

# THE UNITED STATES SHRIMP FISHERY OFF NORTHEASTERN SOUTH AMERICA (1972-74)<sup>1</sup>

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## ABSTRACT

The Guianas-Brazil shrimp fishery off the northeastern coast of South America is supported by four principal species—pink-spotted shrimp, *Penaeus brasiliensis*; brown shrimp, *P. subtilis*; pink shrimp, *P. notialis*; and white shrimp, *P. schmitti*. The areas off Guyana, Surinam, and western French Guiana were dominated by pink-spotted shrimp; brown shrimp were most prevalent off eastern French Guiana and Brazil, pink shrimp off Guyana, and white shrimp off Guyana, French Guiana, and Brazil, chiefly in shallow waters.

U.S.-flag vessels landed 5.0 million pounds of shrimp during the second half of 1972, 13.6 million pounds in 1973, and 9.0 million pounds in 1974. In 1973 and 1974 U.S.-flag vessels took 50% and 39% of the total international landings. Mean annual catch rates for 1972, 1973, and 1974 were 20.0, 26.0, and 18.3 lb/h, respectively. Monthly catch rates peaked each year in March and April and declined gradually thereafter. The catch rates off Brazil were higher than off the Guianas. Most fishing was carried on at night and at depths of 21-35 fathoms.

Small shrimp appeared to be recruited to the fishery mainly in April and October and mainly off French Guiana, Brazil, and Guyana.

An exponential surplus yield model estimated the maximum sustainable yield to be 28.7 million pounds and a linear model estimated the maximum sustainable yield to be 27.1 million pounds. Maximum observed yield was 27.3 million pounds (1973).

The shrimp resource off the northeastern coast of South America (Figure 1) is the basis of a major international fishery. This fishery consists of four principal species—pink-spotted shrimp, *Penaeus brasiliensis*; brown shrimp, *P. subtilis*; pink shrimp, *P. notialis*; and white shrimp, *P. schmitti*. *Penaeus subtilis* and *P. notialis* until recently were known as *P. aztecus subtilis* and *P. duorarum notialis*, respectively (Pérez Farfante in press). The earliest exploratory fishery survey of the continental shelf off the northeastern coast of South America was made in 1944 by Whiteleather and Brown (1945). Commercial shrimp fishing by U.S. vessels began in 1959 stimulated by exploratory surveys made in 1957 and 1958 (Higman 1959; Bullis and Thompson 1959). Thereafter the fishery expanded rapidly and soon included vessels of other nations. The history of the fishery through 1959, and a description of the fishing grounds, species, fishing fleets, and stock status, is given by Naidu and Boerema (1972).

This report is based on data collected in 1972-74 from U.S.-flag vessels and from processing plants under the terms of the bilateral United States-Brazil Shrimp Agreement. This paper evaluates and reviews the status of the fishery based on analysis of these data. Information from processing plant records before 1972 is also used.

The United States-Brazil Shrimp Agreement of 1972 dealt with conservation of shrimp resources and operations of U.S. shrimp vessels off northern Brazil (Allen 1973). The agreement stated that the information on catch and effort, and biological data relating to the shrimp fishery in that area, be collected from U.S. vessels. Similar agreements were effected between Brazil and Barbados, Surinam, and Trinidad and Tobago.

## SOURCES OF DATA AND METHODS

Catch data for U.S. vessels came from logbooks and landing records for July 1972-December 1974 (Figure 2; Appendix Table 1). Logbook records were submitted for approximately 50% of the fishing trips, but this percentage varied monthly from 10% at the beginning of data collection to 80% later in the period. Landing records were submitted for all trips. Information on area of cap-

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species, and commercial tail-weight. The retained catch was reported; no estimate was made of the discarded catch. Landing records for each fishing trip included the total weight of shrimp in each commercial weight category. The landings were recorded in two categories: "mixed" shrimp (pink-spotted, brown, and pink) and white shrimp. In our treatment of the landing data, however, we combined the landings of "mixed" and white shrimp. Information on area of catch was not available in the landing records. In addition, processing plants reported total yearly landings of shrimp and average fleet sizes, including both U.S.- and other-flag vessels.

We estimated total monthly areal catches by adjusting the monthly catches reported by area in logbooks for 1) catches unreported by area and 2) landings unreported in logbooks. For example, the total U.S. catch off northern Brazil (fishing zones 78-81) in April 1974 was estimated as follows:

$$A = A' \times \frac{B}{B'} \times \frac{C}{C'}$$

where  $A$  = estimated total catch in zones 78-81, April 1974;

$A'$  = catch reported in logbooks for zones 78-81, April 1974;

$B$  = total catch reported in logbooks, April 1974;

$B'$  = total catch reported in logbooks by fishing zone, April 1974;

$C$  = total landings reported in landing records, April and May 1974;

$C'$  = total catch reported in logbooks, April and May 1974.

The ratio  $B/B'$  adjusted  $A'$  for the logbook catch that was unreported by fishing zone and the ratio  $C/C'$  adjusted for the landings that were unreported in logbooks. The second ratio used data for 2 mo, since catches made in a given month often were landed in both that and the following month. This method resulted in estimates of the total annual catches by areas of capture which were within 2% of the total reported annual landings. The logbook sample was not random and the catch off Brazil was probably overestimated, since more vessels probably submitted information when fishing off Brazil than when fishing off the Guianas. However, there was no way to assess the difference in completeness of reporting of vessels fishing different areas. For this reason, estimates

of catches were not made for smaller subareas.

The size index was a weighted mean value calculated by assigning the values 1, . . . 9 to the commercial tail-weight categories >50, . . . <15.

## ANNUAL LANDINGS AND CATCHES

During the second half of 1972, total landings by U.S.-flag vessels were 5.0 million pounds; in 1973 and 1974, they were 13.6 and 9.0 million pounds, respectively (Table 1). Landings of U.S. vessels were 50% and 39% of total international landings in 1973 and 1974. Monthly catches (Table 2) vary slightly from landings since they are estimated values and because catches are often landed in months subsequent to the month of capture.

To gain a perspective of the entire fishery, we assembled the historical landings of U.S.- and foreign-flag vessels for 1960-74 (Table 3, Figure 3) and the number of shrimp trawlers by country for 1961-74 (Table 4). There was a continuous increase in landings from 1960 (3.9 million pounds) through 1968 (27.3 million pounds). The landings declined slightly in 1969 and 1970 to 27.1 and 27.0 million pounds, respectively. There was a sharp decline in landings in 1971 and 1972 (to 22 million pounds). In 1973 the fishery attained a maximum catch of 27.3 million pounds. The following year there was a decline in landings to 23.1 million pounds.

Ninety percent of the landings from 1960 through 1974 were made in Guyana (46%), French Guiana (21%), Surinam (14%), and Trinidad (10%). The remaining landings were made in Barbados (6%), Brazil (3%), and Venezuela (1%). National- and foreign-flag vessels landed in Barbados, Trinidad, Guyana, Surinam, and French

TABLE 1.—Landings of shrimp in pounds, heads-off weight, reported for U.S. vessels in the Guianas-Brazil shrimp fishery, 1972-74. This table is based on data submitted by processing plants; monthly data for January-June 1972 were not available.

