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Title: Effects of Fishing Pressure on the Reef Flat Fisheries of Guam.

Approved: ______________________________
Steven S. Amesbury, Chairman, Thesis Committee

To demonstrate the impacts of reef flat fishing pressure, comparisons of the fishery catch and effort data and the standing stock densities of fished species were made on three pairs of reef flats on Guam. Members of each reef flat pair were comparable physiographically but differed in the amount of fishing effort to which they were subject. Comparisons revealed lower standing stock densities, lower catch rates, generally smaller sized fish in the catch, and the reduction of certain large carnivores in the catch on the heavily fished reefs. The results suggest that overfishing has occurred on the heavily fished reefs. Schaefer surplus production curves constructed from the catch and effort data of the three reef flat pairs indicated that decreased effort on the heavily fished reefs and increased effort on the lightly fished reefs would result in increased yields. Differences in the size and shapes of the Schaefer curves among the three types of reef flats indicate that the potential yields and optimal levels of effort vary depending on the intrinsic characteristics of the reefs. Although highly preferred fishes from a variety of trophic levels were affected by the fishing pressure, it was the larger bodied

carnivores that were most influenced. Certain preferred fishes, such as the siganids, seemed to be unaffected by fishing pressure, whereas the undesired species, Scolopsis cancellatus, exhibited higher densities on the heavily fished reefs. Heavy fishing pressure did not seem to affect recruitment rates significantly. In light of the various signs of overfishing on some of Guam's most accessible reef flats, management measures which would increase reef flat productivity are discussed.

TO THE GRADUATE SCHOOL AND RESEARCH

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EFFECTS OF FISHING PRESSURE ON THE REEF FLAT FISHERIES OF GUAM

by

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INTRODUCTION

In recent years there have been reports of the decline of shallow water reef fisheries in the Pacific islands (Johannes 1978b, Johannes 1979, Pauly 1979a, R. E. Brock, pers. comm. 1981). Deterioration of the fisheries has been quite recent in some areas, and fishermen interviewed by Johannes (1979) in the Northern Mariana Islands indicated that the fishery had declined markedly in the past few years (with these trends becoming obvious around 1970 on Saipan). Reasons for these declines may be attributed to a variety of different factors. Rapid population growth and subsequent urbanization on some Pacific islands have resulted in the environmental degradation (generally localized) of the inshore reef communities. Such degradation, as a result of sedimentation, sewage, thermal and oil pollution, etc. (Johannes 1975), has had negative effects on the fish populations associated with these reef communities. Another factor that perhaps poses a more serious threat to inshore fisheries of the Pacific islands is overfishing. Stevenson and Marshall (1974) stated that there are many examples in which some of the highly territorial fishes of reef habitats have been quickly fished out under localized fishing pressures. A proposed model (Munro 1978) for estimating potential harvests from reef areas in the Western Pacific predicts that as human population density relative to reef area increases, catch rate will tend to decline exponentially. Johannes (1978b) maintained that the decline of Pacific island fisheries is largely a result of the transformation of Pacific island economic systems to westernized monetary economies and subsequent erosion of ancient marine tenure laws and traditional island conservation ethics. These socio-economic changes, combined with human population growth, have occurred in Palau within the past two decades, and the result has been the overharvesting of many important reef fishes and the rapid depletion of rich reef areas. In the Great Barrier Reef fishing pressures have reduced grouper populations to less than one-tenth of their original abundance (Goeden 1977) and have reduced the size of fish caught in other species (Great Barrier Reef Marine Park Authority 1978). Overexploitation of the inshore fish stocks in Malaysia and Southeast Asia has led to a rapid decline in the average catch per unit effort, decline in the proportion of high valued species, decline in the size of fish caught, and an increase in the quantity of trash fish, all classic signs of overfishing (Huat 1980). Although much of this decline has been attributed to the inshore trawl fishery, a large number of artisanal fishermen using less efficient traditional methods in very shallow waters can also overexploit fish stocks (Pauly 1979b). A similar fate has probably occurred on Guam's reef flats. Ikehara et al. (1970) stated that the shallow inner reefs appear to be fully exploited at present and that strong signs of overfishing are evident over most of the area.

In the past, traditional fishing methods (cast net, gill net, surround net, spear, hook and line, etc.) assured Guam's inhabitants of an ample supply of reef fish. Most of the fish caught in the subsistence fishery was either consumed by the fishermen and their families or was shared with the local community and with other fishermen who helped with the catch. The fish was additionally used for social obligations such as funerals, marriages, and fiestas (Jennison-Nolan 1979). However, in recent years, a larger portion of the fish has entered commercial markets (Amesbury and Callaghan 1980). Although the fishery still retains its subsistence nature, rapid population growth (the present population exceeds 100,000 people) and the expanded reef fish market have increased the demand for reef flat fishes. Fishermen interviews on Guam have indicated an overall decline in the reef flat fishery over the past years. In the advent of these changes, there is a need for data on the state of Guam's reef flat fishery.

The subsistence nature of Guam's reef flat fishery has made it very difficult to obtain precise and accurate catch and effort data on Guam's reef flats. These data are obtained principally from fishermen interviews carried out by the Guam Division of Aquatic and Wildlife Resources (GDAWR) and limitations of manpower and funding have hindered the development of a consistent, efficient fishermen interview system. Consequently, only very general comparisons can be made with the past and present creel census data. Also, the creel census data have been collected almost entirely from the most accessible and most heavily fished reefs of Guam. Major declines in the fishery on some of these heavily fished reef flats may have appeared well before accurate creel census data collection was initiated.

In the absence of a detailed historical record of changes in the fishery and the species composition of reefs subject to heavy fishing pressure, the present study was designed to assess the impacts of reef flat fishing pressure by comparing fishing catch and effort and standing stocks of reef flat species on reefs which have been subject to heavy fishing pressure with similar data from reefs which, because of their inaccessability, have been subject to relatively light fishing pressure. This study demonstrates the effects of fishing pressure on the catch rates and catch composition, standing stock densities of resource groups, and rates of recruitment on reef flat fish communities.

METHODS

The influence of fishing pressure was determined by comparing the fishery catch and effort and the standing stock densities of fished species on three pairs of reef flats in which the members of each pair were comparable physiographically but differed in the amount of fishing effort to which they were subject. In general, reef flats that are easily accessible and nearer to the population centers receive the greatest fishing pressures. This is partly because fishermen prefer to fish on reefs close to their homes and also because they are inhibited from fishing on reefs where accessibility is hampered by lack of convenient access roads or by restrictions imposed by adjacent private or military lands (Jennison-Nolan 1979 and fishermen interviews). Although close in geographical proximities, the lightly fished reefs are all farther away from population centers than are the heavily fished reefs, and, in two cases (Facpi and Uruno), they are virtually inaccessible to fishermen. Two of the lightly fished reef flats (Ajayan and Uruno) were considered as pristine marine communities on Guam by Stojkovich (1977).

Impacts from factors other than fishing pressure, e.g., pollution, siltation, dredging, etc., may also be affecting the fish population on the reef flats. The close geographical proximities between the reef flats in each pair should act to hold these other effects somewhat constant. Except for isolated cases, Guam's inshore reef habitats have been relatively unharmed from any major environmental degradation as a result of urbanization (C. E. Birkeland and J. A. Marsh, Jr., pers. comm. 1981). Tsuda (1981) lists some examples of environmental degradation on Guam.

The physical and biological aspects of Guam's reef flats are quite variable. This variability can be attributed to differences in wave exposure (windward vs leeward), to the presence or absence of surface drainage from adjacent land (southern vs northern), and to the inherent substrate type and topography of the original geological formation. Reefs with similar wave exposure, surface drainage, substrates, and associated biological features are said to be of the same biotope (Cloud 1959). Within each reef biotope, various types of reef flats (fringing reef channel, intertidal reef flat, etc.) are found. The study sites were chosen to give a good representation of Guam's reef flat types (Figure 1). Each reef flat pair that was compared is found within the same biotope and contains comparable zones and habitats. It is assumed that there should also be comparable fish populations within each reef flat pair, particularly within comparable habitats, because of the abiotic and biotic similarities.

Field observations and aerial photographs were used to divide the reef flats into specific habitats. Using the Atlas of the Reefs and Beaches of Guam (Randall and Eldredge 1976), maps (1:4800 scale) were prepared showing all the habitats on each reef flat (Figures 2, 3, 4). The latter source also aided in describing each of the reef flats and habitats.

The censusing employed in the present study was similar to that of Amesbury et al. (1979) and was performed by swimming freely at a constant speed within each habitat being censused. Fishes ahead of and

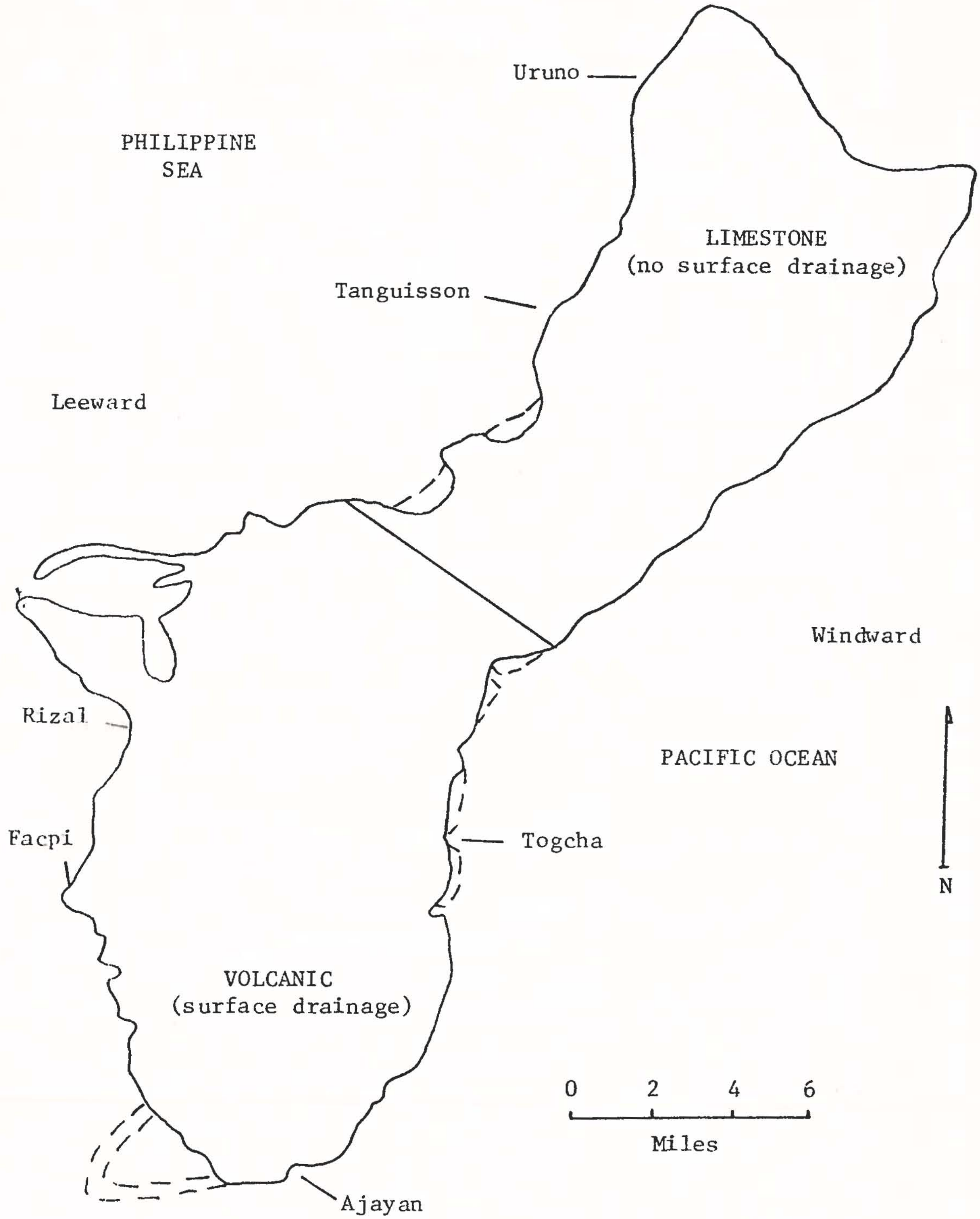

Figure 1. Map of Guam with the study sites.

