The By-catch From the Artisanal Shrimp Trawl Fishery, Gulf of Paria, Trinidad

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Introduction

The continental shelf of northeastern South America is a highly productive fishing zone extending from east Venezuela to east of the Amazon River (Naidu and Boerema, 1972). The annual shrimp landings range from 15,000,000 to 20,000,000 kg (Villegas and Dragovich, 1984). However, an estimated yearly average of 200,000,000 kg of demersal finfish by-catch is thought to be discarded

ABSTRACT—Samples of shrimp trawl catches were collected from a commercial artisanal vessel fishing inside the 6-fm isobath in the Gulf of Paria, Trinidad. From August 1986 to May 1987, 34 late evening-early morning trawl trips were made and 97 hauls were sampled.

Annual ratio estimates were 9 (SD 1.3) finfish:shrimp and 14.7 (SD 2.0) by-catch: shrimp, with the highest ratios observed August through December and the lowest from late January through May, the dry season. Extrapolation of ratios, using shrimp catch statistics, indicates that for 1986, 974,000 kg of finfish and 620,000 kg of crabs, Callinectes spp., were caught incidentally by artisanal shrimp trawlers fishing in the Gulf of Paria. Of this total incidental catch (1,594,000 kg), about 1,500,000 kg were discarded (94 percent).

Four penaeid shrimp species are targeted: Penaeus schmitti, P. notialis, P. subtilis, and Xiphopenaeus kroyeri. Callinectes spp. were caught in large quantities from August to mid-January. Small (4-15 cm) pelagic and demersal species of little commercial importance dominated the finfish by-catch: Harengula spp., Cetengraulis edentulus, Chloroscombrus chrysurus, Eucinostomous spp., Diapterus rhombeus, and Cyclopsetta spp. Altogether, the monthly percentage of the species ranged from 70 to 85 percent of the total finfish by-catch.

in this region (Jones and Villegas, 1980). For the western central Atlantic region, Klima (1976), concluded that the shrimp fisheries discarded approximately 1,000,000,000 kg of finfish. For most penaeid shrimp fisheries, this by-catch is the main component of trawl catches at 75-95 percent of the total weight (Alsopp, 1982; Griffiths and Simpson, 1972).

Finfish weight to shrimp weight ratios have been used to estimate quantities of by-catch. However, most reported ratios are calculated for the nonartisanal fishery. Finfish:shrimp ratios vary widely from area to area even in the same region. Slavin (1982) reported estimates of 19 for the north central Gulf of Mexico and 40 for the northeast Gulf of Mexico. In the South Carolina offshore shrimp fishery, Keiser (1976) found the finfish:shrimp ratio to be highly variable (3-136), with a definite seasonal trend. Furnell, (1982) estimated a ratio of 13 inside the 10-fm isobath off Guyana and observed that this ratio decreased with increasing depth. Other work in this region indicates values of 4 for the offshore fishery in Guyana (de Mesquite, 1982), 15 for the northern coast of Venezuela, and 10 for Brazil (Griffiths and Simpson, 1972). Watts and Pellegrin (1982) estimated finfish: shrimp ratios in Texas, and reported variation between years (12.94 in 1980 and 2.55 in 1981), attributed to the Texas closure in 1981. Dragovich and Villegas (1983) reported ratios ranging from 2 to 130 (average 19.5) for the artisanal trawl fishery operating along the northern coast of Brazil.

In Trinidad, the artisanal trawlers fish within the nearshore region (mainly inside the 5-fm isobath) of the Gulf of Paria. Four penaeid shrimp species are the main target of this artisanal trawl fishery: Penaeus schmitti, P. subtilis, P. notialis, and Xiphopenaeus kroyeri.

Commercial landing statistics for Trinidad and Tobago are collected by the Fisheries Division, Ministry of Food Production, and accordingly in 1986 the artisanal trawl fishery was responsible for 30 percent (108,000 kg) of the total shrimp catch (Fisheries Division, Trinidad and Tobago, 1986). This study was formulated to determine by-catch:shrimp weight ratios to estimate the magnitude of the incidental catch, and to describe species composition and seasonality of trawl catches for the artisanal trawl fishery in the Gulf of Paria.