Month of landing	1972	1973	1974
January		774,056	757,189
February		967,677	772,844
March		1,145,173	704,377
April		1,589,147	1,072,920
May		1,346,502	948,434
June		1,226,817	832,016
July	715,929	1,291,120	864,596
August	940,223	1,362,976	813,548
September	777,443	1,049,902	548,299
October	888,829	1,147,035	617,972
November	747,252	824,470	523,404
December	889,776	844,284	520,493
Total	4,959,452	13,569,159	8,976,092

TABLE 2.—Estimated total catch of shrimp in pounds, heads-off weight, by area of capture for U.S. vessels in the Guianas–Brazil shrimp fishery, 1972–74. Monthly data for January–June 1972 were not available.

Month of capture	1972			1973			1974		
	Zones 69–77	Zones 78–81	Total	Zones 69–77	Zones 78–81	Total	Zones 69–77	Zones 78–81	Total
January				884,040	—	884,040	924,749	—	924,749
February				943,550	—	943,550	558,397	—	558,397
March				354,064	1,028,331	1,382,395	405,853	635,532	1,041,385
April				319,021	1,214,699	1,533,720	434,842	597,420	1,032,262
May				349,367	838,737	1,188,104	415,514	497,284	912,798
June				480,020	805,609	1,285,629	352,805	448,404	801,209
July	253,057	561,134	814,191	541,619	969,059	1,510,678	337,820	566,662	904,482
August	560,547	316,461	877,008	464,255	690,750	1,155,005	240,074	502,583	742,657
September	425,187	410,184	835,371	386,446	737,912	1,124,358	269,655	266,952	536,607
October	550,666	337,679	888,345	531,989	482,733	1,014,722	428,949	114,212	543,161
November	649,768	149,558	799,326	518,332	238,878	757,210	512,751	11,956	524,707
December	713,867	—	713,867	669,802	—	669,802	318,141	—	318,141
Total	3,153,092	1,775,016	4,928,108	6,442,505	7,006,708	13,449,213	5,199,550	3,641,005	8,840,555

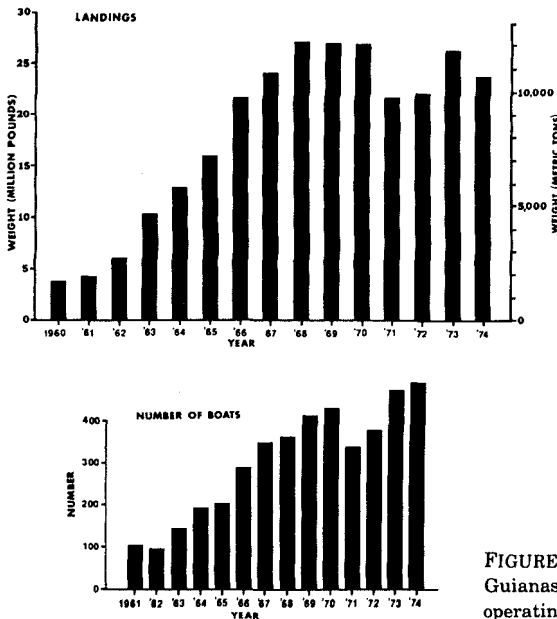
TABLE 3.—Annual landings of shrimp for the Guianas–Brazil shrimp fishery, 1960–74. Figures are in thousands of pounds, heads-off weight. Figures in parentheses are estimated values. Data for 1960–69 are from Naidu and Boerema (1972).

Year	Barbados	Trinidad	Venezuela	Guyana	Surinam	French Guiana	Brazil	Total
1960	—	—	—	3,568	381	—	—	3,949
1961	—	—	—	3,942	447	—	—	4,389
1962	—	—	—	5,126	1,072	—	—	6,198
1963	319	—	—	6,040	1,387	2,789	—	10,535
1964	1,481	—	—	6,984	1,709	2,961	—	13,135
1965	1,891	—	—	8,048	2,223	3,960	—	16,122
1966	2,400	2,386	—	9,546	2,943	4,668	—	21,943
1967	2,179	3,392	—	9,036	2,536	7,279	—	24,422
1968	2,570	4,280	—	9,161	3,438	7,860	—	27,309
1969	2,069	4,469	—	10,469	3,477	6,577	74	27,135
1970	1,339	4,373	—	11,807	3,534	4,867	1,137	27,057
1971	0	3,346	—	9,642	3,083	4,559	1,349	21,979
1972	0	2,082	—	10,743	3,518	4,553	(1,500)	22,396
1973	462	1,514	12,454	12,000	3,949	5,442	(1,500)	27,321
1974	864	1,808	<sup>2</sup> NA	11,213	4,457	3,260	(1,500)	<sup>3</sup> 23,102

<sup>1</sup>Novoa, D. 1974. Pesquería Venezolana en el área de las Guayanas durante 1973. Unpubl. manusc., 14 p. FAO Governmental Consultation on Shrimp Resources in the CICAR Area, FIR: SR/74/NR-9.

<sup>2</sup>Not available.

<sup>3</sup>Does not include catch of 11 Cuban-flag trawlers.



Guiana; but only national-flag vessels operated in Brazil and Venezuela. The variation in landings between countries reflects mainly the differences in the sizes of the fleets supplying the processing plants in these countries (Table 3).

### SPECIES COMPOSITION AND DISTRIBUTION

Our discussion about the species caught and their geographic distribution is based on data from logbooks. Vessel captains recorded a single, most abundant species to represent their daily catch; however, if two or more species were present, they recorded their catch as mixed. Single species were recorded in 58% of the catch and mixed species in 42%. Since the four species of shrimps are easily

FIGURE 3.—Total landings of shrimp (heads off) for the Guianas–Brazil fishery, 1960–74 and the number of vessels operating each year. Data are from Tables 2 and 3.

TABLE 4.—Number of shrimp trawlers for the Guianas–Brazil shrimp fishery, 1961–74. The figures represent the average number of vessels fishing each year. Data for 1961–69 are from Naidu and Boerema (1972).

Year	Barbados	Trinidad	Venezuela	Guyana	Surinam	French Guiana (St. Laurent & Cayenne)	Brazil	Total
1961	—	—	—	60	40	—	—	100
1962	—	—	—	72	24	—	—	96
1963	—	—	—	89	25	33	—	147
1964	30	—	—	81	25	51 (20 + 31)	—	187
1965	24	—	—	96	25	58 (30 + 28)	—	203
1966	32	43	—	105	34	67 (28 + 39)	—	281
1967	32	58	—	113	50	89 (40 + 49)	—	342
1968	35	48	—	134	55	90 (53 + 37)	—	362
1969	36	63	—	142	51	110 (65 + 45)	1	403
1970	25	78	—	162	55	83 (37 + 46)	18	421
1971	—	60	—	160	45	60 (18 + 42)	21	346
1972	—	55	—	175	55	60 (17 + 43)	25	370
1973	6	42	140	200	63	68 (22 + 46)	24	443
1974	21	39	NA	202	106	62 (16 + 46)	30	3460

<sup>1</sup>In 1973, 80 Venezuela-flag trawlers operated for a 6-mo period.

