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LAGOONAL FISH AND FISHERIES OF DRAVUNI, GREAT ASTROLABE REEF, FIJI, SOUTH PACIFIC.

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by

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INTRODUCTION

The island complex of Fiji is located in the South Pacific approximately between the latitudes of 15° and 20°S and longitudes 170° and 180°E. Fiji began forming by island arc volcanism some 34 million years ago, and may still be active today in the north and east due to tensional rifting[1]. Almost all the islands are high volcanic peaks surrounded by fringing or barrier reefs. Few of the reefs are sufficiently developed to have established low islands on their peripheries.

This study was carried out as a co-operative effort between the Institute of Marine Resources (IMR) of the University of the South Pacific in Suva, and the ROM - CF Canadian 1983 Expedition to Fiji. The expedition had as its main intent a series of synoptic fish collections for use in the zoogeographic analysis of the fish fauna of Fiji. Fiji is strategically set between Pacific and Indo-Australian plates, and is thus an ideal location for zoogeographic analysis.

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[1] Rodda, P. and L. W. Kroenke. Fiji: a fragmented arc. In: Kroenke, L. W. 1984. Cenozoic development of the southwest Pacific. U.N.ESCAP, CCOP/SOPAC Tech.Bull. 6: 87-109.

This analysis is aimed at documenting the origins of the Fiji fish fauna - that is, whether its origins lie with the fauna of the Central Pacific plate or with that of the western Pacific. Certainly, our present knowledge of the Fijian fishes indicates that an affinity with the western Pacific simply because of the number of species common to these two areas that are not found among the islands of the Central Pacific. However, this intuitive analysis has not been assessed by any rigid scientific testing. We plan to conduct such an analysis by studying the phylogenetic relationships of selected groups of species, and seeing how these compare with the geological history of the three areas (Western Pacific, Fiji, and Central Pacific). Such studies have, potentially, information relevant to fisheries management, since they enable predictions concerning the original source of fish stocks, and therefore whether these stocks are robust or fragile. Thus, a subsidiary aim of the expedition was to provide, where possible, an analysis of the fishery potential of any of the local areas studied.

An opportunity to travel to the Great Astrolabe Reef was made possible through the use of the Research Vessel Aphareus, and the IMR Field Station on the island of Dravuni, located within the Astrolabe lagoon (18°45'S, 178°32'E) was used as the base camp. The study is particularly relevant to Fiji and the South Pacific islands because of the ubiquitous rising cost of fish, the rapid increase in fuel cost, and the struggle of a community (whose transport was recently entirely wind-driven) to cope with the mechanical difficulties of diesel and gasoline engines. The communities were traditionally non-economically based (community ownership of all resources including freshly caught fish), and are now trying to combine western technology with the traditional subsistence fishery. In addition, the contact with western society has made tourists aware of the fascinating culture of the Pacific islanders. Responding to tourist requests, ships have visited coastal villages where the local inhabitants perform for the tourists in return for payment. The island of Dravuni was one such, sharing the duties and the profits with the island of Bulia. The impact of these ships and their loads of tourists will also be assessed briefly.

Finally, there is the tradition of Canadian assistance to Fiji, and in involving a major Canadian museum and members of the Canadian Armed Forces, this study is an extension of that tradition.

METHODS AND MATERIALS

Sampling of various habitats was carried out using SCUBA gear to depths of 30 m. Fish were collected while on SCUBA using rotenone (either in liquid or powder form), which was applied to carefully selected areas in small quantities. Rotenone collecting is effective for cryptic and territorial fishes, but samples free-ranging and large species irregularly. Thus we augmented these collections using spears to sample species that were not affected by the rotenone. Two types of spears were used: large gun-fired spears and pole spears for large specimens, and small multibarbed spears fired from slings for intermediate and small specimens.

On several occasions, we sampled open sand areas by using gill nets (2.5" stretch mesh) and traps (0.75" mesh). Traps were also placed on patch reefs overnight.

The Dravuni fishing cooperative was sampled by interviewing the fishermen and woman; by counting and estimating the weight, or by weighing, the fish brought in; by accompanying the fishermen (especially those spearing) and observing their techniques, and by interviewing the accounting clerk of the village.

In making the fish collections, a variety of habitats were sampled:

1) Shoreline tide pools (using rotenone).
2) Shoreline sandy beaches

    (a) above the tide line (using rotenone)
    (b) below the tide line (using gill and seine nets, and spears)

3) Patch reefs (using traps, spears and rotenone)
    (a) shallow
    (b) deep
        i) top
        ii) on sides
        iii) at sand/coral interface from 5 - 30 m.

4) Inside main reef (using rotenone and spears)
    (a) on the top
    (b) on current-swept patches

Each collection was sorted for previously uncollected species, and these were photographed, noting the species name or with a short description of the specimen. Field numbers were assigned each collection, and field notes documented the location, depth, habitat, date, time, water quality, etc at each site. Informal notes were also taken, describing the different habitats and relative abundances of the larger, and potentially exploitable, species.