Materials and Methods

Study Area

This study was based on the local artisanal shrimp trawl fishery operating from Orange Valley in the Gulf of Paria, Trinidad (Fig. 1), or, more specifically, the Caroni platform in the depth range 0-6 fm. This Gulf is shallow with a mean depth of 15 fm, flat bottomed, and gently sloping, particularly along the coast (Gines, 1972). Composition of the bottom is mainly mud and silty-mud brought in by the Orinoco River and its tributaries (VanAndel and Sachs, 1964).

The Gulf of Paria has been described as a relatively calm, slightly stratified, semi-enclosed estuarine zone, where outflows from the Orinoco and other rivers mix with the water from the open ocean (Gines, 1972). Seasonal variability in the

surface salinity is tied to the Guyana current and Orinoco River (VanAndel and Sachs, 1964). During the wet season (June-December), surface salinities can be low (10-20⁰/oo), while in the dry season (January-late May) salinities may be as high as 35⁰/oo (Kenny and Bacon, 1981).

The coastal zone in the Gulf of Paria is considered to be heavily polluted due to the highly populated areas nearby and industrial development[1].

The Commercial Fishery and Catch Statistics

The local artisanal trawl fleets fish within the 6-fm isobath in the Gulf of Paria close to their home ports, where they usually land most of their catch (Maharaj, 1989). Commercial statistics are collected on a daily basis by the Fisheries Division, Ministry of Food Production. Shrimp landings were extracted from these records for 1986 from the key sites Orange Valley, San-Fernando, and Otaheite in the Gulf of Paria (Maharaj, 1989). Also, members of the fishing community were interviewed informally during the course of this study.

Vessel, Gear, and Operation

The commercial vessel used in this study was an artisanal trawl vessel operating out of Orange Valley. This vessel was 9.8 m in length, wooden, and powered by an inboard diesel engine. There were no other mechanical aids on the vessel, nor were there any electronic devices. The crew consisted of two individuals: The captain and a deck hand.

A single four-seamed trawlnet was used with head rope length of 10 m, and codend mesh size of 3.8 cm. The ground rope, 14 m long, was weighted using lead pieces of 7-13 cm. Paired wooden rectangular doors (1.2 m × 0.5 m) were attached to this net.

The entire operation of setting and hauling in the trawl gear was done manually. Initially the cod end was set over-

Figure 1.—Location of 97 trawl catches (hatched areas) by an artisanal trawler, August 1986 through May 1987, Gulf of Paria, Trinidad and Tobago.
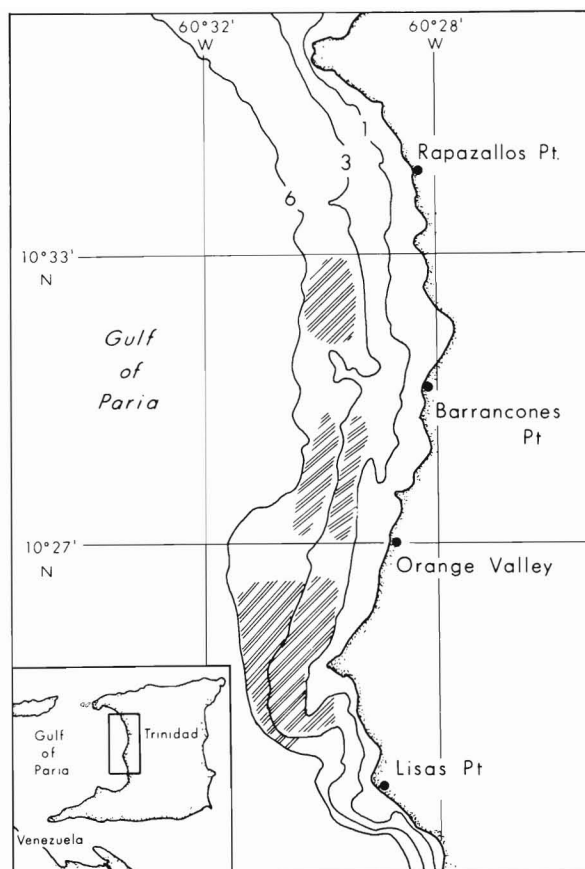
board from the stern; then the rest of the net was let out as the vessel moved forward. Finally, the otter doors were thrown overboard, and the time at this point was recorded as the start of the tow. The ratio of warp to depth was usually between 2:1 and 3:1 (according to the vessel's captain). Each warp was made fast to the fishing vessel.