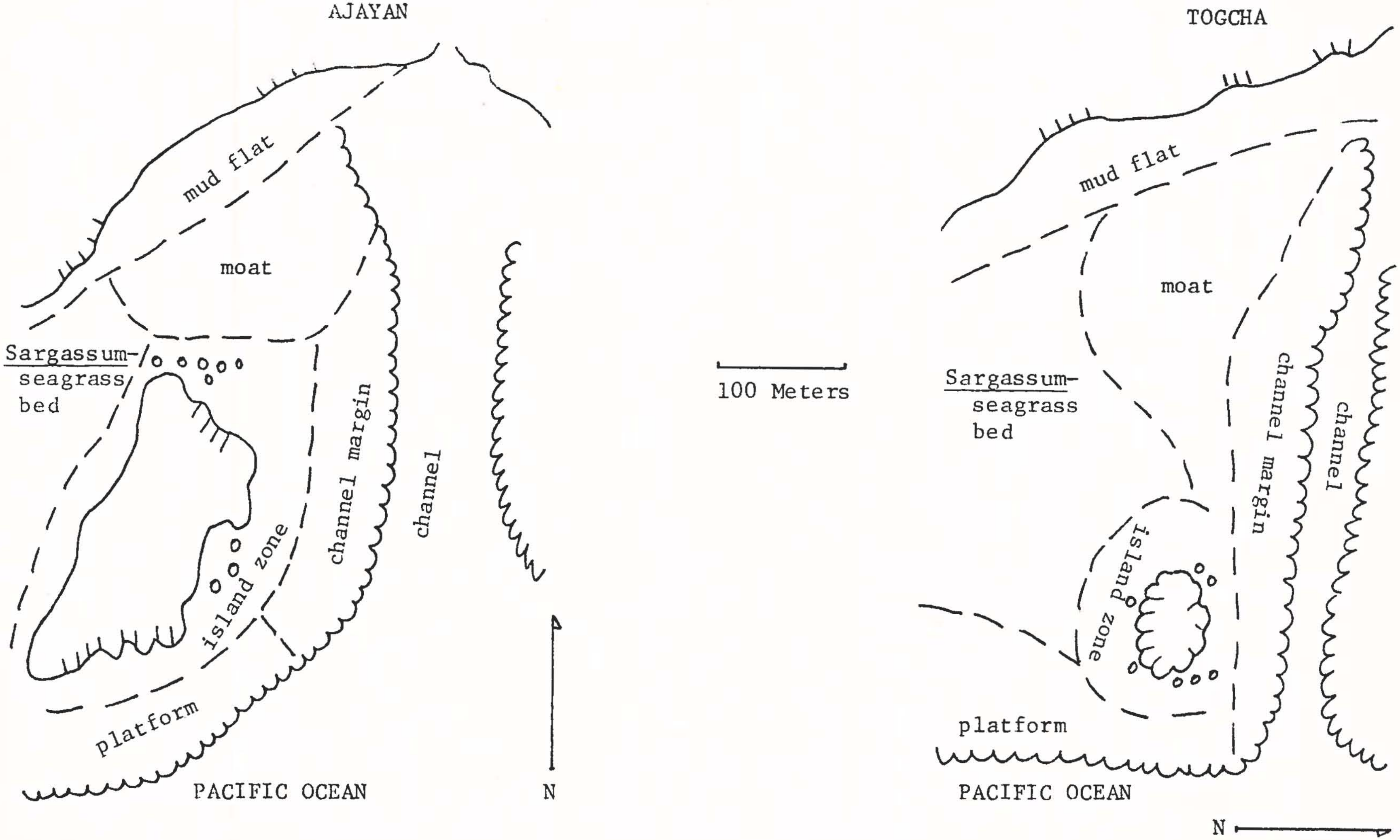

Figure 2. Maps of Ajayan channel and Togcha channel with their respective habitats.

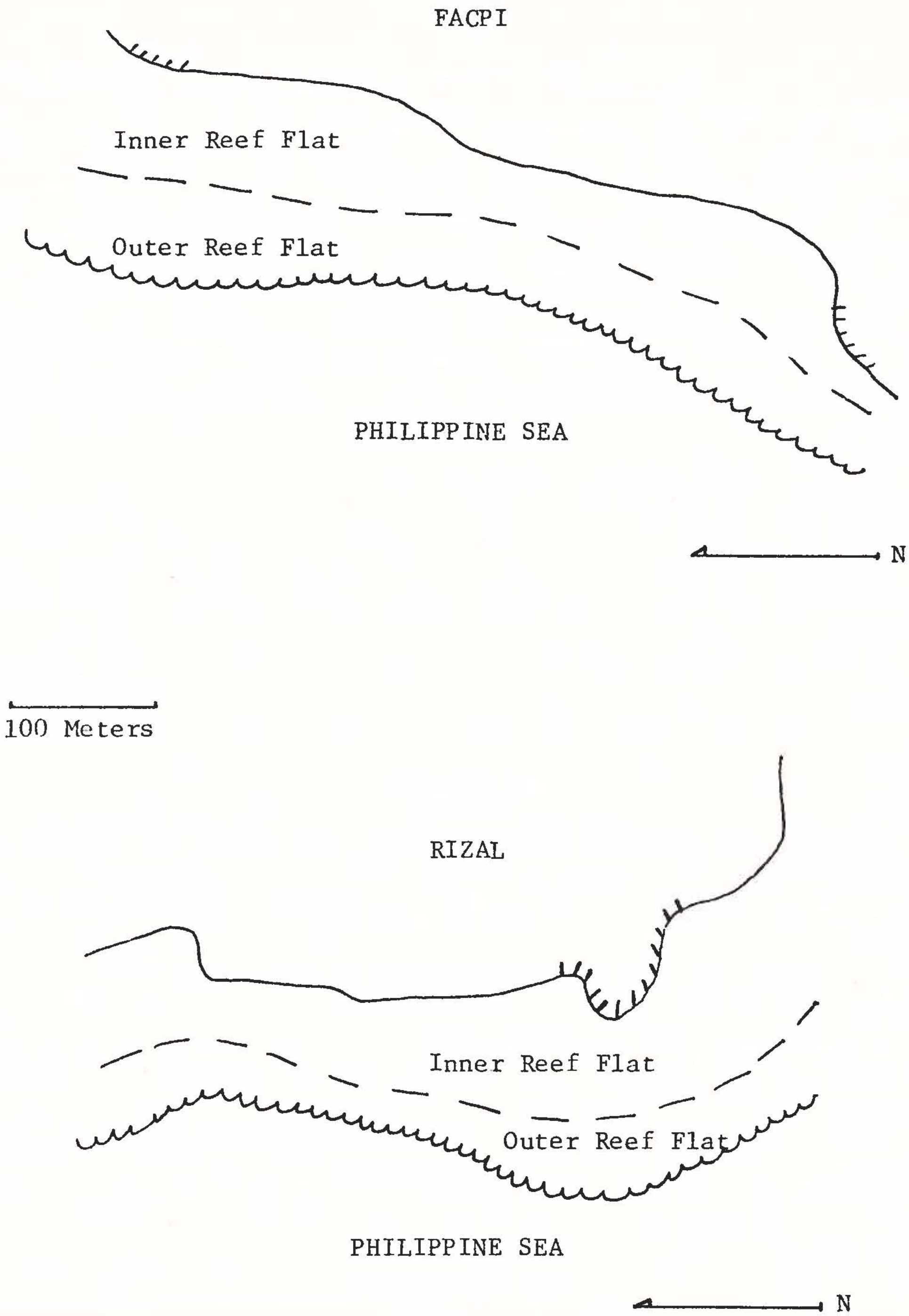

Figure 3. Maps of Facpi reef flat and Rizal reef flat with their respective habitats.

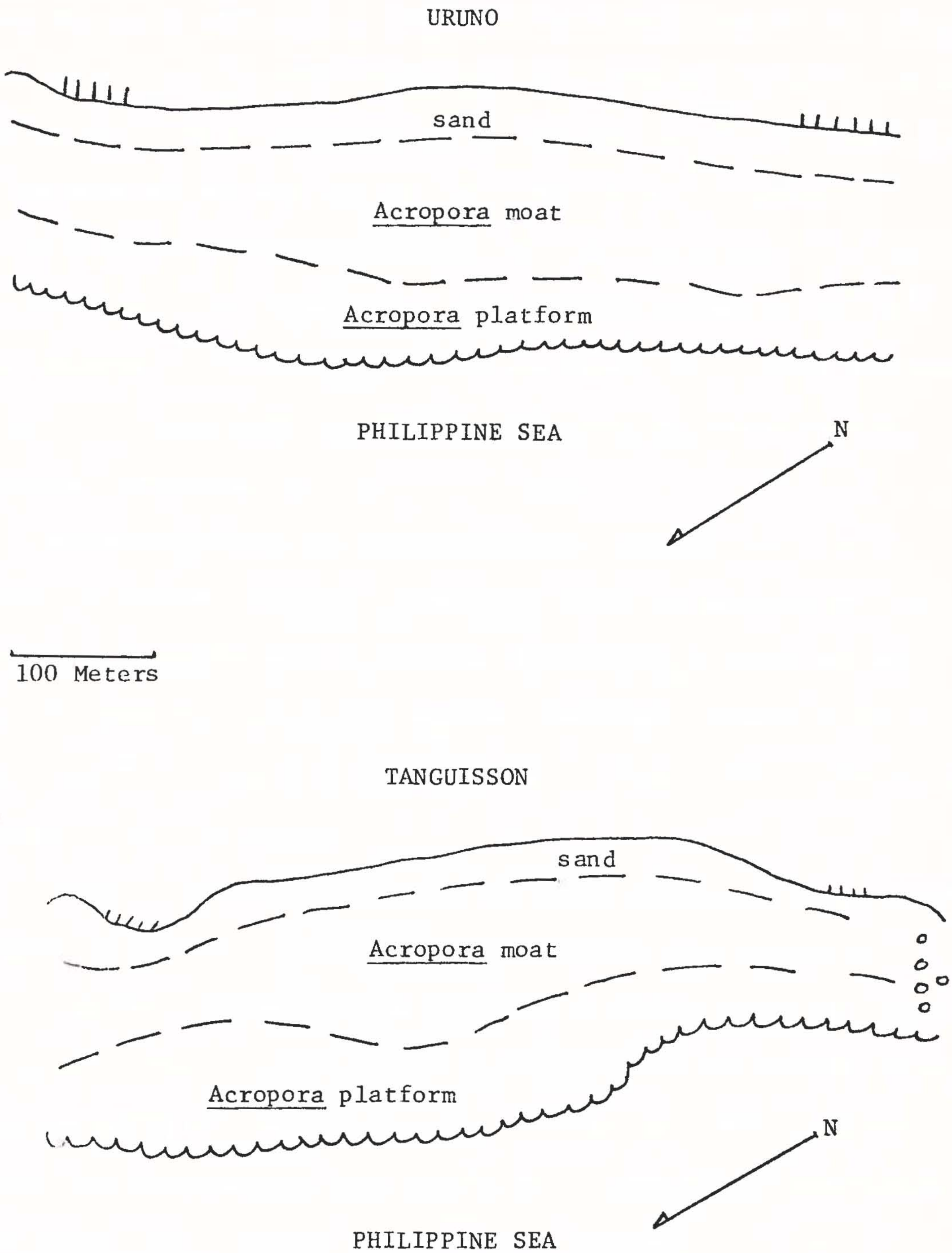

Figure 4. Maps of Uruno reef flat and Tanguisson reef flat with their respective habitats.

three meters to each side of the investigator were counted and categorized by size. This rather wide field of vision was justified, as the density of fishes censused was fairly low, and many of the fishes were rather wide ranging and wary of the investigator's presence.

Each count lasted five minutes, and four replicates were completed for each habitat on census days. Approximately 100 meters (600 m^2) were censused in five minutes. This was determined by doing replicate swims at the same speed the censuses were swum and measuring the distances travelled.

Censusing occurred at high tide on days without rain, large swells, or extreme currents. Comparable reefs and habitats were censused on consecutive days to minimize differences in tidal periods, time of censusing, and general weather conditions. Transects were run once every two months from September 1980 to August 1981 in the early morning or later afternoon.