<sup>2</sup>Not available.

<sup>3</sup>Does not include 11 Cuban-flag trawlers that fished with a mothership from March to December 1974.

distinguishable and there was no obvious bias in reporting species, we considered the single species to be representative of the entire daily catch, even though this overestimates the more abundant species. The composition of the catch for the entire area, according to this method, consisted of brown shrimp (70%), pink-spotted shrimp (23%), and other shrimps (7%) (Figure 4).

The geographic distribution of the different species of shrimps in the fishery is a subject of continuing research, but certain patterns in areal distribution were apparent (Figure 4). The areas off Guyana, Surinam, and western French Guiana (zones 69–75) were dominated by pink-spotted shrimp. Brown shrimp were listed more frequently off eastern French Guiana and Brazil (zones 76–81); white shrimp off Guyana (zones 69–71) and French Guiana and Brazil (zones 77–80); and pink shrimp off Guyana (zones 70–71).

We also examined the geographic distribution of the U.S.-vessel catch of all species. In 1972, U.S. vessels caught 36% of their catch in the Agreement Area off Brazil and 64% off the Guianas. The analogous catches for U.S. vessels in the Agreement Area were 52% (1973) and 41% (1974) (Table 2). Fishing off the Guianas (zones 69–77) was year-round. In the Agreement Area fishing by U.S. vessels was allowed 1 March–30 November (zones 78–80) and 1 March–30 June (zone 81).

Species composition of shrimp catches as reported by Japanese vessels<sup>3</sup> is in general agreement with our observations. Japanese catches off

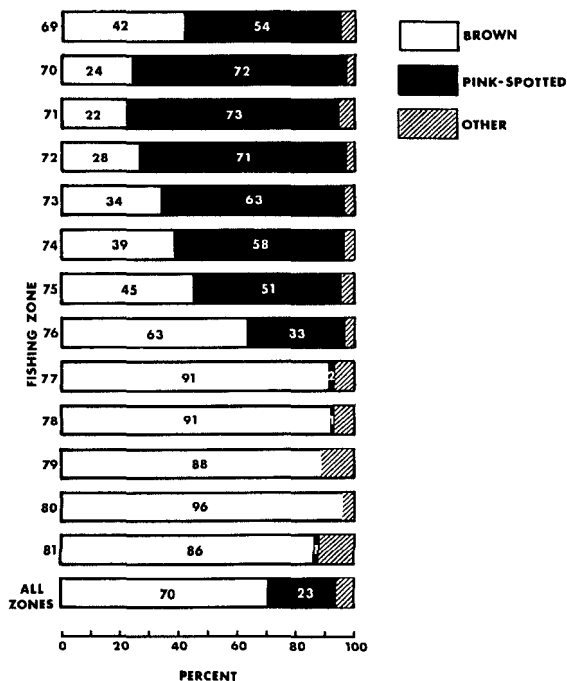


FIGURE 4.—Species composition by fishing zone of the shrimp catches of U.S. vessels in the Guianas–Brazil fishery for the period July 1972–December 1974. The data for this figure were calculated as explained in the text from the fishermen’s log-books.

Guyana and Surinam had higher percentages of “pink shrimp” (presumably mostly *P. brasiliensis*) than off French Guiana and Brazil. There were differences, however, between our data and the Japanese reports. Overall, brown shrimp were less prevalent in the Japanese catches than in the U.S. catches. The Japanese catch from 1969 to 1973

<sup>3</sup>Far Seas Fisheries Research Laboratory. 1971, 1972, 1973, 1974. South America north coast shrimp trawl fishing ground charts, 1969, 1970, 1971, 1972, 1973. Unpubl. manusc., Far Seas Fish. Res. Lab., Shimizu.

was reported as 20%–35% brown shrimp (presumably *P. subtilis*) and 65%–80% pink shrimp (presumably mostly *P. brasiliensis*) (Far Seas Fisheries Research Laboratory see footnote 3).

### SIZE COMPOSITION

The data on temporal and spatial distribution of sizes of shrimp provide information necessary for management of fishery stocks (Rounsefell and Everhart 1953). In particular, data on size reveal information on progressive changes as an indicator of rates of growth, population structure, maturity stages, and potential use of habitat by shrimp of different sizes, the latter being related to spawning, recruitment, and migration.

In our study the more precise data came from landing records, which we used to measure temporal changes in size composition. Size data from logbooks (less precise) were used to measure areal differences in size composition.

The majority of shrimp in U.S. landings for the entire period of 1972–74 were in the 26–30, 21–25, 16–20, and 11–15 tails-per-pound size categories (Figure 5). The sizes of shrimp caught may represent a true picture of size availability, but in many instances are also governed by factors which cause fishermen to select certain sizes (e.g., market price of shrimp, fuel price, feasibility of operation, and physical condition of the boat).

In studying the temporal and, to a lesser extent, the areal distribution of shrimp, we plotted from

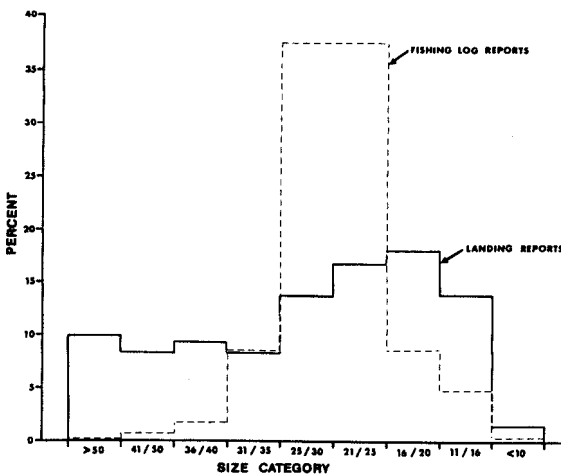


FIGURE 5.—Size composition of the shrimp catches of U.S. vessels as reported in landing records and fishing log reports for the period July 1972 to December 1974. The size categories given are the number of heads-off shrimp per pound.

landing data the average size of shrimp for all ports combined and for Cayenne, French Guiana, only (Figure 6). The landings for all ports include catches from the entire fishery, while Cayenne landings reflect catches primarily off French Guiana and northern Brazil. The shrimp landed at Cayenne generally averaged slightly smaller than the shrimp from all ports combined. The smallest average size of shrimp, for both total landings and Cayenne landings, were in April and October in 1972 and 1973. In 1974, when fishing success was markedly lower than in 1973, small shrimp were present in October, but the expected April peak of small shrimp was less evident. Shrimp were larger in December–January and in June–August of each year.

Trends in average size of shrimp calculated from the logbook data were similar to those of average size calculated from the landing data (Figure 7). This similarity suggested that the size data from logbooks, although less precise, could also be used to compare areas; the smallest shrimp occurred in zones 69–70 and 77–81, and the largest in zones 71–76 (Figure 7). The magnitude of fluctuations in average size calculated from the log data were less than one size category unit, because the original data reported by fishermen are averages.

