RDA International, Inc.

P-145

ECOLOGICAL AND ECONOMIC IMPACTS OF SHRIMP TRAWLING IN BELIZE

Presented to
USAID/Belize
and
the Government of Belize
Ministry of Agriculture, Forestry and Fisheries

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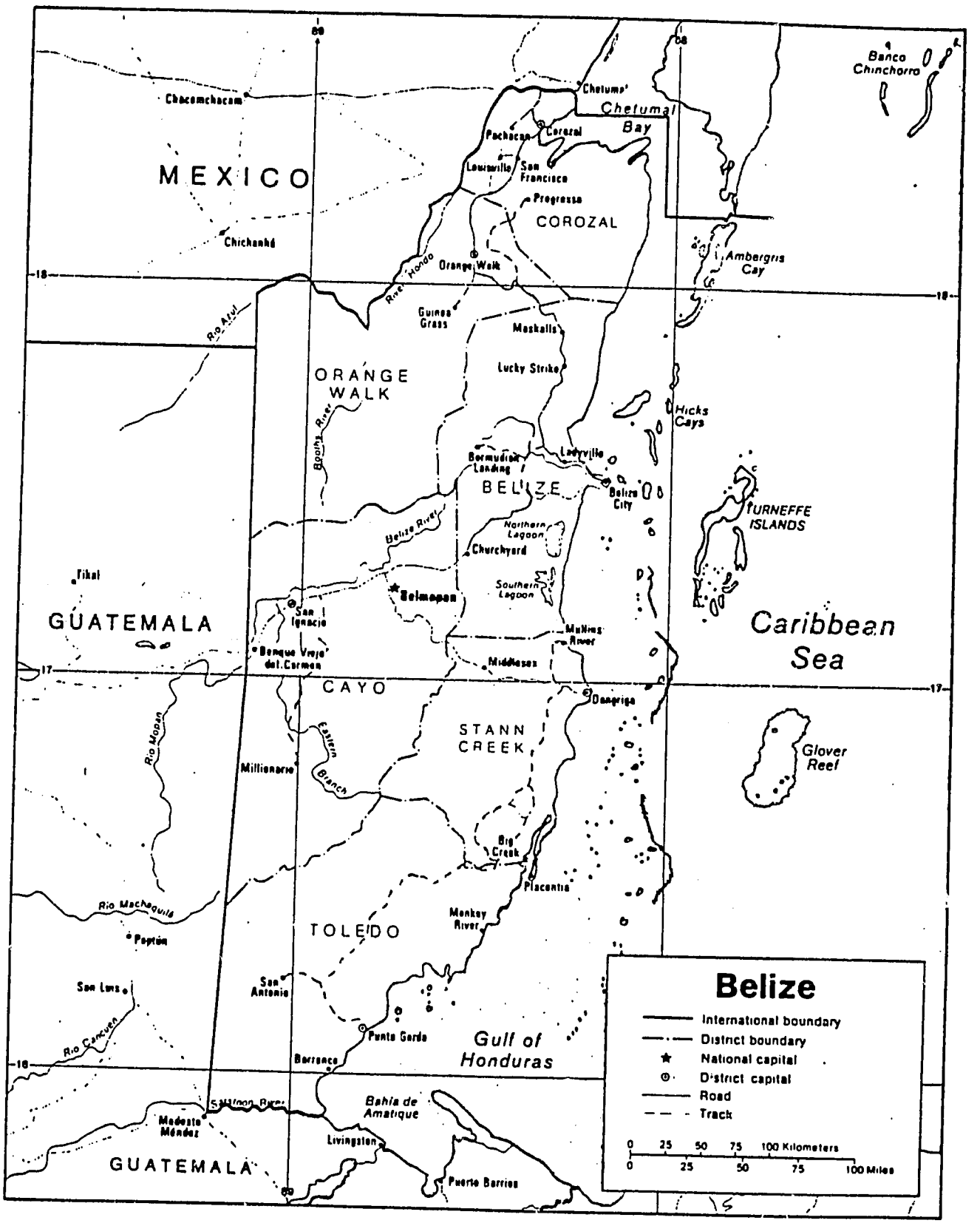
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COROZAL
ORANGE WALK
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Chetumal
Chacomchacam
Chichanhá
Pachacan
Corozal
Lauraville
San Francisco
Progresso
Orange Walk
Banco Chinchorro
Ambergris Cay
Hicks Cays
Turneffe Islands
Glover Reef
Guinea Grass
Maskalls
Lucky Strike
Bermudian Landing
Ladyville
Belize City
Northern Lagoon
Churchyard
Southern Lagoon
Belmopan
San Ignacio
Benque Viejo del Carmen
Tikal
Middlesex
Dangriga
Mullins River
Placentia
Big Creek
Monkey River
Millionario
Eastern Branch
Rio Mopan
Rio Machaquila
Peptún
San Luis
Rio Cancuen
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Barranco
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Livingston
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Puerto Barrios
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Booths River
Belize
International boundary
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1.0 EXECUTIVE SUMMARY

Commercial trawling for shrimp began in Belize in 1985 and has continued to the present. Development of the industry has progressed without knowledge of the magnitude of the bycatch and possible ecological and economic impacts. In 1990, RDA International was contracted by USAID-Belize to identify qualitative and quantitative attributes of the bycatch in shrimp trawls, assess reefs and critical habitats for possible impacts of the trawling operations, and recommend management measures to guide sustainable and environmentally sound development of the industry. The originally conceived study intended to monitor a minimum of one full trawling season. However, due to the limited funding available for this study, it was not possible to obtain data from a full season. Because of this, the conclusions and recommendations in this report must be considered preliminary.

Data was collected in the field in two ways. First, a RDA technician sampled the total catch aboard the shrimp trawlers for taxonomic composition and quantitative information from September 1990 to March 1991. Second, two RDA marine biologists conducted an ecological survey of reefs and critical habitats in and around the shrimp trawling grounds for a qualitative assessment of conditions.

Results of the shrimp/bycatch assessment found a catch ratio of 1:7.3, which is consistent with that from other areas. Juveniles of shad and snapper were the most common members of the catch. Essentially all of the bycatch was thrown overboard and eaten by fish, birds and benthic carnivores. No alternative use that was economically feasible was found for these fishes due to their quantity and small size, but they would have substantial value at maturity. The shrimp industry may be impacting certain stocks in Belize as evidenced in the assessed bycatch such as the predominance of pre-spawned juveniles, decreases in CPUE over time, and the fact that 88% of the total catch was fish. The fishing industry is a major contributor to the Belizean economy and to foreign exchange. Any impact on local fisheries by the reduction of stocks due to trawling would be apparent as a country-wide decline in the fishery due largely to the wide-ranging dispersal larval stage of fish. Several indirect lines of evidence do suggest that the shrimp industry is adversely affecting local fishermen. Total finfish bycatch was over five times the annual finfish exports. As the majority of the bycatch was juvenile, the consequent reduction in the spawning stock may produce a significant impact. Fish stocks inside the barrier reef are believed to be mostly fully exploited. Assuming the (extrapolated) snapper bycatch of 340,000 lb could be exported, the direct economic loss would total around B$680,000 annually, which is more than the net earnings from shrimp by the Belizean Fishery Cooperatives. However, the actual loss of income by local fishermen would be different due to several complications and unknowns. Victoria Channel, which was deeper and more seaward than the Inner Channel, produced significantly less bycatch while shrimp production was

similar for both channels (based on CPUE). The shrimp industry benefits the Government of Belize economically through foreign exchange and export tax earnings for shrimp sold internationally, and from employment for Belizeans locally.

The ecological assessment of reefs, mangroves and beaches revealed no major or consistent differences in condition between treatment sites proximate to the trawling grounds and control sites distant from direct effects of the shrimp trawlers. Overall, the reef, mangrove, and beach ecosystems appeared quite rich and healthy, in spite of increased water turbidity due to recent heavy rains.

From the results of this brief study several preliminary recommendations for prudent management and environmentally sound development can be made: Greater fishing effort should be made in Victoria Channel, where bycatch was less, relative to the Inner Channel. Alternate areas of the Inner Channel should periodically be closed to serve as juvenile nursery grounds. A catch quota for total allowable fish bycatch should be established, monitored and enforced. Fish bycatch excluder devices should be installed on the shrimp trawl nets as soon as they are available. To reduce total bycatch loss the maximum number of vessels permitted to trawl in a season should be reduced to 6 with a maximum of 8.

Proper development and management of the shrimp industry in the nearshore waters of Belize will now require a long-term comprehensive program of research and monitoring on: the shrimp/bycatch; biological aspects of shrimp in their habitat; biological aspects and fishery parameters of fish common in the catch; ecological ramifications of trawling; and effectiveness of experimental management regulations. Ecological surveys, similar to the one reported here, should be conducted periodically as long as shrimp trawling continues in Belize waters. For future development, economic benefits of the shrimp industry should be weighed against competing economies such as marine recreational tourism and local fisheries. It is now the responsibility of the GOB to determine their priorities for marine resources development and act accordingly.

2.0 BACKGROUND

2.1 Shrimp Trawling in General

Nocturnal trawling for shrimp in Western Atlantic tropical and subtropical waters essentially began in 1947 with the discovery of pink shrimp (*Penaeus duorarum*) in the waters of the Dry Tortugas and nearby Key West in the eastern Gulf of Mexico. Although some shrimping activity had occurred in the northern Gulf of Mexico sporadically since the mid-1920s, this activity had been limited to single-net, daylight drags (technology based upon New England groundfish trawling) which produced the white shrimp (*Penaeus setiferus*). The discovery of pink shrimp, caught during nighttime dragging, provided the impetus for the developing fishery. Fleets of boats quickly grew and shrimp trawling effort expanded throughout the Gulf, Caribbean waters and along the northern coast of South America. Almost all of the commercial catch from these fleets is comprised of shrimp from the family Penaeidae.

The "standard" Gulf trawler, now in use around the world, is typically 65-90 ft in length, constructed of wood, steel or fiberglass and is powered by a diesel engine with a 250—350 hp capacity. The catch is stored onboard, either iced or frozen. Ice boats store catch below-deck in holds and generally fish from 7-14 nights per trip. Freezer boats remain at sea for longer periods (30 nights or more). Initial freezing is accomplished within a deck-mounted brine freezer. Shrimp are then stored in freezing compartments.

Modern vessels tow either 2 or 4 trawl nets when fishing for shrimp. A typical trawl net is constructed of a heavy mesh netting material (No. 15 nylon twine, usually 1-7/8 in. stretched mesh in size) with an opening 40 by 5 ft that tapers to the cod end. The cod end has rings sewed completely around it through which a drawstring or rope is threaded and used to tie the end closed. The surface or upper panel of the trawl opening is buoyed by floats attached to the leading edge, and chain along the leading edge of the bottom panel of the net ensures that it remains on the bottom. The net is held open horizontally by the spreading action of water pressure on wooden trawl doors attached at each side of the trawl net by cable and in the case of the 4-net or double-rig system, a sled or "dummy door" is rigged between the 2 nets (Fig. 1). Average towing speed is around 2-2.5 knots.

2.2 Shrimp Trawling in Belize

In 1984, a Belizean fishermen's cooperative, working in conjunction with the Fisheries Unit of the Government of Belize (GOB), commissioned a shrimp trawling feasibility study. Utilizing an experienced commercial crew from Roatan, Honduras,

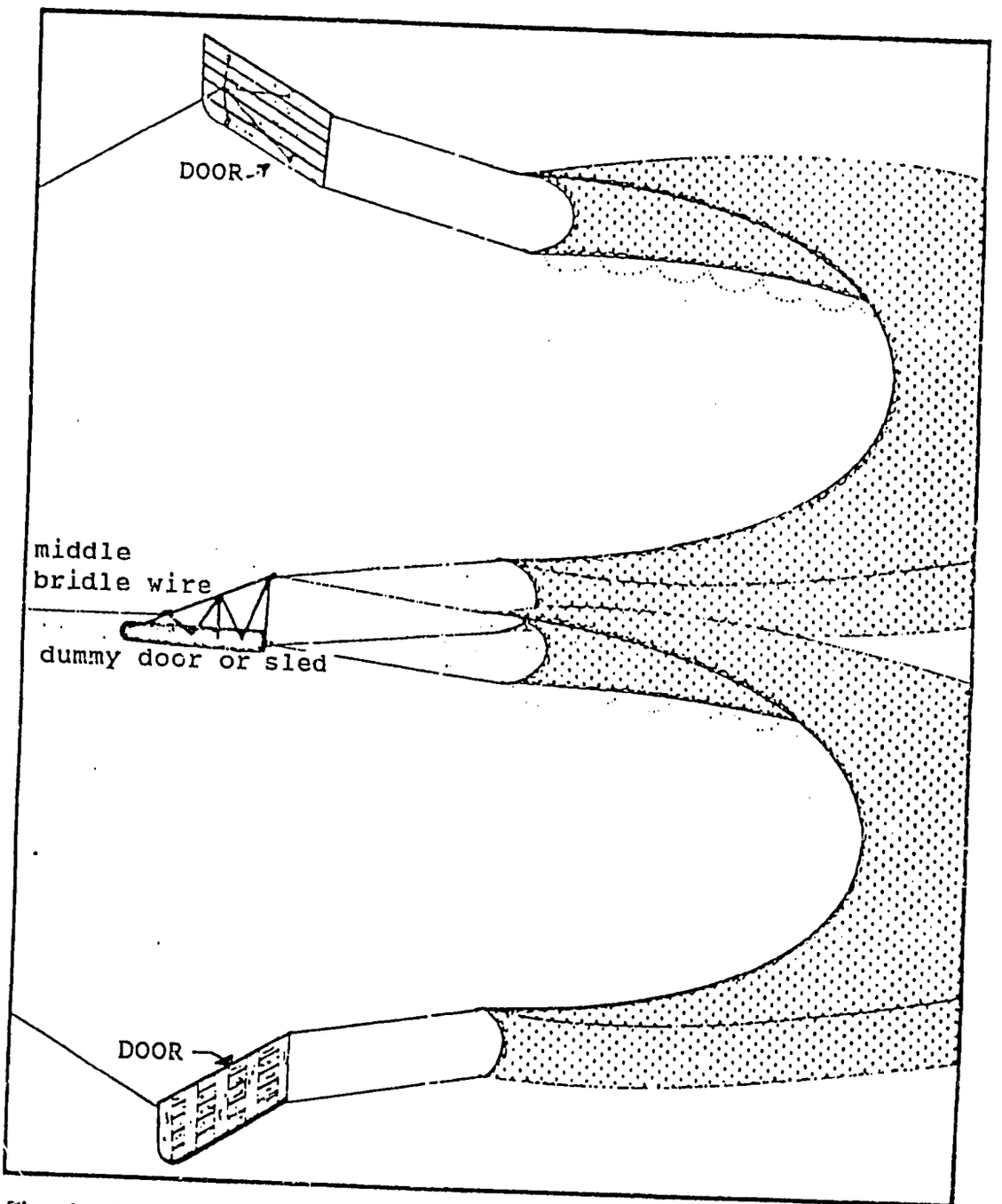

Fig. 1. A typical shrimp trawl net: the twin-trawl system.

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the study began on 6 December 1984. It was terminated on 30 April 1985 due to a reported increase of small shrimp in the catch. The shrimp caught were identified as the pink shrimp.

In the fall of 1985, several Honduran vessels were invited to participate in joint ventures with one or more of the major fishery cooperatives in Belize. Prior to the first full shrimping season regulations were established by the Department of Fisheries of the Ministry of Agriculture and Fisheries. The open season for shrimp trawling was arbitrarily designated as mid-August to mid-April. These regulations also provided a partial Belizean crewing requirement, ensuring local employment. With the exception of minor modifications the original regulations are still in effect. (During the 1989-90 and 1990-91 seasons shrimping was closed from 1 December to 15 January.) The commercial fleet consists entirely of Honduran freezer boats (Fig. 2). Since 1986, 10 boats have participated to various degrees each year within joint-venture efforts with the 4 major fishery cooperatives within Belize. This development has progressed in spite of the lack of information on the magnitude of the bycatch and possible ecological and economic impacts of the shrimp trawling operation.

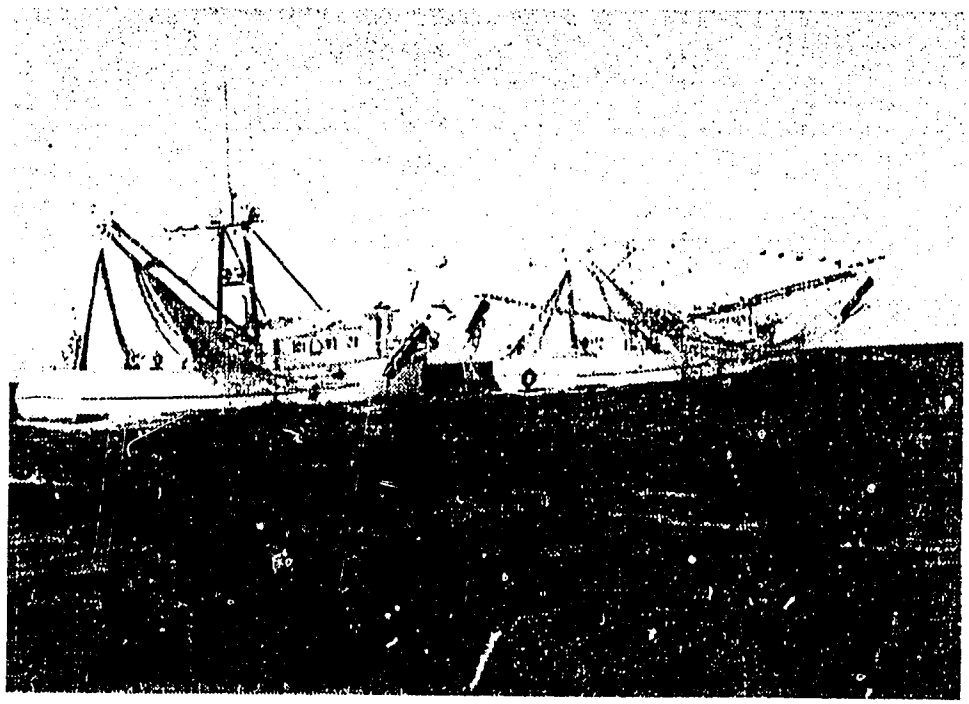

Fig. 2. Commercial shrimp trawlers anchored off Placencia in the Inner Channel.

