*Sargocentron* sp.3	Holocentridae	99.97	<0.01	0.03	-	0.03	-	-	-	-
305	*Amblyglyphidodon aureus*	Pomacentridae	99.98	<0.01	0.03	-	0.03	-	-	-	-
306	*Upeneus tragula*	Mullidae	99.98	<0.01	0.03	0.03	-	-	-	0.03	3.87
307	*Diodon hystrix*	Diodontidae	99.98	<0.01	0.01	-	-	0.01	-	0.03	0.05
308	*Pseudobalistes flavimarginatus*	Balistidae	99.98	<0.01	0.01	0.01	-	-	-	0.06	0.05
309	*Petroscirtes breviceps*	Blenniidae	99.98	<0.01	0.01	0.01	-	-	-	-	19.44
310*	*Lethrinus reticulatus*	Lethrinidae	99.98	<0.01	0.01	-	-	0.01	-	-	7.32
311	*Syngnathoides biaculeatus*	Syngnathidae	99.98	<0.01	0.01	0.01	-	-	-	-	39.67
312*	*Acanthurus glaucopareius*	Acanthuridae	99.98	<0.01	0.01	-	-	0.01	-	0.25	-
313	*Pardachirus pavoninus*	Soleidae	99.98	<0.01	0.01	0.01	-	-	-	-	1.65
314	*Lethrinus lentjan*	Lethrinidae	99.98	<0.01	0.01	-	-	0.01	-	-	1.23
315	*Parupeneus heptacanthus*	Mullidae	99.98	<0.01	0.01	0.01	-	-	-	0.03	0.11
316	*Thalassoma lutescens*	Labridae	99.99	<0.01	0.01	0.01	-	-	-	0.20	-
317	*Gerres oyena*	Gerreidae	99.99	<0.01	0.01	0.01	-	-	-	-	1.56
318	*Pseudomonacanthus macrurus*	Monacanthidae	99.99	<0.01	0.01	0.01	-	-	-	-	0.04
319	Goby sp.5	Gobiidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
320	*Solenostomus paradoxus*	Solenostomidae	99.99	<0.01	0.01	-	-	0.01	-	-	-
321*	*Gerres acinaces*	Gerreidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
322	Pomacentrid sp.1	Pomacentridae	99.99	<0.01	0.01	0.01	-	-	-	0.15	-
323	*Hippocampus* sp.	Syngnathidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
324	*Chaetodon bennetti*	Chaetodontidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
325	*Amblyeleotris fasciata*	Gobiidae	99.99	<0.01	0.01	0.01	-	-	-	0.13	-
326	*Chaetodon unimaculatus*	Chaetodontidae	99.99	<0.01	0.01	0.01	-	-	-	0.16	-
327	*Scorpaenopsis* sp.	Scorpaenidae	99.99	<0.01	0.01	-	-	0.01	-	-	-
328	*Abudefduf leucozonus*	Pomacentridae	99.99	<0.01	0.01	0.01	-	-	-	-	-

Continued

Appendix 4 (Continued)

Rank	Species	Family	Cum%	%	Total	Flat A	Flat B	Flat C	Flat D	Overlap Slope Total	Overlap Trawl Total
329	Serranid sp.4	Serranidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
330	Goby sp.4	Gobiidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
331	Scolopsis sp.3	Nemipteridae	99.99	<0.01	0.01	0.01	-	-	-	-	-
332	Scarid sp.10	Scaridae	99.99	<0.01	0.01	-	-	0.01	-	-	-
333	*Acanthurus bariene*	Acanthuridae	99.99	<0.01	0.01	0.01	-	-	-	-	-
334	*Lutjanus russellii*	Lutjanidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
335	*Epinephelus maculatus*	Serranidae	99.99	<0.01	0.01	0.01	-	-	-	-	-
336	*Labroides bicolor*	Labridae	100.00	<0.01	0.01	-	-	0.01	-	-	-
	Others			-	-	-	-	-	-	23.90	398.15
	Totals			100.00	1,871.60	405.63	661.14	409.60	395.19	396.89	1,257.38

Appendix 5. Reef flat fish families recorded from visual census from August 1988 to June 1991 and sorted by frequency of occurrence (ind./1,000 m^2).

Rank	Family	Cum%	%	Total	Corals and sand	Corals and seagrass	Seagrass	*Sargassum*
1	Pomacentridae	31.74	31.74	593.97	119.83	370.06	36.97	67.11
2	Labridae	44.20	12.46	233.17	59.06	51.06	37.58	85.47
3	Clupeidae	54.24	10.05	188.08	2.36	72.22	57.94	55.56
4	Scaridae	64.20	9.95	186.26	40.29	77.81	43.67	24.50
5	Engraulididae	73.04	8.84	165.42	36.53	-	73.33	55.56
6	Apogonidae	80.56	7.53	140.86	26.06	9.28	47.61	57.92
7	Atherinidae	87.42	6.86	128.40	52.08	17.83	58.49	-
8	Plotosidae	90.02	2.59	48.54	27.78	5.56	15.21	-
9	Siganidae	91.36	1.34	25.17	4.96	2.28	7.96	9.97
10	Mullidae	92.69	1.32	24.79	5.93	2.14	4.31	12.42
11	Mugiloididae	93.95	1.27	23.72	8.03	2.33	10.83	2.53
12	Serranidae	95.03	1.07	20.11	2.68	12.14	3.85	1.44
13	Acanthuridae	95.96	0.93	17.44	3.68	9.92	1.93	1.92
14	Chaetodontidae	96.82	0.86	16.18	2.38	8.08	1.64	4.08
15	Lethrinidae	97.38	0.55	10.36	1.07	0.42	0.85	8.03
16	Blenniidae	97.89	0.51	9.61	2.97	2.39	2.44	1.81
17	Lutjanidae	98.36	0.47	8.81	0.51	7.81	0.04	0.44
18	Nemipteridae	98.74	0.38	7.14	1.58	1.47	1.81	2.28
19	Tetraodontidae	98.94	0.20	3.75	1.69	0.97	0.69	0.39
20	Holocentridae	99.13	0.18	3.42	0.33	2.31	0.19	0.58
21	Zanclidae	99.30	0.17	3.15	1.28	0.44	0.32	1.11
22	Pseudochromidae	99.41	0.12	2.21	0.21	1.53	0.28	0.19
23	Pomacanthidae	99.50	0.09	1.64	0.39	1.06	0.08	0.11
24	Gobiidae	99.57	0.07	1.26	0.60	0.25	0.25	0.17
25	Haemulidae	99.63	0.06	1.13	0.18	0.17	0.28	0.50
26	Monacanthidae	99.69	0.06	1.10	0.46	0.19	0.11	0.33
27	Centriscidae	99.73	0.05	0.89	0.47	0.36	0.06	-
28	Muraenidae	99.77	0.04	0.69	0.26	0.11	0.24	0.08
29	Syngnathidae	99.81	0.03	0.65	0.54	0.00	0.06	0.06
30	Balistidae	99.84	0.03	0.61	0.26	0.03	0.07	0.25
31	Synodontidae	99.87	0.03	0.57	0.36	-	0.07	0.14
32	Grammistidae	99.89	0.03	0.47	0.15	0.17	0.13	0.03
33	Ostraciidae	99.92	0.02	0.46	0.13	0.11	0.14	0.08
34	Scorpaenidae	99.94	0.02	0.43	0.21	0.08	0.08	0.06
35	Belonidae	99.96	0.02	0.36	0.03	0.33	-	-
36	Fistulariidae	99.98	0.02	0.31	0.04	0.19	0.04	0.03
37	Aulostomidae	99.99	0.01	0.21	0.13	0.06	0.03	-
38	Ophichthidae	99.99	<0.01	0.06	0.03	-	-	0.03
39	Gerreidae	99.99	<0.01	0.03	0.03	-	-	-
40	Percichthyidae	99.99	<0.01	0.03	-	-	-	0.03
41	Cirrhitidae	99.99	<0.01	0.03	0.03	-	-	-
42	Ephippidae	99.99	<0.01	0.03	0.03	-	-	-
43	Diodontidae	99.99	<0.01	0.01	-	-	0.01	-
44	Soleidae	99.99	<0.01	0.01	0.01	-	-	-
45	Solenostomidae	100.00	<0.01	0.01	-	-	0.01	-
	Totals		100.00	1,871.56	405.63	661.14	409.60	395.19

Appendix 6. Reef flat fish caught at night by a roller beam trawl in the seagrass beds of Santiago Island from October 1988 to June 1991 and sorted by frequency of occurrence (ind./1,000 m^2). (* denotes uncertain identification).