At present we have no satisfactory explanation for the greater prevalence of smaller shrimp off French Guiana and Brazil than in other areas of this fishery. We can offer some plausible hypotheses. Cayenne landings consist primarily of small brown shrimp caught off French Guiana and northern Brazil. These shrimp are probably recently recruited to the fishable population. Small

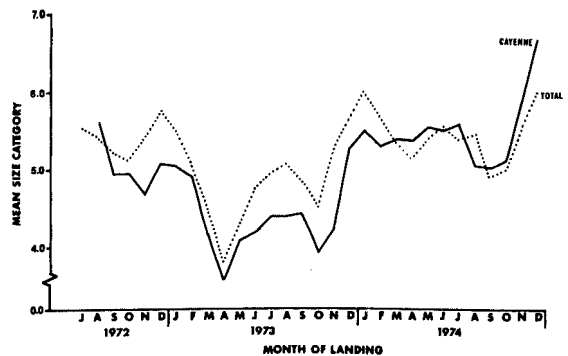


FIGURE 6.—Distribution by month of the mean size index of shrimp calculated from landing records of U.S. vessels at all ports of the Guianas shrimp fishery (marked as total on the graph) and at the Port of Cayenne, French Guiana. The size index was calculated as described in the text.

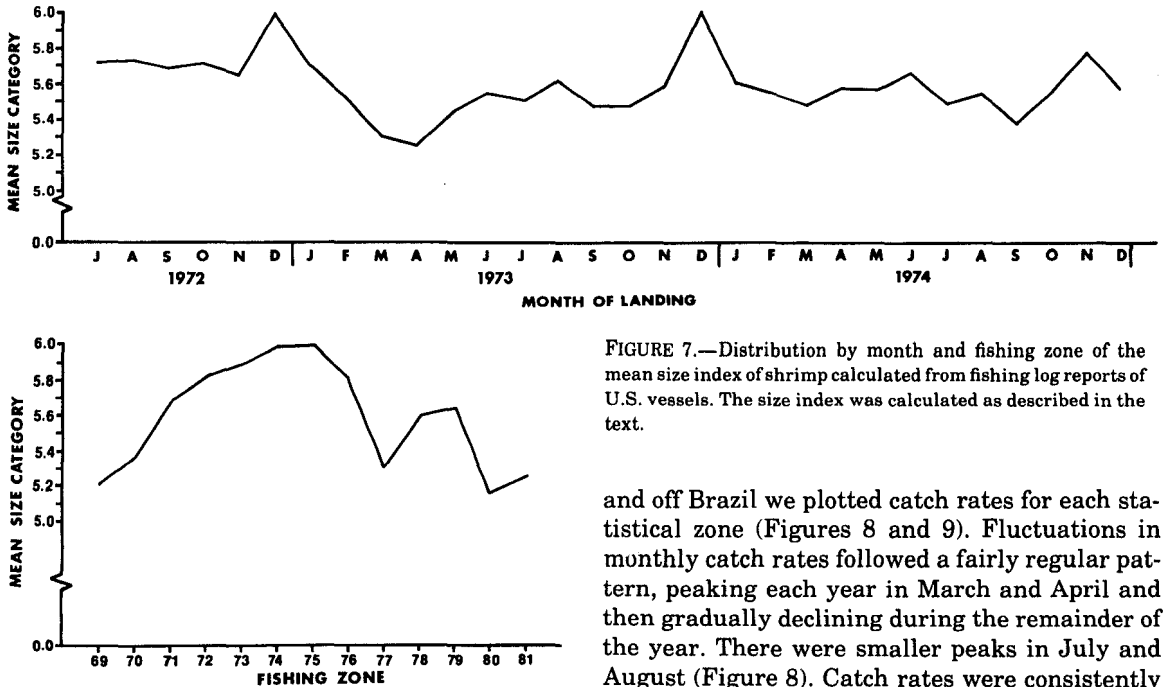


FIGURE 7.—Distribution by month and fishing zone of the mean size index of shrimp calculated from fishing log reports of U.S. vessels. The size index was calculated as described in the text.

shrimp also are present off Guyana. The smaller size of shrimp and higher catch rates in both areas, as compared with the larger shrimp and lower catch rates off Surinam, suggest that the East and West Grounds represent the principal areas of recruitment (Figure 1). Furthermore, the peaks of small shrimp in March, April, and October may indicate seasonal recruitment. Seasonal peaks in spawning and recruitment are common in penaeid shrimp populations, even where these activities occur throughout the year (Cook and Lindner 1970; Costello and Allen 1970). To determine the exact areas and chronology of recruitment for each species off the Guianas and northern Brazil will require additional research.

VARIATION IN CATCH RATES

Fishing success, or catch rate, provides a measure of the relative densities and availability of shrimp to the fishing gear and to the skilled fishermen. We examined the variations in catch rate by year, month, area, depth, and time of day to learn about the biology and ecology of the shrimp.

The average annual catch rates for U.S. vessels were 20.0 lb/fishing hour (1972 half year), 26.0 lb (1973), and 18.3 lb (1974). To observe the monthly differences in average catch rates off the Guianas

and off Brazil we plotted catch rates for each statistical zone (Figures 8 and 9). Fluctuations in monthly catch rates followed a fairly regular pattern, peaking each year in March and April and then gradually declining during the remainder of the year. There were smaller peaks in July and August (Figure 8). Catch rates were consistently higher off Brazil (zones 78-81) than off the Guianas (zones 69-77). The highest catch rates were recorded in zones 78-81, intermediate in zones 75-77 and 69-71, and lowest in zones 72-74 (Figure 9).

Information on water depth without specific knowledge of the type of sediment, chemical content of water masses, and information on water temperature and speed and direction of the current means little in ecological terms. But, in a pragmatic sense, the statistics on shrimp catches versus depth are important. In our study the distribution of shrimp catches varied with water

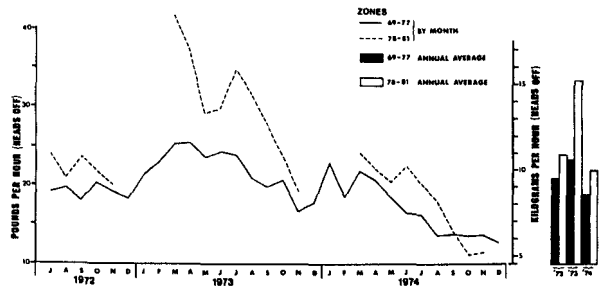


FIGURE 8.—Distribution by month of the mean catch rate of shrimp for U.S. vessels fishing off the Guianas (zones 69-77) and off Brazil (zones 78-81), July 1972 to December 1974. Catch rate is expressed as pounds and kilograms of shrimp (heads-off weight) per hour of fishing.