In September 1990, RDA International, Inc. was contracted by USAID-Belize to implement a study to assess the ecological and economic impacts of shrimp trawling in Belize. The study had two main components: 1) onboard observation and sampling of the catch to assess species composition, relative abundance and

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possible impacts of bycatch, and 2) assessment of beach, mangrove and reef habitats near the shrimp grounds to determine if they are being adversely impacted by shrimp trawling operations. (See Appendix A for complete Statement of Work/Terms of Reference.)

3.0 ASSESSMENT OF THE SHRIMP/BYCATCH FISHERY IN BELIZE

3.1 Introduction

The main shrimp habitat and trawling grounds are the soft sand-mud bottom of the Inner (or Main) Channel and Victoria Channel (Fig. 3). The Inner Channel lies adjacent to the coastline with trawling concentrated between Colson Point and Placencia Point 32 miles to the south. This channel averages 4 miles wide and 60 ft deep. Occasionally, some trawling is conducted between Colson Point and the Southern Grennels Channel to the north while transiting to/from Belize City or San Pedro for unloading the catch. Victoria Channel lies seaward of the Inner Channel off the Placencia peninsula. Victoria Channel, which is 8 miles long by 1 mile wide and mostly 120 ft deep, is bordered by numerous cays, with Lagoon Cay defining the north border and Moho Cay the south. This channel represents less than 10% of the total area of the Inner Channel grounds, so less trawling occurs here.

Prior to this study, no independent assessment had been made of the shrimp fishery and related impacts of bycatch harvesting in Belize waters. The reef fish community is integrally related with neighboring habitats of soft bottom, mangroves, seagrass beds, and inshore pelagic waters. Many species spend various phases of their life-cycle in these different habitats. Possible changes in fish species composition due to commercial trawling may have unknown and potentially detrimental ecological ramifications.

The purpose of the shrimp/bycatch assessment phase of the present study was to:

- design and implement a valid program to assess the current shrimp trawl fishery in Belize;
- quantify the actual ratio of fish bycatch to commercial shrimp landed and the relative abundance of dominant bycatch taxa;
- determine the impact of the bycatch fishery on the ecology of inshore resources and on artisanal fishermen, and propose measures to properly dispose of the bycatch;
- assess the general economic benefits of shrimp trawling to the GOB and fishery cooperatives; and
- recommend policy strategies to guide management of the shrimp trawling industry and protect the critical marine environment.

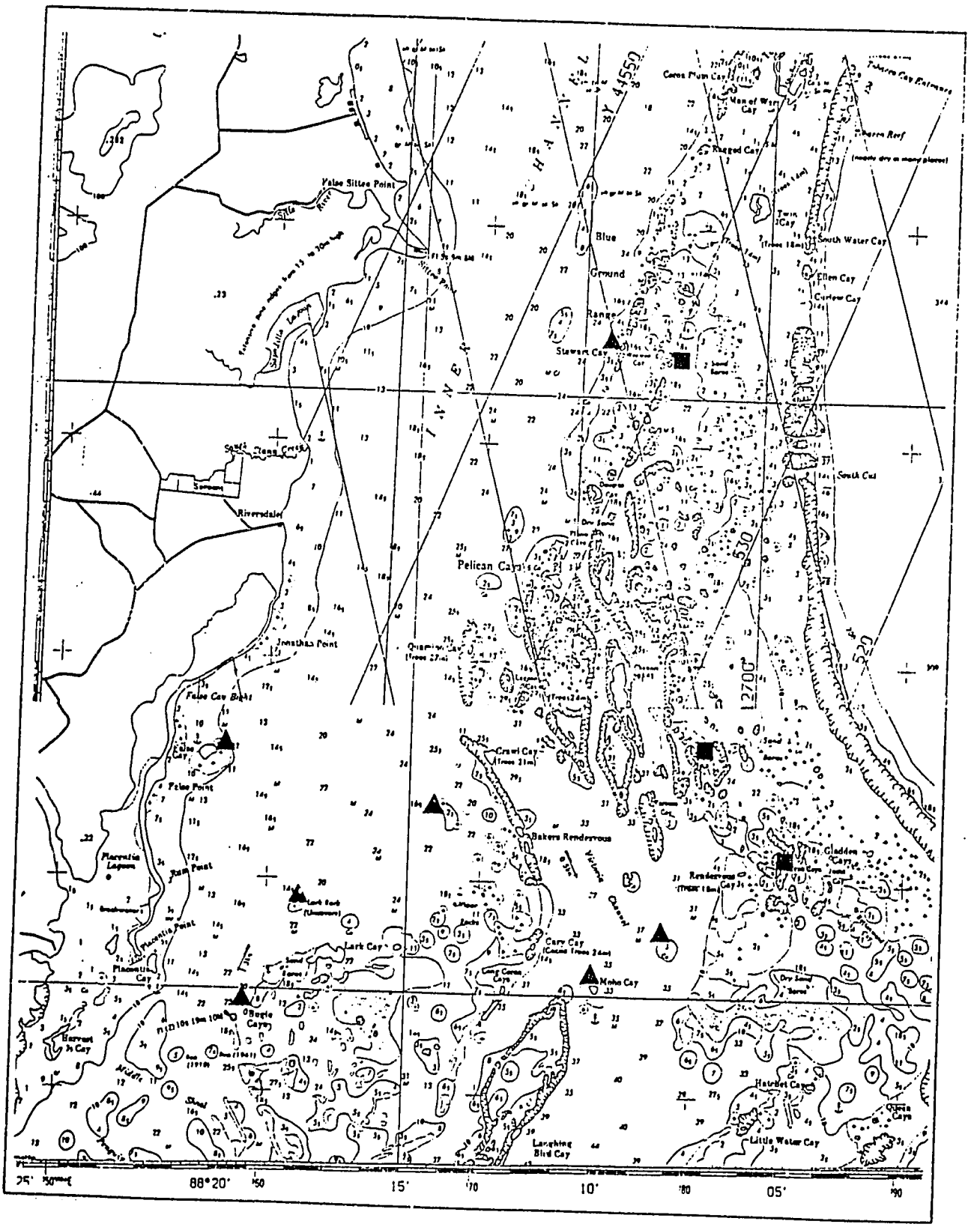

Fig. 3. Map of the shrimp trawling grounds and primary area surveyed for the ecological assessment. Sites of detailed reef surveys are indicated: Triangles = treatment reefs; squares = control reefs. [Depths indicated in meters.]

3.2 Methodology

A catch sampling program was designed based on standardized methods developed for similar shrimp trawling bycatch assessments in the Gulf of Mexico (e.g., by the U.S. National Marine Fisheries Service, the Florida Department of Natural Resources and the Sea Grant Programs of U.S. Gulf States). A Belizean fisheries technician (Stephen Seawall) was hired by RDA, and trained in the use of these methods. This onboard observer recorded shrimp catch and bycatch data from the joint venture shrimp trawlers during the 1990-91 season (14 September to 29 November 1990 and 15 January to 13 March 1991). An effort was made to sample equally from as many as possible of the vessels present in the trawling grounds each month.

Data was collected by initially taking a random subsample of one basket of catch from the center of the entire contents of a drag on the deck. This sample basket weighed about 60 lb. The contents of the basket were then sorted into families for fish (Fig. 4) and invertebrates, and into other miscellaneous categories (i.e., trash). Major animal groups were identified to family (some to species) and total sample weight and number of individuals for each taxa were recorded. Plant material and trash were also weighed and recorded as a percentage of the total catch. After the crew had removed all commercial shrimp from the total catch of the drag, the RDA technician shoveled the remaining bycatch into identical sample baskets and recorded the total number of bycatch baskets prior to their being emptied overboard (Fig. 5). Total weight of the drag for shrimp and bycatch families was determined by multiplying the subsample weight by the total number of bycatch baskets. Total shrimp weight of each trawl drag was also obtained from the captain's records. Data for the economic analysis were gathered from meetings with staff of the Department of Fisheries and the fishery cooperatives. All data were entered into computerized format and analyzed at the RDA Home Office in California using QuattroPro and SAS programs. Total weight for major families taken from Belize waters during the 1990-91 season was extrapolated by the formula (CPUE = catch per unit effort; h = hours; n = number).

$$\text{TOTAL} = (\text{CPUE-lb/h})(\text{n-nights})(\text{n-boats})(\text{n-drags/night})(\text{n-h/drag})$$

The extrapolation assumed an average of 2.5 drags per night and 25 nights of fishing per month for each boat present (10 boats during the fall and 6 boats during the winter of the 1990-91 season).

3.3 Results

Over the course of the study, the RDA technician recorded data from 188 sample drags during 98 nights of trawling aboard the joint-venture shrimp vessels present on the grounds. All samples were from the main trawling grounds of

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Fig. 4. RDA technician (Stephen Seawall) sorting bycatch into fish families to assess weights and abundances.

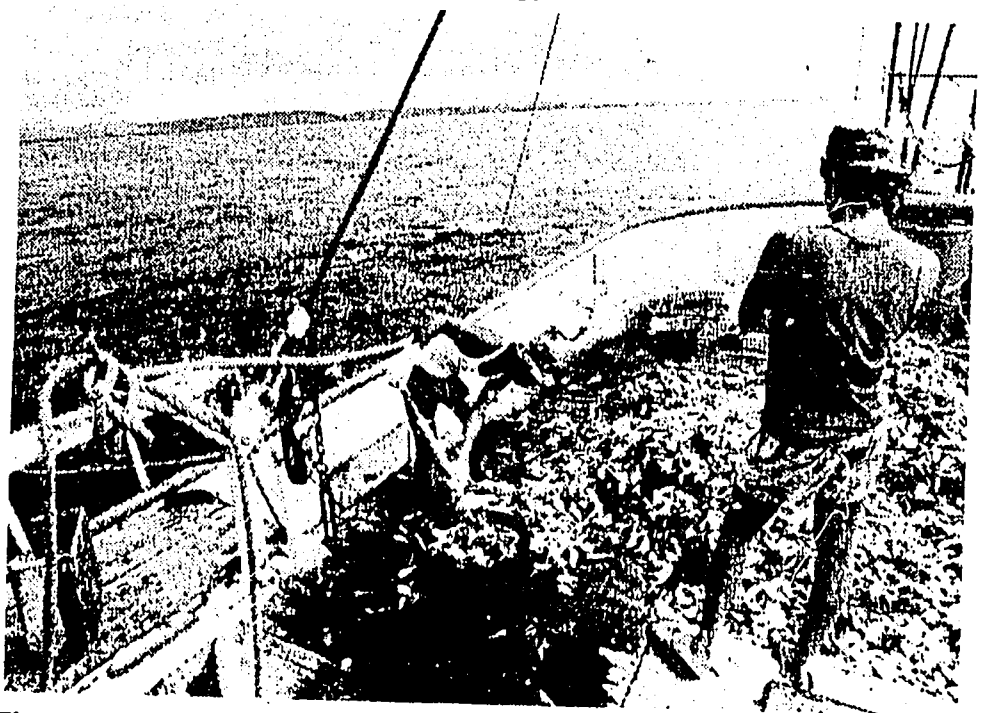

Fig. 5. RDA technician (Stephen Seawall) counting baskets of bycatch on the deck of a Honduran shrimp trawler.

Inner Channel and Victoria Channel. Assuming our sampling was representative of the fleet, approximately 85% of this fishing effort was conducted in the Inner Channel.

3.3.1 Shrimp/Bycatch Ratio

Finfish bycatch represented 88% of the total weight of all catch sampled, with the remaining 12% the pink shrimp (*Panaeus duorarum*, Fig. 6). This represents a shrimp:fish ratio of 1:7.3. Not included in these figures are various groups recorded as "trash" that often represented half of the wet mass of the drag, but varied widely. Typical "trash" groups included invertebrates (e.g., sea cucumbers, squid, brittle and sea stars, crabs, lobsters, sponges, scallops, conchs, black coral), vertebrates too large for the sample bucket (e.g., sharks, rays, turtles), seaweed and inanimate items (e.g., rocks, mud, fishing nets).

3.3.2 Turtle Bycatch

A total of 6 turtles were caught during the entire sampling period (188 drags), all from the Inner Channel. Four were loggerheads (*Caretta caretta*) and 2 were green turtles (*Chelonia mydas*). Three of these were caught during a 5 day period in September 1990, and the other 3 were caught during a 2 week period in January-February 1991. Extrapolation of these figures indicates that a total of about 87 turtles would be caught during the 1990-91 Belize shrimp season. (This translates to a rate of less than one turtle per 100 h of trawling). Loggerhead turtles reaching the deck alive were returned to the water as soon as possible and were believed to have survived. Green turtles, dead or alive, were retained by the crew and eaten.

3.3.3 Fish Bycatch

Catch composition in terms of relative abundance by weight revealed 6 common fish families in the sampled bycatch (Fig. 6). These were, in decreasing order of importance by weight, shad or moharra (*Gerridae*), snapper (*Lutjanidae*, essentially all Lane Snapper, *Lutjanus synagris*), pearlfish (*Carapidae*), catfish (*Ariidae*), croaker (*Sciaenidae*), and sardines or menhaden (*Clupeidae*). The remaining fish bycatch was composed of 23 rarer families, each representing less than 3% of the total catch (Table 1).

Composition of an average trawl drag in terms of total number of individuals and weight per common family (extrapolated from the subsample) is described in Table 2. The mean drag yielded just over 100 lb of commercial pink shrimp, with an average of 33 shrimp/lb. (As shrimp from the bulk of the catch were removed by the crew prior to counting the full number of baskets representing the total catch, the true total number of baskets, and therefore actual extrapolated weights, should

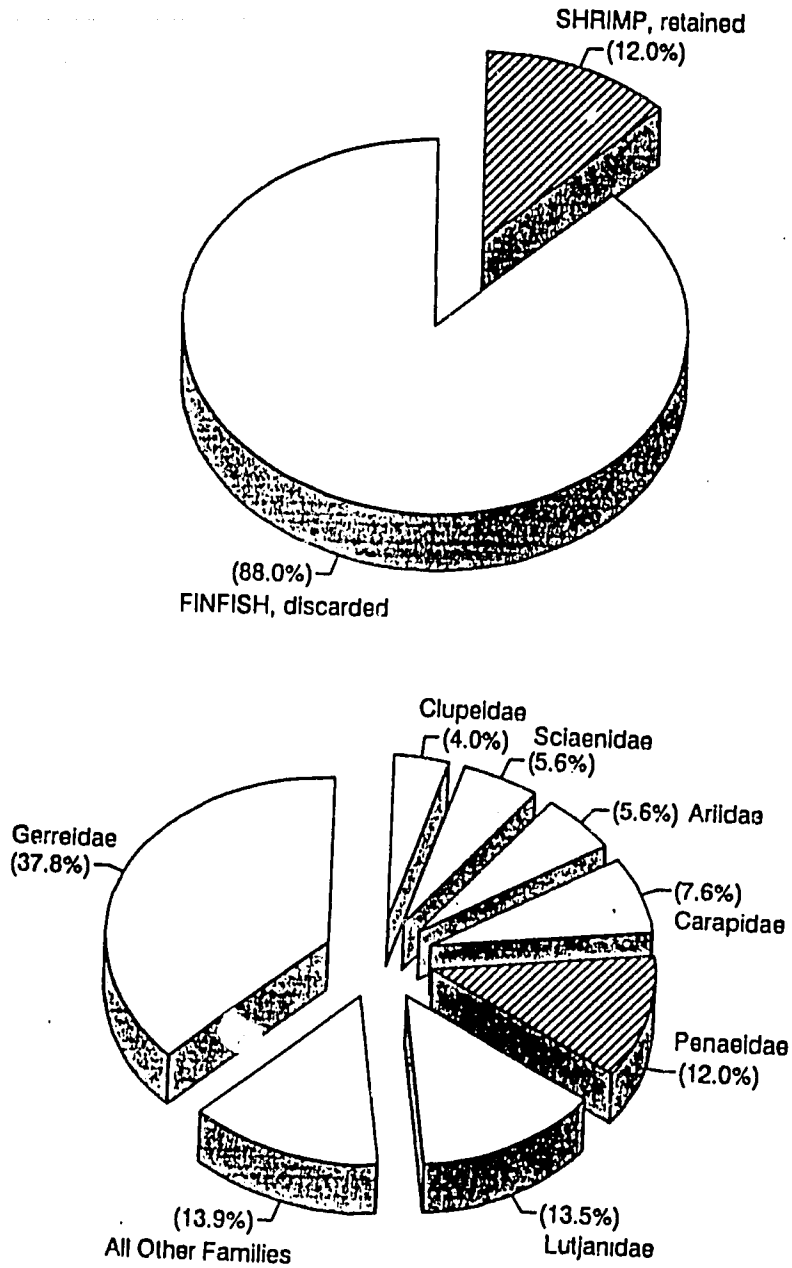

Fig. 6. Relative abundance (by total weight) of shrimp to finfish bycatch and taxonomic composition of the catch.

