A Synopsis of the Tortugas Pink Shrimp, *Penaeus duorarum*, Fishery, 1981-84, and the Impact of the Tortugas Sanctuary

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Introduction

The Gulf of Mexico Shrimp Fishery Management Plan established an area commonly known as the Tortugas Shrimp Sanctuary off south Florida (Fig. 1) and prohibited all trawling activity within that area between 15 May 1981 and 15 April 1983 (GMFMC, 1980). This regulation was founded on scientific data indicating that the sanctuary is a nursery area for the Tortugas stocks of pink shrimp, *Penaeus duorarum*, and that recruitment to the offshore fishery is dependent on the sanctuary. Lindner (1965) and Berry (1970), utilizing growth and mortality data, indicated that the yield of pink shrimp would be greater if harvest was delayed until shrimp were larger than the minimum legal size (69 count[1]) for landing shrimp in Florida.

Therefore, the concept of the Gulf of Mexico Fishery Management Council in reestablishing the sanctuary was to protect small, undersized shrimp from fishing. Furthermore, it was assumed that the distribution of small shrimp was confined mainly inside the sanctuary line and that shrimp outside the line were of legal size or larger. Thus, the establishment of a permanent sanctuary would result in an increase in annual yield of about 1 million pounds (GMFMC, 1980). A small portion of the sanctuary, the "toe of the boot" area was opened to trawling from April 1983 until 15 August 1984 to determine whether catch would increase and to determine the impact on shrimp yield, and trawling was prohibited in the permanent sanctuary thereafter.

This paper reviews the characteristics of the Tortugas fishery from the closure in May 1981 through December 1984. Also, catch, effort, size composition of the landings, and catch per unit effort (CPUE) are compared with the historical data from 1960 to 1979. We determined whether these characteristics were affected by the regulations or lack of regulations for May 1981 through December 1984.

[1]The number of shrimp without heads that constitutes 1 pound.

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ABSTRACT—Trawling for pink shrimp, Penaeus duorarum, *in the Tortugas Sanctuary off south Florida was prohibited from 15 May 1981 through 15 April 1983. A small portion of the sanctuary, the "toe of the boot" area, was opened to trawling from April 1983 until 15 August 1984, when it was again closed to trawling. This paper describes the impacts of the closure, opening, and subsequent closure of the "toe of the boot" area on shrimp trawling.*

Opening the toe area seemed to adversely affect the shrimp catch on the grounds, but the subsequent closure in August 1984 provided a bonanza catch during winter 1984. The Tortugas fishery shrimp yield is based upon the recruitment of the fishing effort expended on small shrimp in the sanctuary and/or toe of the boot area. The 1981 and 1982 recruitment was very poor, while the spring recruitment in 1983 and 1984 was good. The 1983 recruitment was quickly caught by the fleet fishing within the toe area, whereas the 1984 recruitment was saved from heavy exploitation by prohibiting trawling in the toe area. We concluded that fishing in the toe area has a negative impact on the overall shrimp yield on the Tortugas Grounds.