						Trawl				Overlap	
						Seagrass density and depth					
Rank	Species	Family	Cum%	%	Total	Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m	Slope Total	Flat Total
1	*Siganus fuscescens*	Siganidae	28.34	28.34	356.32	161.10	78.29	107.15	9.78	0.13	5.63
2	*Fowleria variegata*	Apogonidae	46.80	18.46	232.10	63.37	5.33	159.02	4.38	-	-
3	*Apogon sangiensis*	Apogonidae	55.03	8.24	103.57	29.05	15.81	57.58	1.13	-	-
4	*Plotosus lineatus*	Plotosidae	63.19	8.16	102.55	98.63	0.10	3.13	0.69	12.18	48.54
5	*Syngnathoides biaculeatus*	Syngnathidae	66.35	3.15	39.67	9.61	2.19	7.94	19.94	-	0.01
6	*Sphaeramia orbicularis*	Apogonidae	69.23	2.88	36.26	8.45	0.19	27.62	-	-	-
7	*Acreichthys tomentosus*	Monacanthidae	71.97	2.74	34.43	7.27	8.95	11.64	6.57	-	0.97
8	*Apogon coccineus*	Apogonidae	73.89	1.92	24.12	4.74	1.05	14.57	3.76	-	0.11
9	*Cheilodipterus quinquelineatus*	Apogonidae	75.54	1.65	20.78	5.34	0.95	5.57	8.92	4.70	31.82
10	*Siganus virgatus*	Siganidae	77.16	1.62	20.39	10.94	4.29	4.99	0.17	0.09	0.13
11	*Petroscirtes breviceps*	Blenniidae	78.71	1.55	19.44	5.28	2.95	6.99	4.21	-	0.01
12	Apogonid sp.5	Apogonidae	80.20	1.49	18.77	3.97	1.14	8.60	5.05	0.08	30.96
13	*Lethrinus harak*	Lethrinidae	81.57	1.37	17.21	9.25	2.57	4.02	1.37	0.05	1.10
14	*Parupeneus barberinus*	Mullidae	82.84	1.28	16.03	6.48	3.43	2.79	3.33	0.69	1.33
15	*Siganus spinus*	Siganidae	83.99	1.15	14.43	5.43	1.05	5.10	2.85	5.73	19.10
16	*Arothron immaculatus*	Tetraodontidae	84.92	0.93	11.71	3.87	0.86	3.37	3.62	-	0.38
17	*Centrogenys vaigiensis*	Percichthyidae	85.73	0.81	10.20	2.79	1.14	2.10	4.17	0.11	0.03
18	*Lethrinus ornatus*	Lethrinidae	86.53	0.80	10.06	2.29	0.48	0.73	6.57	0.01	1.31
19	*Scarus rhoduropterus*	Scaridae	87.23	0.69	8.73	3.52	-	4.83	0.38	8.28	33.67
20	*Saurida gracilis*	Synodontidae	87.90	0.68	8.52	2.72	0.86	3.35	1.59	0.15	0.26
21*	*Lethrinus obsoletus*	Lethrinidae	88.56	0.66	8.28	2.64	2.10	2.43	1.11	-	0.06
22	*Siganus argenteus*	Siganidae	89.15	0.59	7.44	0.75	3.33	1.78	1.58	0.90	0.32
23*	*Lethrinus reticulatus*	Lethrinidae	89.74	0.58	7.32	4.02	1.14	1.84	0.32	-	0.01
24	*Scarus ghobban*	Scaridae	90.24	0.50	6.31	3.80	0.19	2.11	0.21	0.58	0.18
25	*Apogon bandanensis*	Apogonidae	90.73	0.49	6.13	3.00	0.19	0.49	2.46	0.04	4.85
26	*Hypoatherina bleekeri*	Atherinidae	91.18	0.46	5.72	0.77	0.38	1.42	3.15	-	60.50
27	*Choerodon anchorago*	Labridae	91.61	0.42	5.34	0.74	0.29	4.26	0.05	0.49	7.07
28	*Apogon amboinensis*	Apogonidae	91.99	0.39	4.89	1.15	0.76	2.81	0.16	-	-
29	*Scarus longiceps*	Scaridae	92.37	0.38	4.76	0.81	-	3.68	0.26	1.14	0.13
30	*Parapercis cylindrica*	Mugiloididae	92.73	0.36	4.47	2.24	0.67	0.92	0.65	0.53	22.99
31	*Epinephelus merra*	Serranidae	93.07	0.34	4.28	1.73	0.38	1.83	0.34	1.87	19.36
32	*Gymnothorax pictus*	Muraenidae	93.39	0.32	4.06	1.27	0.95	0.63	1.21	0.08	0.31
33	*Upeneus tragula*	Mullidae	93.70	0.31	3.87	2.26	1.14	0.41	0.05	0.03	0.03
34	*Aeoliscus strigatus*	Centriscidae	94.00	0.30	3.81	0.40	0.10	0.62	2.70	0.09	0.89
35	*Apogon novemfasciatus*	Apogonidae	94.30	0.30	3.77	0.12	-	0.16	3.49	0.14	9.50
36	*Apogon cyanosoma*	Apogonidae	94.60	0.29	3.69	0.51	0.19	0.05	2.94	0.28	14.24
37	*Apogon* sp.5 (Schroeder 1980)	Apogonidae	94.89	0.29	3.64	1.03	0.57	-	2.04	3.13	32.03
38	*Epinephelus ongus*	Serranidae	95.14	0.26	3.21	0.24	0.19	2.78	-	-	0.51
39	*Cheilinus trilobatus*	Labridae	95.38	0.23	2.95	0.97	0.10	1.27	0.61	7.00	9.43
40	*Stethojulis strigiventer*	Labridae	95.57	0.19	2.39	0.25	0.95	1.14	0.05	0.88	21.94
41	*Parupeneus trifasciatus*	Mullidae	95.75	0.19	2.37	0.25	0.19	0.85	1.08	14.61	21.00
42	*Calotomus japonicus*	Scaridae	95.94	0.19	2.36	0.98	-	0.12	1.26	3.07	20.56
43	*Pelatus quadrilineatus*	Teraponidae	96.13	0.18	2.31	0.13	1.52	0.66	-	-	-
44	*Arothron hispidus*	Tetraodontidae	96.31	0.18	2.30	0.32	-	1.69	0.29	0.01	0.03
45	*Siganus punctatus*	Siganidae	96.49	0.18	2.26	0.63	0.19	1.44	-	-	-
46	*Corythoichthys haematopterus*	Syngnathidae	96.65	0.16	2.07	0.04	0.38	0.33	1.32	-	0.60
47	*Pardachirus pavoninus*	Soleidae	96.78	0.13	1.65	0.13	0.57	0.23	0.71	-	0.01
48	*Parupeneus barberinoides*	Mullidae	96.91	0.13	1.61	0.64	0.10	0.21	0.66	0.06	1.85
49	*Gerres oyena*	Gerreidae	97.04	0.12	1.56	0.04	1.52	-	-	-	0.01
50	*Lutjanus fulviflamma*	Lutjanidae	97.15	0.12	1.49	0.94	0.38	0.11	0.06	0.10	0.10
51	*Sphaeramia nematoptera*	Apogonidae	97.27	0.12	1.46	0.37	-	1.09	-	-	
52	*Lethrinus mahsena*	Lethrinidae	97.38	0.11	1.37	0.29	0.10	0.37	0.61	0.04	0.33
53	Apogonid sp.2	Apogonidae	97.48	0.11	1.32	-	-	-	1.32	-	0.25

Continued

Appendix 6 (Continued)