RESULTS

I. HABITATS AND DOMINANT SPECIES[2]

A. Shoreline Tidepools:

On Dravuni and Vanaukul Islands on the Great Astrolabe Reef, tidepools were all small (less than 3 m in diameter and less than 0.5 m deep), mostly only a few centimetres deep and less than 1 m across. Unlike many areas in the tropics, these tidepools are not productive for food products. We were informed by the locals on Dravuni that a few species of periwinkles were harvested for food on other islands.

Our collections included an abundance of blenniid rockskippers, gobies and damselfish, with a few small mullets, moray eels, and scorpion fish. Even the largest of these would not have been acceptable as food fish. During one of the tidepool collections a sea snake was attracted to the pool, entering it and remaining there until after we had left. Subsequent collections of sea snakes indicated that their diet includes morays of at least up to 50% of their own body length.

DOMINANT SPECIES - TIDEPOOLS

MURAENIDAE - Moray eels (051)
- Gymnothorax pictus (grapsid crabs).

SCORPAENIDAE - Scorpionfishes (381)
- Scorpaenodes guamensis (small invertebrates).

MUGILIDAE - Mullets (437)
- Crenimugil crenilabrus (detritivore).

POMACENTRIDAE - Damselfishes (428)
- Chrysiptera glauca (herbivore).
- Abudefduf sordidus (planktivore).

BLENNIIDAE - Blennies (465) {Herbivores}.
- Istiblennius periophthalmus
- I. lineatus 0
- I. cyanostigma
- I. edentulus
- Praealticus sp.

GOBIIDAE - Gobies (494)
- Bathygobius cocosensis (small invertebrates).

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[2]. The lists of dominant species for most of the habitats are based on the collections we made and include only those species for which 15 or more specimens were taken in a single collection. The exceptions, marked with an asterisk, are those larger, more visible species which were dominant but not particularly susceptible to our collecting methods.

B. Shoreline Sand Beach:
Sand beach areas are extensive on the high islands in the Astrolabe Reef, and are thus important habitats. On Dravuni and Vanuakula Islands, they comprised about 85% of the shoreline. Two areas were sampled:

1. above the tide line
2. below the tide line

An area of ground water seepage was poisoned above the tide line but no specimens were recovered. Thus it seems unlikely that ophichthids, kraemeriids, or creediids are to be found in these areas, and this may be correlated with size of sand grains and thus rates of seepage.

Several different types of samples were taken below the tide line, and a typical sand-associated fish community was found. Juvenile jacks (carangids) foraged in the surge, kuhliids, mullids, gerreids, and mugilids were the dominant forms in the near-shore sand areas to depth of about 3-4 m. The average size of the mullets was about 1.0 kg, of the jacks about 0.3 kg. Mullids and gerreids ranged from 0.3 kg down to small specimens.

DOMINANT SPECIES - SHORELINE

KUHLIIDAE - Flagtails (365)
Kuhlia mugil (planktivore).
CARANGIDAE - Jacks (380)
Trachinotus baillonii (piscivore/invertebrates).
T. blochii
GERREIDAE - Mojarras (395)
Gerres oyena (sand dwelling invertebrates).
MULLIDAE - Goatfishes (403)
Mulloides flavolineatus (invertebrates).
MUGILIDAE - Mullets (437)
Mugil cephalus (detritivore).

The local people utilized this area poorly. They did not use a beach seine and there was only one small gill net on the island. The gill net catches which we initiated were quickly assimilated into the commercial catch, however.

C. Patch Reefs:
Patch reefs are highly variable environments, but can probably be properly classed into two types:

1. Shallow-water reefs occurring just offshore, but separated from it.

2. Deep-water reefs occurring well offshore with a steep outer margin falling to depths where coral growth is severely limited. In the Astrolabe Reef Lagoon, we found this depth to be about 15 m.

Type 1: Shallow-water reefs. Two gross habitats are located in these reefs. The first is the shallow, wave-swept tops with abundant coral and coralline algae growth. This area is dominated by damselfish, blenniids, butterflyfish and wrasses. The second major habitat is one utilized by local spear-fishermen, especially the youngest. It is the outer face of the patch which slopes to a sand or rubble bottom, and is pierced by small caves and interstices. Once again, damselfish and wrasses predominate, but in addition, a wide variety of larger species can be found including siganids, acanthurids, cirrhitids, small serranids and balistids. In the caves, apogonids and holocentrids are abundant.[3] Only the acanthurids, serranids and balistids were large enough to be of a value to the local residents as food fish. By example, just after the hurricane (Cyclone Oscar) went over the island, and during the following bad weather, most of the food protein was derived from spearing on these patch reefs. One young lad used a hand-make sling and spear but speared only triggerfish. His catch of 37 specimens was comprised of two species, Sufflamen chrysoptera and Rhinecanthus aculeatus.