A list of the reef flat fishes and their relative size categories is given in Table 1. The reef flat fish species were placed into fishery groups. Fishery groups consisted of certain types of fishes, either of a single species, genus, or family which are similar biologically and which are effectively caught by similar fishing methods. Fishery groups were created to permit better statistical comparisons in cases where single species densities were extremely low. Table 2 distinguishes which reef fishes are found in each fishery group and also indicates which fishery groups make up the carnivores, herbivores, and total standing stocks. Estimations of the standing stock densities of each fishery group in each habitat were made by determining the mean

Table 1. Reef flat fishes and size categories.

Small: <4" Medium: 4"-6" Large: >6"

Acanthurus nigrofuscus
A. nigroris
A. nigrocaudus
A. triostegus
A. guttatus
A. sp.
Ctenochaetus striatus
Siganus spinus
S. argenteus

Small: <4" Medium: 4"-7" Large: >7"

Scolopsis cancellatus

Small: <6" Medium: 6"-8" Large: >8"

Acanthurus lineatus

Small: <6" Medium: 6"-9" Large: >9"

Lutjanus fulvus
L. monostigmus
Lethrinus harak
Scaridae
Cheilinus sp.
Hemigymnus melapterus
Labridae
Serranidae
Caranx melampygus
Mugilidae
Liza vaigiensis
Mulloidichthys flavolineatus
Parupeneus trifasciatus
P. bifasciatus
P. barberinus

Small: <8" Medium: 8"-12" Large: >12"

Naso unicornis
N. lituratus
Cheilio inermis
Kyphosus cinerascens

Table 2. Reef flat fishes and corresponding fishery groups (designated by 3-letter abbreviations).

Reef Fishes	Fishery Group
Herbivores (Herb)	
Acanthurus guttatus	ACS
A. nigroris	ACS
A. nigrocaudus	ACS
A. sp.	ACS
A. nigrofuscus	ACN
Ctenochaetus striatus	CTS
Acanthurus lineatus	ACL
A. triostegus	ACT
Naso unicornis	NAS
N. lituratus	NAS
Siganus spinus	SIG
S. argenteus	SIG
Kyphosus cinerascens	KYP
Carnivores (Carn)	
Cheilinus sp.	LAB
Cheilio inermis	LAB
Hemigymnus melapterus	LAB
Lutjanus fulvus	LUT
L. monostigma	LUT
L. fulviflamma	LUT
Lethrinus harak	LEH
Serranidae	SER
Caranx melampygus	CAM
Mulloidichthys flavolineatus	MUF
Parupeneus trifasciatus	PAS
P. bifasciatus	PAS
P. barberinus	PAS
Ominivore	
Scaridae	SCA
Detritivore	
Liza vaigiensis	MUG
Mugilidae	MUG
Unpreferred Species	
Scolopsis cancellatus	SCO

densities of all 24 counts expressed as the average number of fish per 600 m^2.

Selection of the economically important reef flat fishes was based on fishermen interviews and past catch records, and selection of fish size categories was based on field observation of the relative sizes of the reef flat species, past catch records, and appropriate literature. Scolopsis cancellatus, which is a relatively unfished and economically unimportant species, according to fishermen interviews and field observations, was also included. Fishes were placed into either small, medium, or large size classes when counted on transect runs.

The small size classes are generally those fishes that are biological recruits and have not reached sufficient size to be caught in the fishery (fishery recruits). For a few species, however, some of the small size classes are caught in the fishery. The medium size classes are those fishes that have recruited into the fishery but have not reached the large size class.

Fishing pressures were monitored during the study by interviewing fishermen three times a month (from Sept. 1980 to Aug. 1981) on each of the reef flats and habitats. Effort (man-hours and gear-hours), catch by fishery group (in kg), catch per unit effort (CPUE), and fishing methods were recorded for each habitat on all reef flats. Comparisons of the above data were made between comparable habitats and reef flats. The relative importance of each fishery group (percent by weight) in the total catch was determined for each reef flat to compare possible differences between heavily and lightly fished reefs.

DESCRIPTION OF THE REEFS

Pair 1: Togcha channel (heavier pressure) and Ajayan channel (lighter pressure)

These fringing reef river channels are located along the southeastern and the southern windward coasts of Guam (Figure 1) and are subject to surface drainage from the nearby volcanic highlands. Being further north than Ajayan, Togcha is more directly affected by the northeast wave assault typical of the windward side of Guam. However, waves from the northeast are refracted around the southern coast and reach Ajayan with much of the same force that Togcha receives (R. H. Randall, pers. comm. 1982). Togcha reef flat is about 500 meters wide wide and Ajayan reef flat is about 400 meters wide. Both reef flats can be divided into six distinct habitats: the mud zone, the moat, the channel margins, the intertidal island zone, the reef flat platform, and the *Sargassum*-seagrass bed (Figure 2). Table 3 lists the general physiobiological characteristics of these habitats.

The mud zone which is located near shore is a relatively barren shallow water habitat that exposes during low tide. The deeper moat contains a variety of corals, but it is mostly a network of large, patchy *Porites* coral heads and open spaces of sand. The channel margin, which is adjacent to the river channel, is also fairly deep and has luxuriant coral growth (especially toward the seaward end) and is irregularly honey-combed with deep holes, depressions, and fissures that extend into the channel. The intertidal island zone, which

Table 3. General physiobiological characteristics of the various reef habitats. See description of the reefs for further details. (Topographic relief of reef surface: low: <50 cm, medium: 50 cm - 1 meter, high: >1 meter. Algae: Fleshy macroalgae - FM, Turf - T.)

		Water Depth		Sediments					
Habitat	Reef	High Tide	Low Tide	Distribution	Grain Size	Relative Topographic Relief	Algae	Corals	Seagrass
Mud Zone	Togcha	1 m	exposed	thin veneer	mud, fine sand	low	T	absent	scattered
	Ajayan	1 m	exposed	thin veneer	mud, fine sand	low	T	absent	scattered
Moat	Togcha	2 m	1 m	patchy	sand	medium	FM	patchy	scattered
	Ajayan	2-3 m	1-2 m	patchy	sand	medium	FM	patchy	scattered
Channel Margin	Togcha	3-4 m	2-3 m	patchy	sand	high	FM	abundant	absent
	Ajayan	3-4 m	2-3 m	patchy	sand	high	FM	abundant	absent
Island Zone	Togcha	1 m	exposed	patchy	sand, gravel	low	T	absent	absent
	Ajayan	1 m	exposed	patchy	sand, gravel	low	T	absent	absent
Platform	Togcha	1 m	exposed	patchy	gravel	low	T,FM	absent	absent
	Ajayan	1 m	exposed	patchy	gravel	low	T,FM	absent	absent
Sargassum-Seagrass Bed	Togcha	1 m	exposed	thin veneer	sand	low	FM	absent	patchy
	Ajayan	1 m	exposed	thin veneer	sand	low	FM	absent	abundant
Inner Reef Flat	Rizal	1 m	exposed	thin veneer	fine sand	low	FM	absent	absent
	Facpi	1 m	exposed	thin veneer	fine sand	low	FM	absent	absent
Outer Reef Flat	Rizal	1 m	exposed	patchy	gravel	low	T,FM	absent	absent
	Facpi	1 m	exposed	patchy	gravel	low	T,FM	absent	absent

Table 3 Continued.

Habitat	Reef	High Tide	Low Tide	Distribution	Grain Size	Relative Topographic Relief	Algae	Corals	Seagrass
Sand Zone	Tanguisson	1 m	exposed	thin veneer	coarse sand	low	T	absent	absent
	Uruno	1 m	exposed	thin veneer	coarse sand	low	T	absent	absent
Acropora Moat	Tanguisson	1-2 m	1-.5 m	patchy	coarse sand	high	T	abundant	absent
	Uruno	1-2 m	1-.5 m	patchy	coarse sand	high	T	abundant	absent
Acorpora Platform	Tanguisson	1 m	exposed	patchy	gravel	medium	T,FM	patchy	absent
	Uruno	1 m	exposed	patchy	gravel	medium	T,FM	patchy	absent

extends around the island perimeter, is mostly reef rock pavement. Much of this habitat exposes during low tide except for some of the depressed areas near the channel margin. The reef flat platform is also reef rock pavement that exposes during low tide except where the low rimmed terraces retain pools of water a few centimeters deep. The Sargassum-seagrass bed is a mixed assemblage of Sargassum polycystum and Enhalus acoroides. The seagrasses are generally more abundant as one moves farther away from the channel and closer to shore. The opposite holds true for the Sargassum. The seagrasses are more abundant at Ajayan, and there is an extremely dense seagrass bed just west of this habitat at Ajayan.

Even though the reef flats show striking similarities in physical and biotic factors, there is a tremendous difference in the amount of fishing pressure seen on these reefs. Both are fairly accessible; however, Togcha is farther north and closer to dense population centers. Consequently, Togcha has received much more fishing pressure in the past than Ajayan (creel census data and GDAWR aerial surveys 1965-66, 1975-76, 1978-79). It is important to note that aerial surveys compare fishing activities on Guam's reef flats at a regional level. Therefore, aerial surveys do not show the differences seen specifically at Ajayan or Togcha, but they do reflect regional differences in fishing pressure as a result of close proximity to population centers.

Pair 2: Rizal (heavier pressure) and Facpi (lighter pressure)

These reef flats are located on the southern leeward coast and are influenced by direct surface drainage of adjacent steep volcanic highlands (Figure 1). Both are intertidal reef flats about 100 meters wide and contain an outer reef flat and an inner reef flat (Figure 3). Table 3 lists the general physiobiological characteristics of these habitats. Fine sand deposits veneer the substrate in the inner zone along with scattered patches of the fleshy alga Sargassum polycystum. The outer zone is similar to the reef flat platforms the river channels. It is basically reef rock pavement with occasional holes and depressions.

Rizal is easily accessible whereas Facpi is surrounded by private lands with no access roads. Because of the relative inaccessibility of Facpi, there are no data on past fishing pressure that might have occurred there. Both are in the same aerial survey region, but past aerial surveys showed fishing pressure to be more concentrated near the more accessible reefs such as Rizal (Mike Molina, pers. comm. 1981). Present data clearly show that Rizal receives more fishing pressure than Facpi and fishermen interviews also suggest that Rizal has received more in the past.

Pair 3: Tanguisson (heavier pressure) and Uruno (lighter pressure)

These reef flats are located along the northwestern semi-leeward coast of Guam (Figure 1). The nearby coastal region consists of raised limestone deposits and thus the adjacent reef platforms are not influenced by surface drainage. Freshwater lens discharge along the intertidal zone slightly reduces salinity, particularly during the low tide when the reef platform is partially exposed. Both reef flats are about 200 meters wide and have been divided into 3 habitats: the sand zone, the Acropora moat, and the Acropora platform (Figure 4). Table 3 lists the general physiobiological characteristics of these habitats. The sand zone borders the shoreline and is approximately 20 meters wide. The bottom is unevenly veneered by sand which shows evidence of scouring caused by longshore currents that are generated when swells transport large amounts of water onto the reef platform. The *Acropora* moat is largely a mosaic pattern of arborescent *Acropora* thickets, *Porites* colonies, and open spaces of sand intermixed with coral rubble. The *Acropora* platform has slightly more topographic relief than the platforms described earlier. Although sections of it are reef rock pavement, a large portion of the habitat contains depressions, holes, live and remnant stands of *Acropora*, and other corals.

Uruno is bordered by military and private land. Consequently, it has been closed to all fishing activities except by specific landowners or guests. Tanguisson is more accessible and closer to more populated villages; hence, it has received much heavier fishing pressure in the past than Uruno. Uruno and Tanguisson are also in the same aerial survey region, but past pressures seen in this aerial survey region have been more concentrated near Tanguisson than Uruno (Mike Molina, pers. comm. 1981). Data collected from this study showed Tanguisson to be much more heavily fished than Uruno.

RESULTS

Effort

In total, the heavily fished reefs were subject to about 6 times more fishing effort than were the lightly fished reefs (Table 4). All fishing methods were used more heavily on the heavily fished reefs, with surround net, hook and line, and spear fishing effort showing the greatest difference between heavily and lightly fished reefs.