Rank	Species	Family	Cum%	%	Total	Trawl: Seagrass density and depth Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m	Overlap: Slope Total	Flat Total
54*	*Asterropteryx semipunctatus*	Gobiidae	97.59	0.10	1.31	-	-	1.26	0.05	0.03	-
55	*Lethrinus lentjan*	Lethrinidae	97.69	0.10	1.23	0.60	0.57	0.05	-	-	0.01
56	*Ariosoma anagoides*	Colocongridae	97.78	0.09	1.19	0.09	0.10	0.26	0.74	-	-
57	*Leptoscarus vaigiensis*	Scaridae	97.86	0.07	0.94	0.23	-	0.28	0.43	-	0.06
58	*Dampieria cyclophthalma*	Pseudochromidae	97.93	0.07	0.93	0.24	-	0.42	0.28	2.66	1.97
59	*Amblyapistus taenianotus*	Congiopodidae	98.00	0.07	0.88	-	0.29	-	0.59	-	-
60	*Cheilodipterus macrodon*	Apogonidae	98.07	0.07	0.83	0.09	-	-	0.74	0.28	2.75
61	*Sardinella* sp.	Clupeidae	98.13	0.07	0.83	-	0.10	0.06	0.67	-	125.38
62	*Cheilio inermis*	Labridae	98.19	0.06	0.79	0.14	-	0.12	0.53	0.80	2.76
63	*Amblygobius albimaculatus*	Gobiidae	98.25	0.06	0.75	-	-	0.59	0.16	0.05	0.39
64	*Scolopsis bilineatus*	Nemipteridae	98.31	0.05	0.69	0.13	0.38	0.18	-	1.44	6.57
65	*Canthigaster bennetti*	Tetraodontidae	98.36	0.05	0.69	-	-	0.69	-	0.46	0.32
66	*Exyrias puntang*	Gobiidae	98.42	0.05	0.69	0.13	0.10	0.46	-	-	0.10
67	Goby sp.11	Gobiidae	98.47	0.05	0.67	-	0.19	0.32	0.16	-	-
68	*Archamia lineolata*	Apogonidae	98.52	0.05	0.67	-	0.19	-	0.48	-	-
69	*Escualosa thoracata*	Clupeidae	98.58	0.05	0.66	0.04	0.10	0.21	0.32	-	1.57
70	*Dunckerocampus dactyliophorus*	Syngnathidae	98.63	0.05	0.61	-	-	0.61	-	-	-
71	*Parupeneus indicus*	Mullidae	98.67	0.05	0.57	0.38	0.19	-	-	0.02	-
72	*Synaptura marginata*	Soleidae	98.72	0.04	0.56	-	0.10	0.05	0.41	-	-
73	*Scarus prasiognathus*	Scaridae	98.76	0.04	0.54	0.16	-	0.38	-	0.30	0.19
74	*Chelonodon patoca*	Tetraodontidae	98.80	0.04	0.53	0.05	0.09	0.26	0.13	-	-
75	*Scolopsis ciliatus*	Nemipteridae	98.84	0.04	0.48	0.04	-	0.44	-	0.58	-
76	*Scorpaena* sp.	Scorpaenidae	98.88	0.04	0.47	0.09	0.10	0.06	0.22	-	-
77	*Plotosus canius*	Plotosidae	98.91	0.04	0.46	0.24	-	0.17	0.05	-	-
78	*Chaetodon auriga*	Chaetodontidae	98.95	0.04	0.45	0.04	0.19	0.17	0.05	0.32	2.54
79	*Sphyraena jello*	Sphyraenidae	98.98	0.03	0.44	0.05	-	0.12	0.28	-	-
80	*Conger cinereus*	Congridae	99.02	0.03	0.42	0.10	-	0.26	0.06	-	-
81	*Aluteres scriptus*	Monacanthidae	99.04	0.03	0.33	0.08	0.10	0.11	0.05	-	-
82	*Synodus variegatus*	Synodontidae	99.07	0.03	0.32	-	-	-	0.32	0.26	0.31
83	*Mulloidichthys flavolineatus*	Mullidae	99.09	0.02	0.30	0.20	-	-	0.11	0.10	0.13
84	*Platycephalus indicus*	Platycephalidae	99.12	0.02	0.30	0.05	0.19	0.06	-	-	-
85	*Halicamphus dunckeri*	Syngnathidae	99.14	0.02	0.30	-	-	0.30	-	-	-
86	*Scolopsis cancellatus*	Nemipteridae	99.16	0.02	0.28	0.09	-	-	0.19	-	0.53
87	Goby	Gobiidae	99.18	0.02	0.28	0.09	-	0.19	-	0.15	0.42
88	*Canthigaster valentini*	Tetraodontidae	99.21	0.02	0.28	-	-	0.28	-	1.69	2.39
89	Apogonid sp.7	Apogonidae	99.23	0.02	0.27	0.08	0.19	-	-	-	-
90	*Siganus guttatus*	Siganidae	99.25	0.02	0.26	0.05	-	0.21	-	-	-
91	*Lactoria cornuta*	Ostraciidae	99.27	0.02	0.26	0.09	-	-	0.17	-	-
92	*Ostracion cubicus*	Ostraciidae	99.29	0.02	0.24	0.04	0.10	0.05	0.05	0.36	0.39
93	*Hippocampus histrix*	Syngnathidae	99.31	0.02	0.23	0.05	-	0.18	-	-	-
94	*Dischistodus chrysopoecilus*	Pomacentridae	99.32	0.02	0.22	-	-	0.17	0.05	0.48	31.19
95	*Cheilinus bimaculatus*	Labridae	99.34	0.02	0.22	0.10	-	0.13	-	1.48	0.26
96	*Exyrias bellissimus*	Gobiidae	99.36	0.02	0.21	-	-	0.21	-	-	-
97	*Encheiliophis vermicularis*	Carapidae	99.37	0.02	0.20	0.04	-	-	0.16	-	-
98	*Hypodytes rubripinnis*	Congiopodidae	99.39	0.02	0.19	-	0.19	-	-	-	-
99	Goby sp.9	Gobiidae	99.40	0.02	0.19	-	-	0.19	-	-	-
100	*Yongeichthys criniger*	Gobiidae	99.42	0.01	0.19	0.04	0.10	-	0.05	-	0.06
101*	*Scorpaenopsis cirrhosa*	Scorpaenidae	99.43	0.01	0.18	0.13	-	0.05	-	0.01	0.08
102	*Naso* sp.	Acanthuridae	99.45	0.01	0.18	-	-	0.06	0.12	0.08	0.11
103	*Plectorhynchus lineatus*	Haemulidae	99.46	0.01	0.17	0.05	-	0.13	-	0.28	0.40
104	*Chaetodon melannotus*	Chaetodontidae	99.48	0.01	0.17	-	-	0.12	0.05	0.45	2.99
105	*Antennarius nummifer*	Antennariidae	99.49	0.01	0.16	-	-	0.16	-	-	-
106	*Pseudobalistes fuscus*	Balistidae	99.50	0.01	0.16	-	-	0.11	0.05	0.01	-
107	*Hippocampus kuda*	Syngnathidae	99.51	0.01	0.16	-	0.10	0.06	-	-	-

Continued

Appendix 6 (Continued)