DOMINANT SPECIES - SHALLOW INSHORE REEFS

MORINGUIDAE - Spaghetti eels (049).
Moringua sp. (sand-dwelling invertebrates).
CLUPEIDAE - Herrings (079)
Spratelloides delicatulus (planktivore).
SYNODONTIDAE - Lizard fishes (120)
Synodus dermatogenys (invertebrates and fishes).
PLOTOSIDAE - Eeltail Catifishes (198)
Plotosus lineatus (invertebrates).
BYTHITIDAE - Cuskeels (245)
Dinematichthys iluocoeteoides (invertebrates).
HEMIRAMPHIDAE - Halfbeaks and Gars (247)
Hemiramphus far (herbivore).
HOLOCENTRIDAE - Squirrelfishes and Soldierfishes (277)
Myripristis kuntee (primarily crustaceans).
Myripristis murdjan (ditto).
Myripristis violaceus (ditto).
Sargocentron diadema (ditto).
SCORPAENIDAE - Scorpionfishes (318)
Parascorpaena mossambica (primarily crustaceans).
SERRANIDAE -Rockcods and Groupers (350)
Epinephelus merra (crustacea and fishes).

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[3]. Our collections from these sites often contained components of both habitats, and we provide a single list of dominant species.

Pseudogramma polyacantha (crustacea).

PSEUDOCHROMIDAE - Dottybacks (353)

Cypho purpurascens (crustacea).

Pseudochromis tapeinosoma (crustacea).

PLESIOPIDAE - Longfins (357)

Plesiops verecundus {ms name - do not use} (crustacea).

APOGONIDAE - Cardinalfishes (369) (plankton, benthic crustacea). Apogon aureus

Apogon bandanensis

Apogon coccineus ?

Apogon exostigma

Apogon guamensis

Apogon kallopterus

Apogon nigrofasciatus

Apogon novemfasciatus

Apogon robustus

Apogon taeniophorus

Cheilodipterus macrodon (also fishes).

Cheilodipterus quinquelineatus

Fowleria variegata

MULLIDAE - Goatfishes (403)

Parupeneus barberinus (sand-dwelling invertebrates).

POMACENTRIDAE - Damselfishes (428)

Chrysiptera cyanea (omnivore).

Dascyllus aruanus (zooplankton, some algae).

Plectroglyphidodon lacrymatus (benthic algae).

Pomacentrus amboinensis (algae, some zooplankton).

Pomacentrus lepidogenys (zooplankton).

Pomacentrus philippinus (algae).

Pomacentrus vaiuli (algae).

Stegastes fasciolatus (benthic algae).

Stegastes nigricans (benthic algae).

LABRIDAE - Wrasses (440) {Invertebrates}.

Halichoeres margaritaceus

Halichoeres trimaculatus

Pseudocheilinus hexataenia

Stethojulis bandanensis

Thalassoma hardwickii

SCARIDAE - Parrotfishes (442)

Scarus sp {probably S. sordidus} (benthic algae).

CREEDIIDAE - Sand Borrowers (453)

Limnichthys fasciatus ? (zooplankton).

BLENNIIDAE - Blennies and Rockskippers (465) {Herbivores}.

Cirripectes castaneus

Ecsenius bicolor

Ecsenius fijiensis
Entomacrodus caudofasciatus
Entomacrodus striatus
Istiblennius cf periophthalmus
Praealticus sp

TRIPTERYGIIDAE - Triplefins (471)
Enneapterygius sp (invertebrates).

GOBIIDAE - Gobies (494)
Amblygobius phalaena (detritivore).
Asterropteryx semipunctatus (small invertebrates).
Eviota afelei (invertebrates).
Eviota albolineata (ditto).
Eviota nebulosa (ditto).
Eviota zebrina (ditto).
Gobiodon histrio (ditto).
Trimma caesiura (ditto).
Trimma benjamini {ms name - do not use} (ditto).

ACANTHURIDAE - Surgeonfishes (504)
Acanthurus triostegus (herbovore).
Ctenochaetus striatus (ditto).

SIGANIDAE - Rabbitfishes (505)
Siganus spinus (herbivore).

BALISTIDAE - Triggerfishes and Filefishes (536)
Rhineacanthus aculeatus*
Sufflamen chrysoptera*

Type 2: Deep water patch reefs. At least four habitats are located on these reefs:

1. The top of the reef which is dominated by plankton-picking fishes and active herbivores.
2. The near-surface slope dominated by territorial damselfish, butterflyfishes and a moderate variety of wrasses. A few small serranids were present as well.
3. The deeper-water slope characterized by large caves, but little live coral growth. The dominant fish were apogonids, serranids, holocentrids, wrasses and a few species of surgeonfishes. While gobies are present in virtually all the habitats, they reach a maximum abundance on the coralline algae-covered coral slopes of the patch reefs.
4. The interface of the slope with the sand/rubble bottom. The deeper water habitats contained the larger predators including wrasses (Bodianus, Cheilinus), serranids (Plectopomus, Cephalopholis), lutjanids and many gobies.

Other obvious, but not necessarily dominant species include Zanclus canescens, several plankton-picking, but territorial damselfish, and some larger chaetodontids (particularly Heniochus spp). Centropyge multispinis is variable in occurrence, but can be quite common down to depths of 20-25 m.

Large patch reefs contained the greatest diversity of species and habitats within the lagoon. Samples taken in areas only slightly different in depth often had quite different species associated with them.

DOMINANT SPECIES - DEEP INSHORE REEFS

HOLOCENTRIDAE - Squirrelfishes and Soldierfishes (277)
- Neoniphon argenteus (benthic crabs and shrimps).