After the completion of each haul, the net was brought aboard the vessel, the cod end untied, and the catch sequentially emptied into a number of bins (each bin held about 25 l). During the following haul, this catch was sorted by the crew. Shrimp and some finfishes were kept and the rest of the catch was discarded at sea.

The start and end of each haul were recorded as the time when the trawl doors were thrown overboard, and retrieved aboard the vessel, respectively. Tow duration varied from 1 to 3 hours depending on the area, depth, time of year, and other conditions. Also, the number of hauls per trip (per day's fishing) was dependent on these and other factors.

Sampling Method

It was decided that samples would be taken from a "typical" artisanal vessel operating under "normal" commercial conditions. Trawl catches were sampled at sea from this vessel which operated out of Orange Valley. The senior author was on board to collect weekly samples from 8 August 1986 to 26 January 1987 and bimonthly from 6 February 1987 to 22 May 1987.

Prior to the study, it was decided to stratify the sampling period (August 1986 to May 1987) into weekly intervals (each week began on Monday and ended on Sunday). Weekly stratification was chosen to capture the short-term fluctuations reported in trawl catches (Bazigos, 1974). One sample day per week was then

chosen randomly using a Lotus 123[2] function (@rand), which generated random numbers between 1 and 7.

Aboard the vessel the following data were recorded for each haul: Tow duration, fishing area, depth, number of bins filled, and approximate weight (to the nearest kilogram) of finfishes, shrimp, and crabs retained by the captain for market.

On each sample day, all trawl hauls were sampled by choosing one of the bins into which the catch was placed. The bin was chosen haphazardly and considered representative of that particular haul. Samples were kept on ice for later processing (Maharaj, 1989). Catch samples were sorted and classified to the lowest taxon possible. Total weight and number of each taxon were recorded.

Data Analysis

Estimation of Catch Rates From the Sample Data

Total weight per haul and total numbers per haul were calculated by multiplying the number of filled bins per haul by the weight and numbers in the sample, respectively. Catch rates expressed as weight per unit time (kg/hour) and numbers per unit time (no./hour), were determined from the catch data and the haul duration. The following order statistics were used to summarize these results: Median (M), lower fourth (L_f), and upper fourth (U_f).

Ratio Estimators

Two sets of ratios were calculated for each haul sampled: Finfish weight to shrimp weight (finfish:shrimp), and total by-catch weight (weight of finfish and crabs) to shrimp weight (by-catch: shrimp).

In an effort to reduce the bias of ratio estimators, the Jacknife method, modified according to Tukey (Rey, 1983), was used to calculate monthly ratios and variances:

$$R_o = \sum_{i=1}^{n} F_i \div \sum_{i=1}^{n} S_i,$$

$$\bar{R}_i = (\sum_{i=1}^{n} F_i) - F_i \div (\sum_{i=1}^{n} S_i) - S_i,$$

$$R_i = nR_o - (n-1)\bar{R}_i,$$

$$R_m = \sum_{i=1}^{n} (R_i) \div n,$$

$$Var(R_m) = \frac{\sum_{i=1}^{n} (R_i - R_o)^2}{n(n-1)},$$

where:

R_o = monthly ratio,
F_i = finfish weight in the ith haul,
S_i = shrimp weight in the ith haul,
n = number of hauls sampled per month,
R_i = Jacknife pseudo value, and
R_m = Jacknife ratio estimate.

By-catch Estimates for The Artisanal Fishery

Jacknife monthly ratio estimates were used together with the commercial landing statistics, i.e. the shrimp landings (for 1986), to estimate the total incidental by-catch for the artisanal fishery (B):

$$B = R_m \times S,$$

$$Var(B) = Var(R_m) \times S^2$$

$$B_c = B_t - B_f$$

$$Var(B_c) = \frac{\sum_{i-1}^{n} (B_c - \bar{B}_c)^2}{(n-1)}$$

where:

B = by-catch estimate,
S = shrimp landings 1986,
B_t = total by-catch,
B_c = crab by-catch,
B_f = finfish by-catch, and
$\bar{B}_c$ = annual average crab by-catch.

Monthly by-catch estimates (total by-catch and finfish by-catch) were calculated for all three landing sites in the Gulf of Paria. The crab by-catch was computed as the difference between the total by-catch and finfish by-catch, and its annual variance was calculated as indicated above. Since no data were collected for June and July 1987, mean ratios for May 1987 and August 1986 were used as ratio estimates for June and July, respectively.