Rizal received about 8 times more man-hours and 9 times more gear-hours of effort than did Facpi (Table 5). No spear or hook and line fishing occurred at Facpi. Spearfishing contributed to half of the total effort on the outer reef flat at Rizal, and hook and line effort was most prevalent in the inner reef as well as second in importance on the outer reef flats. Four times more man-hours and nearly 3 times more gear-hours of effort were expended on Tanguisson than on Uruno reef flat (Table 6). This was largely a result of surround netting in the _Acropora_ moat plus spear and hook and line fishing on the _Acropora_ platform at Tanguisson. None of these methods were observed in the comparable habitats at Uruno. Togcha had 7 times more man-hours and 6 times more gear-hours of effort than did Ajayan (Table 7), primarily because of the more common use of hook and line, surround net, and spear at Togcha. The channel margin and the moat were the habitats showing the greatest difference in fishing pressure between Togcha and Ajayan. More extensive use of hook and line and spear at the Togcha channel margin and more extensive use of surround net, gill net, and

Table 4. Effort and catch results of all heavily fished reefs vs all lightly fished reefs. (H&L = Hook and Line, SP = Spear, CN = Cast Net, GN = Gill Net, SN = Surround Net)

	All Heavily Fished Reefs					All Lightly Fished Reefs				
	EFFORT		CATCH	CPUE		EFFORT		CATCH	CPUE	
METHODS	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H
H&L	182	182	16.96	.10	.10	21.5	21.5	20.40	.95	.95
SP	62	62	11.52	.19	.19	5.5	5.5	4.79	.87	.87
CN	37.5	37.5	16.52	.44	.44	19.0	19.0	17.60	.93	.93
GN	65	31	19.51	.30	.63	33	20.5	30.59	.93	1.49
SN	153	31.5	36.91	.24	1.20					
TOTALS	499.5	344	101.42	.21	.30	79	66.5	73.38	.93	1.10

Table 5. Effort and catch results of all methods in all fished habitats of Rizal vs Facpi. (H&L = Hook and Line, SP = Spear, CN = Cast Net, GN = Gill Net, SN = Surround Net)

		RIZAL					FACPI				
		EFFORT		CATCH	CPUE		EFFORT		CATCH	CPUE	
HABITATS	METHODS	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H
Inner Reef Flats	H&L	7.5	7.5	.59	.08	.08					
	SP										
	CN	1.0	1.0	.80	.80	.80	1.0	1.0	.64	.64	.64
	GN	2.5	2.5	.51	.20	.20	1.0	1.0	.86	.86	.86
	SN										
	Subtotal	11.0	11.0	1.90	.17	.17	2.0	2.0	1.50	.75	.75
Outer Reef Flat	H&L	9.0	9.0	0	0	0					
	SP	18.0	18.0	1.46	.08	.08					
	CN	4.0	4.0	2.60	.65	.65	2.0	2.0	3.00	1.50	1.50
	GN	6.0	3.0	.67	.11	.22	2.0	1.0	1.58	.79	1.58
	SN										
	Subtotal	37.0	34.0	4.73	.13	.14	4.0	3.0	4.58	1.15	1.53
	TOTAL	48.0	45.0	6.63	.14	.15	6.0	5.0	6.08	1.01	1.22

Table 6. Effort and catch results of all methods in all fished habitats of Tanguisson vs Uruno. (H&L = Hook and Line, SP = Spear, CN = Cast Net, GN = Gill Net, SN = Surround Net)

		TANGUISSON					URUNO				
		EFFORT		CATCH	CPUE		EFFORT		CATCH	CPUE	
HABITATS	METHODS	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H	Man-Hrs	Gear-Hrs	Total Wt (kg)	kg/M-H	kg/G-H
Sand	H&L	11.0	11.0	.28	.03	.03	6	6	12.25	2.04	2.04
	SP										
	CN	2.5	2.5	.64	.26	.26	1.5	1.5	.56	.38	.38
	GN										
	SN										
	Subtotal	13.5	13.5	.92	.07	.07	7.5	7.5	12.81	1.71	1.71
Acropora Moat	H&L										
	SP	5.0	5.0	.79	.16	.16	3.5	3.5	2.52	.72	.72
	CN										
	GN	7.0	6.0	4.14	.59	.69	3.0	3.0	3.69	1.23	1.23
	SN	33.0	5.5	15.09	.46	2.74					
	Subtotal	45.0	16.5	20.02	.44	1.21	6.5	6.5	6.21	.96	.96
Acropora Platform	H&L	15.0	15.0	1.05	.07	.07					
	SP	12.0	12.0	4.08	.34	.34					
	CN	10.0	10.0	4.78	.48	.48	5.5	5.5	6.92	1.26	1.26
	GN	10.0	5.0	4.59	.46	.92	5.0	5.0	12.24	2.45	2.45
	SN										
	Subtotal	47.0	42.0	14.50	.31	.35	10.5	10.5	19.16	1.82	1.82
	TOTAL	105.5	72.0	35.44	.34	.49	24.5	24.5	38.18	1.56	1.56

Table 7. Effort and catch results of all methods in all fished habitats of Togcha vs Ajayan. (H&L = Hook and Line, SP = Spear, CN = Cast Net, GN = Gill Net, SN = Surround Net)

		TOGCHA					AJAYAN				
		EFFORT		CATCH			EFFORT		CATCH		
		Man-Hrs	Gear-Hrs	Total Wt	CPUE		Man-Hrs	Gear-Hrs	Total Wt	CPUE	
HABITATS	METHODS	Hrs	Hrs	(kg)	kg/M-H	Kg/G-H	Hrs	Hrs	(kg)	kg/M-H	kg/G-H
	H&L						2.0	2.0	2.11	1.06	1.06
Sargassum-Seagrass	SP										
	CN						.5	.5	.26	.52	.52
	GN										
	SN	56.0	8	5.30	.09	.66					
	Subtotal	56.0	8	5.30	.09	.66	2.5	2.5	2.37	.92	.92
	H&L										
	SP										
Platform	CN	13.5	13.5	6.36	.47	.47	2.0	2.0	3.83	1.92	1.92
	GN						2.0	1.0	.84	.42	.84
	SN	16.0	8	2.00	.13	.25					
	Subtotal	29.5	21.5	8.36	.28	.39	4.0	3.0	4.67	1.17	1.56
	H&L	1.5	1.5	.21	.14	.14	8.5	8.5	.90	.11	.11
	SP										
Mud	CN	6.5	6.5	1.34	.21	.21	6.5	6.5	2.39	.37	.37
	GN						1.0	1.0	.21	.21	.21
	SN										
	Subtotal	8.0	8.0	1.55	.19	.19	16.0	16.0	3.50	.23	.23

Table 7 Continued.

HABITATS	METHODS	TOGCHA EFFORT Man-Hrs	TOGCHA EFFORT Gear-Hrs	TOGCHA CATCH Total Wt (kg)	TOGCHA CPUE kg/M-H	TOGCHA CPUE kg/G-H	AJAYAN EFFORT Man-Hrs	AJAYAN EFFORT Gear-Hrs	AJAYAN CATCH Total Wt (kg)	AJAYAN CPUE kg/M-H	AJAYAN CPUE kg/G-H
Moat	H&L						3.0	3.0	4.10	1.37	1.37
	SP	17.0	17.0	1.52	.09	.09	2.0	2.0	2.27	1.14	1.14
	CN										
	GN	39.5	14.5	9.60	.24	.66	14.0	5.5	9.56	.68	1.74
	SN	48.0	10.0	14.52	.30	1.45					
	Subtotal	104.5	41.5	25.64	.25	.62	19.0	10.5	15.93	.84	1.52
Channel Margin	H&L	138.0	138.0	14.83	.11	.11	2.0	2.0	1.04	.52	.52
	SP	10.0	10.0	3.67	.37	.37					
	CN										
	GN						4.5	2.5	1.21	.27	.48
	SN										
	Subtotal	148	148	18.50	.13	.13	6.5	4.5	2.25	.35	.50
	TOTAL	346	227	59.35	.17	.26	48.0	36.5	28.72	.60	.79

spear at the Togcha moat accounted for these large differences. As a result of more hook and line fishing, the Ajayan mud zone was the only habitat on a lightly fished reef flat that had more fishing pressure than a comparable habitat on a heavily fished reef flat.

Catch

The total fishery catch on all the heavily fished reefs combined was greater than on the lightly fished reefs (Table 4). The greater total catch on the heavily fished reefs was the result of large catches by surround nets (a method not used on the lightly fished reefs) and by larger spearfishing catches. All other methods resulted in somewhat larger total catches on the lightly fished reefs than on the heavily fished reefs.

The overall catches by weight were fairly similar on the comparable reef flat pairs of Rizal and Facpi (Table 5) and Tanguisson and Uruno (Table 6), but the catch on the heavily fished reef of Togcha was double that of its lightly fished counterpart, Ajayan (Table 7).

Catch Rates

The total catch rates (kg/man-hr and kg/gear-hr) for all fishing methods combined were about 4 times greater on the lightly fished reefs than on the heavily fished ones (Table 4). For all the comparable fishing methods (except the surround net) catch rates were much lower on the heavily fished reefs than on the lightly fished reefs. The cast net showed the least difference in catch rates between the heavily and lightly fished reefs, whereas hook and line fishing showed the greatest difference.

On comparable reef flats, the total catch rates (all methods combined) at Facpi were 7 to 8 times greater than those at Rizal (Table 5). Total catch rates at Uruno were 3 to 4 times those at Tanguisson (Table 6), and catch rates at Ajayan were about 3 times larger than those at Togcha (Table 7).

The most effective method (in terms of gear-hours) used on the heavily fished reefs was the surround net (Table 4), but, because an average of 5 men normally operate a single net, the effectiveness of the surround net in terms of man-hours was not greatly different than other fishing methods used on the heavily fished reefs. The most effective fishing method in terms of man-hours was the cast net, while the hook and line was least effective on the heavily fished reefs. On the lightly fished reefs, gill nets were the most effective harvesting method with respect to gear-hours, but, in terms of man-hours, all methods were almost equally effective. The use of surround nets was not observed on the lightly fished reefs during this study.

Catch by Fishery Groups

There were major differences in the relative importance that certain fishery groups played in the total catch between heavily and lightly fished reefs (Table 8). The large importance of the *Siganus* spp. (mostly *Siganus spinus*) in the total catch on the heavily fished reefs in relation to the lightly fished reefs was the most apparent contrast. *Caranx melampygus* and *Lethrinus harak*, on the other hand, showed much more importance in the total catch on the lightly fished reefs than on the heavily fished reefs. Although *Mulloidichthys flavolineatus* was third in relative importance on both heavily and

Table 8. Order of relative importance (percent [%] of total catch weight) of the fishery groups caught by all methods on the heavily and lightly fished reef flats. Fishery group abbreviations are given in Table 2.

Pair 1				Pair 2				Pair 3							
Rizal (H)		Facpi (L)		Tanguisson (H)		Uruno (L)		Togcha (H)		Ajayan (L)		All heavily fished reefs (H)		All lightly fished reefs (L)	
Fishery Group	%	Fishery Group	%	Fishery Group	%	Fishery Group	%	Fishery Group	%	Fishery Group	%	Fishery Group	%	Fishery Group	%
SIG	39	ACT	56	SIG	38	CAM	31	SIG	34	LEH	21	SIG	35	ACT	35
ACT	29	SIG	21	ACT	26	ACT	29	ACT	30	MUF	20	ACT	29	CAM	20
CAM	9	SCA	13	MUF	14	MUF	11	NAS	9	ACT	13	MUF	6.8	MUF	14
SCA	8	CAM	5	SCA	6	NAS	6	SCA	6	CAM	9	SCA	6.1	LEH	9.4
LAB	5	ACS	3	MISC	4	ACS	4.6	LAB	5	SCA	7	NAS	5	SIG	6
ACL	3	MISC	2	CAM	3.3	LAB	4.5	CAM	3.3	SIG	6	LAB	4.4	SCA	6
CTS	1.7			LAB	2.9	SCA	3.0	MUF	3	KYP	5	CAM	4.7	NAS	4.8
MISC	1.7			KYP	2.5	SIG	2.6	LEH	2	NAS	4.8	MISC	2.3	LAB	4.0
PAS	1.5			ACL	2.0	LEH	2.0	MUG	1.6	LAB	4.6	KYP	1.7	ACS	3.0
SCO	1.4			SER	.7	MISC	1.6	KYP	1.5	MISC	3	LEH	1.4	KYP	2.4
ACN	1.1			LEH	.6	ACL	1.5	MISC	1.3	SER	2.4	MUG	1.0	MISC	2.0
				PAS	.2	SER	1.2	ACS	1.2	MUG	2	ACL	.9	SER	1.6
						KYP	.9	SCO	.8	ACS	1.2	ACS	.7	ACL	.8
						LUT	.8	SER	.6	CTS	1.0	SCO	.6	MUG	.6
						PAS	.7	PAS	.5	ACN	.4	SER	.5	LUT	.5
								CTS	.4	LUT	.2	PAS	.4	PAS	.3
								ACN	.3			CTS	.3	CTS	.2
												ACN	.2	ACN	.1

lightly fished reefs, it made up a larger percent of the catch of the lightly fished reefs. Acanthurus triostegus was a very important component of the total catch on both the heavily fished reefs (where it was second in importance) and the lightly fished reefs (where it was first in importance). The Siganus spp. and A. triostegus accounted for 64% of the total catch by weight on the heavily fished reefs, while these relatively small herbivores (Table 1) made up only 31% of the total catch on the lightly fished reefs. The larger carnivores C. melampygus and L. harak made up 29.4% of the total catch by weight on the lightly fished reefs and only 5.1% on the heavily fished reefs.