						Trawl				Overlap	
						Seagrass density and depth					
Rank	Species	Family	Cum%	%	Total	Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m	Slope Total	Flat Total
108	Apogonid sp.11	Apogonidae	99.53	0.01	0.16	-	-	0.16	-	-	-
109	*Aulostomus chinensis*	Aulostomidae	99.54	0.01	0.16	-	-	-	0.16	0.06	0.21
110*	*Lethrinus nematacanthus*	Lethrinidae	99.55	0.01	0.16	-	-	0.11	0.05	-	0.06
111	*Naso unicornis*	Acanthuridae	99.56	0.01	0.16	0.04	-	0.05	0.06	0.25	0.18
112	*Pterois volitans*	Scorpaenidae	99.58	0.01	0.16	0.04	-	0.06	0.05	0.01	0.24
113	*Fistularia petimba*	Fistulariidae	99.59	0.01	0.15	0.05	-	-	0.11	0.07	0.31
114	*Lutjanus decussatus*	Lutjanidae	99.60	0.01	0.15	0.05	0.10	-	-	0.10	0.24
115	*Lutjanus lineolatus*	Lutjanidae	99.61	0.01	0.13	0.04	0.10	-	-	0.02	0.03
116*	*Lethrinus variegatus*	Lethrinidae	99.62	0.01	0.13	-	-	-	0.13	-	-
117	*Grammistes sexlineatus*	Grammistidae	99.63	0.01	0.13	0.13	-	-	-	0.07	0.40
118	Goby sp.8	Gobiidae	99.64	0.01	0.13	-	-	0.06	0.06	-	-
119	Scarid	Scaridae	99.65	0.01	0.13	-	-	0.13	-	2.35	33.01
120	*Apogon* sp.8 (Schroeder 1980)	Apogonidae	99.66	0.01	0.13	-	-	-	0.13	-	-
121	Clupeid	Clupeidae	99.67	0.01	0.13	-	-	0.13	-	2.50	61.14
122	*Apogon* sp.	Apogonidae	99.68	0.01	0.12	-	-	-	0.12	3.36	11.32
123	*Sphyraena barracuda*	Sphyraenidae	99.69	0.01	0.12	-	-	-	0.12	-	-
124	*Parupeneus heptacanthus*	Mullidae	99.70	0.01	0.11	0.05	-	-	0.06	0.03	0.01
125	Apogonid sp.10	Apogonidae	99.71	0.01	0.11	-	-	0.05	0.05	-	-
126	*Antennarius moluccensis*	Antennariidae	99.72	0.01	0.11	-	-	0.11	-	-	-
127	*Histrio histrio*	Antennariidae	99.72	0.01	0.11	-	-	0.05	0.05	-	-
128	*Arothron nigropunctatus*	Tetraodontidae	99.73	0.01	0.11	-	-	0.05	0.05	0.50	0.39
129*	*Corythoichthys schultzi*	Syngnathidae	99.74	0.01	0.11	-	-	0.11	-	-	0.03
130	*Eupomacentrus nigricans*	Pomacentridae	99.75	0.01	0.10	0.04	-	0.06	-	0.23	142.10
131	*Platax orbicularis*	Ephippidae	99.76	0.01	0.10	0.05	-	0.05	-	-	-
132	*Arothron stellatus*	Tetraodontidae	99.77	0.01	0.10	0.05	-	0.05	-	0.08	0.14
133	*Plectorhynchus chaetodontoides*	Haemulidae	99.77	0.01	0.10	0.05	-	0.05	-	0.01	0.15
134	*Oostethus brachyurus*	Syngnathidae	99.78	0.01	0.10	-	0.10	-	-	-	-
135	Acanthurid	Acanthuridae	99.79	0.01	0.10	0.10	-	-	-	-	-
136*	*Eleotris fusca*	Gobiidae	99.80	0.01	0.10	-	0.10	-	-	-	-
137	Saurida sp.	Synodontidae	99.80	0.01	0.10	-	0.10	-	-	-	-
138	Siganid	Siganidae	99.81	0.01	0.08	0.08	-	-	-	-	-
139	Labrid	Labridae	99.82	0.01	0.08	0.08	-	-	-	0.89	0.25
140	*Myrichthys aki*	Ophichthidae	99.82	0.01	0.06	-	-	-	0.06	-	0.03
141	Balistid	Balistidae	99.83	0.01	0.06	-	-	0.06	-	0.06	-
142	*Hippichthys spicifer*	Syngnathidae	99.83	0.01	0.06	-	-	0.06	-	-	-
143	*Chaetodon lunula*	Chaetodontidae	99.84	0.01	0.06	-	-	0.06	-	0.05	0.15
144	Conger sp.	Congridae	99.84	0.01	0.06	-	-	-	0.06	-	-
145	*Chaetodon trifasciatus*	Chaetodontidae	99.85	<0.01	0.05	-	-	0.05	-	0.43	3.65
146	*Abudefduf saxatilis*	Pomacentridae	99.85	<0.01	0.05	-	-	-	0.05	0.20	3.13
147	*Pentapodus macrurus*	Nemipteridae	99.85	<0.01	0.05	-	-	-	0.05	0.08	-
148	*Antennarius* sp.1	Antennariidae	99.86	<0.01	0.05	-	-	0.05	-	-	-
149	*Bothus pantherinus*	Bothidae	99.86	<0.01	0.05	-	-	0.05	-	-	-
150	Scorpaenid	Scorpaenidae	99.87	<0.01	0.05	-	-	-	0.05	0.02	-
151	*Scarus ovifrons*	Scaridae	99.87	<0.01	0.05	-	-	0.05	-	0.42	4.83
152	*Plectorhynchus* sp.	Haemulidae	99.88	<0.01	0.05	-	-	0.05	-	0.01	-
153	*Pempheris oualensis*	Pempheridae	99.88	<0.01	0.05	-	-	-	0.05	-	-
154	*Diodon hystrix*	Diodontidae	99.88	<0.01	0.05	-	-	-	0.05	0.03	0.01
155	*Dischistodus notopthalmus*	Pomacentridae	99.89	<0.01	0.05	-	-	0.05	-	-	2.86
156	Apogonid	Apogonidae	99.89	<0.01	0.05	-	-	-	0.05	5.90	2.28
157	*Lutjanus gibbus*	Lutjanidae	99.90	<0.01	0.05	-	-	0.05	-	0.04	0.10
158	*Dendrochirus zebra*	Scorpaenidae	99.90	<0.01	0.05	-	-	-	0.05	0.24	0.10
159	*Epinephelus tauvina*	Serranidae	99.90	<0.01	0.05	-	-	0.05	-	-	-
160	*Ophichthus* sp.	Ophichthidae	99.91	<0.01	0.05	-	-	-	0.05	-	-
161	*Glossogobius olivaceous*	Gobiidae	99.91	<0.01	0.05	-	-	0.05	-	-	-

Continued

Appendix 6 (Continued)

Rank	Species	Family	Cum%	%	Total	Trawl				Overlap	
						Seagrass density and depth					
						Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m	Slope Total	Flat Total
162	*Arothron* sp.2	Tetraodontidae	99.92	<0.01	0.05	-	-	0.05	-	-	-
163	*Pseudobalistes flavimarginatus*	Balistidae	99.92	<0.01	0.05	-	-	0.05	-	0.06	0.01
164	*Arothron mappa*	Tetraodontidae	99.93	<0.01	0.05	-	-	0.05	-	-	-
165	*Eupomacentrus lividus*	Pomacentridae	99.93	<0.01	0.05	0.05	-	-	-	0.36	46.94
166	*Drepane longimana*	Ephippidae	99.93	<0.01	0.05	0.05	-	-	-	-	-
167	*Takifugu rubripes*	Tetraodontidae	99.94	<0.01	0.05	0.05	-	-	-	-	-
168	*Aesopia cornuta*	Soleidae	99.94	<0.01	0.05	0.05	-	-	-	-	-
169	*Cheilinus fasciatus*	Labridae	99.94	<0.01	0.05	0.05	-	-	-	0.18	0.11
170	*Amblygobius* sp.	Gobiidae	99.95	<0.01	0.05	0.05	-	-	-	-	-
171	Tetraodontid sp.2	Tetraodontidae	99.95	<0.01	0.05	0.05	-	-	-	-	-
172	*Scorpaena* sp.1	Scorpaenidae	99.96	<0.01	0.05	0.05	-	-	-	-	-
173	*Lutjanus kasmira*	Lutjanidae	99.96	<0.01	0.04	0.04	-	-	-	-	-
174	*Siganus puellus*	Siganidae	99.96	<0.01	0.04	0.04	-	-	-	-	-
175	*Naso lituratus*	Acanthuridae	99.97	<0.01	0.04	0.04	-	-	-	0.61	0.26
176	*Acanthurus gahhm*	Acanthuridae	99.97	<0.01	0.04	0.04	-	-	-	1.39	1.25
177	*Scarus schlegeli*	Scaridae	99.97	<0.01	0.04	0.04	-	-	-	0.43	2.29
178	*Pseudomonacanthus macrurus*	Monacanthidae	99.97	<0.01	0.04	0.04	-	-	-	-	0.01
179	*Amblygobius phalaena*	Gobiidae	99.98	<0.01	0.04	0.04	-	-	-	-	0.06
180	*Caesio erythrogaster*	Lutjanidae	99.98	<0.01	0.04	0.04	-	-	-	0.98	0.14
181*	*Lethrinus nebulosus*	Lethrinidae	99.98	<0.01	0.04	0.04	-	-	-	-	-
182	*Ctenochaetus binotatus*	Acanthuridae	99.99	<0.01	0.04	0.04	-	-	-	33.12	7.93
183	*Pomacentrus tripunctatus*	Pomacentridae	99.99	<0.01	0.04	0.04	-	-	-	0.03	8.86
184	*Lethrinus* sp.	Lethrinidae	99.99	<0.01	0.04	0.04	-	-	-	-	-
185*	*Choerodon shoenleinii*	Labridae	99.99	<0.01	0.04	0.04	-	-	-	-	-
186	*Epinephelus fuscoguttatus*	Serranidae	100.00	<0.01	0.04	0.04	-	-	-	-	-
	Others			-	-	-	-	-	-	262.24	928.07
	Totals			100.00	1,257.37	483.29	154.29	491.15	128.65	396.89	1,871.56