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Table 1. Taxonomic composition of the total catch from shrimp trawls (N = 188 sample drags).

Family:	Common Name	Extrapolated Total Weight (lb)	Relative Percent (%)
Penaeidae	Shrimp	19954.1	12.00
Gerreidae	Shad	62891.9	37.81
Gutjanidae	Snapper	22463.3	13.50
Carapidae	Pearlfish	12703.4	7.64
Ariidae	Catfish	9362.3	5.63
Sciaenidae	Croakers	9243.7	5.56
Clupeidae	Sardine	6579.0	3.96
Pomadasyidae	Grunts	4314.4	2.59
Albulidae	Bonefish	3362.9	2.02
Tetraodontidae	Pffers	2938.1	1.77
Triglidae	Searobins	2662.3	1.60
Zoarcidae	Eelpouts	2227.3	1.34
Soleidae	Sole	1486.5	0.89
Diodontidae	Porcupinefish	1019.6	0.61
Carcharhinidae	Shark	760.9	0.46
Cynoglossidae	Tonguefish	671.1	0.40
Dasyatidae	Rays	627.1	0.38
Ostraciidae	Boxfish	561.0	0.34
Bothidae	Flounder	465.9	0.28
Ogcocephalidae	Batfish	457.3	0.27
Sparidae	Porgies	447.9	0.27
Paralepididae	Barracudinas	440.1	0.26
Carangidae	Jack, Pompano	304.8	0.18
Scorpaenidae	Rockfish	124.9	0.08
Echeneidae	Remora	112.3	0.07
Scombridae	Mackerel, Tuna	84.6	0.05
Scaridae	Parrotfish	48.6	0.03
Sphyraenidae	Barracudas	13.5	0.01
Balistidae	Triggerfish	9.0	0.01
Serranidae	Sea Bass	2.5	<0.01
TOTAL FISH BYCATCH		146,386.0	88.0
TOTAL SAMPLE		166,340.0	100.0

Table 2. Abundance composition of an average trawl drag during the 1990-91 season (N = 188 sample drags).

	OVERALL MEAN PER DRAG		
	Total Number	Total Weight (lb)	Weight per Individual (lb)
FAMILY:			
Shrimp	3,573.6	106.2	0.03
All Bycatch	10,274.3	795.9	0.08
Shad	5,627.2	334.5	0.06
Snapper	1,085.8	119.5	0.11
Pearlfish	1,039.2	67.6	0.07
Catfish	235.1	50.3	0.21
Croakers	326.3	49.2	0.15
Sardines	379.5	34.8	0.09

be about 7-10% higher, following the formula N = n+[(n)(0.12)-1]). The relatively small shad (0.06 lb) were the most abundant bycatch family in terms of both number of individuals and weight. Snapper, about twice the size of shad (0.11 lb), were about a third as abundant by weight. Catfish, while even less abundant, were the largest common member of the bycatch (0.21 lb).

3.3.4 Spatial and Temporal Variation in CPUE

For valid comparison of spatial and temporal variation in the fishery, standardization in terms of catch per unit effort (CPUE) was required. CPUE is typically expressed as the total weight (lb) of the catch for a unit time of effort (h). Variability in overall CPUE, as expressed by the standard error of the mean ($\pm$SE) was typical (Table 3). As expected, the relative family rankings of the catch composition for overall mean CPUE paralleled that for total abundance, above. Comparison between areas revealed a slightly higher overall mean shrimp catch (26.9 lb/h) from Victoria Channel, however the difference was not statistically significant (t-test comparison). The mean CPUE for snapper also did not differ significantly between the two channels. However, all bycatch considered as a whole produced a significantly greater CPUE from the Inner Channel, as did the families shad, catfish, croaker and sardines, each considered alone.

Table 3. Mean catch per unit effort (CPUE: total lb/hr) per channel and year for the 1990-91 season.

	OVERALL (Mean ± SE)		CHANNEL (Mean)					
			Inner			Victoria		
	Pounds per hour	Individuals per hour	1990	1991	Overall	1990	1991	Overall
FAMILY:								
Shrimp	22.9 ± 1.1	764.1 ± 44.3	20.7	23.7	22.2	27.3	25.5	26.9
All Bycatch	178.1 ± 10.3	2284.2 ± 127.3	189.9	202.9	196.2	83.1	56.0	77.3
Shad	74.7 ± 4.9	1255.7 ± 79.7	75.3	96.1	85.5	16.3	12.4	15.5
Snapper	26.2 ± 2.1	240.0 ± 18.7	27.4	24.0	25.8	31.4	18.5	28.7
Pearlfish	14.3 ± 1.0	221.2 ± 14.1	13.7	14.3	14.0	16.9	12.8	16.1
Catfish	12.1 ± 3.5	58.2 ± 18.5	19.7	8.5	14.2	0	0	0
Croakers	11.3 ± 1.5	75.8 ± 11.2	13.7	12.7	13.2	1.2	0.6	1.1
Sardines	7.9 ± 1.0	86.3 ± 10.2	7.9	10.4	9.1	1.5	1.6	1.5
N Sample Drags	188	188	81	78	159	23	6	29

Comparison within each channel between fall and winter of the 1990-91 trawling season revealed greater consistency in mean CPUE for most families than for between channel variance (Table 3). Exceptions to this were catfish in the Inner Channel and snapper in Victoria Channel. CPUE for both families was significantly less in 1991. Catfish were absent from the Victoria Channel bycatch in both years.

Temporal variability in CPUE (monthly mean lb/h) is illustrated for shrimp and the 2 dominant bycatch families in Fig. 7. No data was available for the month of December 1990 as the trawling season was closed. As expected, shad was the most abundant member of the catch in each month. Monthly CPUE for shrimp and snapper were mostly similar. Decreasing temporal trends for all families were apparent for both the fall and winter periods (Fig. 7 and Table 4). Following the 45 day year-end closure, shrimp and the dominant bycatch families recovered in January to CPUE levels equal or greater than that of the fall, then decreased as fishing continued.

3.3.5 Economic Aspects of Shrimp Trawling

After the commercial shrimp are sorted from the bycatch, they are "headed" (de-headed) by the crew members, sorted into large and small sizes and then frozen in bulk and stored in freezers below deck. Vessels typically remain at sea until 4,000-5,000 lb of shrimp have accumulated (about 2-3 week). The catch is then unloaded at the particular joint-ventured cooperative. Participating fishery cooperatives are National, Northern, Placencia and Caribena. Upon arrival at the cooperative the shrimp are unloaded and thawed in tanks of water. They are then graded into size categories, grouped into 5-pound institutional packages and refrozen. Most of the small shrimp are sold locally to hotels and restaurants, as are a limited volume of the medium to large shrimp. A majority of the medium to large shrimp are exported, primarily to Jamaica via refrigerated boat.

Annual export production and earnings for the Belize shrimp trawling industry are summarized in Table 5. With the exception of the first year of the industry in Belize, annual production of trawled shrimp for export from Belize averaged 245,000 lb/yr. The values for earnings in Table 5 reflect the net value of exports following payment of the 5% tax/administrative fee. The calculated mean price per pound was B$9.22 (U.S.$1 = B$2). This compared to other records from the cooperatives where the mean price paid for all sized shrimp (10-80 individuals per lb) was B$8.80 over the past 3 yr.

The main species having economic potential in the bycatch was the Lane Snapper which accounted for nearly 14% of the entire catch by weight. This direct trawl-induced loss of juvenile snapper from their natural habitat is approximately

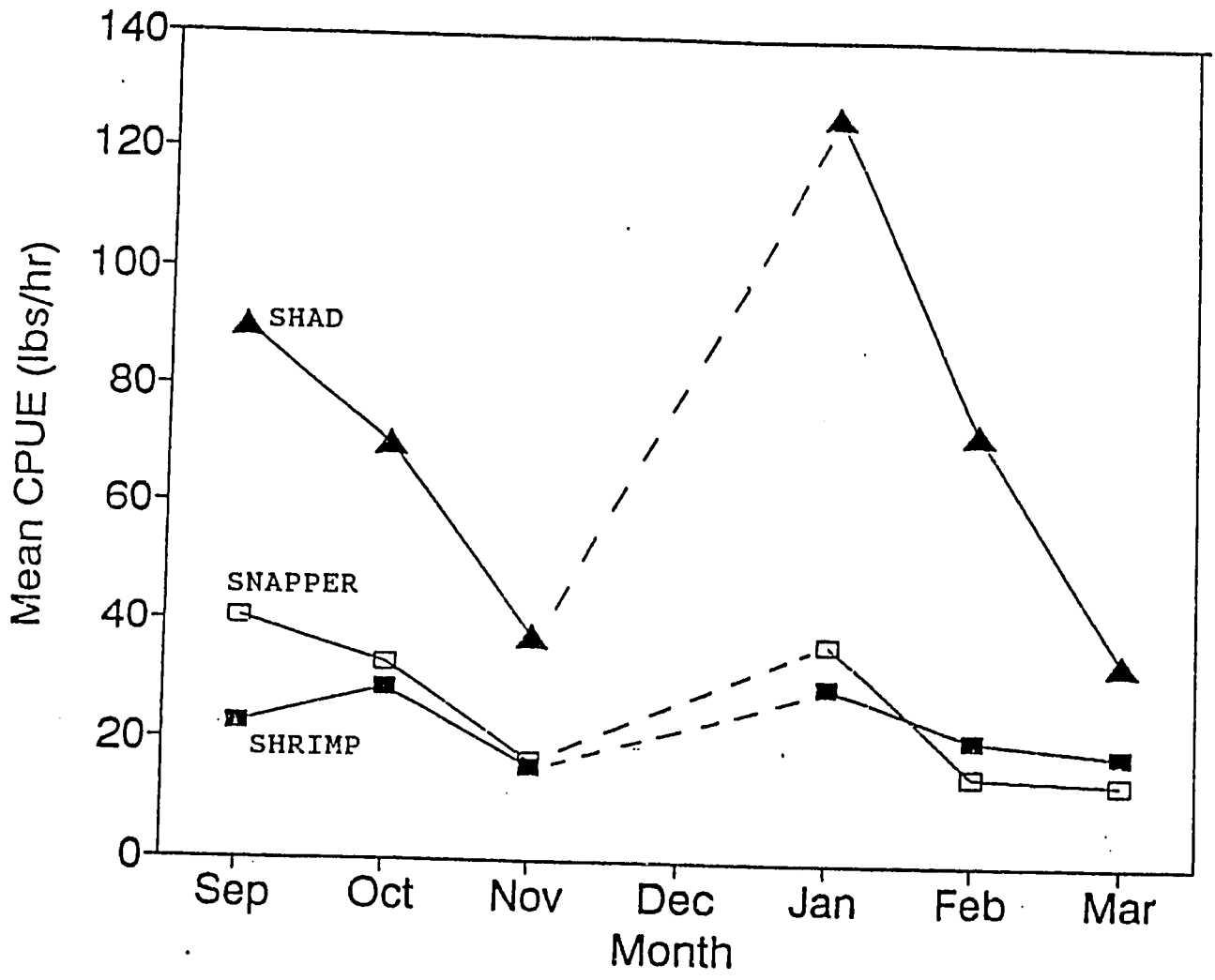

Fig. 7. Temporal variation in catch per unit effort (monthly mean lb/hr) for shrimp and the two most common bycatch families over the 1990-91 trawling season.

Table 4. Mean catch per unit effort (CPUE: total lb/hr) per month.

	MONTH						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar
FAMILY:							
Shrimp	22.5	28.4	15.7	-	29.1	20.6	18.3
All Bycatch	273.4	174.2	96.0	-	272.2	154.9	80.7
Shad	89.9	70.0	37.5	-	126.5	73.0	33.8
Snapper	40.3	32.6	16.6	-	36.3	14.8	13.7
Pearlfish	18.3	15.2	11.1	-	14.2	14.4	13.8
Catfish	46.0	6.5	4.9	-	10.1	7.7	0.5
Croakers	24.8	6.3	6.8	-	15.4	11.6	1.4
Sardines	10.8	6.2	4.0	-	18.4	4.2	1.1
N Sample Drags	25	39	40	0	35	38	11

Table 5. Annual production and export earnings for trawled shrimp from Belize.

	ECONOMIC PARAMETERS		
	Volume (lb)	Price (B$/lb)	Earnings (B$)
YEAR:			
1985	100,780	7.00	705,460
1986	235,952	10.00	2,359,520
1987	200,302	10.07	2,017,799
1988	249,650	9.24	2,307,689
1989	305,800	9.50	2,905,100
1990	233,750	9.49	2,217,162
Annual Average	221,039	9.22	2,085,455

340,000 lb/yr. The average price paid for finfish exports in recent years was B$2.00-3.00/lb. In 1990, one cooperative exported a small quantity of frozen Lane Snapper to Jamaica for B$2.00. Difficulty in obtaining sufficient and regular quantities prevented market expansion. The local price for Lane Snapper was about B$1.50. Average marketable size for snapper was 0.5-1.0 lb, as compared to the mean size in our bycatch samples of 0.1 lb.

3.4 Discussion

3.4.1 Shrimp/Bycatch Ratio

Extrapolation of total catch, based on results of the assessment, suggest that about 2.6 million lb of fish and shrimp were taken from Belize waters during the 1990-91 trawling season. Of this figure only about 290,000 lb were shrimp. This shrimp:bycatch ratio of 1:7.3 from Belize, which is slightly biased in favor of shrimp, is consistent with that from the Gulf of Mexico (1:9.1) and FAO's worldwide average of 1:10 (Pellegrin 1982; Fishing News International 1990, 1991). Had the large sharks and rays that escaped the present sampling method been included in the calculated sample weight, the Belize ratio would be even closer to these other ratios. This does not imply approval of that ratio.

3.4.2 Trawl Bycatch and Implications

Fish bycatch in shrimp trawls is a worldwide problem, with an average of 90% of the catch comprising unutilized fish (FAO estimate reported in Fishing News International 1990, 1991). An extrapolated total of 2.3 million lb (or more than 1,000 t) of bycatch (all fish families) were taken by the fleet from Belize waters during the 1990-91 trawling season. This tonnage probably represents a considerable fraction of the unquantified total fishery production. In most geographic regions, only a small percentage of bycatch are true "trash fish", although little is typically sold. The majority of the bycatch is often immature fish that have not spawned. Most weigh less than a half pound and essentially all of the bycatch dies (Gregory 1988). At these levels of juvenile mortality, maintenance of future stocks is often questionable.

Shad or mojarra (*Gerreidae*, Fig. 8), the dominant member of bycatch composition from Belize, accounted for just under 1 million lb (16 million individuals). Shad commonly inhabit coastal waters, predominantly over mud-sand bottoms and feed on a variety of small benthic organisms. They commonly reach 15-20 cm in length, or more, with maximum sizes of 25-40 cm (Fischer 1978). The median size in our samples was 5-12 cm for shad, which suggests that the trawls may be taking predominantly juveniles. This family can be processed into fish meal for use as fertilizer or animal feed. However, at the Belize bycatch volume, fish meal production is not economically feasible. Shad is commonly used as baitfish in some areas of the Gulf of Mexico and foreign Caribbean. However, in Belize shad is not used as such since the popular bait for line fishing is the silverside minnow. Lobster traps (known in Belize as habitat traps) are typically set without bait, virtually eliminating yet another option for the utilization of the shad bycatch.

The second most common fish in the bycatch, the Lane Snapper (*Lutjanus synagris*, Fig. 8), had an extrapolated total of 340,000 lb (3 million individuals) caught during the 1990-91 season. This snapper inhabits all types of bottoms often in large schools. Its diet consists of small benthic fishes and invertebrates. It commonly reaches 25 cm in length with a maximum size of 35 cm (Fischer 1978). The median size of Lane Snapper in our samples was 6-12 cm, which indicates that the juvenile stage is most impacted by the trawling operation. Like the shad, this species could be utilized as meal or bait, but this is not economically feasible for the reasons given earlier. Lane Snapper are used by locals as a food fish although no statistics were available on total annual production from Belize. The only figures available for Lane Snapper were from one of the fishery cooperatives who indicated that they had handled (export sales and local sales) only 3,050 lb during 1990. The Belize Fishermen Cooperative Association's (BFCA) total production figures for the 1989-90 season indicate a whole-fish total production figure of 681,000 lb, 30,000 lb of which were fish fillets. Undoubtedly some of these fish were Lane Snapper. However, because of the small individual size of this species (0.5-0.7 lb in total average weight), the portion of Lane Snapper fillets would be expected to be low. The common size of Lane Snapper from Belize shrimp trawlers was even smaller (0.1 lb average).