The relative importance of fishery groups on the comparable reef flat pairs (Table 8) was quite similar to the overall pattern for combined heavily and lightly fished reefs. There was somewhat greater difference in fishery groups rankings among the lighly fished reefs than among the heavily fished reefs where the same two fishery groups (Siganus spp. and A. triostegus) are ranked first and second in importance on each of the heavily fished reefs. Except for Facpi, a large carnivore was ranked number one in importance (L. harak at Ajayan and C. melampygus at Uruno) on each lightly fished reef flat.

Catch by Method

C. melampygus was the most important fishery group caught in both total number and weight with the hook and line (Table 9). Next of importance by weight was L. harak and Naso spp. and by number was A. triostegus and Siganus spp. Fishery yields by hook and line on the heavily fished reefs differed sharply from those on the lightly fished reefs. The top three fishery groups by weight on the heavily fished

Table 9. Hook and line fishery yields for each of the heavily (H) and lightly (L) fished reef flat pairs. In parentheses is the number of fish caught which is followed by the weight of fish in kg for each fishery group caught by hook and line. Fishery group abbreviations are given in Table 2.

Fishery Groups	H Rizal	L Facpi	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Total	L Total	H+L Total
ACS					(1) .31		(1) .31		(1) .31
ACT					(62)4.79		(62)4.79		(62)4.79
NAS					(7)5.05		(7)5.05		(7)5.05
SIG					(36)3.39		(36)3.39		(36)3.39
LAB			(1) .10		(2) .18		(3) .28		(3) .28
LEH					(3) .30	(30)5.88	(3) .30	(30)5.88	(33)6.18
SER			(1) .23	(1) .25	(1) .28	(3) .71	(2) .51	(4) .96	(6)1.47
CAM	(46) .59		(15) .28	(8)11.85	(14) .23	(62)1.56	(75)1.10	(70)13.41	(145)14.51
PAS				(1) .15				(1) .15	(1) .15
MISC			(3) .72		(6) .51		(9)1.23		(9)1.23
Total	(46) .59	0	(20)1.33	(10)12.25	(132)15.04	(95)8.15	(198)16.96	(105)20.40	(303)37.35
Avg wt (kg)	.01	-	.07	1.23	.11	.09	.09	.19	.12
Effort (man-hrs)	16.5	0	26	6.0	139.5	15.5	182	21.5	203.5
Effort (gear-hrs)	16.5	0	26	6.0	139.5	15.5	182	21.5	203.5

reefs (in decreasing order of importance) were *Naso* spp., *A. triostegus*, and *Siganus* spp. None of these groups were caught with hook and line on the lightly fished reefs. By weight and number on the lightly fished reefs, *C. melampygus* was the most important fishery group followed by *L. harak*. Although the number of *C. melampygus* caught was quite similar between heavily and lightly fished reefs, larger individuals were caught on the lightly fished reefs and the total weight of this fishery group on lightly fished reefs was 10 times that from heavily fished reefs. *L. harak* was much less important in the hook and line fishery on the heavily fished reefs than it was on the lightly fished reefs.

The major fishery group caught by spear (by total number and weight) was the scarids (Table 10). Following the scarids in importance by weight were the labrids, *Kyphosus cinerascens*, and miscellaneous fishes; by number the order was *Siganus* spp., *A. lineatus*, and Labridae. Although the differences in catches by spear were not great between the heavily and lightly fished reefs, the most obvious differences were seen with the fishery groups Scaridae, Labridae, *K. cinerascens*, and miscellaneous fishes. The catches of these fishery groups from the heavily fished reefs all exceeded the catches from lightly fished reefs.

Siganus spp. (by total number) and *A. triostegus* (by total weight) were, by far, the most prominent fishery groups caught with the cast net (Table 11). Also of importance numerically were *C. melampygus* and *M. flavolineatus* juveniles. By weight the fishery groups *Acanthurus* spp., Kyphosidae, *C. melampygus*, and *M. flavolineatus* were relatively important. The cast net catches were quite similar on both the heavily

Table 10. Spear fishery yields for each of the heavily (H) and lightly (L) fished reef flat pairs. In parentheses is the number of fish caught which is followed by the weight of fish in kg for each fishery group caught by spearfishing. Fishery group abbreviations are given in Table 2.

Fishery Groups	H Rizal	L Facpi	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Total	L Total	H+L Total
ACS				(1) .07	(1) .11		(1) .11	(1) .07	(2) .18
ACN	(1) .07				(2) .18	(1) .13	(3) .25	(1) .13	(4) .38
CTS	(1) .11				(3) .19	(1) .11	(4) .30	(1) .11	(5) .41
ACL	(2) .17		(5) .48	(3) .42			(7) .65	(3) .42	(10)1.07
ACT			(1) .10	(4) .40			(1) .10	(4) .40	(5) .50
NAS				(1) .21	(1) .11		(1) .11	(1) .21	(2) .32
SIG	(4) .17		(3) .25	(1) .05	(3) .24	(3) .28	(10) .66	(4) .33	(14) .99
KYP			(1) .90		(2) .61		(3)1.51		(3)1.51
SCA	(4) .40		(9)1.88		(6)1.60	(1)1.34	(19)3.88	(1)1.34	(20)5.22
LAB	(2) .24		(2) .49		(5)1.38		(9)2.11		(9)2.11
LUT				(1) .30				(1) .30	(1) .30
LEH				(2) .58		(1) .20		(3) .78	(3) .78
SER				(1) .21				(1) .21	(1) .21
SCO	(1) .09						(1) .09		(1) .09
MUF			(1) .09			(2) .21	(1) .09	(2) .21	(3) .30
PAS	(1) .10				(2) .27		(3) .37		(3) .37
MUG					(1) .23		(1) .23		(1) .23
MISC	(1) .11		(3) .68	(2) .28	(2) .27		(6)1.06	(2) .28	(8)1.34
Total	(17)1.46	0	(25)4.87	(16)2.52	(28)5.19	(9)2.27	(70)11.52	(25)4.79	(95)16.31
Avg wt (kg)	.09	-	.19	.16	.19	.25	.16	.19	.17
Effort (man-hrs)	18.0	0	17.0	3.5	27.0	2.0	62.0	5.5	67.5
Effort (gear-hrs)	18.0	0	17.0	3.5	27.0	2.0	62.0	5.5	67.5

Table 11. Cast net fishery yields for each of the heavily (H) and lightly (L) fished reef flat pairs. In parentheses is the number of fish caught which is followed by the weight of fish in kg for each fishery group caught by cast net. Fishery group abbreviations are given in Table 2.

Fishery Groups	H Rizal	L Facpi	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Total	L Total	H+L Total
ACS		(4) .20		(10)1.60	(1) .12	(4) .35	(1) .12	(18)2.15	(19)2.27
ACL			(3) .24	(1) .15			(3) .24	(1) .15	(4) .39
ACT	(19)1.10	(27)2.04	(35)1.78	(80)4.68	(89)4.57	(23)1.32	(143)7.45	(130)8.04	(273)15.49
SIG	(221)2.16	(10)1.01	(39)2.76	(6) .42	(23)1.41	(20)1.01	(283)6.33	(36)2.44	(319)8.77
KYP				(2) .32	(2) .26	(8)1.47	(2) .26	(10)1.79	(12)2.05
SCA	(1) .14						(1) .14		(1) .14
LAB				(1) .10		(1) .03		(2) .13	(2) .13
CAM		(15) .30	(10) .18		(61)1.04	(34) .66	(71)1.22	(49) .96	(120)2.18
MUF			(49) .46	(15) .21	(25) .30	(67)1.21	(74) .76	(82)1.42	(156)2.18
MUG						(13) .43		(13) .43	(13) .43
MISC		(1) .09						(1) .09	(1) .09
Total	(241)3.40	(57)3.64	(136)5.42	(115)7.48	(201)7.70	(170)6.48	(578)16.52	(342)17.60	(920)34.12
Avg wt (kg)	.01	.06	.04	.07	.04	.04	.03	.05	.04
Effort (man-hrs)	5.0	3.0	12.5	7.0	20.0	9.0	37.5	19.0	56.5
Effort (gear-hrs)	5.0	3.0	12.5	7.0	20.0	9.0	37.5	19.0	56.5

and lightly fished reefs. Differences were noticeable, however, for Siganus spp., Acanthurus spp., and K. cinerascens.

A. triostegus and M. flavolineatus made up a major portion of the gill net fishery yields (Table 12). Scarids, labrids, Naso spp. and siganids were next in importance in total catches. With some exceptions, the gill net catches of these major fishery groups tended to be greater on the lightly fished reefs than the heavily fished reefs. A notable difference was seen for Naso spp. which was third of importance in catch by weight and number on the lightly fished reefs and not caught at all on the heavily fished reefs.

The surround net fishery yields were dominated by Siganus spp. (Table 13). Siganids accounted for well over 50% of the total surround net catch in both weight and numbers. Also of relative importance in the surround net catches was A. triostegus.

The average weight of fishes caught by the different methods varied (Tables 9-13). Of all methods, spearfishing harvested fishes of the greatest average weight. Fishes taken by hook and line were the next highest in total average weight followed by fishes taken by gill net, surround net, and cast net. The range in average weights (among reef flats) of fishes caught by a specific method was much larger for the hook and line than it was for any other method. The average weight of fishes taken by cast net was smallest because it selected for fishes of smaller body size (A. triostegus and Siganus spp.) and for juveniles of certain fishery groups. Since the surround net did not take juveniles, the average weight of fishes taken by this method was greater than that of fishes taken by cast net. Juveniles were occassionally

Table 12. Gill net fishery yields for each of the heavily (H) and lightly (L) fished reef flat pairs. In parentheses is the number of fish caught which is followed by the weight of fish in kg for each fishery group caught by gill net. Fishery group abbreviations are given in Table 2.