Mean annual ratios were estimated from data collected during the 10-month sampling period, using the equations listed above, with the exception that $n = 97$ and R_m is the mean annual ratio. Each of the annual by-catch quantities was then calculated as the product of these ratios and the annual shrimp landings for 1986.

Discards from the Artisanal Fishery

In this artisanal trawl fishery, not all of the by-catch is discarded at sea. Some of this by-catch is marketed at landing sites, and these quantities are recorded by the Fisheries Division. From these records were obtained annual estimates of by-catch sold by this artisanal fishery. Discards were then calculated as the difference between the estimates of total by-catch and these commercial data.

Results

During this 10-month study, 97 hauls were sampled from 33 trawl trips (each trawl trip = 1 day's fishing). The entire artisanal fleet made over 5,000 trips during 1986 (Table 1). The sample hauls represented 220 hours of trawling time. From the fishing pattern of the vessel used in this study, it was concluded that artisanal vessels trawl in depths between 1.5 and 2.5 fm from August until mid-January, and after this period they move further offshore into depths exceeding 3 fm (Maharaj, 1989).

Catch Components and Abundance

The total (shrimp, finfish, and crab) catch per unit effort (CPUE; expressed as kg/hour) was highest (usually >100 kg/hour) during August. Thereafter, this CPUE steadily declined throughout the remainder of the wet season (Fig. 2). This trend of declining catch rates continued through the dry season where CPUE did not exceed 50 kg/hour, with median values between 10 and 20 kg/hour (Fig.

Table 1.—Disposition of sampling effort with total artisanal fleet effort (number of trips) for 1986. Jacknife monthly ratios based on 97 trawl catches by an artisanal trawler, August 1986 through May 1987, Gulf of Paria, Trinidad and Tobago. Commercial shrimp landings for the artisanal fishery, 1986, provided by the Fisheries Division, Ministry of Food Production, Trinidad and Tobago. Estimates of crab, finfish, and total by-catch, together with their standard deviations, calculated from the ratios and commercial data.

Item	Jan.	Feb.	Mar.	Apr.	May	June[1]	July[1]	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Number of trips													Total
Fleet effort	638	510	550	598	586	423	404	442	347	350	367	264	5,479
Sampling effort	5	3	2	2	2			3	3	5	4	4	33
Estimated ratios													Mean
Finfish:shrimp	7.06	2.22	2.41	3.26	5.21	5.21	27.86	27.86	6.17	7.90	58.34	23.04	8.99
S. D.	1.86	0.40	1.15	0.38	1.12	1.12	22.25	22.25	1.45	2.56	22.29	16.84	1.25
By-catch:shrimp	8.75	3.33	2.72	4.46	7.22	7.22	53.47	53.47	13.74	16.14	87.32	35.03	14.71
S. D.	2.30	0.60	1.15	0.72	2.21	2.21	25.91	25.91	3.32	5.88	31.09	25.66	2.03
Weight (kg)													Total
Shrimp landings, 1986	11,844	10,951	14,797	15,775	11,679	7,973	6,588	9,181	5,733	5,073	4,577	4,186	108,357
Crab by-catch	20,058	12,133	4,549	18,930	23.475	16,027	168,718	235,117	43,402	41,778	132,623	50,186	619,804
Finfish by-catch	83,575	24,334	35,700	51,426	60,848	41,541	183.540	255,774	35,375	40,099	267,027	96,438	974,132
S. D.	22,030	4,380	17,017	5,994	13,081	8,930	146,582	204,270	8,313	12,987	102,018	70,487	135,447
Total by-catch	103,634	36.467	40,249	70,355	84,323	57,568	352,258	490,891	78,777	81,877	399,650	146,624	1,593,935
S. D.	27,241	6,571	17,017	11,358	25,811	17,621	170,694	237,871	19,035	29,829	142,294	107,405	219,965