Similarly, in the Gulf of Mexico snapper was also a dominant member of bycatch, represented by the commercially prized red snapper. Here it was estimated that 80% of red snapper are killed in commercial shrimp trawls before reaching 2 years of age. They are unmarketable primarily due to their small size. After this juvenile stage they migrate to nearby reefs to live and are no longer vulnerable to the trawlers. There is clear evidence that the shrimping industry has had a significant negative impact on commercial and recreational fishing of red snapper. Management plans are needed to remedy the situation (Sport Fishing Institute 1990). Experi-

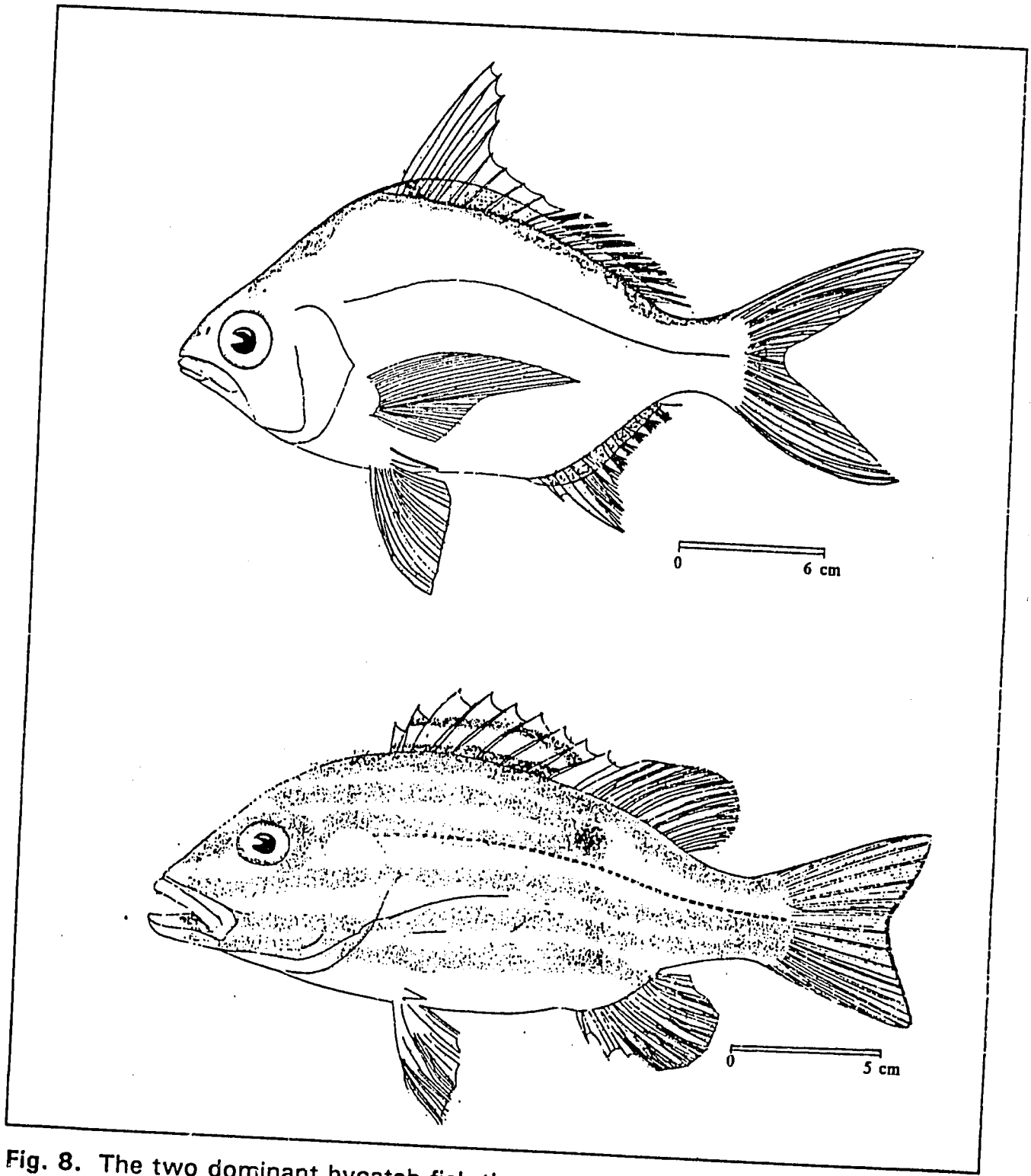

Fig. 8. The two dominant bycatch fish that accounted for over half of the entire catch of the shrimp trawlers in Belize. Top: a species of mojarra or shad. Bottom: thc Lane Snapper (from Fischer, 1978).

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mental evidence suggests that reduction in bycatch could increase fishery production of valuable red snapper in the Gulf of Mexico up to 90% (Gregory 1988).

Results from this study indicate that the catch of turtles in the shrimp trawls from Belize waters was low relative to distant geographic areas. All sea turtles in the U.S. are now listed as endangered (Fishing News International 1990). The U.S. government is requiring countries that export shrimp to the U.S. to use turtle excluder devices (TEDs) in their nets where turtles are caught by shrimp trawls in more than negligible numbers. From September to April it is legal to catch turtles in Belize. Even though the limited sample data from the present bycatch assessment suggest that turtles are less of a bycatch problem in Belize, a more thorough survey needs to be conducted to determine long-term variation in trawl induced turtle mortality.

Some bycatch was reportedly found on beaches in the Dangriga area during the first year of shrimp trawling when crews, unfamiliar with the area, discarded their bycatch too close to shore. Since then, the crews have learned wind and current patterns and there has been little complaint regarding beach deposition. Discarded bycatch is immediately consumed by both fish and birds at the water surface while the portion that may reach the bottom is undoubtedly utilized by other fish and invertebrates, such as crabs. Therefore, it is reasonable to presume that the entire biomass of bycatch is ultimately reincorporated into the food chain. There was no indication from this study that fish mortality attributed to bycatch had any significant direct or indirect impact on local stocks of lobster, stone crab, or conch. Some of these commercial invertebrate species were taken in the trawls, but in numbers too few to warrant concern.

Considering finfish, however, results of this assessment suggest that there may indeed be an impact on the local stocks (e.g., shad, snapper, etc.) induced by bycatch mortality. Main lines of evidence include the predominance of pre-spawned juveniles in the bycatch, the rapid decreases in CPUE over time, and the substantial volume of fish killed relative to the size of the trawling grounds.

The fishing industry is a major contributor to the Belizean economy and to foreign exchange. The most valuable target species are lobster, shrimp, conch and finfish, and the sport fishing industry for pelagic and demersal game fish is growing rapidly. Common members of the catch include snappers, groupers, porgies, sharks, jacks, and grunts. Over the past few years total finfish exports have averaged around 400,000 lb/yr with a value of about B$1 million/yr. Additional production from shallow nearshore areas goes to local markets and personal consumption and is unquantified (Midwest Universities Consortium for International Activities, 1988).

Comparing abundance and composition of the catch of local fishermen in the trawled areas to that of Belize waters remote from the shrimping grounds may not necessarily indicate the industry's impact on these fishermen. Following spawning, essentially all tropical inshore fishes are characterized by a wide-ranging dispersal larval stage. Very few postlarval juveniles would be expected to return to their natal habitat (i.e., the trawling grounds) to where impacts on a scale finer than the Belize coastline could be detected. Rather, any impact on local fisheries by the reduction of stocks (directly or indirectly through reduction of spawners) by trawling would be indicated through a country-wide decline in the fishery.

Several indirect lines of evidence do suggest that the shrimp industry is adversely affecting local fishermen. Based on extrapolations from results of this study, the biomass of snapper bycatch alone nearly equals that of total finfish exports of the past few years. Total bycatch (all fish) removed from the fishing grounds each year is over five times the annual finfish exports. Species considered "trash fish" by the Honduran shrimp trawlers may actually be valuable targets of artisanal fishermen in Belize. Considering that the majority of the bycatch is juvenile, and therefore the much larger potential total production (landed weight) available following growth and recruitment to the fishery, the potential loss is even greater. Further complicating the estimate is the probable loss attributed to reduction of stock size by the elimination of many potential spawners. As many tropical fishes have been found to be recruitment limited (Munro & Williams 1985; Sale 1985; Schroeder 1989), such a reduction in the spawning stock may produce a significant impact. Consistent with this, local fishermen had complained to us of diminishing catches and blamed the trawlers. It cannot be determined with certainty from existing data whether such a causative accusation is valid, or if these fishermen are simply feeling the effect of a possible overall long-term increase in fishing pressure on these reefs, as is common in many countries circumtropically. It is known that the number of fishermen in Belize has been increasing steadily in recent years to where there is significant pressure on valued stocks. Based on limited information, it is believed that fish stocks inside the barrier reef are mostly fully exploited (Midwest Universities Consortium for International Activities, 1988).

It was beyond the scope of the present survey to estimate natural stock sizes from the area for target finfish species of the artisanal and commercial sectors. Knowledge of such an estimate would be valuable to assess the magnitude of this impact. Due to the unavailability of data, it is also not possible to determine whether fish population sizes have been decreasing during the past few years since trawling began in Belize.

Stock size of large long-lived species (e.g., snappers, groupers, croakers, rays, catfish, sharks, goatfish, bream, lizardfish) tend to be reduced faster than small short-

lived species (Fishing News International 1991). Many of these long-lived species were also common in the Belize bycatch. Following continued heavy bycatch fishing, a shift in the fish community structure may result due to restructuring of trophic relationships. As predators higher on the food chain are reduced, small prey species, many of which are less valuable as food fish, may increase in relative abundance. Alternately, the removal of 1.3 million lb of juvenile shad and snapper from inshore waters would expect to have a major ecological impact on population sizes of their predators and on alternate prey populations.

It was also beyond the scope of the present study to determine the ecological ramifications of the unquantified "trash" (i.e., benthic invertebrates, large vertebrates, etc.) being removed from the channel floor which, along with mud and rocks, represented about half of the drag's volume.

3.4.3 Implications of Spatial and Temporal Variation in the Catch

The proportion of bycatch in shrimp trawls is known to vary widely with factors such as season, year, area, depth and trawling technique (Gregory 1988). Knowledge of the spatial and temporal distribution of bycatch in shrimp fisheries can be used to determine effective management measures such as seasonal or area closures to reduce bycatch mortality (Nichols 1990).

Two major differences between the Inner Channel and Victoria Channel were depth and shoreward proximity, with the latter being about twice as deep and twice as far from shore as the former. Significantly less bycatch was taken from Victoria Channel for most common families, while shrimp production from both channels was similar. All else considered equal, Victoria Channel should be the trawling grounds of choice for both economic and ecological reasons. However, Victoria Channel is smaller than the Inner Channel by an order of magnitude. The habitat of catfish, which were absent in the bycatch from Victoria Channel, is most likely shallower than 100 ft. The significant reduction of snapper from Victoria Channel toward the end of the season may reflect their life-history event of growing juveniles emigrating to nearby reef habitat and/or actual reduction of stock size by trawling as evidenced by the pattern of variation in CPUE. With sufficient corroborative evidence toward less commercially important bycatch taken in the spring, recommending a shift in the shrimping season may be appropriate.

Significant differences between depths were likewise found for fish bycatch in the Gulf of Mexico. Species composition in waters 60 ft or less was fairly constant, while more variable in deeper water (Watts and Pellegrin 1982). Also in the Gulf, fewer juvenile red snapper were caught at deeper depths. In addition, bycatch

from offshore trawling grounds was less than from inshore (Gregory 1988), which is consistent with findings of the present study.

The Belize data indicate that the 6-week closure of shrimp trawl fishing in the middle of the season had a positive effect in terms of increases in the average catch abundance and size of shrimp from fall to winter. The decreases in CPUE for common families within both the winter and fall periods may be indicative of the total fishing pressure by the trawlers on shrimp and finfish resources. The existence of both of these impacts suggest that total effort in the shrimp trawling grounds may need to be reduced for future seasons. The decreases in shrimp CPUE to the near "break-even" point may in itself have an economic self-regulation effect on the industry. This is consistent with information from the vessel captains.

3.4.4 Economic Implications of Shrimp Trawling

The joint-venture agreement for shrimp fishing in Belize waters operates on a shared profit basis with 30% for the local fishery cooperative and 70% for the Honduran shrimp vessel, of which the captain gets 25% of this. Such an arrangement appears to be more economical for the cooperatives than having to assume the costs of vessel purchase/maintenance and risks of unpredictable stocks.

Considering the economic feasibility of shrimp trawling in Belize, the catch volume necessary to "break-even" is 150-200 lb/night. With a calculated mean catch of 106 lb/drag (Table 2) an average of 265 lb of shrimp are caught per night, which translates into a gross profit of B$830. Assuming these estimates are representative of the true fishery, net take home earnings for the Honduran vessels would then approximate B$550 per night. As this is an average for the season, it may be unprofitable for the vessels to remain on the grounds the full season, in consideration of the winter and fall decreases in shrimp CPUE. With 70% of profits going to the Honduran vessels, the four Belize fishery cooperatives thus earn a total of B$626,000 from wild caught shrimp annually. In addition to these foreign exchange earnings for Belize, the GOB receives just over B$100,000 per year from the export tax on total gross profits. The requirement to carry several Belizeans as crew also contributes in a small way to the local economy.

Sufficient data are not available to accurately quantify the impact of the shrimp trawling industry on local and artisanal fishing but there is clearly cause for some concern. Two species, shad and Lane Snapper, comprise the majority of the discarded bycatch and together equal nearly five times the total volume of shrimp caught. This is particularly interesting, given that the trawl catch of these fish species overwhelmingly consists of juveniles. As noted earlier in this report, with

these levels of juvenile mortality, maintenance of the fisheries stocks is questionable.

In Belize, demand for all snapper is high, compared to most other finfish species, and there is also substantial export demand. The Lane Snapper, being a relatively small Lutjanid, does not command as high an export price as some others, such as reds or mutton snapper. The local price is about B$1.50 per pound, with frozen Lane Snapper recently exported to Jamaica at B$2.00 per pound. The export market has been constrained by limited supply available, and could clearly expand.

If the 3 million individual Lane Snapper caught in shrimp trawls and discarded each year were allowed to grow, they would not all be harvested by local fishermen. Natural mortality (predation) would reduce this number somewhat, although highest mortality rates occur during earlier life stages than those represented here. A larger unknown involves the differential catch efforts and efficiencies attributed to shrimp trawls and local fishermen. If these 3 million fishes, 340,000 pounds of juveniles, were left undisturbed to grow, their total weight and value would increase by a factor of five or more, but this would not translate as a 1:1 increase in landings of snapper by hook-and-line or spear fishermen. It is interesting to note, however, that at the B$2.00 export price, then only 340,000 pounds of Lane Snapper would be valued at B$680,000, which is more than the total amount currently realized annually by the Belizean fishery cooperatives from the shrimp industry.

This issue is clearly non-trivial and deserves further study. The existing shrimp trawl industry has a negative impact on finfish and the economic value of that resource lost may well exceed the short-term gain from shrimp harvesting. We do not believe the existing data is sufficient to justify a shut-down of the shrimp trawl industry. We note, however, that bycatch of some common taxa in some areas appears to be substantially higher than in others. Regulation of trawling areas could decrease this mortality. Similarly, the effects of changes in allowable shrimp trawling season should be examined, to decrease mortality of some other important species (e.g., Lane Snapper).

4.0 ECOLOGICAL STATUS OF REEFS AND CRITICAL HABITATS

4.1 Introduction

Essentially no prior known studies have been conducted on shrimp ecology or environmental impacts of the shrimp fishing industry in Belize waters. Of foremost concern is the possible effect of shrimp trawling on the reef environment. The coral reef ecosystem represents one of Belize's greatest natural resources and provides the country one of its best options for economic development. This is primarily through tourism for skin and scuba diving, recreational fishing, and related tropical marine sports, largely by Americans. Coastal reefs also function as an essential ecological base for the country's valuable subsistence and commercial fisheries. Appropriate conservation and management of nearshore coastal resource systems is of critical importance to Belize.

Shrimp trawling is concentrated on the soft sand-mud bottom of the Inner Channel and Victoria Channel, which is ideal shrimp habitat. The trawlers do not drag nets on reef or seagrass areas directly. The main potential adverse effect of trawling is the increased sedimentation load on reef habitat due to nearby trawl drags stirring up silt from adjacent soft bottom habitat of the channel. Heavy sedimentation can foul and kill sensitive coral polyps upon which the reef community is dependent for survival. Reefs with little or no live coral do not support abundant and diverse fish communities. The ecological link that nearshore habitats such as coral reefs, mangroves, and seagrasses provide is essential to the productivity and sustainability of nearshore and offshore fisheries. The effect of trawl-induced reef sedimentation may be short-term (i.e., from the present shrimping season) or long-term (i.e., a gradual accumulation of sediment on the reefs over the past six years of the industry's presence).

Another indirect environmental effect could be a change in community composition of reef fish due to the killing of large numbers of finfish as by-catch in the shrimp trawls. The reef fish community is integrally related with neighboring habitats of soft bottom, mangroves, seagrass beds, and inshore pelagic waters. Many species spend various phases of their life-cycle in these different habitats. Possible changes in fish species composition due to commercial trawling may have unknown and potentially detrimental ecological ramifications.

The purpose of the ecological/habitat assessment phase of the present study was to assess critical nearshore habitats (e.g., coral reefs, mangroves, beaches) for any possible ecological effects due to shrimp trawling adjacent to or near these areas, and to contribute these findings to the scientific body of information upon which to base environmentally sound policies and strategies for development of the

commercial shrimp industry and for conservation and management of Belize's valuable coastal resources.

4.2 Methodology

Coral reefs and critical marine habitats were surveyed visually adjacent to and distant from the trawling grounds to assess their status and quality. A quantitative assessment was not possible due to the limited time available for field observations (i.e., one week) on this aspect of the study.

Sites for detailed reef observations were classified as treatments or controls. Treatment sites were reefs adjacent to or in close proximity to the trawling grounds, and represent the most likely candidates to reveal any effects due to trawling. Control sites were reefs isolated geographically (e.g., by distance, cays and/or shallow shoals) and/or oceanographically (e.g., by prevailing currents) from the trawling areas, and would be expected to exhibit minimal or no effects due to trawling. Reefs among both classification groups were selected to be as similar as possible in all other regards. Such designation also assumed that any other environmental influence (e.g., terrestrial derived sedimentation) does not differ significantly between control and treatment reefs. Potential reef sites on or outside the barrier reef were avoided (with one exception) since they might expect to differ naturally from the set of inshore protected reefs due to increased oceanic influence. Coral reef sites were selected to provide as broad and uniform coverage of the area as possible. The treatment sites were Bugle Cay; Lark Rock; Shark Bank; False Cay; the large shoal NE of Moho Cay; Moho Cay; and Stewart Cay (Fig. 3). The control sites were Hol Chan Marine Reserve (outside the barrier reef) of South Ambergris Cay; Hol Chan Marine Reserve (inside the barrier reef); Weewee Cay; Round Cay; and Funk Cay.