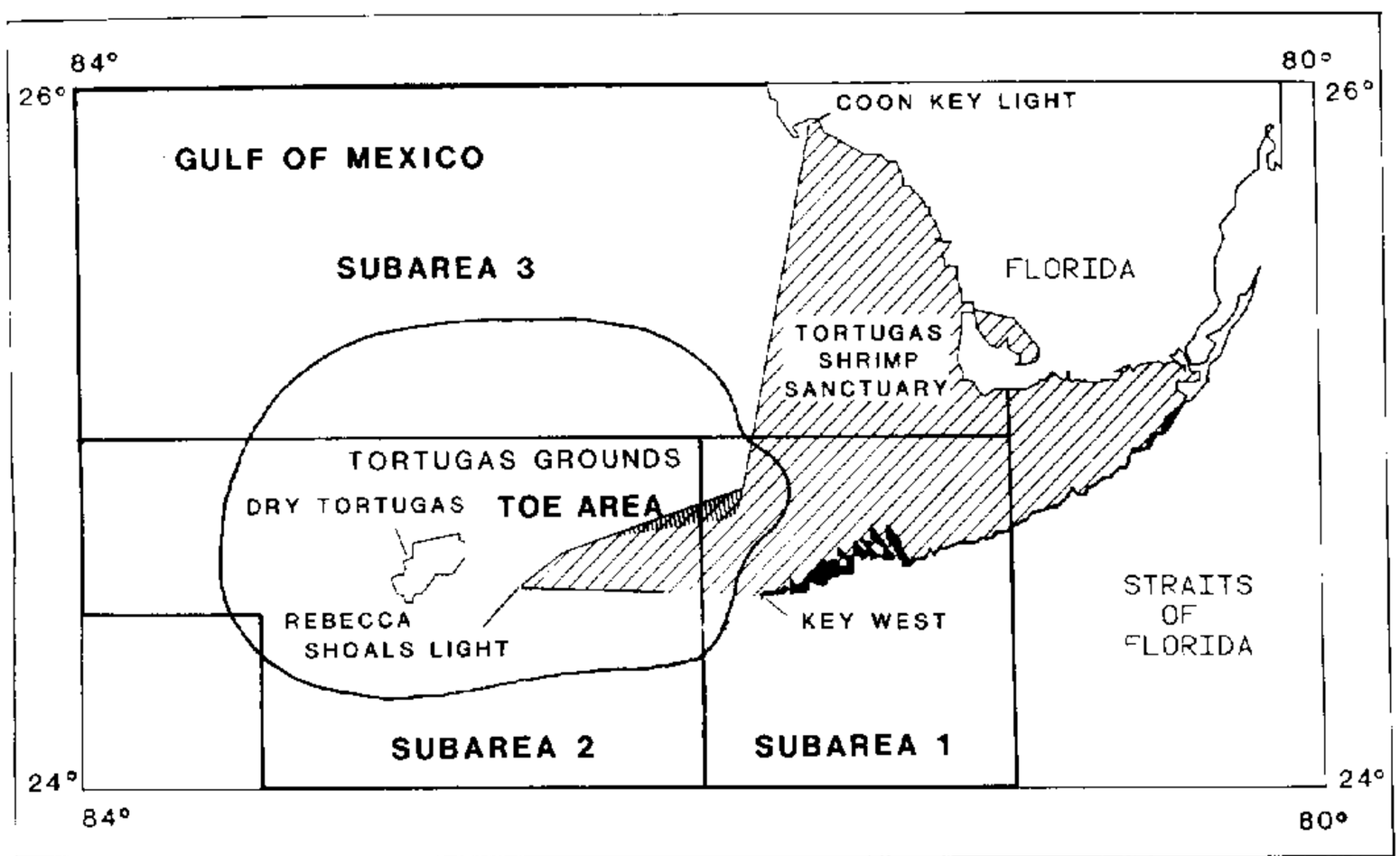

Figure 1.—The Dry Tortugas fishing grounds and statistical subareas.

Materials and Methods: Fishery Statistics

Detailed catch statistics describing the U.S. Gulf of Mexico shrimp fishery since 1956 are available, and the procedures used to collect them have been described by Klima (1980). The statistics compiled by the Southeast Fisheries Center (SEFC), Fishery Information Management Division (FIMD), were used to determine the effects of the Tortugas Shrimp Sanctuary.

Catch and effort statistics were grouped and analyzed by biological years (May-April) for ease of comparing the historical data with the period May 1981-December 1984. The statistics consisted of catch by statistical subarea (Fig. 1), fishing effort (in 24 hours of fishing time expressed as days fished), and size composition of the catch in eight size groupings. Locations and amount of fishing effort expended in 24 hours were obtained by interviewing vessel captains at the termination of their trips. All catch data were recorded as pounds of shrimp heads-off by species and size category, by statistical subarea, depth zone, and month.

Size composition of the reported catches was examined in units of pounds caught in eight "count" or size categories representing number of shrimp per pound, heads-off (<15, 15-20, 21-25, 26-30, 31-40, 41-50, 51-67, and ≥68). The weighted average number of shrimp per pound was calculated by multiplying the pounds landed in each of the size categories by the respective size grouping.