[1]Ratios used for June and July were ratios calculated from May and August data, respectively.
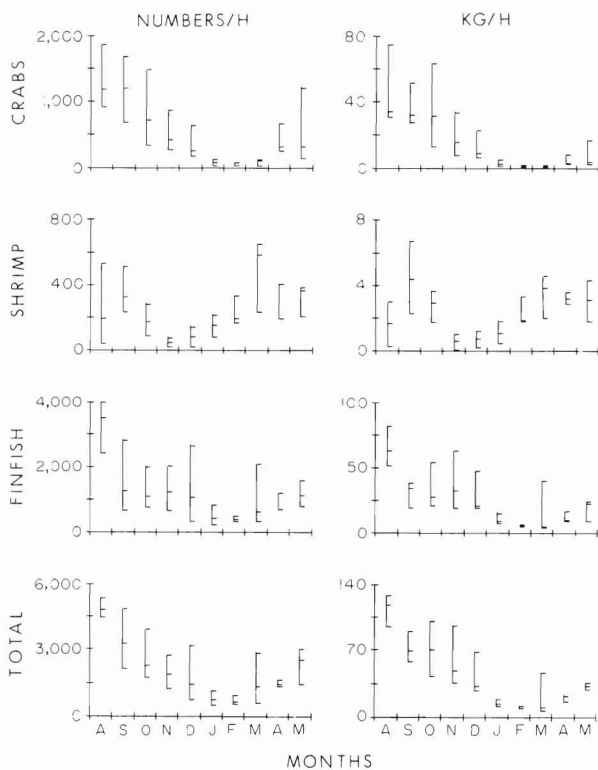

Figure 2.—Median monthly catch rates bounded by lower and upper fourths, based on the 97 trawl catches by an artisanal trawler, August 1986 through May 1987, Gulf of Paria, Trinidad and Tobago.

2). The annual median total catch rate observed, from these 97 hauls sampled, was 34 kg/hour (Maharaj, 1989).

Distinct seasonality in abundance was depicted by the crab catch rate data (Fig. 2). Catch rates were highest in the wet season and 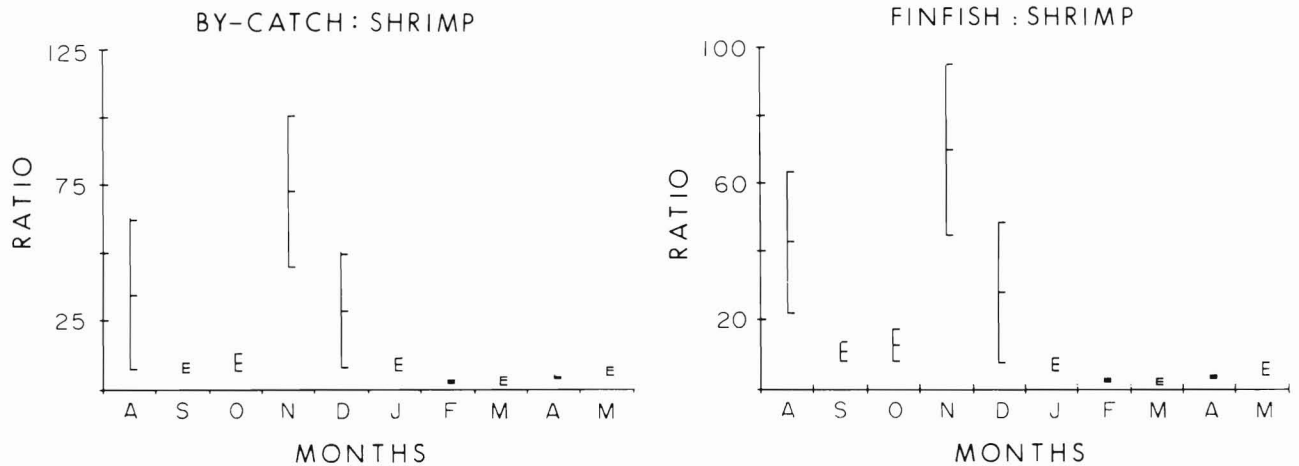decreased markedly from November (median of 31 kg/hour in October to 16 kg/hour in November). Thereafter the catch rates fell off further, remaining at low levels (<10 kg/hour) in the dry season.

Catch rates of finfishes fluctuated throughout the year, with a less pronounced seasonal trend than described above. The lowest catch rates were observed during the dry season (median of <10 kg/hour).

In contrast to the crab and finfish components, the highest shrimp catch rates were observed from mid-September to mid-October in the wet season and from January to May (Fig. 2). Catch rates were consistently higher during the period from March to May (median of 3-4 kg/hour) and lowest during November and December.

Ratio and By-catch Estimates

Annual Jacknife ratio estimates were 9.00 (SD 1.25) finfish:shrimp and 14.70 (SD 2.00) by-catch:shrimp (Table 1). The distribution of monthly ratio estimates could also be linked to seasonality, with the highest ratios observed during the wet season. The lowest ratios, <10, were frequent from late January to May, in the dry season (Fig. 3).