The field survey was conducted in Belize from 16-23 January, 1991. Visual observations of the reefs were recorded while scuba diving and an underwater camera (Nikonos V with 28 mm lens) was used to document characteristic features. Diving was conducted from a 23 ft ALVIA Mexican-built outboard motorboat operated by local guides. At each site the reef was surveyed from its top shallowest areas to the transition zone between the deepest hard substrate of the reef and the soft sand-mud channel. Horizontal assessment of the reef was conducted to the extent possible — more than an hour of underwater observation for most sites on a single tank of air. Descriptive notes were recorded on characteristic features of the substrate, and on communities of fish, plants and invertebrates from direct visual observations and from the photographs.

Several mangrove habitats and beaches were inspected between stops at diving sites. Our subjective impression of the quality of these areas was noted, with

particular consideration to possible effects of the nearby shrimp trawling activity (e.g., excessive siltation, dead fish bycatch).

4.3 Results

Observations concentrated on coral reefs due to their abundance in the area, sensitivity to sedimentation and major ecological importance to the coastal ecosystem and economy of Belize. Results from sites surveyed are described for reefs adjacent to the trawling grounds (treatment reefs) and reefs distant or otherwise isolated from the trawling grounds (control reefs). Mangrove habitats and beaches were the other critical marine habitats generally surveyed throughout the study area for any major visible signs of direct or indirect effects of shrimp trawling.

4.3.1 Treatment Reefs

Bugle Cay (1T)

Bugle Cay should be a prime candidate to reveal any possible effects of sedimentation outfall due to shrimp trawling, primarily because of its geographic and oceanographic situation (Fig. 3). The prevailing nearshore currents (i.e., between the mainland and barrier reef) flow south and Bugle Cay is positioned in the middle of the Inner Channel (i.e., the primary trawling grounds) and at the southern extreme of the main area trawled.

Substrate: The top of the reef observed was 3 to 10 ft deep (Fig. 9), gently sloping to the N to a sand-silt channel floor at 50 ft. The reef was composed of nearly 100% cover of numerous species of soft and hard corals (the former dominated the shallower areas) of which an estimated 90% was live. Hard corals included species of *Acropora* (staghorn and elkhorn coral), *Diploria* (brain coral) and *Agaricia* (leaf, ribbon and scroll coral). Such characteristics would classify this coral reef as excellent in health and richness. Small sand patches occurred between the corals. These were easily disturbed by intentionally directed fin kicking to produce a cloud of silt. This action produced larger silt clouds above 30 ft and below 50 ft. It is notable that a brain coral colony (*Diploria*) occurred about 6 ft away from the base of the reef at 50 ft on the channel floor. It was live and healthy (i.e., not fouled with sediment).

Fish: Fish life was abundant on this reef. Large schools, most of which were recently recruited postlarval forms, and small juveniles (e.g., parrotfish: *Scaridae*) were common (Fig. 10). Noted adults were Spanish Mackerel (*Scombridae: Scomberomorus maculatus*), deep bodied jacks (*Carangidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), squirrelfish (*Holocentridae*), wrasses (*Labridae*),

Fig. 9. Shallow area of the reef bordering Bugle Cay with characteristic corals, gorgonians and seagrass.

Fig. 10. RDA marine biologist observing dense schools of juvenile fishes at Bugle Cay reef.

surgeonfish (*Acanthuridae*), a manta ray (*Mobulidae*; with a 6 ft wingspan), a few butterflyfish (*Chaetodontidae*) and angelfish (*Pomacanthidae*), among others.

Plants and Invertebrates: Turtle grass (*Thalassia*) was common on top of the reef (e.g., in less than 6 ft of water) along with numerous gorgonians (sea rods, sea fingers, sea fans) and sponges. A variety of encrusting algae species covered dead coral branches and rocks. Common macro-invertebrates that were noted included spiny lobster, sea stars, brittle stars, conch, sea anemone, hermit crabs, and a squid.

Lark Rock (2T)

Lark rock is an isolated shoal, with a small area exposed, near the center of the southern end of the Inner Channel trawling grounds (Fig. 3). Since the current runs to the south, this reef would be among the most likely to be affected by sedimentation caused by trawling in the channel.

Substrate: The shoal was a shallow reef 5-15 ft deep. During the dive the team swam entirely around the small sand cay. The bottom was composed of a variety of hard (e.g., massive star, brain and elkhorn coral) and soft corals with small sand patches (Fig. 11). Hard corals were most abundant on the N side of the shoal and soft corals were common throughout the shallow water.

Fish: Small juveniles dominated the fish fauna. Various adult species of snappers, grunts and wrasses were noted. Other than a few grouper (*Serranidae*) large fish were not numerous.

Plants and Invertebrates: Turtle grass (Fig. 12), encrusting algae, sponges, sea rods and sea fans were the most conspicuous members of this category.

Shark Bank (3T)

The large shoal Shark Bank, as locals call this unlabeled feature on the chart, lies in the southeastern part of the Inner Channel, just SW of Crawl Cay and NW of Bakers Rendezvous (Fig. 3). Its position would suggest that it is most susceptible to possible sedimentation effects from disruption of the Inner Channel floor by trawl nets. The underwater survey was conducted along the west side adjacent to the channel.

Substrate: This shoal was characterized by nearly full and diverse coral cover (mostly hard corals) from the top at 10 ft to the bottom at 55 ft. Staghorn coral was very abundant on this reef and nearly 90% was live. The few patches of soft

Fig. 11. Typical shallow reef habitat at Lark Rock.

Fig. 12. Turtle grass and abundant juvenile fishes in the shallowest areas of Lark Rock.

substrate easily produced silty clouds when purposely disturbed by hand (Fig. 13). Soft substrate below 30 ft could be disturbed more easily and horizontal visibility near the bottom was about half that near the surface. Average sized healthy brain coral colonies occurred at the 50 foot level. The reef overall appeared very healthy. A small patch reef (about 30 ft in diameter and 20 ft high) was found in the channel roughly 20 ft away from the base of the reef slope. It was also characterized by abundant and diverse substrate and marine life.

Fish: Fish were abundant, especially juveniles which occurred in large dense schools. Adult taxa noted were butterflyfish, angelfish (Fig. 14), juvenile parrotfish (*Scaridae*), grunts (e.g., porkfish: *Aniostremus surinamensis*), damselfish (*Pomacentridae*), hamelets (*Serranidae*), barracuda (*Sphyraenidae*), snapper (yellowtail, schoolmaster and mutton snapper), surgeonfish, jacks (*Carangidae*) and Spanish mackerel.

Plants and Invertebrates: Various gorgonians (e.g., sea fans, sea rods) were common in shallow water. Sponges and encrusting algae occurred throughout the reef. A number of lobsters (*Panulirus argus*) and sea urchins were also seen.

False Cay (4T)

False Cay lies just offshore of the mainland in the southwestern part of the Inner Channel (Fig. 3). This position, combined with the southward current, should render this area highly susceptible to sedimentation from trawling of the Inner Channel floor.

Substrate: The reef around the cay sloped gently from 8 to 20 ft. Soft coral, plants and invertebrates dominated the shallows (Fig. 15) and scattered coral boulders characterized the deeper areas. Forms included brain coral, star coral, finger coral and dead encrusted rock. Benthic life was diverse and abundant in spite of murky water, supposedly due to the heavy consistent rains of the past two months. (The shrimp trawlers had only been operating for a few days following the 6 week closed period).

Fish: Fish were numerous with unidentifiable species of postlarval recruits being particularly abundant. Among the adult forms were butterflyfish, groupers, wrasses, angelfish, snapper, bigeyes (*Priacanthidae*), hamelets (Fig. 16), grunts and spadefish (*Ephippidae*).

Plants and Invertebrates: Soft corals, gorgonians and sponges dominated the benthic terrain. Encrusting algae and seagrass were abundant and diverse in less than 10 ft of water. Other invertebrates noted on this dive were sea anemones, sea pens, and a sea hare (*Anaspidae*).

Fig. 13. Cloud of silt produced by the fin-kick test for relative sedimentation on the reef at Shark Bank.

Fig. 14. Gray angelfish swimming above staghorn coral at Shark Bank reef.

Fig. 15. Characteristic shallow habitat of gorgonians and a pair of Spotfin butterflyfish (*Chaetodon ocellatus*) at False Cay.

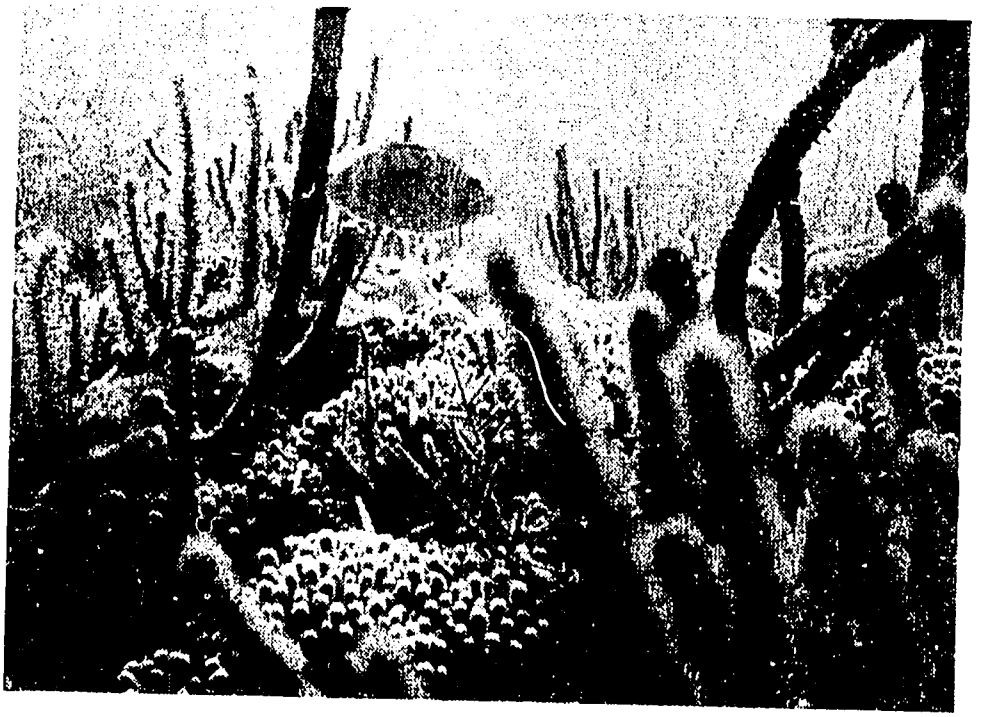

Fig. 16 A barred hamlet (*Hypoplectrus puella*) and the reef environment at False Cay.

Shoal NE of Moho Cay (5T)

The large reef shoal NE of Moho Cay lies in the center of the south end of Victoria Channel, the second major shrimp trawling grounds in Belizean waters (Fig. 3). With the prevailing southward current, this area should show any possible sedimentation damage due to trawling upcurrent.

Substrate: The reef sloped, steeply in some places, from the top at 10 ft (Fig. 17) to the sand-silt channel floor at 100 ft deep. Coral cover was nearly 100% and mostly live. Branching staghorn coral dominated the shallower regions. Numerous encrusting forms occurred down the slope (Fig. 18). Other coral types on the slope included brain, finger, leaf, scroll, and massive star coral. Sediment between the corals was little or absent as directed fin kicking failed to produce much of a silt cloud. It is notable that live corals occurred all the way down to the 100 ft depth and some isolated hard coral colonies even occurred away from the reef base on the soft floor of the deep channel.

Fish: Juveniles and newly recruited postlarval forms dominated the fish fauna. Recorded adult species were barracuda, queen trigger (*Balistidae*), trumpetfish (*Aulostomidae*), rock hind and other groupers, yellowtail snapper, wrasses, parrotfish, angelfish, bar jacks, king mackerel, hamlets, and grunts.

Plants and Invertebrates: Plant life included turtle grass and various species of encrusting algae. Highly visible macro-invertebrates recorded were sea anemones, sea fans, sea rods, feather stars, vase, basket and tube sponges (covered with brittle stars), queen conch, and spiny lobster.

Moho Cay (6T)

Moho Cay marks the southern end of the shrimp trawling ground in Victoria Channel (Fig. 3). Like the reef-shoal just to the NE, the reef bordering Moho Cay should be a most likely candidate of any reefs in the area to exhibit ecological effects due to trawling in the channel.

Substrate: The reef sloped from 10 ft on top to 65 ft at its base in the channel. The slope was characterized by nearly full coral cover but an estimated 20% of staghorn branches above 30 ft were broken, dead and encrusted with algae or various soft corals (Fig. 19). Surrounding, less fragile corals (e.g., ribbon, brain [Fig. 20] and massive star coral) were intact, live and healthy. Sedimentation as determined by the fin-kick test was slightly heavier than on the reef-shoal to the NE of Moho Cay.

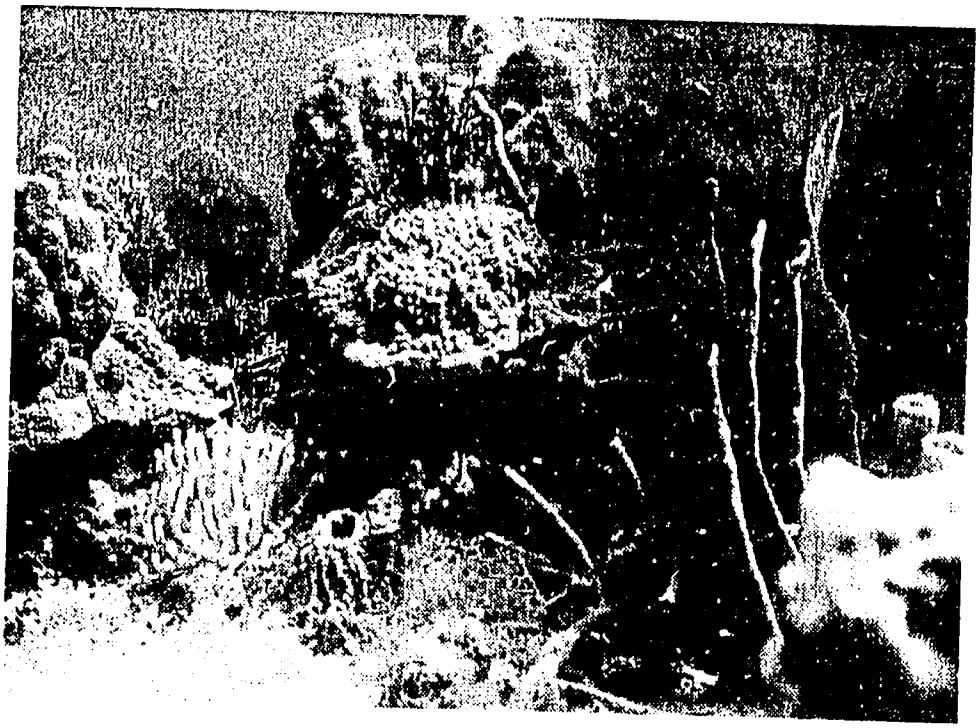

Fig. 17. Shallow reef environment on the shoal NE of Moho Cay.

Fig. 18. RDA marine biologist assessing the reef slope of the shoal NE of Moho Cay.

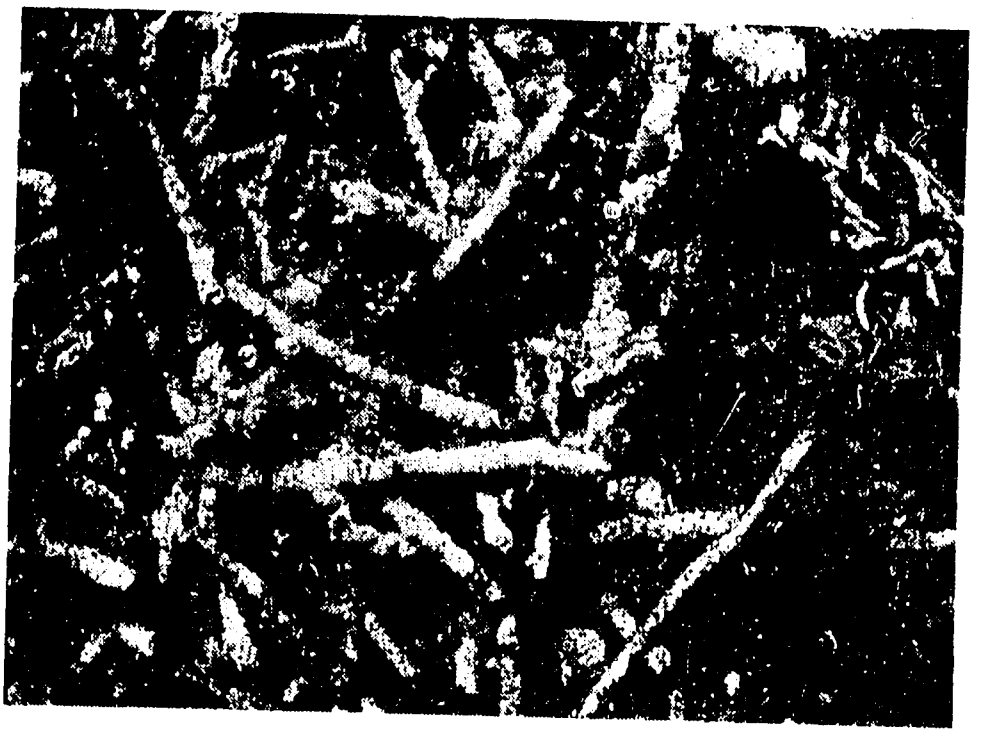

Fig. 19. Dead encrusted staghorn coral on the shallow part of the reef at Moho Cay.