Catch and effort data from 1960 to the present are on file at the SEFC, FIMD office and are available for inspection. Ernest Snell (SEFC, FIMD) has provided specific information on Tortugas shrimp fishery fleet activities, changes in the fleet, number of trips, discards, and specifics of catch and effort for the fishing area during 1981-84.

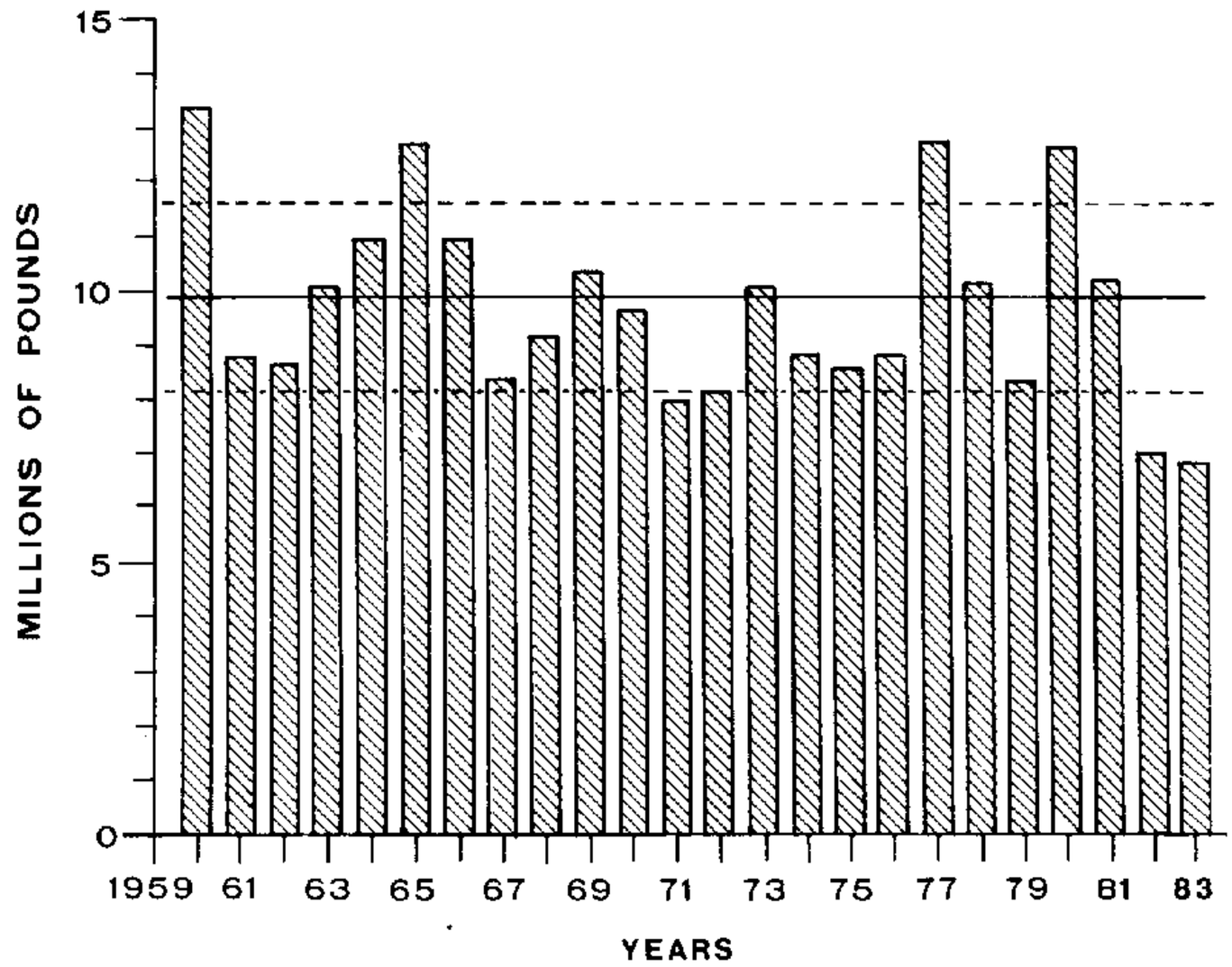

Figure 2.—Annual pink shrimp landings from the Tortugas grounds (SS 1-3) by biological years, 1960-83 (solid line is the mean; each broken line is one standard deviation from the mean).