Fishery Groups	H Rizal	L Facpi	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Total	L Total	H+L Total
ACS				(1) .06	(1) .23		(1) .23	(1) .06	(2) .29
ACL			(2) .06				(2) .06		(2) .06
CTS						(1) .10		(1) .10	(1) .10
ACT	(17) .85	(23)1.38	(54)2.72	(97)6.00	(50)3.36	(38)2.35	(121)6.43	(158)9.73	(279)16.66
NAS				(12)1.87		(9)1.42		(21)3.29	(21)3.29
SIG	(7) .25	(3) .26	(16) .70	(3) .53	(3) .26	(8) .58	(26)1.21	(14)1.37	(40)2.58
SCA		(2) .80	(2) .15	(10)1.20	(5)2.02	(4) .80	(7)2.80	(16)2.17	(23)4.97
LAB	(1) .08		(3) .44	(6)1.62	(3).55	(7)1.31	(7)1.07	(13)2.93	(20)4.00
LUT						(1) .05		(1) .05	(1) .05
LEH				(1) .24				(1) .24	(1) .24
CAM				(2) .03	(7) .50	(13) .26	(7) .50	(15) .29	(22) .79
SCO					(5) .45		(5) .45		(5) .45
MUF			(54)4.53	(43)3.98	(19)1.49	(32)4.35	(73)6.02	(75)8.33	(148)14.35
PAS			(1) .10	(1) .10			(1) .10	(1) .10	(2) .20
MUG					(5) .74		(5) .74		(5) .74
MISC			(2) .03	(1) .30		(4) 1.0	(2) .03	(5)1.30	(7)1.33
Total	(25)1.18	(28)2.44	(134)8.73	(177)15.93	(98)9.60	(117)12.22	(257)19.51	(322)30.59	(579)50.10
Avg wt (kg)	.05	.09	.07	.09	.10	.10	.08	.10	.09
Effort (man-hrs)	8.5	3.0	17.0	8.0	39.5	22.0	65.0	33.0	98.0
Effort (gear-hrs)	5.5	2.0	11.0	8.0	14.5	10.5	31.0	20.5	51.5

Table 13. Surround net fishery yields for each of the heavily (H) and lightly (L) fished reef flat pairs. In parentheses is the number of fish caught which is followed by the weight of fish in kg for each fishery group caught by surround net. Fishing group abbreviations are given in Table 2.

Fishery Groups	H Rizal	L Facpi	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Total	L Total	H+L Total
ACT			(79)4.49		(75)5.20		(154)9.69		(154)9.69
SIG			(159)9.68		(268)14.50		(427)24.18		(127)24.18
LAB					(6)1.02		(6)1.02		(6)1.02
LEH			(1) .22		(10) .90		(11)1.12		(11)1.12
CAM			(1) .70		(1) .20		(2) .90		(2) .90
Total	0	0	(240)15.09	0	(360)21.82	0	(600)36.91	0	(600)36.91
Avg wt (kg)	-	-	.06	-	.06	-	.06	-	.06
Effort (man-hrs)	0	0	23.0	0	120.0	0	153.0	0	153.0
Effort (gear-hrs)	0	0	5.5	0	26.0	0	31.5	0	31.5

taken by hook and line and gill net, but were not taken by spear-fishermen.

For every method, the average weights of fishes caught on the lightly fished reefs were greater than the average weights taken on the heavily fished reefs (Tables 9-13). This was true for most of the comparable heavily and lightly fished reef flat pairs as well. The differences in average weights were not large for most methods, but were quite noticeable for the hook and line.

Standing Stock Densities

The great majority of the fishery groups censused, of all size classes, were more abundant on the lightly fished reefs than on the heavily fished ones (Table 14). Because of the high seasonal and inter-habitat variability in abundance over the sampling period, only a few of the fishery groups showed statistically significant differences in their densities on heavily and lightly fished reefs. Most of the statistically significant differences were among the large size classes which are the major target groups and which would be expected to show the greatest effects of fishery mortality. Fishes that had significantly different densities tended to be the larger bodied carnivorous species.

The fishery groups which were most abundant on the heavily fished reefs were either groups whose juveniles enter reef flat environments in highly seasonal "runs" (such as siganids, mugilids, mullids, and scarids) or Scolopsis cancellatus, a species which is not desired and not targeted by fishermen on the reef flat. This latter species was

Table 14. Overall mean densities (no. per 600 m^2) of fishery groups by size, calculated by averaging the mean densities of all the comparable heavily (H) and lightly (L) fished habitats (Tables 15-17). Habitats within which the fishery groups were never observed were omitted, and the number of habitat pairs within which representatives of the fishery group size class were observed at least once is designated by N. The total possible N equals 11. Asterisks indicate signficant difference as determined by the paired comparisons test. Fishery group abbreviations, size class boundaries, and trophic categories are given in Tables 1-2. Densities that are larger for either the heavily or lightly fished reefs are underlined. (*Scolopsis cancellatus* [SCO] is not included in total, herbivore, or carnivore because it is not considered a target species. Significance levels: $p<.05$[*], $p<.01$[**].)

Fishery Groups	Small			Medium			Large		
	N	H	L	N	H	L	N	H	L
ACS	9	.44	.59*	8	.44	.60	7	.26	.53
ACN	8	.56	1.34	7	.75	1.54	6	.42	.74
CTS	9	.89	.90	7	.82	1.20	6	.57	.68
ACL	8	.45	.61	7	.27	.66	7	.25	.47
ACT	11	6.28	9.29	11	5.31	6.02	11	1.35	2.79*
NAS	8	.97	1.55	6	.24	.90	7	.11	.54
SIG	10	18.48	3.39	10	2.21	1.08	8	2.08	1.90
KYP	4	.13	.21	5	.10	.24	4	.18	.25
SCA	10	7.85	7.01	9	1.85	3.04	8	1.05	2.23*
LAB	9	.73	.93	9	.51	.69	9	.13	.47**
LUT	6	.25	.26	6	.19	.35	4	.01	.08
LEH	9	.20	.74	10	.26	1.45*	9	.07	.90*
SER	1	0	.04	5	.04	.23	3	.02	.18**
CAM	5	.33	.96	7	.03	.14	7	.01	.20
SCO	9	1.31*	.61	10	5.39	1.78	7	1.39	.71
MUF	8	2.87	2.09	8	1.75	1.28	8	1.10	1.47
PAS	10	.43	.58	10	.19	.30	8	.10	.24*
MUG	5	.47	.43	6	.78	.52	4	.43	.59
TOTAL	11	36.57	28.59	11	13.18	16.47	11	5.82	10.36*
HERB	11	25.69	16.22	11	8.95	10.21	11	3.85	6.05*
CARN	11	3.52	4.08	11	2.24	3.51	11	1.06	2.48

the only one which was significantly more abundant (at small sizes) on heavily fished reef flats than on lightly fished ones.

Comparisons of fishery group densities between comparable reef habitats showed more cases of significant differences between heavily and lightly fished reef flats (Tables 15-17). In most cases for the small size classes, significant differences varied between the heavily and lightly fished habitats with few fishery groups being consistently more dense in either heavily or lightly fished habitats (Table 15). However, the undesired species Scolopsis cancellatus was significantly more dense in four habitats of the heavily fished Togcha channel than it was at Ajayan channel. Siganid juveniles were also generally more abundant in heavily fished habitats and significantly more abundant in two of them. L. harak juveniles showed the opposite trend with the densities being greater in the lightly fished habitats. Obvious differences in the small size class densities were seen at the moats of Ajayan and Togcha. The lightly fished habitat of Ajayan moat had five small size class fishery groups, in addition to carnivore densities, that were significantly more dense than at the moat of Togcha. Scolopsis cancellatus was significantly more dense at the Togcha moat.

In general, significantly greater medium size class densities of individual fishery groups appeared more often in the comparable lightly fished habitats than in the heavily fished habitats (Table 16). For at least two habitat pairs, the siganids, M. flavolineatus, and S. cancellatus exhibited the reverse trend and had significantly greater densities in heavily fished habitats. The difference in S. cancellatus densities were quite extreme in Togcha moat and channel margin as compared to the moat and channel margins at Ajayan. Certain comparable

Table 15. Mean densities (for all 24 counts) of the small size classes for fishery groups of comparable habitats on heavily (H) and lightly (L) fished reefs. Asterisks indicate significantly different densities as determined by the least significant range test. Fishery group abbreviations, size class boundaries, and trophic categories are given in Tables 1-2. (<u>Scolopsis cancellatus</u> [SCO] is not included in total, herbivore, or carnivore because it is not considered a target species. Significance levels: p<.05 [*], p<.01 [**].)

Fishery Groups	Inner Reef Flat H Rizal	Inner Reef Flat L Facpi	Outer Reef Flat H Rizal	Outer Reef Flat L Facpi	Sand Zone H Tanguisson	Sand Zone L Uruno	<u>Acropora</u> Moat H Tanguisson	<u>Acropora</u> Moat L Uruno
ACS	.04	.08	.21	.42*			.33	.25
ACN	.13	.08	.17	1.21***			.17	.08
CTS	.33	.08	.21	.21			1.79*	.75
ACL	.29		.63	.96			.04	.33
ACT	2.0	15.13**	17.08*	9.42	9.92	28.71**	6.46	7.75
NAS	.38	.38	1.63	.88			1.38	.75
SIG	35.58*	4.79	19.17	.08	8.04	2.33	8.38	1.46
KYP						.25		
SCA	.71	.58	2.58	.96		.54	14.79	19.00
LAB	1.46**	.54	.04	.08			1.58	2.21*
LUT	.08	.25					.13	
LEH	.21	.13	.04				.13	.33
SER								
CAM	.17	.54			.83	.96		.04
SCO	.17				.08		.50	.13
MUF	.42	.04			6.21*	2.00	6.42*	1.29
PAS	1.58**	.54	.38	.42	.08		.21	.08
MUG					1.21	1.54		.21
TOTAL	48.28	23.17	42.13*	14.63	26.29	36.66	41.79	43.54
HERB	39.21	20.54	39.08*	13.17	17.96	31.29	18.54	11.38
CARN	3.92	2.04	.46	.50	7.13*	2.96	8.46*	3.96

Table 15 Continued.

	Acropora Platform		*Sargassum*-Seagrass Bed		Island Zone		Platform	
Fishery Groups	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Togcha	L Ajayan	H Togcha	L Ajayan
ACS	.96	1.21*	.42	1.00**	.13	.13		
ACN	.50	.83	.04		.50	.25		
CTS	.50	.96	.08	.08	.96	.38		
ACL	1.21	1.67*		.08	.17			
ACT	10.42	8.21	3.17	1.46	5.38	8.75	8.63	14.63
NAS	1.46	1.21	.13	.17	.25	.38		
SIG	4.63		91.71**	11.50	9.75	6.08		
KYP					.29	.42		
SCA	14.75	19.00	4.50	9.67	15.67**	4.88		
LAB	.58	1.33*	.88	1.04	.71	.92	.04	
LUT					.38*	.08		
LEH		.08	.50	3.00**	.04	.71		
SER								
CAM					.17	2.17		
SCO	.63	.17	1.13	1.04	1.67**	.63		
MUF			.63	3.17	5.21	2.75		
PAS		.08	.38	1.71**	.25	.63		
MUG					.08			
TOTAL	35.00	34.58	102.50**	32.88	39.92	28.50	8.67	14.63
HERB	19.67	14.08	95.54**	14.29	17.42	16.38	8.63	14.63
CARN	.58	1.50	2.38	8.92**	6.75	7.25	.04	

Table 15 Continued.

Fishery Groups	Mud Zone H Togcha	Mud Zone L Ajayan	Moat H Togcha	Moat L Ajayan	Channel Margin H Togcha	Channel Margin L Ajayan
ACS	.58	.71	.58	.71	.71	.83
ACN			.58	1.21	2.38	7.08**
CTS	.08	.29	1.29	2.92**	2.79	2.42
ACL				.04	1.25	1.83**
ACT	.67	2.54	1.88	2.63	3.50	3.00
NAS			.92	3.83**	1.58	4.83**
SIG	1.83	1.33	3.50	2.46	2.25	3.83
KYP			.21	.13		.04
SCA	2.21	1.92	7.54	10.42	15.75**	3.13
LAB			.63	1.46*	.63	.75
LUT	.17		.29	.86**	.46	.38
LEH	.04		.54	1.13	.33	1.25*
SER				.04		
CAM	.50	1.08				
SCO	1.46*	.67	2.83**	1.46	3.33**	1.38
MUF	1.63	2.38	1.54	4.79	.88	.29
PAS		.04	.42	1.08*	1.00	1.17
MUG	1.04*	.25		.13		
TOTAL	8.75	11.54	19.92	33.83	33.50	40.83
HERB	3.17	4.88	8.96	13.92	14.46	23.88
CARN	2.33	4.50	3.42	9.38**	3.29	3.83

Table 16. Mean densities (for all 24 counts) of the medium size classes for fishery groups of comparable habitats on heavily (H) and lightly (L) fished reefs. Asterisks indicate significantly different densities as determined by the least significant range test. Fishery group abbreviations, size class boundaries, and trophic categories are given in Tables 1-2. (*Scolopsis cancellatus* [SCO] is not included in total, herbivore, or carnivore because it is not considered a target species. Significance levels: p<.05[*], p<.01[**].)