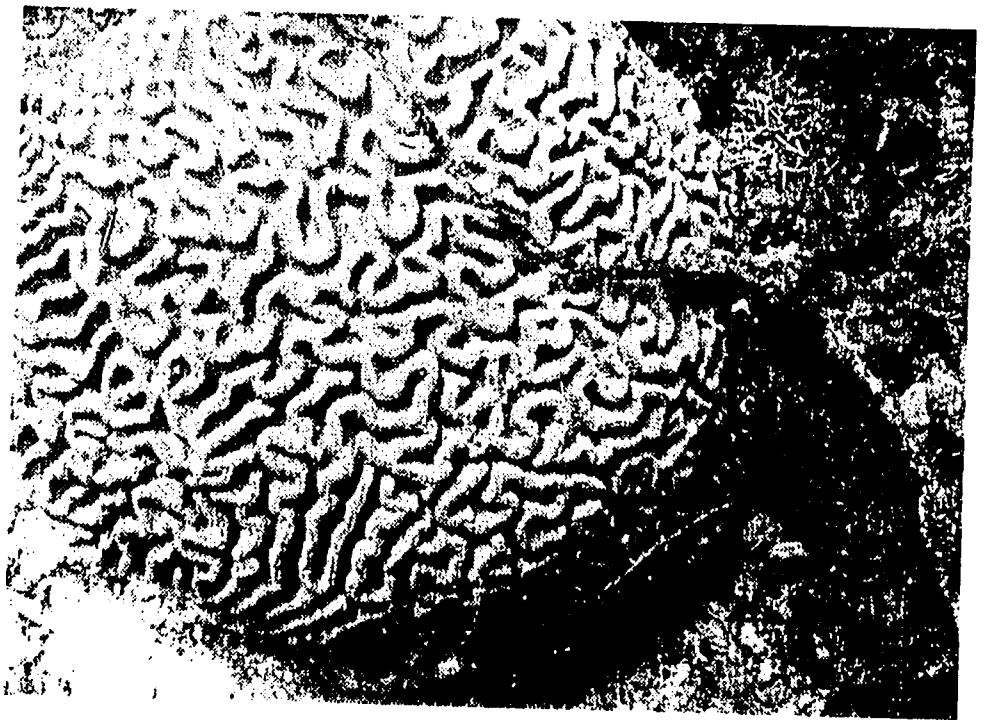

Fig. 20. Healthy brain coral colony on the reef at Moho Cay.

Fish: Fish life was good on this reef and adults seemed more common than on the reef-shoal to the NE of Moho Cay. Many species were observed (e.g., Spanish mackerel, jacks, angelfish, surgeonfish, parrotfish, goatfish, jack-knife fish [*Sciaenidae*], Nassau grouper, gray angelfish, blue tangs [*Acanthuridae*], and others). Juveniles and schools of newly recruited forms were also common (Fig. 21). Butterflyfish appeared more numerous here than on previous reefs.

Plants and Invertebrates: A mixture of soft corals, gorgonians and sponges characterized the reef above 15 ft. Major invertebrates seen on the dive were arrow crabs, fairy shrimp, queen conch, and spiny lobster.

Stewart Cay (7T)

Stewart Cay lies on the eastern side of the Inner Channel off Sittee Point of the mainland and considerably to the north of the other treatment sites (Fig. 3). Its position is about central in the main trawling grounds between Dangriga and Placencia of the Inner Channel. The reef on the western side of Steward Cay would expect to exhibit possible sedimentation due to trawling in the adjacent channel.

Substrate: The reef surveyed was 8 ft on top and 65 ft deep at its base in the channel. It was characterized by typical bar bottom substrate with little hard coral other than isolated rocks, mainly in the shallow areas. The sandy slope had abundant coverage of gorgonians, soft corals, sponges and algae. Horizontal visibility was poor and sediment was easily stirred-up by the fin-kick test. This site was just east of the Sittee River, a major watershed of the mainland.

Fig. 21. School of juvenile parrotfish in the shallow areas of the reef at Moho Cay.

Fish: Fish life did not appear abundant at this site relative to many of the previous reefs surveyed. Species seen and recorded were Spanish Mackerel, butterflyfish (Fig. 22), wrasses, juvenile parrotfish, a large Nassau Grouper, and a sting ray (*Dasyatidae*). Most common were dense schools of recently recruited postlarval fishes (Fig. 23).

Plants and Invertebrates: Turtle grass was the dominant plant life in the shallow areas and a variety of algae species occurred down the slope, along with the gorgonians, soft corals and sponges. A pair of Queen Conch were seen breeding and several Milk Conch were likewise seen together.

4.3.2 Control Reefs

Hol Chan Marine Reserve (outside barrier reef: 1C)

The Hol Chan Marine Reserve was established in Belize in 1987 with assistance in part from USAID. The reserve includes the reef area inside and outside the barrier reef, the seagrass bed of the lagoon, and the mangrove areas of the cay. It is prohibited to collect or disturb marine life here in any way.

The Hol Chan reserve is located on the southern end of Ambergris Cay over 70 miles north of the trawling grounds. The exact site surveyed was an area about 100 m outside the cut in the barrier reef. It served as a control in that it was in no way affected by shrimp trawling. However, this reef differed much from the other reefs of the study by being a seaward reef front exposed to direct oceanic influence, rather than a reef slope of a protected cay. In fact, strong bottom surge was experienced during the dive in 50 ft of water due to large surface swells.

Substrate: Bathymetry was typical of an exposed seaward reef front environment with reef patches of high relief, predominantly live coral structures separated by flat sandy areas. Characteristic of the site was pillar coral (*Dendrigyra*) which has a growth form resembling large stalagmites (Fig. 24). (Pillar coral was not seen at any other sites of the study). Other common corals included brain, elkhorn, staghorn, ribbon, sheet, scroll and large massive star coral.

Fish: Fish life was diverse and abundant and mostly represented by adult forms. Common species noted were Bluestripe grunt, Yellowtail snapper, Queen triggerfish (*Balistidae*), Rock Beauty (*Pomacanthidae*), Bar jacks, and Blue Chromis (*Pomacentridae*). Other species of snapper, grouper, surgeonfish and wrasses were also observed (Fig. 25).

Fig. 22. The banded butterflyfish in the reef shallows at Stewart Cay.

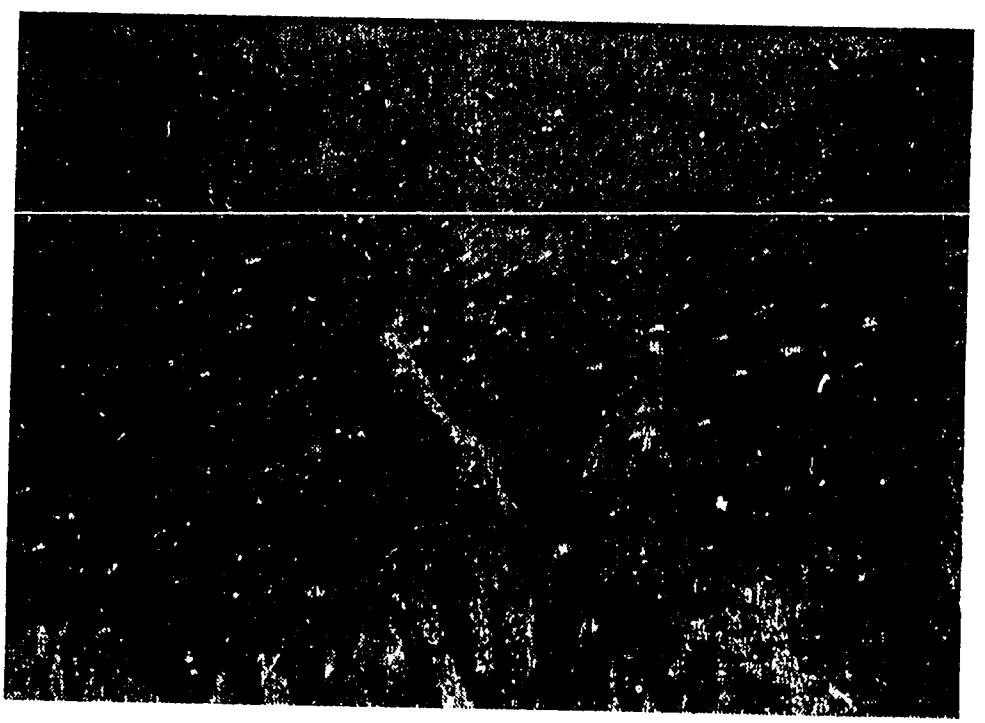

Fig. 23. Dense schools of postlarval juvenile fishes among the gorgonians at Stewart Cay.

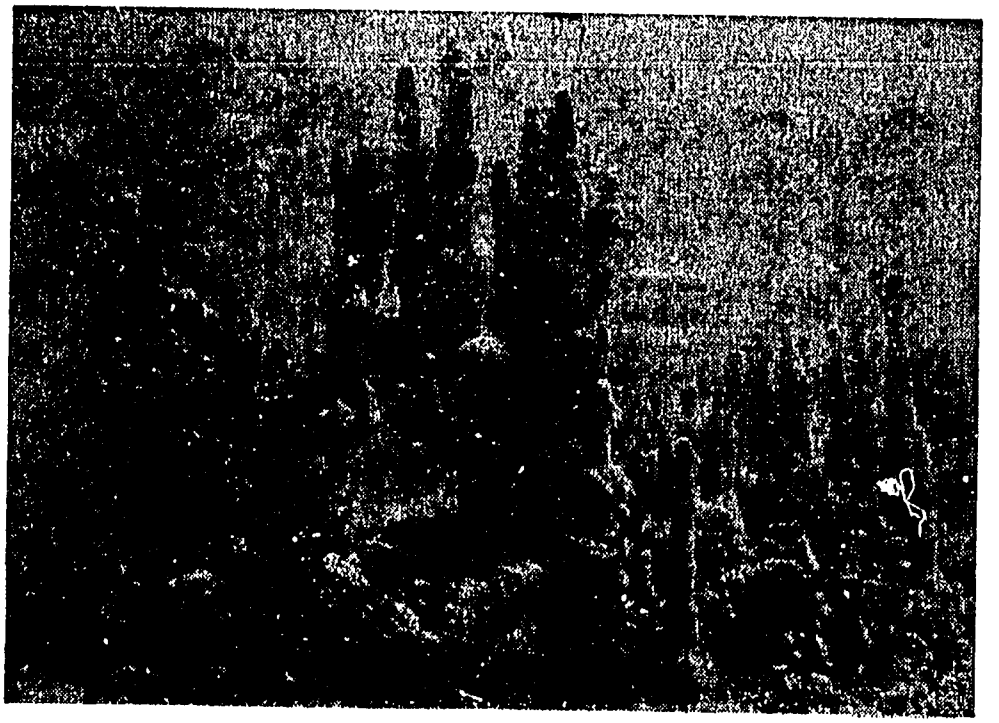

Fig. 24. Characteristic Pillar coral of the barrier reef's seaward reef flat at Hol Chan Marine Reserve.

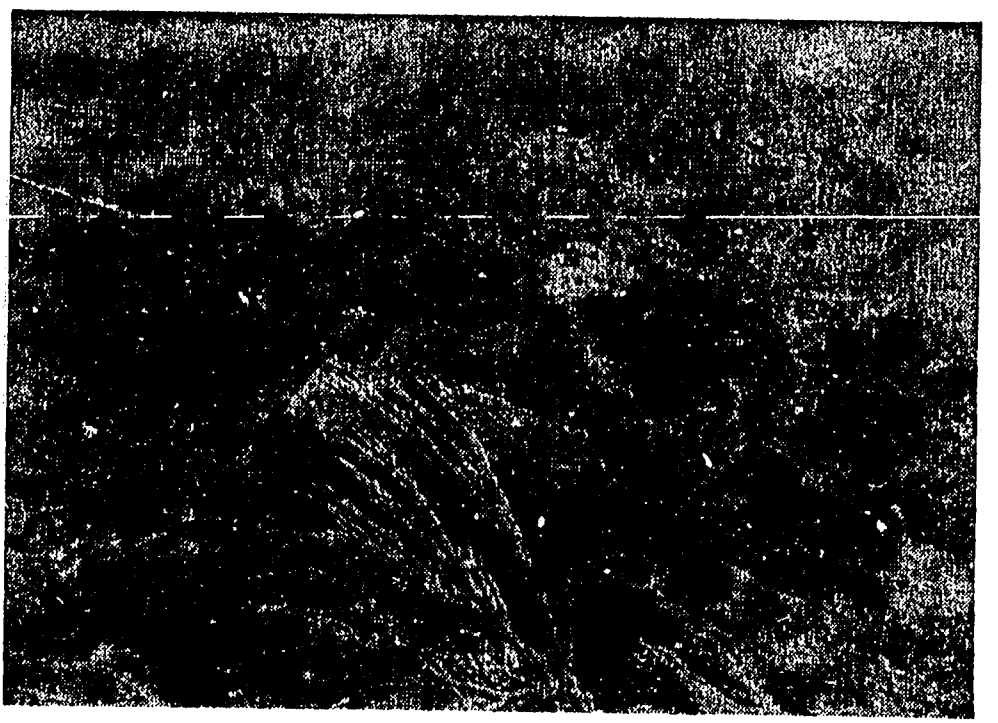

Fig. 25. Large grouper and the benthic environment outside the barrier reef at Hol Chan Marine Reserve.

Plants and Invertebrates: Encrusting algae on the dead parts of coral rocks accounted for the main plant life seen. Gorgonians (large sea rods, sea fans, sea plumes) on the sandy areas were the most conspicuous invertebrates, although less abundant than in the shallower areas of the marine reserve.

Hol Chan Marine Reserve (inside barrier reef: 2C)

The site of this survey was just inside the 'Hol Chan' cut in the barrier reef and east of southern end of Ambergris Cay. It served as a control reef in that it lay between the barrier reef and the Belize mainland while unquestionably removed from any possible effects of trawling, located upcurrent some 70 miles from the nearest shrimp trawling grounds. It was unique in that it is a marine reserve and should represent as nearly an undisturbed environment as possible for comparison. The site differed from the other control and treatment reefs in that it was a shallow outer reef flat (just behind the barrier reef) rather than a reef slope bordering a cay well inside the barrier reef. It also differed in that the scores of tourist divers that visit this spot twice daily are responsible for breaking corals and disturbing benthic sediment by inadvertent fin-kicking. These visitors may also artificially enhance the density of fish through supplemental feeding.

Substrate: Depths ranged from less than 10 ft to 15 ft. Substrate was characterized by a sand-seagrass (*Thallasia*) bottom about half covered with small to large coral boulders (e.g., star, brain and elkhorn coral) which served as habitat for a diverse community of marine life (Fig. 26). A variety of large gorgonians were also common throughout the area. The reef habitat was generally in good health with the exception of some broken coral branches and sedimentation, probably due to fin kicking by recreational divers.

Fish: The fish community was diverse, very abundant and predominantly composed of adults. Common taxa included large groupers, grunts, snappers, damselfish, wrasses, stingrays, jacks, and angelfish (Fig. 27). An electric ray was also seen.

Plants and Invertebrates: Turtle grass dominated the sandy areas. A variety of shallow water gorgonians (sea fans, sea whips, sea rods), some quite large, were the most conspicuous invertebrates, other than the corals themselves.

Weewee Cay (3C)

Weewee Cay lies to the east of Stewart Cay and is physically isolated from the Inner Channel by a series of mangrove cays (Fig. 3). Such an area might expect to exhibit little or less effect from trawling activity in the channel.

Fig. 26. Characteristic benthic habitat inside the barrier reef at Hol Chan Marine Reserve.

Fig. 27. Group of tourist divers viewing the shallow reef flat and a school of Bluestriped grunt (*Haemulon sciurus*) at Hol Chan Marine Reserve.

Substrate: The reef slope on the SE side of the cay was surveyed. Horizontal visibility was poor and the water felt colder than other dives in the area, possibly due to a localized upwelling. The top of the reef was in 5 ft of water dropping gradually to 65 ft at its base. Bottom habitat was similar in composition to most other reefs (controls and treatments) observed in the Placencia area, i.e., a mixture of live hard corals (e.g., brain, leaf, star coral) and dead rocks, gorgonians, sponges, and algae on a substrate which was about 30% sand-silt (Fig. 28). Scattered coral boulders occurred in the shallows among the turtle grass. The fin-kick test produced a good cloud of fine silt.

Fish: Juvenile fish were abundant while large adults were not. Identifiable juveniles included parrotfish, snappers, and groupers. Adults seen were filefish (*Monacanthidae*), angelfish (Queen, French [Fig. 29], and Gray), hogfish (*Labridae*), and jacks, squirrelfish, damselfish, hamlets, and grunts.

Plants and Invertebrates: The typical reef plants and invertebrates of the area were also common on this reef (e.g., Turtle grass, gorgonians, sponges, etc.).

Round Cay (4C)

Round Cay lies about halfway between Victoria Channel and the barrier reef and is well isolated by numerous surrounding mangrove cays (Fig. 3). Any effects of trawling in the channels would be expected to be negligible on this reef. Direct effects of oceanic influences should also be minimal here.