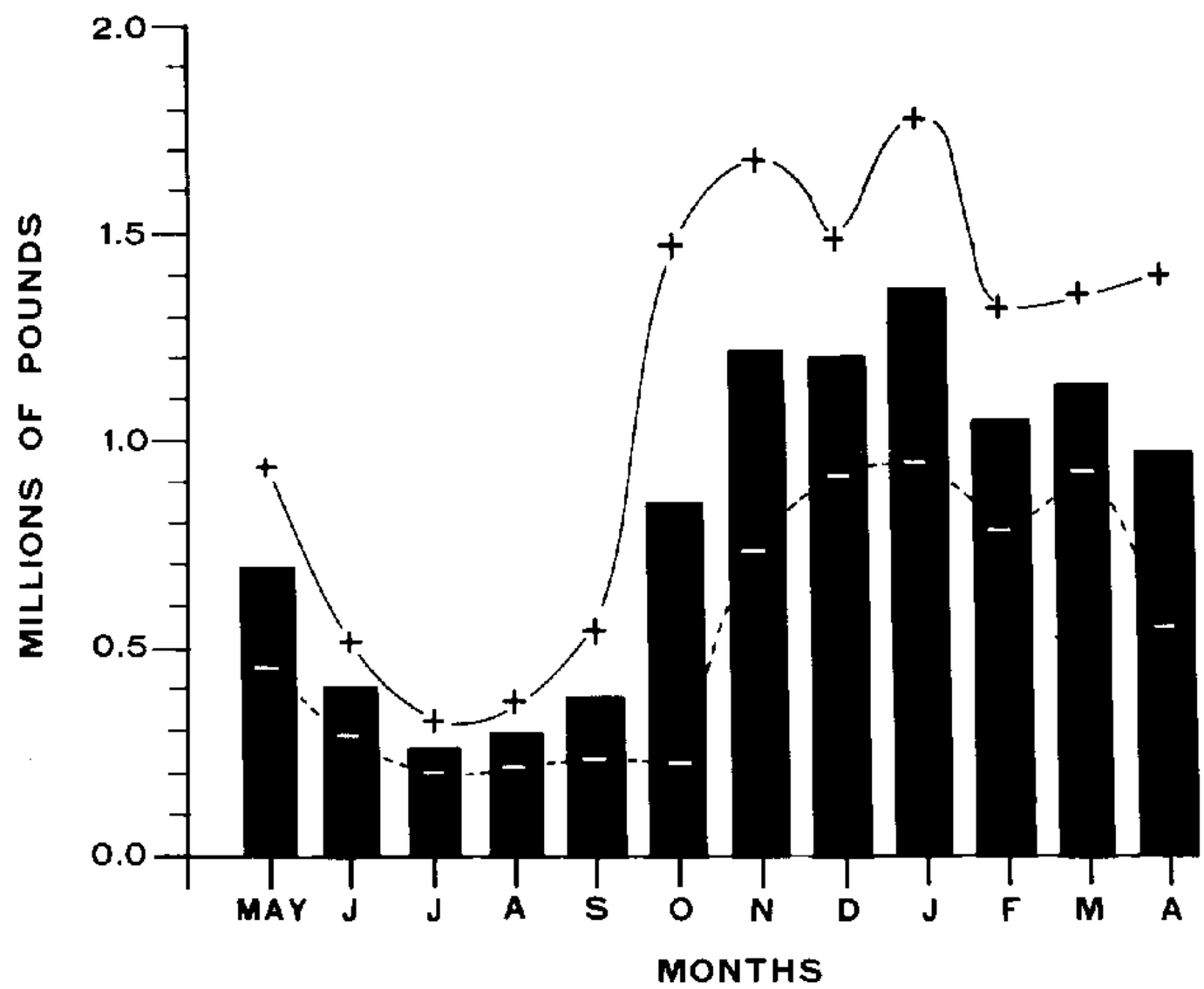

Figure 3.—Mean monthly pink shrimp landings from the Tortugas grounds (SS 1-3) from 1960 to 1979. Each + and − indicates one standard deviation from its mean.