Fishery Groups	Inner Reef Flat H Rizal	Inner Reef Flat L Facpi	Outer Reef Flat H Rizal	Outer Reef Flat L Facpi	Sand Zone H Tanguisson	Sand Zone L Uruno	*Acropora* Moat H Tanguisson	*Acropora* Moat L Uruno
ACS	.04	.08	.21	.54			.46	.54
ACN	.04	.13		1.21			.25	.21
CTS	.04						.83	.54
ACL	.04	.04	.13	.58				.38
ACT	1.58	5.25**	4.88	4.63	.75	.04	11.67	14.88**
NAS			.21	.04				.46
SIG	3.50**	.67	1.33	.25	.04		5.85**	.71
KYP						.13		
SCA		.13	.71	1.00			1.58	4.71**
LAB	1.00	.46	.21	.25		.04	1.25	1.04
LUT	.04	.25						.04
LEH	.13	.21	.04	.29		.13	.13	1.75*
SER							.04	.58*
CAM	.08	.08				.29**	.04	.08
SCO	.08	.13		.17	.04		1.25	.38
MUF					1.21	.42	5.42*	.88
PAS	.75*	.54	.08	.08	.04		.13	.25
MUG					4.17*	.33		2.08
TOTAL	7.24	7.83	7.79	8.88	6.21	1.36	27.38	29.13
HERB	5.25	6.17	6.75	7.25	.79	.17	18.79	17.71
CARN	2.00	1.54	.33	.63	1.25	.88	7.00	4.63

Table 16 Continued.

Fishery Groups	*Acropora* Platform		*Sargassum*-Seagrass Bed		Island Zone		Platform	
	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Togcha	L Ajayan	H Togcha	L Ajayan
ACS	.96	2.33**			.04	.13		
ACN	.46	.96			.25	.17		
CTS	.42	.83	.04	.04	.75	.25		
ACL	.46	1.92**			.42			.17
ACT	11.25	14.00*	.63	.92	6.08	7.71	2.96	2.58
NAS	.08	.88				.04		
SIG	1.08	.42	4.29	3.63	3.38	1.67		
KYP		.08			.33	.13		
SCA	2.67	6.13**	.04	1.00	1.79	3.67*		.25
LAB	.54	.92	.46	.13	.17	.54		
LUT			.04		.17	.04		
LEH	.08	.88	.38	2.04*	.08	1.17		
SER		.13			.04	.04		
CAM	.04					.25*		
SCO	.79	.75	1.46	.33	5.96	1.67		
MUF	.04	.08	.08	.17	1.46	2.29		
PAS	.08	.08		.29**		.33**		
MUG					.17	.29		
TOTAL	18.17	29.63**	5.96	8.21	15.13	18.71	2.96	3.04
HERB	14.71	21.42**	4.96	4.58	11.25	10.08	2.96	2.79
CARN	.79	2.08	.96	2.63	1.92	4.67		.25

Table 16 Continued.

Fishery Groups	Mud Zone H Togcha	Mud Zone L Ajayan	Moat H Togcha	Moat L Ajayan	Channel Margin H Togcha	Channel Margin L Ajayan
ACS		.04	.63	.58	1.17	.63
ACN			1.00	1.50	3.25	6.58**
CTS			.88	2.75**	2.79	3.96*
ACL					.83	1.54
ACT	.58	.29	5.33	7.54*	12.67**	8.42
NAS			.08	.75	1.04	3.25**
SIG	.21	.08	1.42	1.83	1.00	1.54
KYP				.33	.17	.54
SCA			1.83	4.25*	8.04	6.25
LAB			.50	1.75**	.42	1.08*
LUT			.33	1.04**	.54	.75
LEH	.08		.67	4.04**	1.04	4.00**
SER			.08	.29	.04	.13
CAM		.25*	.04	.04		
SCO	.21		17.46**	6.42	26.67**	7.92
MUF	.13		1.38	5.46*	4.25*	.96
PAS		.08	.38	.75**	.46	.63
MUG	.33	.25		.08		.08
TOTAL	1.33	1.00	14.54	33.00**	37.71	40.33
HERB	.79	.42	9.33	15.29**	22.92	26.46*
CARN	.21	.33	3.38	13.38**	6.75	7.54

Table 17. Mean densities (for all 24 counts) of the large size classes for fishery groups of comparable habitats on heavily (H) and lightly (L) fished reefs. Asterisks indicate significantly different densities as determined by the least significance range test. Fishery group abbreviations, size class boundaries, and trophic categories are given in Tables 1-2. (*Scolopsis cancellatus* [SCO] is not included in total, herbivore, or carnivore because it is not considered a target species. Significance levels: $p<.05$[*], $p<.01$[**].)

Fishery Groups	Inner Reef Flat H Rizal	Inner Reef Flat L Facpi	Outer Reef Flat H Rizal	Outer Reef Flat L Facpi	Sand Zone H Tanguisson	Sand Zone L Uruno	*Acropora* Moat H Tanguisson	*Acropora* Moat L Uruno
ACS	.08	.13	.04	.25			.17	.33
ACN		.04		.54				
CTS	.21	.04					.29	.13
ACL		.08	.04	.46				.04
ACT	1.08	2.79*	1.54	2.38	.04		2.0	6.36**
NAS		.04		.25				.17
SIG	.38	.75	.17	.17			3.13	3.03
KYP								
SCA	.08	.08	.08	.54			.71	3.63**
LAB	.08	.08		.13			.38	.63
LUT		.04						
LEH		.08				.08	.04	1.75**
SER							.04	.17*
CAM						.58**		.04
SCO		.20					.58	.21
MUF		.04			.38	.04	4.54	1.79
PAS	.08	.08	.04				.04	.17
MUG							.88	1.96
TOTAL	2.00	4.29	1.92	4.71	.42	.71	12.21	20.17*
HERB	1.75	3.88	1.79	4.04	.04		5.88	10.04**
CARN	.17	.33	.04	.13	.38	.71	5.04	4.54

Table 17 Continued.

	Acropora Platform		*Sargassum*-Seagrass Bed		Island Zone		Platform	
Fishery Groups	H Tanguisson	L Uruno	H Togcha	L Ajayan	H Togcha	L Ajayan	H Togcha	L Ajayan
ACS	.45	1.92**			.04	.08		
ACN	.50	.38			.08	.08		
CTS	.25	.58			.38	.13		
ACL	.65	1.24*			.25			
ACT	1.96	6.46**	.13	.25	2.08	4.88**	1.00	1.25
NAS	.04	.50			.04	.04		
SIG	1.38	1.92	2.88	2.21	3.75*	2.75		
KYP		.33			.33	.33		.04
SCA	.88	4.38**		.04	1.08	1.83		
LAB	.17	.88**	.13	.30	.08	.50*		.13
LUT					.04	.04		
LEH	.21	1.17*	.04	.67	.08	.21	.04	.08
SER								
CAM			.08					.42*
SCO	.75	.29	.21	.13	1.54	1.04		
MUF			.08		.29	1.58		
PAS		.13		.29**	.04	.17		
MUG							.42	.17
TOTAL	6.25	20.25**	3.33	3.75	8.58	12.63	1.46	2.08
HERB	5.00	13.71**	3.00	2.46	6.96	8.29	1.00	1.29
CARN	.38	2.17	.33	1.25	.54	2.50	.04	.63

Table 17 Continued.

Fishery Groups	Mud Zone H Togcha	Mud Zone L Ajayan	Moat H Togcha	Moat L Ajayan	Channel Margin H Togcha	Channel Margin L Ajayan
ACS			.29	.42	.75	.62
ACN			.46	.71	1.50	2.71**
CTS			.63	1.46*	1.67	1.75
ACL			.04		.79	1.46*
ACT	.13	.04	.96	2.96*	3.88	3.29
NAS				.58	.67	2.21**
SIG			2.17	2.71	2.79*	1.67
KYP					.38	.29
SCA			.58	2.67*	5.00	4.67
LAB			.04	.83**	.29	.71*
LUT				.08		.17
LEH			.04	1.46**	.21	1.67**
SER				.17**	.04	.21**
CAM		.25		.04		.08
SCO			1.88	1.33	4.75**	1.75
MUF	.21		1.38	6.54**	1.92	1.75
PAS			.29	.63**	.33	.42
MUG	.38	.04	.04	.17		
TOTAL	.71	.33	6.92	21.42**	20.21	23.67
HERB	.13	.04	4.54	8.83**	12.42	14.00
CARN	.21	.25	1.75	9.75**	2.79	5.00

habitat pairs exhibit a relatively large number of significant differences in fishery group densities than others. These habitat pairs were the Acropora moat and platform of Tanguisson and Uruno and the moat and channel margin of Togcha and Ajayan. The greatest number of significant differences was seen in the moats of Togcha and Ajayan in which 8 fishery group densities along with the total standing stock, herbivore, and carnivore densities of the lightly fished habitat at Ajayan were significantly more dense than the heavily fished habitat at Togcha.

In almost every case where significant differences were evident for the large size class densities in comparable habitat pairs, the densities were greater for the fishery groups in a lightly fished habitat (Table 17). The same was true for the total standing stocks, herbivores and carnivores. As with the medium size class, however, the siganids were significantly more dense in two heavily fished habitats, and S. cancellatus was significantly more dense in one heavily fished habitat. The same habitat pairs that were recognized for the medium size classes (the Acropora moat and platform of Tanguisson and Uruno and the moat and channel margin of Togcha and Ajayan) as having a large number of fishery groups with significantly different densities, also had a large number of fishery groups of the large size class with significantly different densities. Most of the densities were significantly greater in the lightly fished habitats.

DISCUSSION

The heavily fished reef flats are characterized by lower standing stock densities of target groups, lower catch rates, and generally smaller sized fish in the catch than is the case on the lightly fished reef flats. These differences seem clearly attributable to the effects of differing fishing pressures applied to these reefs.

Particularly striking are the differences in catch rates between comparable heavily and lightly fished reefs: the heavily fished reefs are subject to about 6 times the fishing effort (in terms of man-hours), yet the total catches are less than 2 times the catches of the lightly fished reefs; as a consequence, catch rates (in kg/man-hr) on the heavily fished reefs are only 1/4 to 1/5 of what they are on the lightly fished reefs (Table 4). Also, certain fishery groups were almost absent from the catches on the heavily fished reefs despite much greater fishing effort. This was particularly evident in the hook and line fishery in which effort was 6 times greater on the heavily fished reefs, yet the catches of the large carnivores Lethrinus harak and Caranx melampygus, which are typically selected for by hook and line, were less than 10% by weight what they were on the lightly fished reefs (Table 9). Fishermen interviewed on some of the heavily fished reefs indicated that, in fact, the catches of the lethrinids and carangids had decreased noticeably over the past 10 years (especially the largest size classes).

Similar results were witnessed in Hawaii where overfishing led to the decline of two groups of large carnivores (the serranids and carangids) in the fishery catches (R. E. Brock, pers. comm. 1981). These data strongly suggest that the heavily fished reefs are overfished.

If the catch and effort data from comparable reef pairs are used to construct a Schaefer surplus production curve (Figure 5), recognizing that a curve based on only two points can be little more than suggestive, the maximum sustainable yield (MSY) is predicted to be considerably greater than the yield harvested on either the lightly or heavily fished reefs, and the effort which would harvest the MSY lies between the present effort on the lightly fished reefs and that of the heavily fished reefs. This analysis indicates that yields would increase on the lightly fished reefs if more effort were expended in these areas. On the heavily fished reefs, however, improved catch rates and increases in the total yield should result from reduction of fishing effort.