Substrate: The reef surveyed on the west side of the island sloped from 15 ft to 70 ft at its base. The top of the reef was dominated by live staghorn coral and gorgonians on a sand patch bottom. Substrate on the slope was rich with an estimated 80-90% coral cover (Fig. 30). Common were ribbon, brain and staghorn coral. A small percentage of the branching corals were dead and heavily encrusted.

The fin-kick test on the reef slope stirred up a silt cloud as easily as on any other reef surveyed, including those near the channel. The silt was quite fine as evident by the extended length of time it hung in the water column.

Fish: Both juveniles and adults were abundant on this reef. In addition to numerous postlarval recruits, identifiable juveniles were angelfish, snappers, and parrotfish. Mature forms noted were hogfish, blue tangs and other surgeonfish, jacks, snappers, hamlets, grunts, moray eels, squirrelfish, and butterflyfish. It was our subjective impression that the fish community, in terms of diversity, abundance, and age structure, did not differ significantly from most of the previous control and treatment sites visited.

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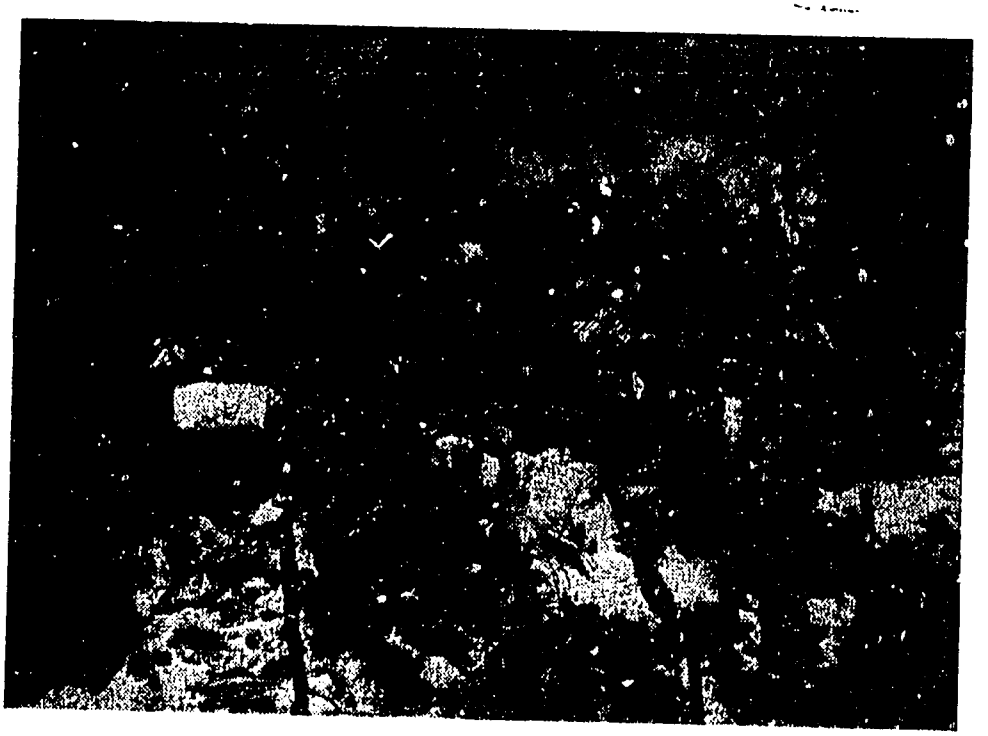

Fig. 28. Typical bottom habitat and juvenile parrotfish in the reef shallows at Weewee Cay.

Fig. 29. Subadult form of the French angelfish (*Pomacanthus paru*) at Weewee Cay.

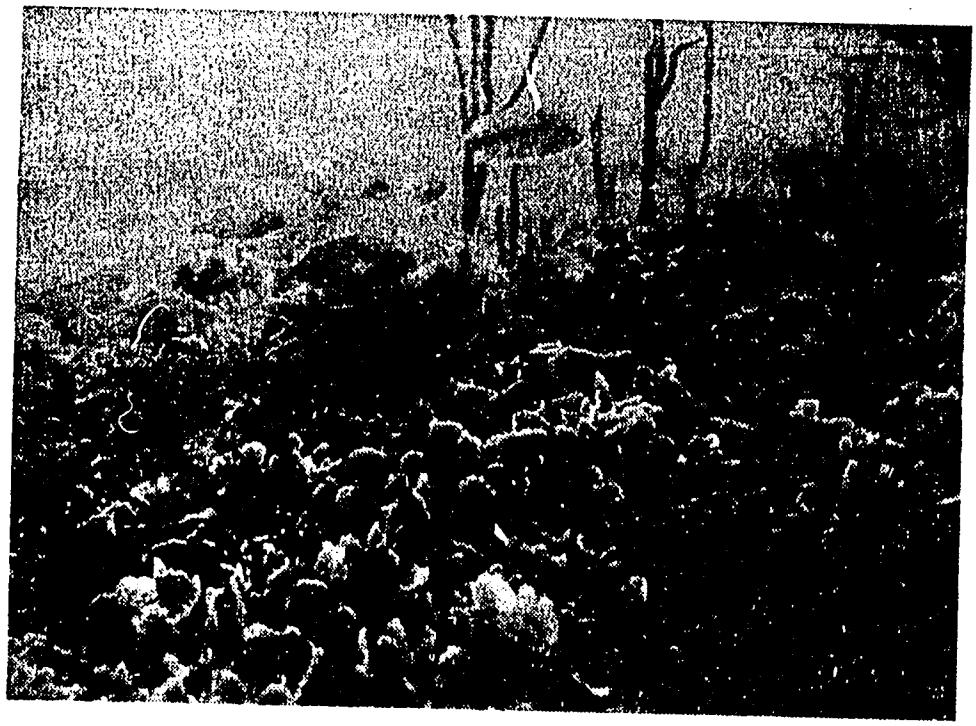

Fig. 30. Abundant coral cover characteristic of the reef slope at Round Cay.

Plants and Invertebrates: The typical reef algae and invertebrates (e.g., encrusting species, gorgonians, sponges, etc.) that characterized all reefs of the study were also present here. A white spined sea urchin was also seen (Fig. 31).

Funk Cay (5C)

A small shoal just to the west of Funk Cay was surveyed. This site was SE of Round Cay and is also well isolated from the channels and the barrier reef by many neighboring cays and shallow reef expanses (Fig. 3).

Substrate: The top of the shoal was predominantly sand with scattered coral boulders in less than 10 ft of water. The slope had approximately 70% cover of hard substrate among large patches of white sand (Fig. 32). Common stony corals were ribbon, star and brain. The fin kick test on the reef slope revealed a silt cloud no less than those generated at treatment sites.

Fish: Juvenile and adult fishes were abundant. Recognizable species included Nassau grouper, barracuda, rock hind, trumpet fish, spotted morey, numerous schools of snappers and grunts, surgeonfish, hamlets, queen angels, gray angels, spotlight parrotfish and juveniles, squirrelfish, butterfly fish (including a longsnout butterfly).

Fig. 31. Sea urchin among the shallow corals at Round Cay.

Fig. 32. The rich and diverse reef environment by Funk Cay.

Plants and Invertebrates: Gorgonians dominated the shallow areas of the shoal and some were quite large (Fig. 33). The benthic community was again similar to most of the previous reef sites visited.

4.3.3 Other Critical Habitats

Mangroves: Mangroves were abundant in the area (Fig. 34). Red mangrove (*Rhizophora mangle*) surrounded most of the numerous cays. Snorkeling among the prop roots revealed (Fig. 35) fish such as schoolmaster and mangrove snapper, juvenile baraccuda, needllefish (*Belonidae*), moharra (*Gerridae*), silversides (*Atherinidae*), and thousands of unidentifiable postlarval fishes. The substrate around the roots was composed of fine sediment, and turtle grass beds lay adjacent to the prop roots.

Beaches: Small beaches occurred on isolated sections of some of the cays, which were mostly surrounded by mangroves, and along some stretches of the mainland coastline. The beaches did not appear unnatural in any way. Dead turtle grass (*Thalassia*) was common at the high tide line of mainland beaches (Fig. 36); patches of this sea grass were also seen floating at sea. No dead fish were sighted on any beaches nor at sea during the entire survey throughout the area.

4.4 Discussion

The terms of reference for the ecological aspect of the study aim to determine the impact of shrimp trawling operations in Belize on sensitive coastal habitats of reefs, mangroves and beaches. During the field survey reefs of the area were assessed for substrate quality and the status of their fish and plant/invertebrate communities. Comparison of ecological conditions were made between reefs adjacent to the trawling grounds and reefs isolated from the nearshore channels trawled. Mangrove areas and beaches were generally surveyed to assess their condition and health both near and far from the trawling grounds. The ecological status of reefs and critical marine habitats is discussed here in relation to the shrimp trawling operation. The possible affect of discarding fish bycatch on reef fish communities and critical habitats is also discussed.

4.4.1 Reefs

Reef Designations: The selection of reef sites as controls or treatments in relation to possible environmental influences due to shrimp trawling seems reasonable. However, one could question the validity of the assumption regarding differential effects that other environmental parameters may exert upon reefs between the two sets. For example, since the Inner Channel and Victoria Channel trawling grounds run along the coastline, it is a geographic consequence that the set of treatment

Fig. 33. RDA marine biologist with large gorgonians in the shallow areas of the shoal off Funk Cay.

Fig. 34. RDA marine biologist examining the prop root environment of red mangroves of Lark Cay.

Fig. 35. The rich subtidal habitat offered by the mangrove prop roots.

Fig. 36. The beach at Placencia bordering the Inner Channel shrimp trawling grounds.

reefs are closer to shore than the set of control reefs. Therefore, the compounding influence of terrestrial derived sediment (e.g., agricultural runoff) might be expected to have a greater influence upon nearshore treatment reefs adjacent to the channels than upon the control reefs that lay further offshore. Underwater horizontal visibility was substandard for Belize at all sites monitored. This increased turbidity was believed due to land-based runoff from the heavy consistent rains during the previous two months (November-December, 1990).

It would be difficult to isolate the causative source of reef sedimentation as due to terrestrial origins following extended rains or due to disruption of the channel floor by trawling. Chemical analysis of the reef sediment may provide clues (e.g., abundances of nitrates or phosphates from agricultural practices). Such a result may still not be conclusive as the channel floor may be an intermediate holding site for terrestrial derived sediment that reaches the reef upon subsequent disruption by trawls. It is not known whether other suitable tests for separating these effects exist. If so, such tests would no doubt be cost prohibitive.

Substrate Quality: Substrate quality among the control set of reefs was no greater than that of the treatment set (Table 6). There were no apparent significant differences in percent of hard coral cover, percent of live coral cover, or degree of sedimentation, as determined by the fin-kick test. In fact, within-group variation was greater than between groups for these ecological characteristics of the substrate. Broken dead branches of staghorn coral (Fig. 19), found on a minority of reefs within both groups, were probably due to storm damage, possibly several years old. A small percentage of dead branches and branch tips is a common characteristic of this species (*Acropora cervicornis*) even on the most pristine reefs.

These results suggest that, regardless of the source (i.e., from channel trawling or from terrestrial runoff), the present effects of sedimentation upon reef habitat are minimal in nearshore waters of Belize and reef quality has not been adversely affected by either cause.

Other circumstantial evidence support this conclusion. On several of the treatment reefs, live colonies of hard coral were thriving at the deepest reaches of the reef (e.g., 50 to 100 ft), including some isolated colonies on the channel floor away from the base of the reef, in spite of the turbid water. These occurences suggest that water quality is not adversely affecting light penetration and that sedimentation, even near the bottom of the channel, is not great enough to smother sessile coral polyps.

Fish Community: Our visual impression of the fish communities on the surveyed reefs revealed no major or consistent differences between the treatment and control groups for most ecological parameters of comparison. Fish abundance and

Table 6. **Summary of visual impressions (rough estimates) of ecological characteristics of reefs adjacent to (T = treatments) and isolated from (C = controls) shrimp trawling grounds.**

	SUBSTRATE QUALITY			FISH COMMUNITY			
REEF SITE	% Hard Cover	% Live Coral	Sediment Test[1]	Reef Fish Abundance	Reef Fish Diversity	Adult/ Juvenile[2]	Butterfly-fish[3]
Treatment							
1T	100	90	Moderate	High	High	A = J	Present
2T	30	90	Moderate	Moderate	Moderate	A < J	?
3T	100	90	Moderate	High	High	A < J	Present
4T	30	80	Moderate	High	High	A < J	Present
5T	100	90	Light	Moderate	Moderate	A < J	?
6T	100	80	Moderate	High	High	A > J	Present
7T	20	90	Moderate	Low	Low	A < J	Present
Control							
1C	60	90	Light	High	High	A > J	?
2C	50	90	Moderate	High	High	A > J	Present
3C	70	90	Moderate	Moderate	Moderate	A < J	?
4C	80	90	Moderate	High	Moderate	A = J	Present
5C	70	90	Moderate	High	High	A = J	Present

1) Subjective impression of relative degree of sediment on the reef as determined by the fin-kick method.
2) Relative abundance of adults to juvenile fish on the reef.
3) As indicator species of the health of the reef based on the abundance of live coral as food.

diversity was moderate or high on all but one of the twelve total reefs observed. Butterflyfish are sometimes considered as ecological indicators of the health of a coral reef. Since many butterflyfish feed on coral polyps, their presence is correlated with the abundance of live coral cover. Butterflyfish were no more or less present on either set of reefs assessed.

The only possible apparent difference in the fish community between treatment and control reefs was the greater abundance of juveniles, relative to adults, on reefs of the former group. Such a result is difficult to explain. A major recruitment pulse was obviously occurring on all reefs in the Placencia area during the survey. Possibly nearshore waters harbor higher nutrient and plankton densities which may provide better postlarval food than areas farther from shore.

Reef Fish Communities and the Shrimp-Trawl Bycatch: Results from the shrimp/bycatch assessment indicate that about 88% of the weight of the catch of shrimp trawlers is finfish bycatch. Snapper (*Lutjanidae*), which accounted for about 14% of the finfish, is the only major bycatch taxa which also inhabit coral reefs. This figure is represented primarily by the potentially commercial species Lane snapper (*Lutjanus synagris*, Fig. 8). It is suspected that the sandy-mud bottom of the channels serves as an intermediate habitat in the life-cycle of the snapper between its pelagic larval stage and its adult life on reefs. At present levels of effort the commercial shrimp industry kills an estimated 3 million (extrapolated) subadult Lane snapper annually (or 340,000 pounds). Lane snapper did occur on the reefs surveyed in this study but were no more or less common on either the treatment or control set of reefs. No known data exist to determine whether the overall population size of Lane snapper on Belize reefs is now significantly different than before commercial shrimping began in 1985. Local fishermen did complain of diminishing catches for targeted species. Alternately, this may simply reflect a long-term increase in total fishing pressure on the reefs and sheltered inshore waters, as is common in many other places around the world.

Plant/Invertebrate Community: Although each reef differed somewhat in its benthic community composition, there were no major obvious differences in plant and invertebrate life between the treatment and control sets of reefs.

Results of the assessment of fish and plant/invertebrate communities further support the conclusion that the present shrimp trawling activity in the channels has yet to impact the ecological status of reefs in Belize waters in any noticeable way. Furthermore, the study reefs appeared typical in all regards based on our combined experience of over a thousand hours observing coral reef communities in many other places circumtropically.

4.4.2 Other Critical Habitats

Mangroves: The quality and health of the mangrove tidal communities assessed appeared typical of such habitat in all respects. Considerable sediment is a typical characteristic of this environment. Shrimp trawling in nearby channels does not appear to be adversely affecting mangrove ecosystems.

Beaches: No discernible effect on beaches was found that could be attributed to shrimp trawling. The mass of dead seagrass on the shores was probably due to recent strong offshore winds and winter storms. Even though the trawlers throw hundreds of pounds of fish bycatch overboard daily, no dead fish were seen floating or washed ashore during our entire visit throughout the area. Hundreds of seabirds were observed feeding on the bycatch as it was shoveled overboard at dawn. In addition to picivorous avian predators, pelagic fishes and porpoises most likely recycle all of the fish bycatch biomass into the marine food chain in very short time and before dead fish are washed ashore.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Major Conclusions

From the present assessment of the ecological and economic impacts of shrimp trawling in Belize the following conclusions can be made:

1) A catch ratio for shrimp:bycatch of 1:7.3 was found for this study at Belize, which is basically consistent with that from shrimp trawl fisheries elsewhere.

2) The high tonnage of finfish bycatch most likely represents a significant portion of potential artisanal fish production.

3) The two most common families of bycatch were juveniles of shad and snapper. These juveniles have essentially no market value at their present trawl-caught size, but would have substantial value at maturity.

4) Results of this assessment indicate that turtle bycatch in shrimp trawls is low in Belize.

5) Essentially all the discarded bycatch is reincorporated into the food chain through consumption by fish, birds and benthic carnivores.

6) Evidence in the assessed bycatch, such as the predominance of pre-spawned juveniles, decreases in CPUE over time, and the considerable volume of fish taken, suggests that the shrimp industry is negatively impacting certain finfish stocks in the trawling grounds.

7) It is unknown whether stock sizes of commercial fish have been significantly reduced since trawling began in 1985.

8) While CPUE for shrimp was similar for both channels, bycatch was significantly less from the deeper and more seaward Victoria Channel for most common fish families.

9) Even though the catch (CPUE) of shrimp and bycatch increased immediately following the mid-season closure, both the fall and winter periods were characterized by substantial decreases in CPUE.

10) Considering these decreases in CPUE in the fall and winter, it may be unprofitable to trawl for more than 2 continuous months at a time.