Figure 3.—Jacknife monthly by-catch ratios with one standard deviation about the mean, based on 97 trawl catches by an artisanal trawler, August 1986 through May 1987, Gulf of Paria, Trinidad and Tobago.

Table 2.—Estimated discards in the artisanal trawl fishery, 1986.

Item	Amt./%	Reference
By-catch landed	93,548 kg	Trawl by-catch sold in 1986, taken from the commercial shrimp landings for the artisanal trawl fishery, 1986[1].
Estimated by-catch	1,593,935 kg	Estimated total discards taken from Table 1
By-catch landed	5.87%	Percentage of total estimated by-catch sold.
By-catch discarded	94.13%	Percentage of total estimated by-catch discarded.

[1]Fish. Div., Minist. Food Prod., 1986.

Figure 4.—By-catch estimates for the artisanal trawl fishery based upon 97 trawl catches by an artisanal trawler, August 1986 through May 1987, Gulf of Paria, and commercial shrimp landings for the artisanal trawl fishery, 1986, provided by the Fisheries Division, Ministry of Food Production, Trinidad and Tobago. The by-catch estimates for June and July (*) were calculated using ratios determined for May and August, respectively.


The total annual by-catch estimate for the Gulf of Paria artisanal trawl fishery in Trinidad was 1,594,000 kg (SD 220,000), composed of 974,000 kg (SD 135,000) finfish and 620,000 kg (SD 70,800) crabs (Table 1), for reported shrimp landings in 1986 of 108,000 kg (Table 1). The highest quantities of by-catch were harvested from July to December, corresponding to the period of the lowest shrimp landings (Fig. 4). About 6 percent (93,600 kg) of the total annual by-catch was probably sold, therefore more than 90 percent of this estimated by-catch was discarded at sea (Table 2).

Species Composition

Four penaeid shrimp species were found in these trawl catches. From this study it appears that *Penaeus schmitti* was mainly present from September to October. In contrast, *P. notialis* and *P. subtilis* dominated the trawl samples from January to May. *Xiphopenaeus kroyeri* only appeared sporadically in the catches from August to January. *Callinectes* spp. were caught in large quantities only during the wet season (Maharaj, 1989).
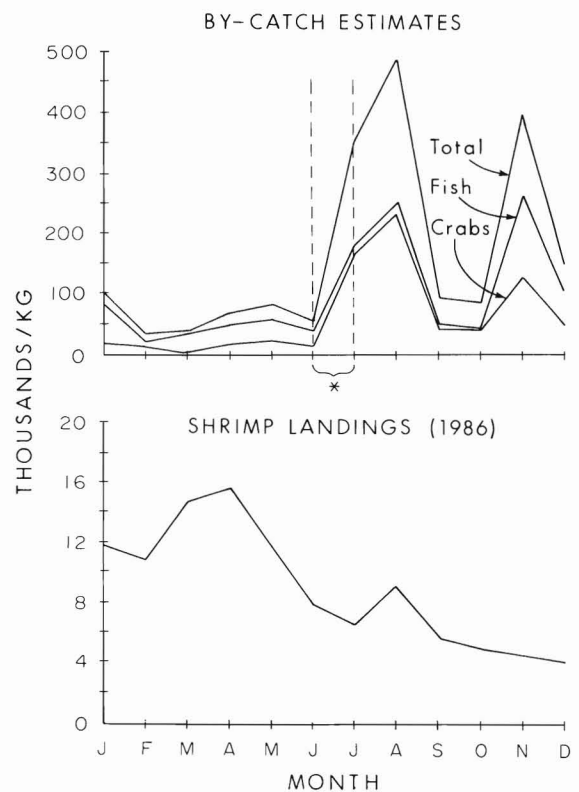
Subadults and juveniles of the following species dominated the finfish by-catch: *Harengula* spp., *Cetengraulis edentulus*, *Chloroscombrus chrysurus*, *Eucinostomous* spp., *Diapterus rhombeus*, and *Cyclopsetta* spp. These species altogether accounted for 70-85 percent of the finfish by-catch. It was clearly apparent that *Harengula* spp. and *Cetengraulis edentulus* were present in significant quantities only in the wet season. For the other finfish species mentioned above, catch rates fluctuated chaotically without any distinct seasonal trend (Maharaj, 1989).