APOGONIDAE - Cardinalfishes (369) (plankton, benthic crustacea).
- Apogon aureus
- Apogon bandanensis
- Apogon cyanosoma
- Apogon exostigma
- Apogon frenatus
- Apogon kallopterus
- Cheilodipterus quinquelineatus
- Siphamia versicolor

LUTJANIDAE - Snappers and Fusiliers (392)
- Pterocaesio trilineata (plankton).

POMACENTRIDAE - Damselfish (428)
- Chromis retrofasciata (plankton, some algae).
- Chromis viridis (plankton).
- Chrysiptera cyanea (plankton and algae).
- Chrysiptera talboti ? (plankton).
- Dascyllus aruanus (zooplankton, some algae).
- Dascyllus reticulatus (zooplankton).
- Pomacentrus lepidogenys (zooplankton).
- Pomacentrus moluccensis (algae).
- Pomacentrus pavo (plankton, filamentous algae).
- Pomacentrus philippinus (algae).
- Stegastes nigricans (benthic algae).

LABRIDAE - Wrasses (440)
- Halichoeres trimaculatus (invertebrates).

GOBIIDAE - Gobies (494) (small invertebrates).
- Asterropteryx ensiferus
- Bryaninops loki
- Eviota afelei
- Eviota zebrina
- Trimma rw sp 18

D. Inside Main Reef:

This area is one of a highly variable environment. Tidal currents alternately sweep one direction over it carrying lagoonal water, which is relatively nutrient and sediment rich, the other

direction carrying clear, offshore water. Because of the heavy currents, the bottom is of coarse sand, consolidated coral rubble and occasional low (shallow) patch reefs. Where solid substrate is available, algae growth is often considerable. The amount of cover available for larger benthic fishes is quite limited, but cover for smaller forms is sometimes abundant and large numbers of plankton-picking, cave-associated species can be found there. In addition, these were the only areas where non-eel, sand-dwelling fishes (gobies, malacanthids) can routinely be found. In many areas there are large channels into which the currents are tunnelled, and these serve as pathways in and out of the lagoon for large fishes such as rays, large snappers and barracuda. The water in the channels varied in depth from a metre to about 4 m depth.

Unlike the large patch reefs in deep water, which serve as major spearing and fishing locations, these areas are not used as much by local residents.

DOMINANT SPECIES - INSIDE MAIN REEF

XENOCONGRIDAE - False Morays (051)
- Kaupichthys hyoproroides (invertebrates).

SYNODONTIDAE - Lizardfishes (120)
- Synodus dermatogenys (invertebrates and fishes).

APOGONIDAE - Cardinalfishes (369) (plankton, benthic crustacea)
- Apogon coccineus ?
- Apogon exostigma
- Apogon frenatus
- Apogon kallopterus
- Apogon nigrofasciatus

POMACENTRIDAE - Damselfishes (428)
- Chrysiptera cyanea (plankton and algae).
- Dascyllus flavicaudatus (zooplankton).
- Pomacentrus amboinensis (algae, some zooplankton).
- Pomacentrus coelestis (zooplankton, some algae).
- Pomacentrus lepidogenys (zooplankton).

GOBIIDAE - Gobies (494) (small invertebrates).
- Eviota afelei
- Eviota albolineata
- Eviota melasma
- Eviota zebrina
- Trimma caesiura
- Trimma dfh sp 09
- Trimma rw sp 18

ACANTHURIDAE - Surgeonfishes (504)
- Acanthurus olivacues* (herbivore).
- Acanthurus pyroferus* (herbivore).

E. Cryptic fauna:

Within all of the habitats listed above, there is a fauna associated with the interstices of the reef. In some caves this fauna makes up a large percentage of the biomass, especially in deep patch reefs. Some of it is relatively large (a few Oholocentrids), but most is small, ranging down to small gobies and Olabrids. Although there are distinct habitats, and a few species that characterize or that can be used as an indicatory of the habitat, most of the cryptic fauna species were not abundant. The major exceptions to this rule were primarily apogonids and holocentrids. A few gobies were quite common. Unlike some other areas we have studied (for example the Chagos Archipelago in the Indian Ocean), the number of coral-dwelling labrids such as Pseudocheilinus hexataenia is relatively small.

Many of the gobies are limited in their distribution to certain species of hard coral or alcyonarians and a few burrowing gobies may be limited by sediment grain size and structure. The presence of a suitable "host" substrate may also hold true for some of the damselfish, such as Dascyllus sp., but these are not normally considered cryptic. There is no evidence to suggest that apogonids or holocentrids are restricted by the distribution of species of invertebrates. Instead they appear to be dependent on sizes of the small caves in which they spend most of the daylight hours.

Little is known for certain of the nocturnal habits of apogonids, but night-diving suggests that they are nocturnal planktivores or invertivores. The largest species encountered was Cheilodipterus macrodon and was clearly an effective nocturnal predator. Most of the others were plankton pickers.

Except for Sargocentron spinifer and S. caudomaculatum, most of the holocentrids are relatively small and do not move from cover in the daylight hours. Sargocentron spp. are nocturnal predators on large invertebrates such as nocturnally active alphaeid shrimp. Myripristis leave the reef area at dusk and travel to open water or channels to feed on plankton. Thus they are importers of energy to the cryptic areas.