Appendix 7. Reef flat fish families caught at night by a roller beam trawl in the seagrass beds of Santiago Island and sorted by frequency of occurrence (ind./1,000 m²).

					Seagrass density and depth			
Rank	Family	Cum%	%	Total	Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m
1	Apogonidae	36.81	36.81	462.81	121.25	26.57	277.77	37.22
2	Siganidae	68.72	31.91	401.21	179.02	87.14	120.68	14.37
3	Plotosidae	76.91	8.19	103.01	98.87	0.10	3.30	0.74
4	Lethrinidae	80.55	3.64	45.83	19.16	6.95	9.56	10.16
5	Syngnathidae	84.00	3.44	43.30	9.69	2.76	9.59	21.26
6	Monacanthidae	86.77	2.77	34.81	7.39	9.05	11.75	6.62
7	Mullidae	88.74	1.98	24.87	10.26	5.05	4.26	5.29
8	Scaridae	90.64	1.90	23.85	9.54	0.19	11.57	2.55
9	Blenniidae	92.19	1.55	19.44	5.28	2.95	6.99	4.21
10	Tetraodontidae	93.45	1.27	15.91	4.38	0.95	6.50	4.08
11	Labridae	94.40	0.94	11.87	2.36	1.33	6.92	1.25
12	Percichthyidae	95.21	0.81	10.20	2.79	1.14	2.10	4.17
13	Synodontidae	95.92	0.71	8.93	2.72	0.95	3.35	1.90
14	Serranidae	96.52	0.60	7.58	2.01	0.57	4.67	0.34
15	Atherinidae	96.97	0.46	5.72	0.77	0.38	1.42	3.15
16	Gobiidae	97.34	0.37	4.65	0.35	0.48	3.33	0.49
17	Mugiloididae	97.70	0.36	4.47	2.24	0.67	0.92	0.65
18	Muraenidae	98.02	0.32	4.06	1.27	0.95	0.63	1.21
19	Centriscidae	98.33	0.30	3.81	0.40	0.10	0.62	2.70
20	Teraponidae	98.51	0.18	2.31	0.13	1.52	0.66	-
21	Soleidae	98.69	0.18	2.26	0.18	0.67	0.29	1.12
22	Lutjanidae	98.84	0.15	1.90	1.11	0.57	0.16	0.06
23	Clupeidae	98.97	0.13	1.62	0.04	0.19	0.40	0.98
24	Gerreidae	99.09	0.12	1.56	0.04	1.52	-	-
25	Nemipteridae	99.21	0.12	1.50	0.25	0.38	0.62	0.24
26	Colocongridae	99.31	0.09	1.19	0.09	0.10	0.26	0.74
27	Congiopodidae	99.39	0.09	1.07	-	0.48	0.00	0.59
28	Scorpaenidae	99.47	0.08	0.96	0.30	0.10	0.18	0.38
29	Pseudochromidae	99.54	0.07	0.93	0.24	-	0.42	0.28
30	Chaetodontidae	99.60	0.06	0.74	0.04	0.19	0.40	0.11
31	Sphyraenidae	99.65	0.04	0.56	0.05	-	0.12	0.39
32	Acanthuridae	99.69	0.04	0.55	0.25	-	0.12	0.18
33	Pomacentridae	99.73	0.04	0.52	0.13	-	0.29	0.11
34	Ostraciidae	99.77	0.04	0.50	0.13	0.10	0.05	0.22
35	Congridae	99.81	0.04	0.49	0.10	-	0.26	0.13
36	Antennariidae	99.84	0.03	0.42	0.00	-	0.37	0.05
37	Haemulidae	99.87	0.03	0.33	0.10	-	0.23	-
38	Platycephalidae	99.89	0.02	0.30	0.05	0.19	0.06	-
39	Balistidae	99.92	0.02	0.28	-	-	0.22	0.05
40	Carapidae	99.93	0.02	0.20	0.04	-	-	0.16
41	Aulostomidae	99.94	0.01	0.16	-	-	-	0.16
42	Fistulariidae	99.96	0.01	0.15	0.05	-	-	0.11
43	Ephippidae	99.97	0.01	0.15	0.10	-	0.05	-
44	Grammistidae	99.98	0.01	0.13	0.13	-	-	-
45	Ophichthidae	99.99	0.01	0.12	-	-	-	0.12
46	Diodontidae	99.99	<0.01	0.05	-	-	-	0.05
47	Pempherididae	99.99	<0.01	0.05	-	-	-	0.05
48	Bothidae	100.00	<0.01	0.05	-	-	0.05	-
	Totals		100.00	1,257.38	482.29	154.29	491.15	128.65

Appendix 8. Reef flat fish caught at night by a roller beam trawl in the seagrass beds of Santiago Island from October 1988 to June 1991 and sorted by weight (g/1,000 m^2). (* denotes uncertain identification).