Discussion

The annual weight ratio estimates of 14.7 (SD 2.00) by-catch:shrimp and 9.0 (SD 1.25) finfish:shrimp were comparable to other results from the western central Atlantic fishing region, which ranged from 10 to 20 inside the 10-fm isobath (Dragovich and Villegas, 1983; de Mesquite, 1982; Griffiths and Simpson, 1972). The annual estimates in this study did not reflect the wide variation in the data; the coefficient of variation (SD/ratio) was less than 15 percent for the annual estimates. However, during August, November, and December when the ratios were high (>30), the coefficient of variation ranged from 50 to 90 percent.

Throughout the dry season, an increase in shrimp catches and a simultaneous decrease in the crab and finfish components were apparently responsible for the low ratios estimated from January to May. In the wet season, the ratios were higher, except for September and October, which corresponded to the peak in abundance of *P. schmitti*, and hence the ratio estimates for these months were lower than those for August, November, and December.

These results indicate that the highest finfish catch rates occurred during August-December in the Gulf of Paria. Many explanations have been given for seasonal finfish catch variations. Lowe-McConnell (1962) found catches of trawled finfishes in Guiana to be highest during the rainy season when they move into shallower areas. Moore et al. (1970) linked high seasonal finfish abundance in an inshore area (1-10 fm in Louisiana)

with recruitment from estuaries. Gunter (1938) associated this trend in Louisiana with seasonal breeding cycles, influx of recruits large enough to be caught in the trawl, or migration of old or young individuals from another locality.

Another factor which could be partly responsible for these abundance fluctuations is the change in depth of fishing. From January to May, fishing depth increased slightly (from 1-2 fm to >3 fm). Furnell (1982) reported that "Assessment of incidental catches of fish by trawlers operating in Guianese waters showed that the largest quantities of fish are caught in shallow waters (less than 15 fm), whereas the largest quantities of shrimp are caught in deeper waters (22-39 fm)."

The wide fluctuation in finfish catch rates observed here are likely typical of finfish assemblages captured by shrimp fleets. This is probably attributable to the nonrandom distribution of finfish populations (Keiser, 1976; Taylor, 1953). In this fishery we observed a tendency for fishermen to avoid areas where large quantities of by-catch were caught. The latter could explain the high variances of the large ratio estimates in August and November-December, when shrimp catches were poor.

The Jacknife method used to calculate the ratio estimates was an appropriate procedure since it not only reduces the bias in these ratio estimates, but it also assumes no particular data distribution (Rey, 1983). All data recorded were used to estimate the monthly and annual average ratios. Most authors exclude high ratios (>100) from their calculations (Keiser, 1976); however, we decided that to do so would lead to an underestimation of by-catch.

Our estimates were based on the assumption that, "on average," the vessel in this study was representative of the fleet at comparable times and area fished. Comparison of sampling effort and commercial fishing effort during 1986 is contained in Table 1. As mentioned, the artisanal trawl fleet fishes within the 6-fm isobath in the Gulf of Paria. The distribution of sampling effort by area for this study vessel is depicted in Figure 1. It is our belief that this area represents about

80 percent of that covered by the commercial fleet; our sampling vessel did not venture into the most southerly sections of the fleet's operational area.

Only 6 percent of the by-catch is marketed, unlike most artisanal trawl fisheries where most by-catch is retained (Saila, 1983). An estimated 1,500,400 kg of finfish and crabs are discarded annually from this artisanal trawl fishery. These discards may provide a large food source for the crab populations and account for the latter's abundance. It was observed during this study that discarded finfish were fed upon by sea birds. Possibly crabs (most of the crabs in the by-catch were returned to the sea alive) and other organisms may also be attracted to these discards (Saila, 1983). However, it is generally believed that most of the discards usually decompose and become remineralized into nitrogen and other nutrients (Cushing, 1981; Sheridan et al., 1984).

One of the important issues for Trinidad and Tobago is whether groundfish landings by the directed fisheries (demersal longlines and trawl) are adversely affected by shrimp trawling. If this were the case, then a host of management regimes, based on closed season/areas (Villegas and Dragovich, 1981; Caddy, 1982; Garcia, 1986) and/or gear restrictions/modifications (Siedel and Watson, 1978; Jones, 1976; Hickey and Rycroft, 1983; McVea and Watson, 1977), could be employed in an attempt to reduce the by-catch.

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