11) The shrimp industry benefits the Government of Belize economically through foreign exchange and export tax earnings for shrimp sold internationally, and from employment for Belizeans locally. Such benefits should be weighed against the benefits of competing economies such as marine recreational tourism and local fisheries.

12) The ecological assessment of reefs, mangroves and beaches revealed no major or consistent differences in condition between treatment sites proximate to the trawling grounds and control sites distant from direct effects of the shrimp trawlers.

5.2 Recommendations for Management and Habitat Protection

The recent commercial development of the shrimp fishery in Belize now presents the government with a number of policy decisions that need to be addressed. While this document addresses only the shrimp fishery, the choices which must be made are reflective of those found in other fisheries. Commercial development of any fishery today quickly reaches the point where, left unregulated, the commercial harvest is capable of disrupting artisanal fishing, and indeed may be capable of fishing a resource to economic extinction. Governments need to recognize that the fishery will be either managed by government policy or by economic forces. Inaction by the government to regulate a fishery is the functional equivalent of a decision to allow economic market forces to manage the resource.

It is also important to understand that a fishery resource cannot be managed by itself, but rather that it interacts with other fisheries resources, both ecologically (e.g. alteration in community composition through shifts in trophic structures) and economically (e.g. competition for limited resources, such as bycatch). Therefore, management concerns regarding the shrimp resource must include the functional role of shrimp in the ecosystem as well as the effect of harvesting a significant biomass of bycatch finfish species.

The following outlines some of the policy decisions which we feel are now facing the government, and provide insight into the ramifications and requirements of the various alternatives.

5.2.1 Resource Preservation

The first major decision facing the government is between the long term value of protecting their fishery resources versus the short term economic gain from immediately harvesting as much of the resource as possible and as quickly as possible. Properly managed to produce optimum sustainable yield (OSY), the Belize shrimp

resource can be used indefinitely, insuring its continued availability as a high-value food source and export commodity.

While the decision to preserve the resource base for future generations may seem to be the only rational choice, it is nonetheless important that the government clearly adopt this as a policy decision. A policy decision by the government to manage the shrimp resource (and hopefully all fish resources) to produce OSY will imply several actions by the government if such a policy is to be successfully implemented. It is only after the government has clearly and unequivocally declared its intent to preserve the shrimp resource that a commitment will be made to implement that policy. Examples of the types of government action necessary to effectively implement this policy include:

1) A complete resource evaluation, including study of the biological aspects of shrimp, to provide the baseline information necessary to measure the health of the resource.

2) Government regulation of levels of catch, gear restrictions, fishing seasons, and closed areas as necessary to provide protection to the resource.

   Regarding areal regulation, it appears that fishing effort should be encouraged in Victoria Channel rather than in the Inner Channel as shrimp CPUE was equally productive and bycatch CPUE was less in the Victoria Channel. Establishing alternate areas of the Inner Channel as seasonal juvenile nursery grounds may improve the catch rate of shrimp and enhance reproductive success of species common in the bycatch.

   Seasonal regulation can be used to achieve two objectives. First, to protect juvenile and breeding stocks of either the target species or of bycatch. Second, to use seasons to limit harvest of the target species or bycatch through limiting fishing effort. The current 45 day year-end closure was reportedly established for two reasons: 1) Shrimp CPUE and size declined during the first half of the season to a level where continued fishing was not economical; and 2) Honduran crews on the shrimp boats prefer to spend the Christmas and New Year's holidays at home.

   Regulation of levels of catch other than by control of seasons will require installation of a mechanism to provide quantitative assessment of catch levels and for enforcement.

3) Development of government capability to enforce fisheries regulations.

SB

With remarkably few exceptions, fishermen around the world tend to view their activities as a divine right which should not be subject to regulation by any political entity. This attitude leads to a situation in which no fisherman is going to obey a fisheries law or regulation in the absence of the apparent capability of a political entity to enforce the particular law or regulation.

A decision by the government that the short term gains from immediate harvest of as much of the shrimp resource as possible implies no need for additional action by the government.

5.2.2 Economic Sector Priorities

The government must also consider its priorities for different economic sectors that will be affected by decisions regarding the allocation and utilization of fisheries resources. For example, the government is going to have to weigh the competing interests of artisanal fishermen, industrial fishermen, and water-related tourism development. While these sectors are not exclusive, they clearly need to be prioritized because changes in the level of development of any one will generally only come at some expense to the others.

A detailed examination of the effects on each sector by development in the others is far beyond the scope of this report. However, some examples may be useful. An industrial fishery is much more efficient than artisanal fisheries. Development of an industrial fishery will effectively reduce the harvests of artisanal fishermen. This, in turn, carries certain socioeconomic consequences and may be expected to increase urban migratory pressures. Likewise, an industrial fishery will cause some habitat damage and will reduce fish stocks, thereby reducing the attractiveness of the area to sport divers. Preservation of stocks for harvest by artisanal fishermen will cause the loss of foreign exchange generated by export of fish caught by industrial fishermen. Industrial fishermen are more likely to pay license fees and taxes than are artisanal fishermen. Water-related tourism development often suggests the establishment of marine parks and sanctuaries, as well as the preservation of coral habitat, generally at the expense of development in the fish harvest sectors. Tourism is usually viewed as a "green" industry, and produces both foreign exchange, job opportunities, and tax revenues.

While the activities of these sectors are not entirely exclusive, the setting of priorities will allow the government to resolve conflicting demands for resource access in a fair and consistent manner. Perhaps more importantly, the setting of clear government policies regarding sector priorities insures that the consequences of those policies are considered and fully understood. When conflicts do arise, as now appears to be the case between artisanal fishermen seeking to harvest Lane Snapper and industrial shrimpers, clear government policy will provide a predictable

resolution of the conflict. Some examples of policy alternatives, and official action required, demanding government attention prioritization may include:

Preservation and Protection of Artisanal Fishing:

1) Areas accessible to artisanal fishermen are closed to industrial fishermen. For example, industrial fishing might only be allowed more than 5 mi off-shore.

2) Implementation of gear and equipment restrictions. Such restrictions might include bans on motors or limits on engine size, bans on nets or restriction of nets to those pulled by hand, or limits on vessel size or construction material.

Development of Industrial Fishing:

1) Providing investment incentives, such as tax holidays and low interest loans, to encourage capital inputs into the sector.

2) Facilitation of infrastructure development, either through direct or indirect government assistance.

Development of Marine Recreational Tourism:

1) Facilitation of tourism infrastructure development, either through direct or indirect government assistance.

2) Creation of marine parks and sanctuaries in areas readily accessible to tourists.

3) Easing of visa requirements for tourists.

5.3 Future Needs for Development of the Shrimp Capture Industry

The present short-term study by RDA International has established a valuable initial baseline on the shrimp/bycatch fishery and its impacts in Belize. Proper development and management of the shrimp industry in nearshore waters of Belize will now require a long-term comprehensive program of research and monitoring. Major considerations of such a program should include:

1) A shrimp/bycatch assessment program conducted over a full trawling season or longer, to provide the necessary data upon which to base accurate management decisions.

2) Biological aspects of shrimp such as life-history characteristics (e.g., maturation, spawning, recruitment), behavioral interactions in their natural habitat and in the presence of trawling operations, and annual variation in parameters of the local finfish fishery (e.g., sustainable yield);

3) Biological aspects and fishery parameters of common fish bycatch such as estimated size of the stocks and size/age composition, annual and spatial variation in CPUE, spawning season, recruitment periodicity, and annual variability in turtle bycatch;

4) Further scientific information on what ecological ramifications disruption of the channel floor by trawl drags has on important vertebrate and invertebrate species;

5) Effectiveness of experimental management regulations such as alternate seasonal and areal closures, use of bycatch excluder devices, catch quotas, and limitations on number of vessels; and

6) Long-term economic and ecological assessment of the relative costs and benefits of alternative usages of Belize's coastal resources, considering shrimp trawling, artisanal and commercial fishing, and marine recreational activities (tourism).

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APPENDICES

ATTACHMENT NO. 1
Amendment No. 5

PIO/T No.505-0012-

STATEMENT OF WORK

A. Background. With permission from the Government of Belize (GOB), Honduran trawlers are currently fishing commercially for shrimp in Belizean waters. Night trawls are made between dusk and dawn from August 15 to March 31. The diverse and abundant finfish bycatch is discarded over the side. There is no information available on the impact of this practice, in particular, and the trawling operations, in general, on the environment and the output of the local fishing industry.

B. Purpose: The purpose of the study is to assess the ecological and economic impact of shrimp trawling fishery in Belize in order to come out with rational and environmentally-sound policies and strategies to improve the management and development of this activity.

C. Specific Tasks: The Contractor shall undertake the following tasks:

a. design and implement a program which shall be able to assess, using reliable and acceptable scientific standards, the operations of trawlers in Belize;

b. determine the ecological impact of shrimp trawling operation on sensitive habitats along the coast including beach, mangrove and reef habitats;

c. quantify the true ratio of fresh fish to actual shrimp landed;

d. examine trawl catch for species composition and relative abundance and importance of each specie group;

e. based on (d.) above, state how, why or if "trash fish" is likely to contribute significantly to the decline in stock of other commercially important species such as lobster and other commercially important finfish species;

f. proposed a suitable mechanism to dispose of discards;

g. evaluate the impact of the trawl fishing on the catch of local fishermen by comparing the abundance and composition of the fish in the trawled areas and the near-shore and other source areas for Belizean fishermen.

h. define appropriate closed season and possible closed areas to optimize yield per recruit in weight and value;

i. recommend the optimum level of exploitation in terms of abundant indices and maximum recruitment with regards to annual catch quota and maximum number of trawlers allowable for the realization of sustained yields;

Appendix A. Statement of Work for the Study.

j. assess the overall economic benefit of shrimp trawling fishery to the Cooperatives and the country; and,

k. recommend policy strategies which may lead to improved management and enviromentally-sound development of shrimp trawling fishery in Belize.

D. Level of Effort. The study is expected to be implemented over a period of eight months between August 1990 and March 1991. It is estimated to require a total of 4 person months of U.S. consultants' services and 8 person months of a Belizean fisheries technician. The Contractor will provide the services of a shrimp/fisheries expert with experience on shrimp trawling activities and fish bycatch analysis and a reef ecologist to assess impact of shrimp trawling on the coastal environment. The local technician, who will be selected in coordination with the GOB's Fisheries Department, will assist the U.S. consultants in the collection and processing of relevant data. The Contractor will pay the local technician's salary, per diem and other related costs.

The Contractor's team will work closely with the Fisheries Department through the Fisheries Administrator and, whenever feasible, involve members of the Department in the study.

E. Reports. The Contractor shall prepare and submit to USAID a one-page monthly status report on the progress of the study. A preliminary report (no more than 10 pages) of initial findings and conclusions based on the fieldwork made and data gathered will be prepared and submitted to USAID and GOB by January 15, 1991. The final report which addresses all the tasks described in Section C above shall be submitted in five copies to USAID and GOB no later than April 15, 1991.

DATE (158) 16 Feb. 91 | VESSEL NAME/CAPTAIN SEACREST Roy Woods | FISHING AREA PLACENCIA | WEATHER REMARKS E 10 Knots.

DRAG NO. 1 TIME: 6:40 - 10:00 PM

WIND NE MOON N +

SUBSAMPLE BASKET WT. 50

TOTAL BASKETS BYCATCH 25

TOTAL SHRIMP: 40 (lg) 15 (sm)

SPECIES: NUMBER / WEIGHT

PENAEIDS: 104/4.7/9

SCIAENIDAE: 2/½ (18, 13)

SARDINE: 2/5oz (13.5)

HERRING: 7/½ (12)

DASYATIDAE:

ARIIDAE:

SPARIDAE:

LUTJANUS SYNAGRIS: 13/3lbs 15.3oz

LUTJANUS VIVANUS: (17, 14, 16)

CARANGIDAE:

OCCOCEPHALIDAE: 2/¼

ECHENEUS NAUCRATES:

OSTRACIDAE: 1/3oz

CARAPIDAE: 4/6oz

PARALEPIDIDAE:

DIODONTIDAE:

S. TESTUDINEUS: 4/6oz

SOLEIDAE: 2/1.3

CYNOGLOSSIDAE: 3/4

TRIGLIDAE: 1/2oz

POMADASYIDAE:

SCARIDAE:

CARCHARHINIDAE:

ALBULIDAE: 2/7.3oz (18)

SPHYRAENIDAE:

MULLIDAE:

GERRIDAE ~~SHAD~~: 96/5½

LYCODES PALLIDUS: 6/½

MISCELLANEOUS:

crabs, brittle stars, Sea cucumbers, starfishes.

OTHER OBSERVATIONS:

¾ trash Mostly finger Sponges.

Appendix B. Sample of raw field data for shrimp/bycatch assessment.

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CODE KEYS

VESSEL = VESSEL NAMES

BW	Blue Water I
CB	Captain Bimbo
CS	Calm Seas
HY	Hybur I
JC	Joni Christine
ME	Miss Erica
ML	Miss Lani
MS	Morning Star
SC	Sea Crest
SS	Sister Sacha
WJ	Wendy Joy II

AREA = FISHING AREAS

BLZ	Belize
DAN	Dangriga
PLA	Placencia
SIT	Sittie Point
VIC	Victoria Channel
EMO	East Moho Caye (part of Victoria Channel)
WMO	West Moho Caye (part of Dangriga area)

OTHER CODES

ST_DATE = Start date of trawl
WIND_D = Wind Direction
WIND_V = Wind Velocity in knots
MOON = Moon Phase
- NM = New Moon
- FM = Full Moon
- FQ = First Quarter
- LQ = Last Quarter

DRAG_N = Drag Number/night
DRAG_T = Median Drag Time (i.e. if Drag took place between 6 and 10 PM, DRAG_T = 20, for 20 hours, or 8 PM)
DRAG_L = Drag Length in hours
SAMP_WT = Weight of sample basket, in pounds
N_BASK = Total number of Baskets
SHRIMP_WT = Total weight of shrimp per drag
FAMILY represented by numbers (see list)
NUMBER = number of sample individuals per drag
WEIGHT = total weight of sample per drag
TRASH = per cent trawl considered trash (sponges, mud, garbage)

Appendix C. Entry codes for variables/values used for computerized shrimp/by-catch database.

BELIZE FISH BYCATCH/SHRIMP TRAWL DATA

REC NO.	VESSEL	AREA	ST_DATE	WIND_D	WIND_V	MOON	DRAG_N	DRAG_T	DRAG_L	SAMP_WT	N_BASK	SHRMP_WT	FAMILY NUMBER	WEIGHT	TRASH
157	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	1	379	11.50	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	7	66	6.75	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	10	3	0.25	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	14	107	6.50	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	15	45	6.00	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	17	1	0.13	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	20	7	0.63	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	22	4	0.25	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	26	14	1.13	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	29	4	0.38	0.25
	SC	VIC	15-Feb-91	SW	2	NM+1	2	3	6.0	60	14	110	30	3	0.25	0.25
158	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	31	11	1.50	0.25
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	1	104	4.68	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	2	2	0.44	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	7	4	0.38	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	9	9	0.81	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	10	3	0.25	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	14	96	5.50	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	15	13	3.94	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	17	2	0.25	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	18	1	0.19	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	22	2	0.50	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	26	2	0.06	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	29	4	0.38	0.75
	SC	PLA	16-Feb-91	NE	10	NM+2	1	20	3.5	50	26	55	30	1	0.13	0.75
159	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	26	55	31	6	0.50	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	1	119	4.75	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	2	1	0.19	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	7	10	1.60	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	9	4	0.38	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	10	1	0.06	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	11	19	2.25	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	14	77	4.50	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	17	1	0.25	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	20	12	1.25	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	22	5	1.50	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	26	3	0.25	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	29	7	0.50	0.75
	SC	PLA	16-Feb-91	NE	9	NM+3	2	0	3.5	50	24	50	30	5	0.44	0.75
160	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	24	50	31	3	0.13	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	1	112	4.60	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	2	3	0.63	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	7	12	1.00	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	9	4	0.50	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	10	4	0.13	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	11	1	0.50	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	14	84	5.60	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	15	7	0.88	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	20	21	2.13	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	22	6	2.00	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	26	6	0.50	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	29	12	0.75	0.75
	SC	PLA	17-Feb-91	NE	11	NM+3	3	4	4.0	50	22	40	31	4	0.19	0.75

Appendix D. Sample of raw shrimp/bycatch data in computerized format.

RDA DIVE LOG

No. 9 Site: Weewee Cay (SE slope) Date: 22Jan91

Purpose: To observe and document ecology of a reef isolated from effects of shrimp trawling visually and photographically

Divers: R.E. Schroeder + D.E. Sweat Visibility: 25'

Dive Times: 1030-1140 Bottom Time: 70 min Depth: 5-65'

Weather: Sunny, calm

Results/Comments: Water felt cooler today - may be upwelling reducing visibility; bottom habitat typical + similar to previous dives; juvenile fish abundant but few large fish; exposed 14 frames of Kodachrome 200 ASA roll (small marine lab on W side of Weewee Cay)

RDA DIVE LOG

No. 10 Site: Stewart Cay (W side) Date: 22Jan91

Purpose: To observe + document ecology of a reef near the shrimp trawling grounds visually and photographically

Divers: R.E. Schroeder + D.E. Sweat Visibility: 25'

Dive Times: 1230-1330 Bottom Time: 60 min Depth: 8-65'

Weather: Sunny, calm

Results/Comments: Slope mostly soft corals, gorgonians + sponges - little hard substrate; fish life not abundant; typical "bare bottom" substrate; this site is just SE of Sitka River mouth + recent heavy rains may account for the poor visibility; exposed frames 15-19 of Kodachrome 200 ASA roll

Appendix E. Sample dive log used for the reef ecological assessment.