						Seagrass density and depth			
						Dense	Sparse	Dense	Sparse
Rank	Species	Family	Cum%	%	Total	<1.5 m	<1.5 m	>1.5 m	>1.5 m
1	*Fowleria variegata*	Apogonidae	24.30	24.30	1212.41	331.31	21.51	838.66	20.94
2	*Arothron immaculatus*	Tetraodontidae	32.12	7.82	390.28	172.96	13.21	77.62	126.50
3	*Apogon sangiensis*	Apogonidae	38.61	6.49	323.76	98.29	31.46	190.84	3.17
4	*Siganus fuscescens*	Siganidae	45.04	6.44	321.16	115.70	55.22	100.98	49.25
5	*Sphaeramia orbicularis*	Apogonidae	49.47	4.42	220.74	54.08	0.16	166.51	-
6	*Syngnathoides biaculeatus*	Syngnathidae	53.41	3.94	196.84	48.10	7.46	35.87	105.41
7	*Acreichthys tomentosus*	Monacanthidae	57.23	3.82	190.69	48.94	29.70	63.69	48.35
8	*Arothron hispidus*	Tetraodontidae	60.10	2.87	143.04	28.98	-	95.54	18.52
9	*Centrogenys vaigiensis*	Percichthyidae	62.39	2.30	114.53	32.04	7.46	9.81	65.22
10	*Lethrinus harak*	Lethrinidae	64.57	2.17	108.47	60.13	8.41	29.13	10.79
11	*Gymnothorax pictus*	Muraenidae	66.63	2.06	102.69	36.54	24.57	12.28	29.30
12	*Siganus virgatus*	Siganidae	68.55	1.92	95.86	52.73	20.33	22.62	0.17
13	*Saurida gracilis*	Synodontidae	70.34	1.79	89.46	38.07	3.02	37.03	11.35
14	*Apogon coccineus*	Apogonidae	71.94	1.60	79.67	17.78	2.46	44.93	14.50
15	*Siganus spinus*	Siganidae	73.51	1.57	78.30	26.84	4.02	30.80	16.65
16	*Scarus ghobban*	Scaridae	74.85	1.34	67.10	43.62	2.21	20.05	1.22
17	*Petroscirtes breviceps*	Blenniidae	76.10	1.25	62.20	16.17	6.25	25.66	14.11
18	*Plotosus lineatus*	Plotosidae	77.33	1.23	61.42	39.44	0.40	20.20	1.38
19	*Parupeneus barberinus*	Mullidae	78.40	1.07	53.38	21.47	6.48	7.89	17.54
20	*Epinephelus merra*	Serranidae	79.46	1.06	52.95	16.56	13.48	13.83	9.09
21	*Scarus rhoduropterus*	Scaridae	80.41	0.95	47.40	21.94	-	23.82	1.64
22	*Parapercis cylindrica*	Mugiloididae	81.35	0.94	47.14	24.96	5.56	10.29	6.34
23	*Choerodon anchorago*	Labridae	82.28	0.92	46.13	10.52	0.63	33.54	1.43
24	*Cheilodipterus quinquelineatus*	Apogonidae	83.13	0.86	42.71	16.00	1.41	8.40	16.90
25	*Calotomus japonicus*	Scaridae	83.93	0.80	39.90	13.28	-	4.92	21.70
26	*Epinephelus ongus*	Serranidae	84.68	0.74	37.09	3.43	0.19	33.47	-
27	*Pardachirus pavoninus*	Soleidae	85.36	0.69	34.27	4.46	4.76	8.06	16.98
28	*Lethrinus reticulatus*	Lethrinidae	86.05	0.69	34.18	19.17	4.10	10.60	0.32
29	Apogonid sp.5	Apogonidae	86.68	0.63	31.55	5.56	1.75	18.62	5.62
30	*Siganus punctatus*	Siganidae	87.29	0.60	30.13	6.12	1.05	22.96	-
31 *	*Lethrinus obsoletus*	Lethrinidae	87.85	0.56	28.00	12.87	4.60	6.83	3.70
32	*Conger cinereus*	Congridae	88.40	0.56	27.73	4.71	-	15.40	7.62
33	*Chelonodon patoca*	Tetraodontidae	88.96	0.55	27.65	3.81	1.98	18.99	2.86
34	*Apogon bandanensis*	Apogonidae	89.50	0.54	27.02	10.81	0.40	1.12	14.69
35	*Lethrinus ornatus*	Lethrinidae	89.95	0.45	22.47	6.81	0.57	2.85	12.24
36	*Diodon hystrix*	Diodontidae	90.39	0.44	21.90	-	-	-	21.90
37	*Siganus guttatus*	Siganidae	90.81	0.42	21.19	2.14	-	19.05	-
38	*Siganus argenteus*	Siganidae	91.21	0.40	19.89	6.15	0.79	4.32	8.62
39	*Apogon amboinensis*	Apogonidae	91.61	0.40	19.82	4.50	2.30	12.54	0.48
40	*Scarus longiceps*	Scaridae	91.96	0.35	17.68	4.26	-	13.15	0.26
41	*Cheilinus trilobatus*	Labridae	92.31	0.35	17.49	5.70	0.32	7.97	3.50
42	*Platycephalus indicus*	Platycephalidae	92.65	0.34	16.84	1.19	8.73	6.92	-
43	*Synaptura marginata*	Soleidae	92.95	0.30	14.76	-	0.16	1.32	13.28
44	*Cheilio inermis*	Labridae	93.21	0.27	13.37	0.67	-	0.65	12.05
45	*Hypoatherina bleekeri*	Atherinidae	93.48	0.27	13.34	0.89	1.83	3.69	6.93
46	*Arothron stellatus*	Tetraodontidae	93.74	0.26	12.83	10.71	-	2.12	-
47	*Lutjanus fulviflamma*	Lutjanidae	93.99	0.25	12.66	9.42	2.27	0.53	0.44
48	*Upeneus tragula*	Mullidae	94.24	0.25	12.48	6.81	3.73	1.88	0.05
49	*Ariosoma anagoides*	Colocongridae	94.49	0.25	12.38	1.26	0.32	4.50	6.31
50	*Plotosus canius*	Plotosidae	94.72	0.23	11.59	5.08	-	5.19	1.32
51	*Amblyapistus taenianotus*	Congiopodidae	94.95	0.23	11.52	-	1.19	-	10.33
52	*Apogon* sp.5 (Schroeder 1980)	Apogonidae	95.17	0.22	11.09	4.47	0.56	-	6.06
53	*Apogon novemfasciatus*	Apogonidae	95.39	0.22	10.94	0.08	-	0.42	10.43
54	*Parupeneus trifasciatus*	Mullidae	95.59	0.20	9.81	1.37	0.95	3.42	4.06
55	*Asterropteryx semipunctatus*	Gobiidae	95.78	0.19	9.69	-	-	9.32	0.37
56	*Apogon cyanosoma*	Apogonidae	95.96	0.18	8.91	1.31	0.56	0.16	6.89

Continued

Appendix 8 (Continued)

Rank	Species	Family	Cum%	%	Total	Seagrass density and depth Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m
57	*Arothron nigropunctatus*	Tetraodontidae	96.13	0.17	8.47	-	-	6.88	1.59
58	*Exyrias puntang*	Gobiidae	96.30	0.17	8.25	2.74	1.59	3.93	-
59	*Lactoria cornuta*	Ostraciidae	96.46	0.16	7.84	3.93	-	-	3.92
60	*Lethrinus lentjan*	Lethrinidae	96.61	0.15	7.55	4.88	2.14	0.53	-
61	*Parupeneus barberinoides*	Mullidae	96.75	0.15	7.29	3.74	0.38	0.37	2.80
62	*Pelatus quadrilineatus*	Teraponidae	96.89	0.14	6.76	0.63	4.90	1.22	-
63	*Aluteres scriptus*	Monacanthidae	97.01	0.12	6.11	0.24	2.22	1.96	1.69
64	*Parupeneus indicus*	Mullidae	97.13	0.12	5.75	4.48	1.27	-	-
65	*Leptoscarus vaigiensis*	Scaridae	97.24	0.11	5.68	0.71	-	1.43	3.54
66	*Canthigaster bennetti*	Tetraodontidae	97.35	0.11	5.40	-	-	5.40	-
67	*Stethojulis strigiventer*	Labridae	97.45	0.11	5.31	0.40	2.71	2.03	0.16
68	*Amblygobius albimaculatus*	Gobiidae	97.56	0.11	5.30	-	-	3.61	1.69
69	*Corythoichthys haematopterus*	Syngnathidae	97.65	0.09	4.58	0.12	0.95	0.76	2.75
70	*Scorpaena* sp.	Scorpaenidae	97.74	0.09	4.41	0.44	0.40	0.38	3.19
71	*Gerres oyena*	Gerreidae	97.83	0.09	4.29	0.40	3.89	-	-
72	*Dampieria cyclophthalma*	Pseudochromidae	97.91	0.09	4.25	1.30	-	2.52	0.43
73	*Synodus variegatus*	Synodontidae	98.00	0.08	4.23	-	-	-	4.23
74	*Scorpaenopsis cirrhosa*	Scorpaenidae	98.07	0.08	3.78	3.25	-	0.53	-
75	*Lethrinus mahsena*	Lethrinidae	98.15	0.07	3.64	0.76	0.16	1.48	1.24
76	*Aeoliscus strigatus*	Centriscidae	98.21	0.06	3.16	0.24	0.08	0.73	2.12
77	*Hypodytes rubripinnis*	Congiopodidae	98.27	0.06	3.10	-	3.10	-	-
78	*Aulostomus chinensis*	Aulostomidae	98.33	0.06	3.02	-	-	-	3.02
79	*Archamia lineolata*	Apogonidae	98.39	0.05	2.72	-	0.56	-	2.17
80	*Sphaeramia nematoptera*	Apogonidae	98.44	0.05	2.70	0.69	-	2.01	-
81	*Dendrochirus zebra*	Scorpaenidae	98.49	0.05	2.65	-	-	-	2.65
82	*Plectorhynchus lineatus*	Haemulidae	98.54	0.05	2.56	0.71	-	1.84	-
83	*Grammistes sexlineatus*	Grammistidae	98.59	0.05	2.34	2.34	-	-	-
84	*Scarus prasiognathus*	Scaridae	98.64	0.05	2.30	1.98	-	0.32	-
85	*Dunckerocampus dactyliophorus*	Syngnathidae	98.68	0.04	2.17	-	-	2.17	-
86	Goby	Gobiidae	98.72	0.04	2.06	0.09	-	1.97	-
87	*Epinephelus fuscoguttatus*	Serranidae	98.76	0.04	1.98	1.98	-	-	-
88	*Exyrias bellissimus*	Gobiidae	98.80	0.04	1.96	-	-	1.96	-
89	*Scolopsis ciliatus*	Nemipteridae	98.84	0.04	1.95	0.40	-	1.56	-
90	Goby sp.8	Gobiidae	98.88	0.04	1.90	-	-	0.63	1.27
91	*Encheiliophis vermicularis*	Carapidae	98.92	0.04	1.84	0.52	-	-	1.32
92	*Yongeichthys criniger*	Gobiidae	98.95	0.03	1.69	0.79	0.79	-	0.11
93	*Ophichthus* sp.	Ophichthidae	98.98	0.03	1.59	-	-	-	1.59
94	*Hippocampus kuda*	Syngnathidae	99.01	0.03	1.54	-	1.35	0.19	-
95	Apogonid sp.2	Apogonidae	99.04	0.03	1.48	-	-	-	1.48
96 *	*Lethrinus variegatus*	Lethrinidae	99.07	0.03	1.46	-	-	-	1.46
97	Apogonid sp.7	Apogonidae	99.10	0.03	1.40	0.36	1.05	-	-
98	*Sphyraena jello*	Sphyraenidae	99.13	0.03	1.40	0.10	-	0.29	1.02
99	*Hippocampus histrix*	Syngnathidae	99.15	0.03	1.35	0.19	-	1.16	-
100	*Arothron mappa*	Tetraodontidae	99.18	0.03	1.32	-	-	1.32	-
101	*Canthigaster valentini*	Tetraodontidae	99.21	0.03	1.27	-	-	1.27	-
102	Scorpaenid	Scorpaenidae	99.23	0.03	1.27	-	-	-	1.27
103	*Naso unicornis*	Acanthuridae	99.26	0.03	1.25	0.40	-	0.79	0.06
104	*Dischistodus chrysopoecilus*	Pomacentridae	99.28	0.02	1.22	-	-	1.11	0.11
105	Tetraodontid sp.2	Tetraodontidae	99.31	0.02	1.19	1.19	-	-	-
106	Goby sp.11	Gobiidae	99.33	0.02	1.19	-	0.56	0.58	0.05
107	*Pseudobalistes fuscus*	Balistidae	99.35	0.02	1.16	-	-	1.11	0.05
108	*Apogon* sp.8 (Schroeder 1980)	Apogonidae	99.38	0.02	1.14	-	-	-	1.14
109	*Takifugu rubripes*	Tetraodontidae	99.40	0.02	1.14	1.14	-	-	-
110	*Scolopsis bilineatus*	Nemipteridae	99.42	0.02	1.13	0.52	0.43	0.18	-
111	*Cheilodipterus macrodon*	Apogonidae	99.44	0.02	1.12	0.44	-	-	0.69
112	*Ostracion cubicus*	Ostraciidae	99.47	0.02	1.11	0.08	0.08	0.05	0.90
113	*Plectorhynchus chaetodontoides*	Haemulidae	99.49	0.02	1.03	0.24	-	0.79	-