Within the Gobiidae, there are 4 distinct assemblages of species. In the shallow, wave-tossed, but consolidated coral areas, two species of Eviota (E. nebulosa and E. zebrina) are abundant and can be used as indicators of the habitat. In open sand and rubble or grass and even in deep water muds, a series of species of Amblygobius (mostly phalaena) and Valencienna (mostly strigosa) build (or inhabit) burrows. Amblyeleotris and Cryptocentrus (identities uncertain) commensally shared burrows constructed by alphaied shrimps. On coral-rock faces on deep patch reefs, there are several gobies, especially Priolepis cincta, Trimma tevegae (a schooling species), T. macrophthalma, T. okinawae and T. caesiura. They are very difficult to see in life, but under the influence of rotenone, fall from what must have been tiny interstices. Where there is living coral near the surface, a number of highly specialized gobies inhabit their branches. Gobies such as Gobiodon spp., Paragobiodon spp., and several others share the specialization of being coated heavily with a mucus layer on their skin, presumably to protect them against the stings of coral nematocysts.

The food habits of these small fishes have never been adequately investigated, but our studies of some of the species indicate that most feed on small to microscopic benthic (or supra-benthic) crustaceans and molluscs. This "pseudo-plankton" has recently become the subject of major controversy: the role of these reef-inhabiting creatures in energy transfer through the ecosystem may well have been vastly underestimated. If this is the case, their predators (the cryptic gobies) are also of extreme importance in the system. Certainly their diversity is impressive: we collected over 18 species of Eviota, 5 Gobiodon, 5 Paragobiodon and 15 of Trimma; more species than in any other single family for all habitats. About 100 species of gobies were collected in total.

Stations at Dravuni and Astrolabe Reef: (Total Number - 40)

1. Shoreline and Shallow Water		17
2. Patch Reefs		10
3. Inside of Main Reef		4
	Subtotal	31

The remaining nine stations were on the outer reef, outside of the lagoon. The average period of time used in making lagoonal stations was about 2.5 hours per station; thus the number of sampling hours represented is approximately 72.5 hours - most of this spent underwater, and much of that using SCUBA. The number of man hours involved is approximately 5 x 72.5 = 362.5. (We were a party of 6, but usually only 4 were on SCUBA - on shallow water stations all six members collected).

II. FISHING VILLAGE RESULTS

A. Observations on Methods:

Dravuni village owns a diesel launch which is used to take the catch to Suva, where it is marketed, to return with ice and to act as a fishing platform. The village has as well, one outrigger canoe and two small outboard punts. There was one outboard motor (12 HP Johnson) which was not in working order. We diagnosed the problem for them, but they did not replace the defective coil during our time with them. It is likely this level of mechanical expertise is general, because incidental observations made in other villages and also in Suva, indicate large numbers of outboard motors in unnecessarily decrepid condition. In other cases, it was apparent that minor repairs would put them back in working order.

Dravuni is the site of the IMR research station which has a small (16') aluminium boat and a 25 HP outboard. One of the villagers is employed as the caretaker and mechanic. The village takes advantage of this boat and motor whenever there is petrol available.

There are two main methods of fishing employed: hand-lining and spear-fishing. In addition, there is a minor fishery for large specimens of Trochus which are utilized to make bracelets and

buttons for the tourist trade. The field station owned a gill net, which was not in use while we were there, until we initiated its use. Several fish traps were also present at the station, but none were in use in the village. The caretaker knew how to use the traps, but it was not possible to ascertain whether his knowledge was gained from tradition or from the use of the specific traps.

B. Spear-fishing in Daytime:

The men of Dravuni are relatively competent spear-fishermen. They use a mask and/or snorkel. Some use fins, but most do not. The gun used was a 5' gun with a single cross-bow rubber and the spear was on a line about 12' long. Two men were noticeably more adept, but the technique was similar: they swim slowly at the surface watching for a fish hidden in a cave, or actively doing something that reduces its awareness of the diver. On deciding to try for the fish, the diver swims directly toward the fish in a deliberate and slow fashion. The gun is aimed immediately and the spear fired from a distance of up to about 2 m from the tip of the gun stock. Specimens up to about 40 lbs. were speared during our observations, but most were quite small, averaging about 2-3 lbs. Divers could reach 30 ft., but rarely exceeded 20 ft. Some were reported to be able to reach 60 ft. depths, but we could not confirm this.

Typical results were such as those of 25 March 1983. From 0700 to 1300 hours, 9 men, spearing on the inside of the windward reef using the 28 foot boat as a platform caught the following:

Species	No.	Av. Wt. (lbs)	Total Wt. (lbs)
Acanthurus (2 spp)	5	½	2½
Cephalopholis argus	4	½	2
Monotaxis grandoculus	3	1	3
Lutjanus bohar	3	2	6
Plectropomus leopardus	2	7	14
Cheilinus undulatus	1	7	7
Sphyraena sp	2	4	8
Acanthurus (spp-pelagic)	5	2½	12½
Macolor niger	3	1	3
Gaterin diagrammus	2	83	6
Epinephelus tauvina	1	8	8
Scarus sp (red teeth)	1	8	8
TOTAL	32		80 lbs.