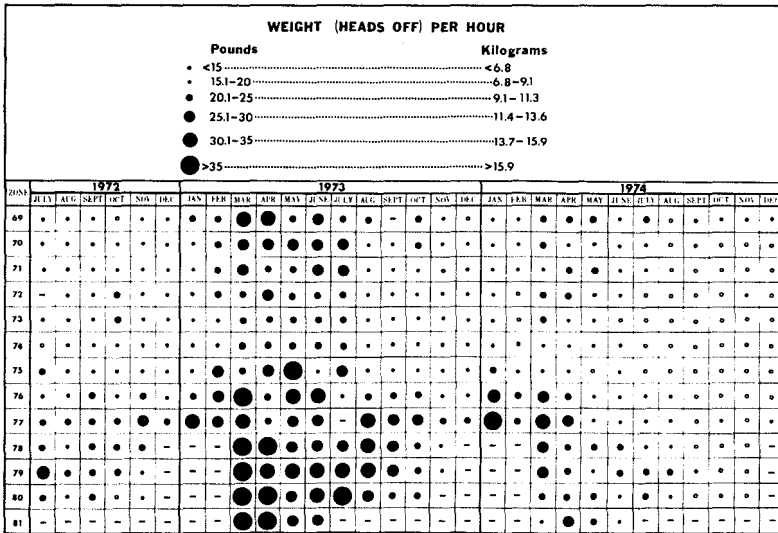


FIGURE 9.—Distribution by month and fishing zone of the mean catch rate of shrimp for U.S. vessels fishing in the Guianas-Brazil fishery, July 1972 to December 1974. See Figure 1 for location of fishing zones. Catch rate is expressed as pounds (and kilograms) of shrimp (heads-off weight) per hour of fishing.

depth. The average catch rates were: 35.4 lb/h (0-5 fm), 25.0 lb/h (6-10 fm), 21.5 lb/h (11-15 fm), 20.5 lb/h (16-20 fm), 21.1 lb/h (21-25 fm), 20.7 lb/h (26-30 fm), 21.1 lb/h (31-35 fm), 23.2 lb/h (36-40 fm), 22.7 lb/h (41-45 fm), and 24.5 lb/h (46-60 fm). Off Guyana, Surinam, and French Guiana (zones 69-77), average catches were lower at the intermediate depths (16-35 fm) than in shallower or deeper water (Figure 10). Off Brazil the average catch did not vary with depth in zones 78 and 79, but in zones 80 and 81 average catches were higher at the intermediate depths than in shallower or deeper water.

We also examined the distribution of fishing effort in relation to depth. Fishing effort was concentrated primarily in intermediate depths. Sixty percent of the fishing effort reported in logbooks occurred between 21 and 35 fm, 18% in <20 fm, and 22% in >36 fm. Off Guyana, Surinam, and French Guiana most fishing was between 16 and 30 fm; off Brazil, it was in deeper water (Figure 11). While the highest catch rates were usually in the shallow and deep zones at the edge of the fishing grounds, these areas supported only a small percentage of the total fishing effort. Shallow and deep zones probably were fished only when good catches could be made, whereas the intermediate depths were fished during times of both good and poor fishing.

The availability of shrimp to the fishermen in relation to time of day varies for each area, species, and time of the year. Most fishing for shrimp was done at night, some during the day, and some on a

24-h/day basis (Figures 12 and 13). The time spent fishing at night was three times that spent during the day. White shrimp were caught primarily during daylight hours off the Guianas and fishing in the East Gullies (zone 79) was usually done during the day. In the Drop-Off and Steeples (zones 80-81), fishing on a 24-h/day basis made up nearly half the total fishing time. The average catch rates for the entire fishery were 29.6 lb/h (day fishing), 18.9 lb/h (night fishing), and 22.1 lb/h (day and night fishing). The mean catch rates were higher for day fishing than night in all zones and at all depth intervals. We conclude that the usual strategy is to fish at night, except for certain species (e.g., white shrimp) or in certain areas (e.g., East Gullies) where day fishing is more successful. During periods of high catches, fishing is usually carried out on a 24-h/day basis until a full catch is made or until the fishermen are exhausted.

### APPRAISAL OF THE FISHERY

The fishery for shrimp in the Guianas-Brazil area reached a historical maximum annual production of 27.3 million pounds heads-off in 1973. We used a surplus yield model to estimate the maximum sustainable yield of the resource (Fox 1970). We also compared predicted annual equilibrium yields with actual annual yields attained to measure the expected variation from equilibrium conditions.

An exponential surplus yield model suggested



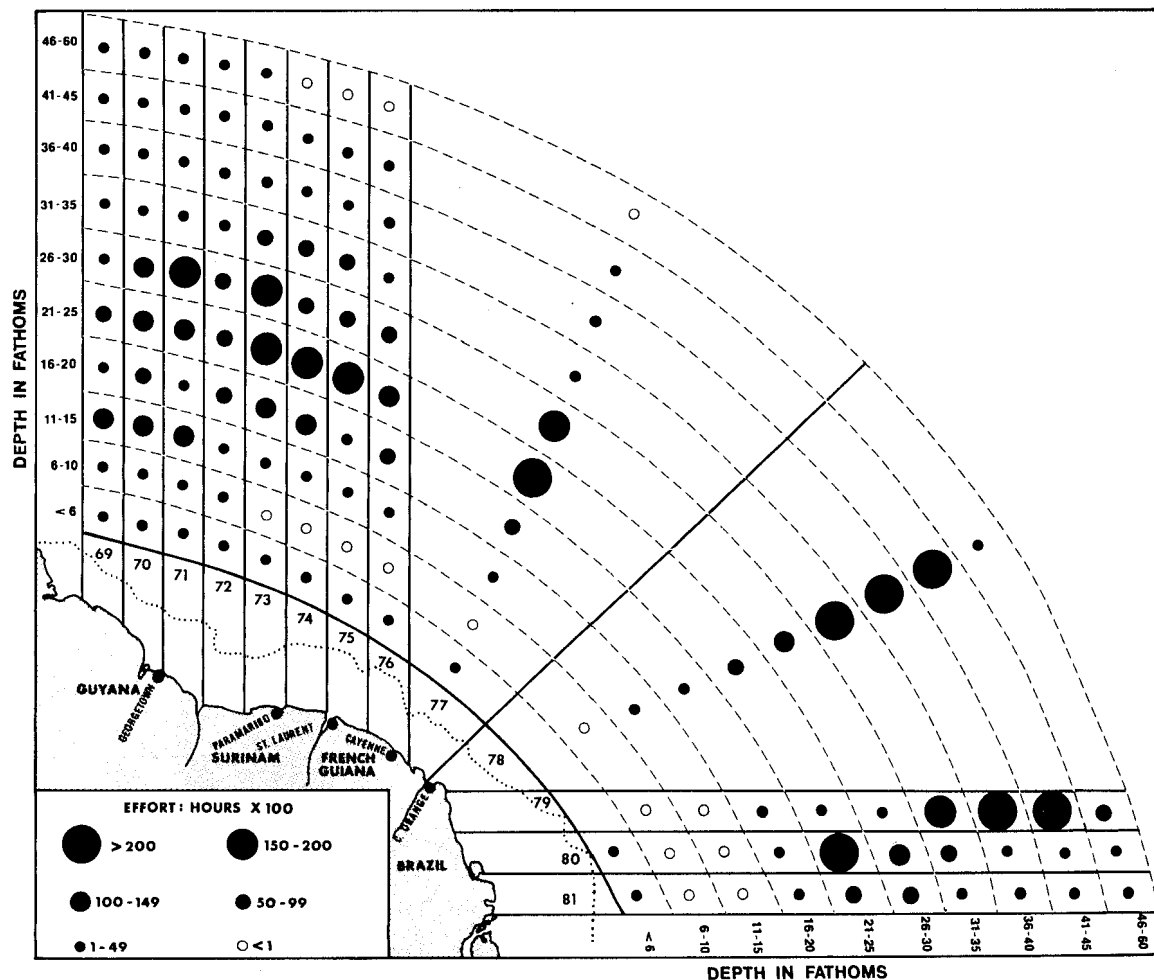


FIGURE 10.—Distribution by fishing zone and water depth of the fishing effort reported on logbooks by U.S. vessels in the Guianas-Brazil fishery, July 1972 to December 1974.

that the maximum sustainable yield was 28.7 million pounds, which could be taken by 692 vessels. This estimate was made from the relationship between the logarithm of the annual catch per vessel and average number of vessels ( $r = 0.80$ ) for the years 1965–74. A linear surplus yield model applied to the data for the same years suggested that the maximum yield was 27.1 million pounds, which could be taken by 531 vessels ( $r = 0.82$ ) (Figure 14).