Continued

Appendix 8 (Continued)

Rank	Species	Family	Cum%	%	Total	Seagrass density and depth			
						Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m
114	*Antennarius moluccensis*	Antennariidae	99.51	0.02	0.95	-	-	0.95	-
115	*Chaetodon auriga*	Chaetodontidae	99.52	0.02	0.94	0.24	0.16	0.43	0.11
116	*Chaetodon melannotus*	Chaetodontidae	99.54	0.02	0.88	-	-	0.46	0.42
117	*Antennarius nummifer*	Antennariidae	99.56	0.02	0.85	-	-	0.85	-
118	*Histrio histrio*	Antennariidae	99.58	0.02	0.85	-	-	0.79	0.05
119	*Pterois volitans*	Scorpaenidae	99.59	0.02	0.82	0.40	-	0.32	0.11
120	*Glossogobius olivaceous*	Gobiidae	99.61	0.02	0.79	-	-	0.79	-
121	*Lutjanus decussatus*	Lutjanidae	99.62	0.02	0.77	0.37	0.40	-	-
122	*Sardinella* sp.	Clupeidae	99.64	0.01	0.75	-	0.08	0.06	0.60
123	*Escualosa thoracata*	Clupeidae	99.65	0.01	0.65	0.04	0.08	0.21	0.32
124	*Lutjanus kasmira*	Lutjanidae	99.66	0.01	0.60	0.60	-	-	-
125	*Cheilinus bimaculatus*	Labridae	99.67	0.01	0.59	0.14	-	0.44	-
126 *	*Lethrinus nematacanthus*	Lethrinidae	99.69	0.01	0.58	-	-	0.32	0.26
127	*Halicamphus duncкeri*	Syngnathidae	99.70	0.01	0.57	-	-	0.57	-
128	*Aesopia cornuta*	Soleidae	99.71	0.01	0.57	0.57	-	-	-
129	*Antennarius* sp.1	Antennariidae	99.72	0.01	0.53	-	-	0.53	-
130	Apogonid sp.11	Apogonidae	99.73	0.01	0.53	-	-	0.53	-
131	*Epinephelus tauvina*	Serranidae	99.74	0.01	0.53	-	-	0.53	-
132	*Bothus pantherinus*	Bothidae	99.75	0.01	0.53	-	-	0.53	-
133	*Naso lituratus*	Acanthuridae	99.76	0.01	0.52	0.52	-	-	-
134	Goby sp.9	Gobiidae	99.77	0.01	0.51	-	-	0.51	-
135	*Platax orbicularis*	Ephippidae	99.78	0.01	0.49	0.33	-	0.16	-
136	*Pentapodus macrurus*	Nemipteridae	99.79	0.01	0.48	-	-	-	0.48
137	*Pomacentrus tripunctatus*	Pomacentridae	99.80	0.01	0.48	0.48	-	-	-
138	*Scorpaena* sp.1	Scorpaenidae	99.81	0.01	0.48	0.48	-	-	-
139	*Amblygobius* sp.	Gobiidae	99.82	0.01	0.48	0.48	-	-	-
140	*Conger* sp.	Congridae	99.83	0.01	0.44	-	-	-	0.44
141	*Amblygobius phalaena*	Gobiidae	99.84	0.01	0.44	0.44	-	-	-
142	*Sphyraena barracuda*	Sphyraenidae	99.85	0.01	0.41	-	-	-	0.41
143	*Fistularia petimba*	Fistulariidae	99.85	0.01	0.40	0.24	-	-	0.16
144	*Eleotris fusca*	Gobiidae	99.86	0.01	0.40	-	0.40	-	-
145	*Mulloidichthys flavolineatus*	Mullidae	99.87	0.01	0.38	0.28	-	-	0.11
146	*Pseudobalistes flavimarginatus*	Balistidae	99.88	0.01	0.37	-	-	0.37	-
147	*Eupomacentrus lividus*	Pomacentridae	99.88	0.01	0.33	0.33	-	-	-
148	*Myrichthys aki*	Ophichthidae	99.89	0.01	0.32	-	-	-	0.32
149	*Naso* sp.	Acanthuridae	99.90	0.01	0.30	-	-	0.06	0.23
150	*Parupeneus heptacanthus*	Mullidae	99.90	0.01	0.29	0.10	-	-	0.19
151	*Lutjanus gibbus*	Lutjanidae	99.91	0.01	0.26	-	-	0.26	-
152	*Dischistodus notopthalmus*	Pomacentridae	99.91	0.01	0.26	-	-	0.26	-
153	*Eupomacentrus nigricans*	Pomacentridae	99.92	0.01	0.26	0.20	-	0.06	-
154	*Drepane longimana*	Ephippidae	99.92	<0.01	0.24	0.24	-	-	-
155	*Cheilinus fasciatus*	Labridae	99.93	<0.01	0.24	0.24	-	-	-
156	*Scolopsis cancellatus*	Nemipteridae	99.93	<0.01	0.23	0.17	-	-	0.06
157	*Arothron* sp.2	Tetraodontidae	99.94	<0.01	0.21	-	-	0.21	-
158	*Corythoichthys schultzi*	Syngnathidae	99.94	<0.01	0.21	-	-	0.21	-
159	*Caesio erythrogaster*	Lutjanidae	99.94	<0.01	0.20	0.20	-	-	-
160	*Siganus puellus*	Siganidae	99.95	<0.01	0.20	0.20	-	-	-
161	*Acanthurus gahhm*	Acanthuridae	99.95	<0.01	0.20	0.20	-	-	-
162	*Pseudomonacanthus macrurus*	Monacanthidae	99.96	<0.01	0.20	0.20	-	-	-
163	*Choerodon shoenleinii*	Labridae	99.96	<0.01	0.20	0.20	-	-	-
164	Balistid	Balistidae	99.96	<0.01	0.19	-	-	0.19	-
165	*Lutjanus lineolatus*	Lutjanidae	99.97	<0.01	0.16	0.08	0.08	-	-
166 *	*Lethrinus nebulosus*	Lethrinidae	99.97	<0.01	0.12	0.12	-	-	-
167	*Ctenochaetus binotatus*	Acanthuridae	99.97	<0.01	0.12	0.12	-	-	-
168	*Apogon* sp.	Apogonidae	99.97	<0.01	0.12	-	-	-	0.12
169	*Scarus ovifrons*	Scaridae	99.98	<0.01	0.11	-	-	0.11	-
170	Apogonid sp.10	Apogonidae	99.98	<0.01	0.11	-	-	0.05	0.05