On this day, the number of man hours was 9 x 6 = 45. The total catch was 80 lbs for an average catch of 80/45 = 1.78 lbs/man hour. The most effective prey for the fishermen are the larger species because of the high yield. Thirteen species were taken.

On some occasions, the catch was a little higher, reaching about 150 to 200 lbs. Rarely, the same boat load of spear fishermen could harvest 400 lbs in a day. On those occasions, the diversity in the catch is lower and usually the fish had become concentrated. On other occasions, they come home with almost nothing, especially if the weather is bad. Following Cyclone Oscar, fishing was suspended for nearly two weeks.

The young men and older boys construct slings of rubber and manufacture simple spears to use in close-to-shore fringing reefs or patch reefs. Almost of the catch was composed of balistids, primarily Sufflamen. This catch did not enter the economy of the island, but was used entirely for food.

C. Spear-fishing at Night:

This happened only once during out stay and we were informed that it was an unusual event, because the cost of lights and batteries was so high. Five men spent four hours at night on the main reef, using two underwater lights and worked from the aluminium skiff belonging to IMR. They speared 10 species of fish and the total catch was about 100 lbs of fish. In addition, they speared 3 turtles. Turtles were speared through one of the front flippers to ensure their survival. On returning, the turtles were kept alive in the shade on their backs until the boat was ready to leave for the market: in this case - 5 days later. We were informed that turtles could survive up to 3 weeks this way, even without wetting.

An exact tally of weights was not possible, but the following species were speared:

Species	Number
Naso lituratus	1
Naso unicornis	1
Naso vlamingii	1
Siganus fuscescens	2
Siganus argenteus	2
Diodon hystrix	1
Plectropomus leopardus	7
Caranx sexfasciatus	3
Caranx melampygus	1
Epinephelus tauvina	4
TOTAL	65 lbs.
Turtles (one large - about 70 lbs, two smaller - about 35 lbs)	3
TOTAL	140 lbs.

Catch per unit effort was 65/(5 x 4 hours) - 3.5 lbs/man hour for fish.
Catch for turtles was 140/20 = 7.0 lbs/man hour.
Total = 10½ lbs/man hour.

D. Handline Fishing:

Handlining was almost always done at night. The single time the village fished in the daytime while we were there was when we invited them to watch us while we poisoned fish at depth on the outside of reef. They caught only four small snappers - barely enough for bait.

Normally the boat travelled to a ridge of underwater reefs that followed a line of islands between Vanuakula and Yanuyanu-i-sau. The water depth was about 30-40 m. Approximately 4 to 7 people would fish, usually from dusk to dawn: (1930 to 0600) - 10½ hours. We were informed by villagers that catches usually varied between 50 and 20 lbs.

Three catches were sampled - 23-24 March 1983 - 5 women, 1 man:

Species	No.	Av. Wt.	Total Wt.
Sphyraena	2	2	4
Lethrinus	2	3.5	7
Epinephelus tauvina	1	1	1
Other species	4	2	8
	9	3	27
Lethrinid (genus undetermined)	6	1.3	8
Lutjanus bohar	1	2.5	2.5
Epinephelus (3 spp)	5	2.5	12.5
TOTALS	30		70

Catch per unit effort: 70 lbs/6 men x 10 hours = 1.167 lbs/man hour. In this case, however, women participated as well as men, which they were unable to do in the spear-fishing.

Two other catches were sampled in detail: 5 April 1983 - 4 women and 1 man, for 10 hours.

Fishermen	Species	Number	Av. Wt.	Total Wt.
A.	Epinephelus tauvina	5	1.5	7.5
	Epinephelus sp. B	1	3	3
	Lethrinus (very terete)	1	4	4
	Lethrinus (silver-yellow)	1	1	1
			15.5	

B.	E. tauvina	3	2.5	7.5
	E. sp. B	1	3	3
	Lethrinus sp.	1	4	4
	Lethrinus sp.	5	0.75	3.75
				18.25
C.	E. tauvina	2	2	4
	Lethrinus	3	0.75	2.25
	Lutjanus bohar	1	0.75	0.75
	Lethrinus (terete)	1	5	5
	Balistoides viridescens	1	3	3
				15.0
D.	E. tauvina	5	2	10
	E. sp. B	1	2	2
	Lethrinus (terete)	2	4	8
	Lethrinus (terete)	2	0.75	1.5
				21.5
E.	E. tauvina	6	2	12
	Lutjanus gibbus	1	0.5	0.5
	Lethrinus (terete)	2	5	10
	Lethrinus (terete)	1	0.25	0.25
	Lethrinus (terete)	2	1.5	3
	Lutjanus bohar	1	2	2
				27.75
GRAND TOTAL		49		98 lbs.

Catch per unit effort: 98 lbs/5 men x 10 hours = 1.96 lbs/man hour. As before, women were able to contribute to the fishing effort.