The average number of vessels is the only index of total effort available for the fishery before 1972. The double-rigged Florida-type shrimp trawler has been, almost without exception, the only type vessel used in the fishery. Increases in fishing ef-

iciency probably occurred as the length and horsepower of the vessels increased (Jones and Dragovich 1973), and as the addition of refrigeration equipment permitted longer and farther ranging fishing trips; but these changes were minor in the 1965–74 period.

Before 1965 the increase in average annual catch per vessel paralleled the increase in fleet size (Table 5). The catch per vessel rose sharply between 1961 and 1962; from 1962 to 1965 the increase continued but was less pronounced. Presumably, during these early years of the fishery, the efficiency of the fleet increased as familiarity was gained with the fishing grounds. The earlier data, therefore, were not used in the model. After

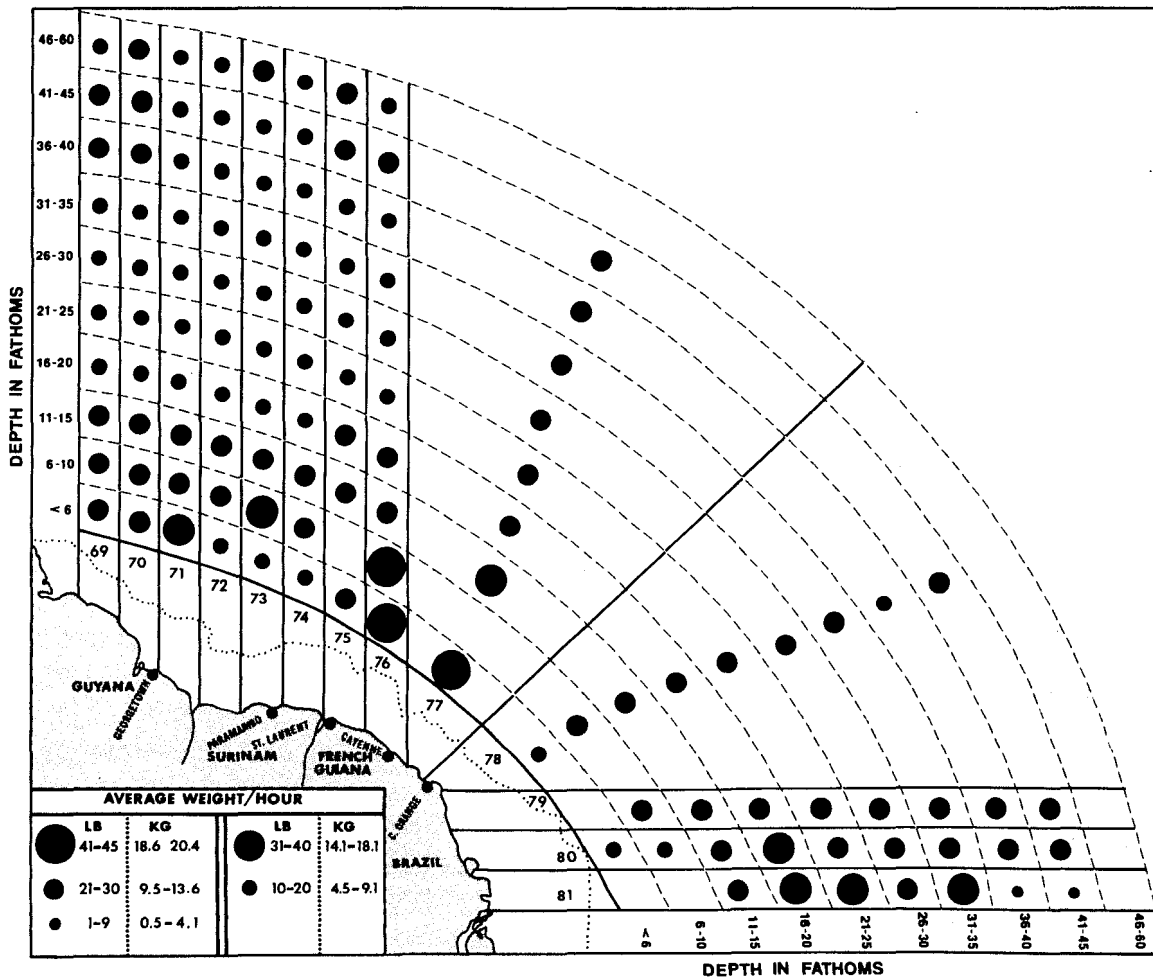


FIGURE 11.—Distribution by fishing zone and depth of the mean catch rate of shrimp for U.S. vessels fishing in the Guianas-Brazil fishery, July 1972 to December 1974. Catch rate is expressed as pounds (and kilograms) of shrimp (heads-off weight) per hour of fishing.

1964, the decline in the average production per vessel was consistent with the increase in the number of vessels. The average annual production per vessel declined from 79,000 lb of shrimp in 1965 to 50,000 lb in 1974; during this time the fleet size increased from 203 vessels (1965) to 460 vessels (1974).

The decline in annual catch per vessel suggests that the average abundance of shrimp available to the fishery has decreased as a result of fishing. Total yields, however, are not depressed at present levels of fishing effort. Apparently the productivity of the resource allows the present level of commercial harvest and also sufficient recruitment to the next generation.

Surplus yield models have been applied in shrimp fishery analysis, though certain assumptions in their use are not completely valid, e.g., instantaneous recruitment, equilibrium conditions, and behavior of the species and populations as a single unit. Also, there is no evidence that the abundance of shrimp recruits is dependent on the abundance of the parent stock in this fishery. Therefore, the prediction of maximum equilibrium yield by a surplus yield model, should be interpreted with caution, especially when the maximum is predicted to occur at fishing effort levels beyond those observed.