Continued

Appendix 8 (Continued)

Rank	Species	Family	Cum%	%	Total	Seagrass density and depth Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m
171	*Pempheris oualensis*	Pempheridae	99.98	<0.01	0.11	-	-	-	0.11
172	Acanthurid	Acanthuridae	99.98	<0.01	0.10	0.10	-	-	-
173	*Saurida* sp.	Synodontidae	99.98	<0.01	0.10	-	0.10	-	-
174	*Oostethus brachyurus*	Syngnathidae	99.99	<0.01	0.10	-	0.10	-	-
175	*Scarus schlegeli*	Scaridae	99.99	<0.01	0.08	0.08	-	-	-
176	Clupeid	Clupeidae	99.99	<0.01	0.06	-	-	0.06	-
177	Scarid	Scaridae	99.99	<0.01	0.06	-	-	0.06	-
178	*Chaetodon lunula*	Chaetodontidae	99.99	<0.01	0.06	-	-	0.06	-
179	*Hippichthys spicifer*	Syngnathidae	99.99	<0.01	0.06	-	-	0.06	-
180	*Chaetodon trifasciatus*	Chaetodontidae	99.99	<0.01	0.05	-	-	0.05	-
181	Apogonid	Apogonidae	99.99	<0.01	0.05	-	-	-	0.05
182	*Abudefduf saxatilis*	Pomacentridae	99.99	<0.01	0.05	-	-	-	0.05
183	*Plectorhynchus* sp.	Haemulidae	99.99	<0.01	0.05	-	-	0.05	-
184	Siganid	Siganidae	99.99	<0.01	0.04	0.04	-	-	-
185	Labrid	Labridae	99.99	<0.01	0.04	0.04	-	-	-
186	*Lethrinus* sp.	Lethrinidae	100.00	<0.01	0.04	0.04	-	-	-
	Totals			100.00	4,989.92	1,518.10	338.48	2,227.18	843.16

Appendix 9. Reef flat fish families caught at night by a roller beam trawl in the seagrass beds of Santiago Island and sorted by weight (g/1,000 m²).

Rank	Family	Cum%	%	Total	Seagrass density and depth			
					Dense <1.5 m	Sparse <1.5 m	Dense >1.5 m	Sparse >1.5 m
1	Apogonidae	40.08	40.08	2000.01	545.67	64.16	1284.79	105.39
2	Tetraodontidae	51.96	11.88	592.80	218.79	15.19	209.35	149.46
3	Siganidae	63.32	11.36	566.76	209.92	81.41	200.74	74.69
4	Syngnathidae	67.48	4.16	207.43	48.41	9.86	41.01	108.16
5	Lethrinidae	71.61	4.14	206.51	104.77	19.98	51.74	30.02
6	Monacanthidae	75.56	3.95	196.99	49.38	31.92	65.65	50.04
7	Scaridae	79.18	3.61	180.31	85.87	2.21	63.86	28.37
8	Percichthyidae	81.47	2.30	114.53	32.04	7.46	9.81	65.22
9	Muraenidae	83.53	2.06	102.69	36.54	24.57	12.28	29.30
10	Synodontidae	85.41	1.88	93.79	38.07	3.11	37.03	15.59
11	Serranidae	87.26	1.85	92.56	21.97	13.67	47.83	9.09
12	Mullidae	89.06	1.79	89.39	38.25	12.81	13.57	24.76
13	Labridae	90.73	1.67	83.36	17.92	3.67	44.63	17.14
14	Plotosidae	92.19	1.46	73.01	44.52	0.40	25.39	2.70
15	Blenniidae	93.44	1.25	62.20	16.17	6.25	25.66	14.11
16	Soleidae	94.43	0.99	49.60	5.03	4.92	9.39	30.26
17	Mugiloididae	95.37	0.94	47.14	24.96	5.56	10.29	6.34
18	Gobiidae	96.07	0.69	34.66	4.53	3.33	23.30	3.49
19	Congridae	96.63	0.56	28.17	4.71	-	15.40	8.06
20	Diodontidae	97.07	0.44	21.90	-	-	-	21.90
21	Platycephalidae	97.41	0.34	16.84	1.19	8.73	6.92	-
22	Lutjanidae	97.70	0.29	14.65	10.66	2.75	0.79	0.44
23	Congiopodidae	98.00	0.29	14.61	-	4.29	-	10.33
24	Scorpaenidae	98.26	0.27	13.39	4.56	0.40	1.23	7.21
25	Atherinidae	98.53	0.27	13.34	0.89	1.83	3.69	6.93
26	Colocongridae	98.78	0.25	12.38	1.26	0.32	4.50	6.31
27	Ostraciidae	98.96	0.18	8.96	4.01	0.08	0.05	4.81
28	Teraponidae	99.09	0.14	6.76	0.63	4.90	1.22	-
29	Gerreidae	99.18	0.09	4.29	0.40	3.89	-	-
30	Pseudochromidae	99.27	0.09	4.25	1.30	-	2.52	0.43
31	Nemipteridae	99.34	0.08	3.79	1.09	0.43	1.74	0.54
32	Haemulidae	99.41	0.07	3.64	0.95	-	2.69	-
33	Antennariidae	99.48	0.06	3.17	-	-	3.12	0.05
34	Centriscidae	99.54	0.06	3.16	0.24	0.08	0.73	2.12
35	Aulostomidae	99.60	0.06	3.02	-	-	-	3.02
36	Pomacentridae	99.65	0.05	2.61	1.01	-	1.44	0.16
37	Acanthuridae	99.70	0.05	2.48	1.33	-	0.86	0.30
38	Grammistidae	99.75	0.05	2.34	2.34	-	-	-
39	Chaetodontidae	99.79	0.04	1.93	0.24	0.16	1.01	0.53
40	Ophichthidae	99.83	0.04	1.90	-	-	-	1.90
41	Carapidae	99.86	0.04	1.84	0.52	-	-	1.32
42	Sphyraenidae	99.90	0.04	1.81	0.10	-	0.29	1.43
43	Balistidae	99.94	0.03	1.72	-	-	1.67	0.05
44	Clupeidae	99.96	0.03	1.46	0.04	0.16	0.34	0.92
45	Ephippidae	99.98	0.01	0.73	0.57	-	0.16	-
46	Bothidae	99.99	0.01	0.53	-	-	0.53	-
47	Fistulariidae	99.99	0.01	0.40	0.24	-	-	0.16
48	Pempherididae	100.00	<0.01	0.11	-	-	-	0.11
	Totals		100.00	4,989.92	1,581.10	338.48	2,227.19	843.16

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