6 April 1983 - 4 women, and 2 men (10 hours):

Fishermen	Species	Number	Av. Wt.	Total Wt.
A.	E. tauvina	1	1	1
	E. sp. B	1	3	3
	Lutjanus bohar	1	4	4
	L. gibbus	1	1	1
	Lethrinus (terete)	4	2.5	10
				19

B.	E. tauvina	1	1	1
	E. sp. B	2	1.5	3
	Lethrinus (terete)	2	3	6
	L. (blue lines on cheek)	1	2.5	2.5
	Lutjanus bohar	1	3	3
	L. gibbus	1	0.75	0.75
				16.25
C.	E. tauvina	1	1	1
	E. sp. B	1	1	1
	Anthias? (Pukapuka)	1	2	2
	Caranx melampygus	1	2	2
	Lethrinus (terete)	1	2	2
				8
D.	Epinephelus sp. B	4	2	8
	Lethrinus (terete)	2	3	6
	Lutjanus gibbus	2	0.75	1.5
				15.5
E.	Lutjanus gibbus	7	1	7
	L. bohar	1	1.5	1.5
	Epinephelus sp. B	1	1	1
	Lethrinus (terete)	1	2	2
	Lethrinus (terete)	1	0.75	0.75
	Sargocentron caudimaculatum 1	2	2	
				14.25
F.	Epinephelus sp. D	1	5	5
	E. sp. B	1	1.5	1.5
	Lethrinus (terete)	2	1.7	3.4
	Lutjanus bohar	1	1	1
	Sphyraena sp.	3	2.3	6.9
				17.8
GRAND TOTAL				81.8 lbs

Ave. Catch per unit effort: 81.8 lbs/6 men x 10 hours = 1.4 lbs/man hour.
Ave. Range of Catches observed: 1.4 lbs/man hour, 1.96 lbs/man hour, 1.167 lbs/man hour.

Overall Ave. = 1.542 lbs/man hour

Individual range of Catch observed = 8/10 = 0.8 lbs/man hour to 27.75/10 = 2.78 lbs/man hour.

E. Impact of Cruise Ship Visits:

Cruise ships with about 1,500 - 2,000 passengers visit Dravuni some 8 - 10 times per year. Passengers who disembark on the island are not fed by the islanders, and so do not make any direct impact on the fisheries resources. The sewerage generated during their stay is either deposited in outhouses located on the fringe of the beach, or is flushed directly into the lagoon from the ship. We are concerned about the possibilities presented by this nutrient load, since corals (in particular) are especially sensitive to high nutrient levels. Although, averaged out over the year (1,750 passengers, 9 times a year), the net effect is an increase of 43 villagers living year round, the sewerage, and hence nutrient, fluctuation is far more dramatic (if cyclical). We would suggest that a fairy simple program (administered by IMR?) could determine leaching and processing rates from the beach latrines. Controls could be established on the island's east coast, and/or sites to the north and south of the village beach. Our main concern is that the high nutrient level potentially resulting from cruise ship visits may result in blue-green algal and dinoflagellate blooms. There is considerable evidence to link these blooms with ciguatera poisoning - a phenomenon already well documented in Fijian waters. Dravuni is remarkably free of the problem just now, and a sudden unexpected incidence of it could have serious, even fatal results. The fragility of lagoonal corals, and their slow growth rate suggests that the villagers on Dravuni would be well advised to demarcate a specific area for anchorage of cruise ships in order to minimize anchor damage to the coral reefs in the vicinity of the village. In addition, dead coral resulting from anchor damage provides an ideal substrate for potential blue-green algal blooms mentioned above, further increasing chance of ciguatera poisoning. The extra cash flow generated for the village by the cruise ship visits (averaging some $27,000 p.a.) undoubtedly reduces pressure on local fisheries (previously one of the few sources of outside income for the islanders). We are concerned (but see no attractive alternatives) that this will gradually lead to a loss of traditional skills and knowledge that previously yielded a significant portion of the villagers' income. We are not totally convinced that the exchange rate between "easy dollar" and "hard-work dollar" is appropriate for all communities.

DISCUSSION

1. Observations of Fish Behaviour:

In a short period of time, it is difficult to make an assessment of the degree of pressure exerted by the residents on their reef fish resources. While it is tempting to speculate that the population level of humans on the island is limited by the protein resources of the reef, there are often a wide variety of factors which are related to the fishery. It is instructive, however, to observe the behaviour of the species commonly hunted by fishermen using spears.

The most commonly speared species included serranids, lutjanids and acanthurids. Most spearing was done at particular locations, these being considered "the best". Plectropomus leopardus is a relatively terete-bodied serranid which normally drifts above the reef as often as it rests on the bottom. This behaviour was considerably modified in areas where spearing was

carried out; the fish retreated immediately from the water column as soon as divers entered the water. Epinephelus tauvina; a well-camouflaged cave dwelling species will approach divers quite closely in other areas, but on Astrolabe Reef in the "best" areas, they were much less likely to do so. Cephalopholis argus, a smaller species showed the same diver-avoidance in well-worked areas of the reef. When we went to areas difficult for local residents to get to, the fish were behaving more as though they were unaware of spearing. In water depths exceeding 20 m, all of the species avoided divers. We were uncertain how to interpret this aspect of the behaviour, except that these were depths where most of the sharks were observed (Triaenodon obesus and Carcharhinus amblyrhynchos). Possibly the fish misinterpreted us as sharks. On the other hand, we were surprised at how few sharks were observe. On many offshore reefs in the South Pacific and Indian Ocean, Carcharhinus amblyrhynchos and C. albimarginata are abundant, with typical observations of over 10 sharks per dive. At Astrolabe Reef, we never say more than three sharks at one time, and even on the offshore reef sharks were present during the dives about 20% of the time.