The historical shrimp catches follow closely the trends predicted by the surplus yield model (Fig-

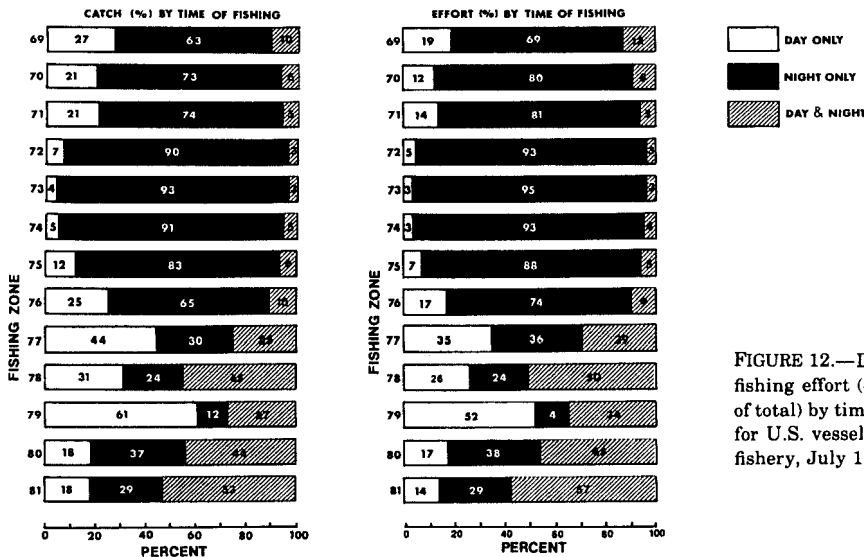


FIGURE 12.—Distribution of catch and fishing effort (expressed as percentage of total) by time of day and fishing zone for U.S. vessels in the Guianas-Brazil fishery, July 1972 to December 1974.

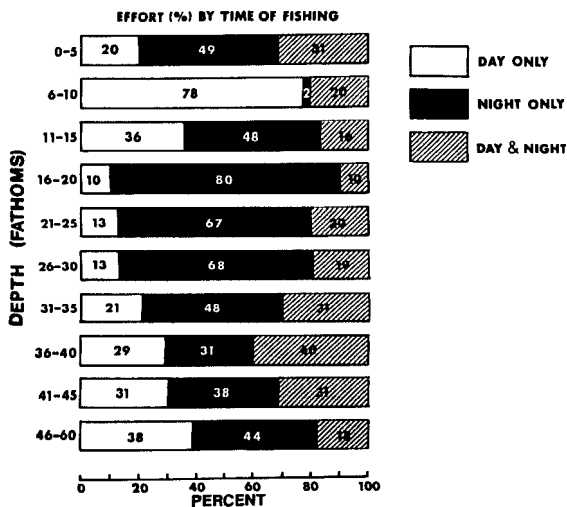


FIGURE 13.—Distribution of fishing effort (expressed as percentage of total) by time of day and water depth for U.S. vessels in the Guianas-Brazil fishery, July 1972 to December 1974.

ure 14). From 1961 to 1968 the total production from the fishery rose in proportion to the increase in the number of fishing vessels. In 1969 and 1970 fishing effort increased, but production remained constant at 27 million pounds. Fishing was reduced in 1971 and the catch, therefore, declined. After 1971, catch and effort continued upwards at rates similar to those in the early years of the fishery and a catch of 27 million pounds was again attained in 1973. In 1974 the number of vessels

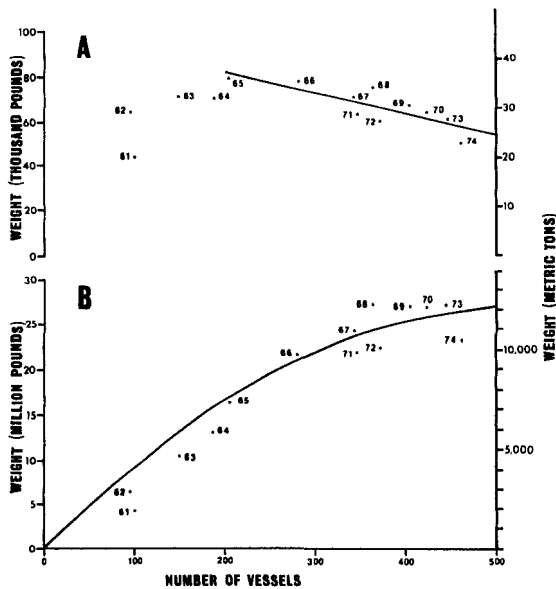


FIGURE 14.—Relationship of the average annual landings per vessel (A) and the total production of shrimp (B) to the total estimated fishing effort (average number of vessels operating) for the Guianas-Brazil shrimp fishery. The linear trend line shown was fitted to the data for the years 1965-74; the estimated production curve was derived from the line in A. The exponential trend line was calculated as explained in the text but is not shown in this figure.

remained high, but the catch declined to 23 million pounds.

The variation of the annual catches from those predicted by the model were 53% and 31% in 1961

TABLE 5.—Average annual catch of shrimp (in pounds, heads-off weight) per vessel by country. Data are derived from Tables 3 and 4.

Year	Barbados	Trinidad	Venezuela	Guyana	Surinam	French Guiana	Brazil	Total
1961	—	—	—	65,700	11,175	—	—	43,890
1962	—	—	—	71,194	44,667	—	—	64,562
1963	—	—	—	67,865	55,480	84,515	—	71,667
1964	49,367	—	—	86,222	68,360	58,059	—	70,241
1965	78,792	—	—	83,833	88,920	68,276	—	79,419
1966	75,000	55,488	—	90,914	86,559	69,672	—	78,089
1967	68,094	58,483	—	79,965	50,720	81,787	—	71,409
1968	73,429	89,167	—	68,366	62,509	87,333	—	75,439
1969	57,472	70,937	—	73,725	68,176	59,791	74,000	67,333
1970	53,560	56,064	—	72,883	64,255	58,639	63,167	64,268
1971	—	55,767	—	60,263	68,511	75,983	64,238	63,523
1972	—	37,855	—	61,389	63,964	75,883	60,000	60,530
1973	77,000	36,048	61,350	60,000	62,683	80,029	62,500	61,673
1974	41,143	46,359	—	55,510	42,047	52,581	50,000	50,222

and 1962, respectively, but for 1963–74 they ranged from 3% to 18%, averaging 8.5%. These variations in catches are deviations about the mean condition predicted by the model. The deviations include the effects of dynamic environmental conditions, but also include random variations and the failure of the model to predict the effects of fishing.

The *Penaeus* shrimp fishery operates mostly on a single year class and year-to-year fluctuations in shrimp populations are to be expected because of the short life cycle of the species. Fluctuations in the annual yield of shrimp are partly the result of variations in spawning success and in survival of young in the inshore nursery grounds, which are generally subject to more extreme variations in environmental conditions than the offshore habitat of adult shrimp. An important management problem for this shrimp fishery is to predict and utilize annual fluctuations in the populations, rather than to only predict an equilibrium yield at a constant level of fishing effort. This will require more detailed knowledge of growth, mortality, and recruitment patterns of the shrimp and the application of yield-per-recruit and stock-recruitment models.

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JONES and DRAGOVICH: UNITED STATES SHRIMP FISHERY

APPENDIX TABLE 1.—Catches by area and month for the Guianas–Brazil shrimp fishery reported by U.S. vessels. Catches are reported by month in which capture was made; landings are reported by month in which trip was completed.