The three curves generated from the catch and effort data from the comparable reef flat pairs varied in size and shape (Figure 5). This suggests that the MSY and the effort needed to obtain the MSY may vary among reef flats depending on the intrinsic qualities of the areas. The small intertidal reef flats of Rizal and Facpi, for instance, could sustain only about 20 kg/ha/year under about 40 man-hours/ha/year of effort. The large channel system of Togcha and Ajayan, with a diverse array of deeper habitats, however, could sustain about 60 kg/ha/year under about 170 man-hours/ha/year of effort. This is, of course, assuming that the methods employed on these reefs are somewhat

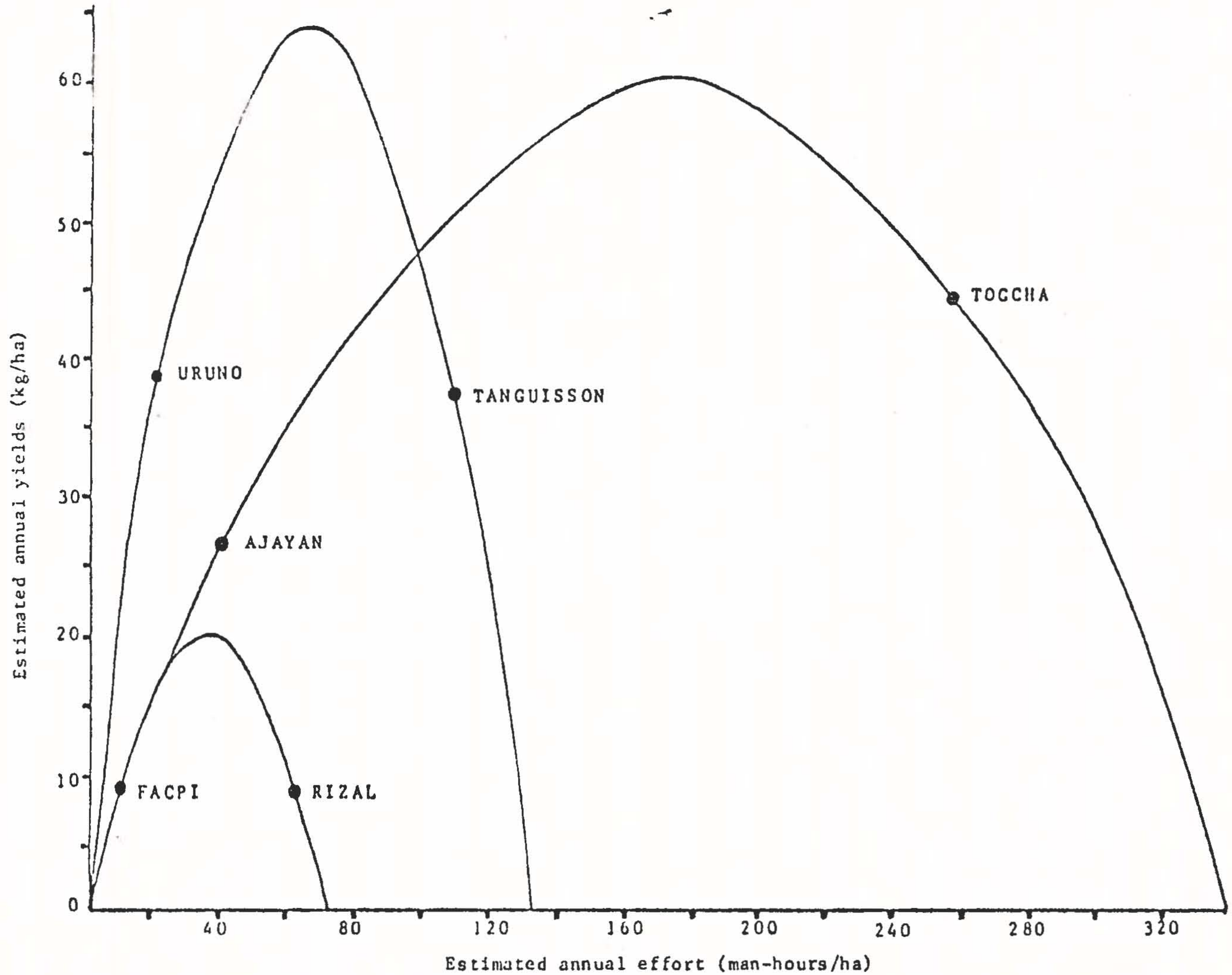

Figure 5. Schaefer surplus production curves for the three reef flat pairs. Each data point represents the sum of catch and effort data for 36 creel census days, multiplied by 10 to estimate annual values.

representative of what is presently being used on the respective reefs. Although the reef flats of Togcha, Ajayan, Tanguisson, and Uruno theoretically could sustain about 60 kg/ha/year, it would take about half the effort to do so on Tanguisson and Uruno than on Togcha and Ajayan. The existence of such differences in the potential yields and optimal levels of effort for certain reef flat types, and perhaps even habitats, suggests that management measures may be most effective in the tropics if they are designed for individual reef areas rather than the entire islands or large regions (however, see Munro 1978).

Presently the estimated annual fish harvests per reef area on the reef flats in this study ranged from 44.6 kg/ha on Togcha to 8.5 kg/ha at Rizal. The estimated annual harvest on four selected Pacific Atolls ranged from 51.4 kg/ha (5.14 g/m^2) on Ifaluk to 0.9 kg/ha (.09 g/m^2) on Raroia, and the range in annual harvests from selected fisheries on the reefs and adjacent shallow water area in other tropical islands ranged from 47 kg/ha (4.7 g/m^2) in Mauritius to 4 kg/ha (.4 g/m^2) in Bermuda (Stevenson and Marshall 1974). The harvest values obtained in this study were within the range of estimated values from a variety of tropical fisheries. If the Schaefer curves in Figure 5 are accurate predictors of potential maximum sustainable yields, the annual harvests could reach 20 kg/ha to 60 kg/ha if harvested optimally.

The overall catch rates on the lightly fished reefs were at least 4 times those of the heavily fished reefs. Assuming that catch rates should be proportional to the density of fishable stocks available to the fishery, one would predict the fish densities to be about 4 times greater on the lightly fished reefs. For some of the larger carnivores this was true (Table 14), but for the majority of fishery groups it was not. Apparently the catch rates were not exactly proportional to the stock densities, which is not an unusual situation (Gulland 1969).

Jane Jennison-Nolan (1979) lists 7 reef fish groups which are most highly preferred as food on Guam: rabbitfish, snappers, surgeonfish, parrotfish, groupers, rudderfish, and jacks. Of these, Acanthurus triostegus (a surgeonfish), Scaridae (parrotfish), Serranidae (groupers), and Caranx melampygus (a jack) were caught at lower rates and were significantly less abundant among the large size classes (except C. melampygus) on the heavily fished reef flats than on the lightly fished ones (Table 14). Preferential harvesting of these preferred groups may be responsible for their reduction in heavily fished areas. This, however, was not the case for the siganids which were more abundant on the heavily fished reefs. Because of their highly seasonal recruitment which shows great differences from year to year in an apparently random pattern (Kami and Ikehara 1976), siganid abundances and catch rates may be unrelated to fishing pressure.

A variety of trophic levels were affected by the heavy fishing pressure. The density of total herbivores of the large size class was significantly less on the heavily fished reefs than it was on the lightly fished ones, although only one herbivore fishery group (A. triostegus) was significantly less dense in the heavily fished reefs (Table 14). The density of total carnivores combined was not significantly less on the heavily fished reefs, although 4 of the 6 fishery groups that were significantly less dense in heavily fished reefs were carnivores. One reason why the collective groups of carnivores was not significantly less dense in the heavily fished reefs was because of the relatively high densities of Mulloidichthys flavolineatus on the heavily fished reefs. Like the siganids, M. flavolineatus is highly variable in abundance and recruits seasonally in large numbers on the reef flats. The only omnivore (Scaridae) was also significantly less dense in the large size class in the heavily fished reefs. Although on an individual fishery group basis the carnivores were most affected by heavy fishing pressure, other trophic groups were also affected.

Fishes that typically grow to a relatively large body size seemed more affected by fishing pressure than were small bodied fishes. In fact, of the large size classes that were significantly less dense in the heavily fished reefs (Table 14) only A. triostegus was of the small body size grouping (Table 1). Gulland (1976) suggested that larger bodied predators should decline more rapidly than would smaller bodied prey in an exploited stock because the larger bodied fishes have slower turnover rates and would be slower to replace individuals lost to the fishery, and populations of these fish would reach equilibrium at smaller stock sizes than short-lived smaller bodied fishes.

The increase of undesirable species as a result of overfishing is well documented in the tropical Pacific (Huat 1980, Pauly 1979b). The undesired species in this study (Scolopsis cancellatus) showed higher densities in the heavily fished reefs for all size classes and a significantly higher density among the small size classes (Table 14). Perhaps the significant reduction of the larger bodied carnivores has reduced predation on this smaller bodied carnivore and permitted an increase in densities. An additional cause for such an increase may be the significant loss of Lethrinus harak on the heavily fished reefs, a species which has very similar feeding habits to those of S. cancellatus (Hiatt and Strasburg 1960). This may be permitting the reapportioning of additional food to the S. cancellatus stocks allowing for higher stock densities. Tables 15-17 show that the two most highly preferred habitats for S. cancellatus are the moat and channel margin of the channel systems (Togcha and Ajayan). These were also the same habitats in which the increases in S. cancellatus densities were greatest on the heavily fished reef of Togcha. This suggests that although increases of undesirable species are likely to occur when target predators or competitors are removed, the effect may be more pronounced in specific habitats.

The overall density of biological recruits (members of the small size class) was actually greater on the heavily fished reefs than the lightly fished ones; however, the majority of individual fishery groups had greater recruit densities on the lightly fished reefs (Table 14). Nonetheless, few significant differences were seen between recruit densities on the heavily and lightly fished reefs, and it appears that heavy fishing pressure did not significantly lower the recruitment rates on the heavily fished reefs.

This result is not surprising considering the nature of recruitment in most tropical reef fishes. It has been generally accepted that tropical species produce many more offspring than would normally be required to occupy the available space on reefs (Sale 1977). Very few breeding fish may be needed to repopulate the reef. Further, the relatively long pelagic larval lives (estimated 2.5 months for Acanthurus triostegus, Randall 1961) of the majority of fishes in this study (Johannes 1978a, Sale 1980) would allow recruits to disperse over wide areas and invade reef flats in densities independent of local breeding stocks. Thus, it is quite possible that fishes from outlying reefs are producing the offspring that recruit to some of the heavily fished reefs.

The heavily fished reef flats surveyed during this study show signs of overfishing, and it is likely that other accessible reef flats on Guam are equally overfished. Under these conditions, management measures designed to increase catch rates and total catch may be appropriate. Two possible objectives of management would be (1) to improve total reef flat fishing catches to provide maximum sustainable yields for the subsistence fishery, and (2) to maximize, to the extent possible, the recreational opportunities offered by reef flat fishing without necessarily striving for maximum sustainable yields.

If the objective is to obtain maximum sustainable yields in the subsistence fishery, then it would be necessary to control fishing effort on the reef flats. This could be achieved by reducing fishing effort on the heavily fished reefs to a level at which maximum sustainable yields could be obtained (as predicted by Schaefer production model analysis) and relocating this fishing effort onto lightly fished reefs to increase yields. Such measures, however, would have to be monitored closely to ensure that increased yields did, in fact, occur. A sample of some of the fishes found to be most highly affected by heavy fishing pressures could be used as indicator species in the monitoring. In addition, any restrictions on fishing effort would have to be designed so that they would not unduly disrupt social and cultural fishing practices and would be equitable to all fisherman. It is possible that certain fishes that are less responsive to fishing pressure, such as the siganids, could continue to be harvested at their present levels, but the harvesting would have to be done with more selective methods, such as the cast net or surround net, which can target on siganids but could avoid other fishery groups.

Because of the small scale of the fishery and the small sizes of the reef flat fishes, it is highly unlikely that the fishery will ever become heavily commercial. However, instances in which local reef flat fishes are sold publicly invite many fishermen to overexploit for increased profits. It also encourages fishermen to use illegal methods (such as dynamite and chlorine) that provide them large catches with a minimum of effort. Restricting commercial sale of reef flat fishes would still allow the local fishermen to catch what they need for subsistence, but would remove incentives for overexploitation.

Maximizing the recreational usage of the reef flat could be an alternative to increasing the yields of the subsistence fishery. Because the objective would be to allow the maximum amount of sports fishermen to fish, restricting fishing on heavily fished reefs would not be necessary (although even recreational fishermen enjoy catching as many fish as possible). It may be possible, however, to achieve higher sustainable yields in a recreational fishery if certain catch limitations were imposed on the fishermen, such as minimum size limits, bag limits, gear restrictions, or other measures.

If wisely managed, the reef flat fishery of Guam can provide substantial subsistence yields and recreational opportunities for the people of the island for many years to come.

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