Acanthurids, both Acanthurus and Naso showed indications of behaviour altered by the influence of spearing. In fact, the Naso in shallow water were quick to leave areas when divers entered the water. On the other hand, a patch reef in a wash-channel on the inside of the reef was frequented by Acanthurus that were more difficult to approach than any others, and we were assured by the locals that no one bothered to spear in that area.

Close to shore, young men and boys shoot balistids with sling spears. We noticed that all species of triggerfish on near-shore reefs were exceptionally quick to leave the area (Balistoides) or to move into the cover of caves (Sufflamen, Rhinecanthus).

2. Comments and Comparisons of Habitats:

The relative scarcity of tide pools in the Astrolabe Reef area, combined with their small size, dictates that they are not suitable for resource exploitation. The same species that we observed in the tide pools were common along the shore-lines which were composed of basaltic rock. Beach rock areas were relatively flat, of low profile, and were not populated with an abundance of intertidal fishes or molluscs. Tide pools usually serve as nursery areas for many species of reef fishes (pomacentrids, mugilids, etc.) but, for the reasons given above, are not important at Dravuni.

The near-shore sand areas were frequented by fairy large numbers of fishes travelling along the beach, especially clupeids, mugilids, gerreids, and mullids. Few carangids (jacks) were present, but the efficiency of the gill net was much higher than any other technique used. Two men could set it, and then go off to do something else for a few hours before harvesting the catch, and this technique could add substantially to the Dravuni fishery. No segregation of adults and juveniles was obvious in the sandy area, other than a possible shallow water preference by juveniles. However, too few observations were made to rely on this impression. Shallow-water patch-reefs represent a somewhat restricted habitat, being confined in most cases to the areas

immediately adjacent to the islands. At Dravuni, they seldom extend more than 30 - 50 m from the shoreline, usually with a narrow, sandy channel parallel to shore between them and the beach.

The outer face of these patch reefs serve as an important nursery area for a number of species of food fish (e.g., Scolopsis, Monotaxis, lethrinids) possibly because of the relative absence of larger predators. However, these predators do make forays into the area; for instance, several times we saw large jacks (Caranx melampygus) patrolling just off the area, and we presume that groupers move into the area at dusk (as they do in other areas in the Indo-Pacific).

The deep water patch reefs consisted of upper and lower habitats. The diversity here is very high, with different forms dominating adjacent areas show significant differences in variables other than their fish faunas, for we did not notice any obvious gross differences other than the upper and lower divisions. There was no apparent segregation between adults and juveniles, and hence no nursery areas were identifiable.

The area inside the main reef has many species found nowhere else (e.g., Cirrhitus pinnulatus; Acanthurus guttatus) and is a high energy system (derived in part form the extensive wave action). Perhaps because of the extremely well-aerated water, fishes in this area are particularly sensitive to rotenone, which acts on their respiratory system. No specific separation of adults and juveniles was noted in this habitat.

3. The Dravuni Fishery:

i) Spearing:

In the case of the two occasions we were able to record the results of spear-fishing forays, daytime spearing yielded 1.8 lbs/man hour whereas nighttime spearing resulted in 10.5 lbs/man hour. We suspect that this discrepancy is the result of small sample size, since the fishermen seldom go spearing at night due to costs of lights and batteries. The above results would indicated that a difference of 8 lbs/man hour should more than offset the additional cost if it were typical, and we conclude that small sample size has skewed the real situation. Certainly the Dravuni spear-fishermen evinced no reluctance to dive at night, so that is unlikely to be a factor. Handlining had the lowest yield per unit effort - approximately 1.5 lbs/man hour. It seems surprising that yields as low as this are worth the effort, but then there are few other sources of potential income for the people of Dravuni. Turtles showed the highest return per pound, 7 lbs/man hour. However, they are only collected at night by spearing and so may represent an under-exploited resource. We did not ascertain the market price for turtles. We were encouraged to note that the supervisor of the Field Station, on his own initiative, was rearing hatchling turtles for subsequent release into the lagoon after they had passed the critical size. These beginnings of resource management should be encouraged.

The low yields of fish did not reflect overfishing, in our opinion, but rather the time-consuming techniques being used. Unlike pelagic or soft-substrate fisheries, there are no high yield/low

effort techniques (such as seines and trawls) available for use in coral reef areas. Gill nets are a possibility, but are costly to maintain in coral reefs where they constantly snag and tear on corals. Another possibility is large (ca. 5 x 3 x 2 m) traps such as in use, for example, in lagoons on Mauritus. But with no history of this technique, they are unlikely to be received with enthusiasm. In addition, since the traps are "passive", yields are low. Their advantages are low maintenance and rapidity of checking and fish removal. They are, however, a danger to reefs because if lost, they continue to fish. Some work is being done on manufacturing traps using degradable materials.

We conclude that at present rates of exploitation, the Astrolabe lagoon in the vicinity of Dravuni is in no danger of over-exploitation and could, if desired by the villagers, sustain considerable greater yields than it does at present.

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