Item	1972					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
<b>Catches:</b>						
<b>Zones 69–77:</b>						
No. drags	501	2,433	2,301	2,740	3,269	3,473
No. hours	2,950	12,705	12,815	14,809	18,580	19,666
Catch (pounds <sup>1</sup> )	56,530	250,097	230,857	300,346	357,385	361,234
Catch/drag	112.8	102.8	100.3	109.6	109.3	104.0
Catch/hour	19.2	19.7	18.0	20.3	19.2	18.4
<b>Zones 78–81:</b>						
No. drags	909	1,184	1,643	1,537	737	
No. hours	5,234	6,785	9,485	8,477	4,120	
Catch (pounds <sup>1</sup> )	125,351	141,194	222,711	184,178	82,260	
Catch/drag	137.9	119.3	135.6	119.8	111.6	
Catch/hour	23.9	20.8	23.5	21.7	20.0	
<b>Total:</b>						
No. drags	1,414	3,617	3,946	4,285	4,006	
No. hours	8,205	19,490	22,310	23,334	22,700	
Catch (pounds <sup>1</sup> )	182,311	391,291	454,518	485,894	439,645	
Catch/drag	128.9	108.2	115.2	113.4	109.7	
Catch/hour	22.2	20.1	20.4	20.8	19.4	
Landings (pounds <sup>1</sup> )	715,929	940,223	777,443	888,829	747,252	889,776
Percent of landings reported on fishing logs	6.1	34.8	56.5	52.6	57.2	53.1
Item	1973					
	Jan.	Feb.	Mar.	Apr.	May	June
<b>Catches:</b>						
<b>Zones 69–77:</b>						
No. drags	3,636	3,119	1,308	1,289	1,580	2,216
No. hours	20,522	16,996	6,804	7,154	8,692	12,677
Catch (pounds <sup>1</sup> )	437,420	390,142	172,585	181,845	205,385	309,276
Catch/drag	120.3	125.1	131.9	141.1	130.0	139.6
Catch/hour	21.3	23.0	25.4	25.4	23.6	24.4
<b>Zones 78–81:</b>						
No. drags			2,366	3,511	3,024	3,208
No. hours			12,005	18,694	16,888	17,435
Catch (pounds <sup>1</sup> )			501,250	692,390	493,075	519,053
Catch/drag			211.8	197.2	163.0	161.8
Catch/hour			41.8	37.0	29.2	29.8
<b>Total:</b>						
No. drags			3,682	4,883	4,629	5,461
No. hours			18,857	26,022	25,726	30,334
Catch (pounds <sup>1</sup> )			674,735	882,175	700,950	832,369
Catch/drag			183.2	180.7	151.4	152.4
Catch/hour			35.8	33.9	27.2	27.4
Landings (pounds <sup>1</sup> )	774,056	967,677	1,145,173	1,589,147	1,346,502	1,226,817
Percent of landings reported on fishing logs	47.9	53.2	35.2	58.6	56.2	62.1
Item	1973					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
<b>Catches:</b>						
<b>Zones 69–77:</b>						
No. drags	2,450	2,007	1,675	2,144	2,422	3,249
No. hours	13,772	11,932	9,663	12,023	14,254	18,683
Catch (pounds <sup>1</sup> )	329,048	251,585	192,636	249,005	237,945	332,835
Catch/drag	134.3	121.1	115.0	116.1	98.2	102.4
Catch/hour	23.9	21.1	19.9	20.7	16.7	17.8
<b>Zones 78–81:</b>						
No. drags	2,922	2,118	2,362	2,746	948	
No. hours	16,920	11,814	13,323	9,612	5,683	
Catch (pounds <sup>1</sup> )	588,729	374,325	367,835	225,950	109,200	
Catch/drag	201.5	176.7	155.7	129.4	115.2	
Catch/hour	34.8	31.7	27.6	23.5	19.2	
<b>Total:</b>						
No. drags	5,409	4,195	4,037	3,903	3,370	
No. hours	30,914	23,746	22,986	21,723	19,937	
Catch (pounds <sup>1</sup> )	922,557	625,910	560,471	476,785	347,145	
Catch/drag	170.6	149.2	138.8	122.2	103.0	
Catch/hour	29.8	26.4	24.4	21.9	17.4	
Landings (pounds <sup>1</sup> )	1,291,120	1,362,976	1,049,902	1,147,035	824,470	844,284
Percent of landings reported on fishing logs	67.3	55.2	52.9	47.0	46.9	44.9

<sup>1</sup>Heads-off weight.

APPENDIX TABLE 1.—Continued.

Item	1974					
	Jan.	Feb.	Mar.	Apr.	May	June
Catches:						
Zones 69-77:						
No. drags	4,028	3,425	2,348	2,473	3,103	2,563
No. hours	22,242	19,319	12,167	12,471	15,962	14,816
Catch (pounds <sup>1</sup> )	509,163	360,836	266,896	259,317	297,838	246,021
Catch/drag	126.4	105.3	113.7	104.9	96.0	96.0
Catch/hour	22.9	18.7	21.9	20.8	18.6	16.6
Zones 78-81:						
No. drags			3,145	2,845	3,039	2,531
No. hours			17,152	16,011	17,388	13,878
Catch (pounds <sup>1</sup> )			417,937	356,270	356,450	312,685
Catch/drag			132.9	125.2	117.3	123.5
Catch/ hour			24.4	22.2	20.5	22.5
Total:						
No. drags			5,551	5,354	6,190	5,163
No. hours			29,649	28,712	33,696	29,203
Catch (pounds <sup>1</sup> )			691,463	624,907	664,083	571,941
Catch/drag			124.6	116.7	107.3	110.8
Catch/hour			23.3	21.8	19.7	19.6
Landings (pounds <sup>1</sup> )	757,189	772,844	704,377	1,072,920	94,834	832,016
Percent of landings reported on fishing logs	55.1	59.2	79.3	58.0	63.5	83.3
Item	1974					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Catches:						
Zones 69-77:						
No. drags	2,183	1,977	2,131	2,813	3,478	3,038
No. hours	13,059	11,599	12,156	16,936	20,658	18,482
Catch (pounds <sup>1</sup> )	213,244	159,665	167,545	229,588	282,405	237,991
Catch/drag	97.7	80.8	78.6	81.6	81.2	78.3
Catch/hour	16.3	13.8	13.8	13.6	13.7	12.9
Zones 78-81:						
No. drags	2,975	3,063	1,959	873	91	
No. hours	17,640	18,486	11,724	5,427	577	
Catch (pounds <sup>1</sup> )	375,697	334,250	165,865	61,130	6,585	
Catch/drag	120.2	109.1	84.7	70.0	72.4	
Catch/hour	20.3	18.1	14.1	11.3	11.4	
Total:						
No. drags	5,158	5,040	4,090	3,686	3,569	
No. hours	30,699	30,085	23,880	22,363	21,235	
Catch (pounds <sup>1</sup> )	571,961	494,915	333,410	290,718	288,990	
Catch/drag	110.9	98.2	81.5	78.9	81.0	
Catch/hour	18.6	16.4	14.0	13.0	13.6	
Landings (pounds <sup>1</sup> )	864,569	813,548	548,299	617,972	523,404	520,493
Percent of landings reported on fishing logs	59.9	66.8	66.4	58.4	47.8	62.4

<sup>1</sup>Heads-off weight.