Results

Landings

Annual landings by biological years, from 1960 to 1983, in statistical subareas 1 through 3 have averaged about 9.9 million pounds/year (Fig. 2). They have fluctuated from a high of slightly less than 13.4 million pounds in 1960 to a low of about 7 million pounds in 1982 and 1983. The small variation in annual landings, (S.D. = ±1.7 million pounds,

Table 1.—Monthly summary of total offshore pink shrimp catch in millions of pounds, total fishing effort in thousands of days, and CPUE for statistical subareas 1, 2, and 3 from 1981 through 1984 (an asterisk indicates period when trawling was permitted in toe of boot area).

Year and item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals Jan.-Dec.	Totals May-Apr.
1984														
Catch	0.99*	0.80*	1.03*	1.18*	1.10*	0.12*	0.39*	0.23*	0.16	0.40	0.59	1.94	8.93	
Effort	1.6	2.3	1.9	1.18	1.16	0.3	0.7	0.5	0.5	0.8	0.9	1.7	15.4	
CPUE	608	341	531	646	684	465	532	451	329	498	678	1,100	580	
1983														
Catch	0.79	0.76	1.19	1.17*	0.85*	0.48*	0.26*	0.18*	0.13*	0.31*	0.29*	0.44*	6.84	6.94
Effort	2.0	1.8	1.9	2.0	1.4	1.1	0.6	0.4	0.3	0.7	0.6	1.0	13.7	13.7
CPUE	397	425	638	575	618	431	424	412	444	461	510	461	500	505
1982														
Catch	1.28	0.79	0.81	0.48	0.57	0.34	0.27	0.32	0.32	0.27	0.47	0.57	6.50	7.04
Effort	1.3	1.3	1.5	1.2	0.7	0.7	0.4	0.7	0.8	1.1	1.2	1.5	12.4	14.7
CPUE	1,003	601	52	404	797	488	611	493	384	258	387	391	526	479
1981														
Catch	1.55	0.74	2.50	2.78	1.58	0.83	0.50	0.44	0.71	0.78	1.02	0.99	14.43	10.22
Effort	2.4	1.5	1.9	2.2	1.3	1.2	0.6	0.6	1.0	0.5	1.6	0.6	15.5	12.8
CPUE	640	483	1,342	1,270	1,235	698	793	695	717	1,422	634	1,524	928	797

17.2 percent coefficient of variation) indicates a relatively stable fishery throughout this 24-year period. During 1960, 1965, 1971, 1972, 1977, 1980, 1982, and 1983, landings fell outside 1 S.D.

The 1981 shrimp catch of 10.2 million pounds was slightly larger than the historical average of 9.9 million pounds for 1960-79 and significantly larger than the 1982 and 1983 catch of 7.0 and 6.9 million pounds, respectively (Table 1).

The average monthly landings for 1960-79 showed an annual cycle with an amplitude that ranged from a high of 1.3 million pounds in January to a low of less than 0.3 million pounds in July (Fig. 3). Landings decrease from May through July, rise slightly in August, increase steadily through December, peak in January, decrease slightly in February, and remain constant through April.

The monthly pattern of shrimp landings in 1981, 1982, and 1983 biological years was substantially different from the historical pattern (Fig. 4, 5; Table 1). Compared with the monthly historical means, the landings in 1981 were significantly greater for May through July, and continued to be above the historical averages in August and September. Landings for October were average. Landings for the remaining months of the 1981 biological year, however, were below normal, particularly during February, March, and April.

Below average landings carried into the 1982 biological year for May and June. Landings for July 1982 were average, and for August they were slightly above normal. The large fall harvest, typical of the historical data, was definitely missing in 1982, with the difference in November being substantial and that in December being statistically lower.

Not until March-June 1983 did the monthly landings exceed the historical average. Below average landings from July through December continued through March 1984. The fall recruitment from September to November 1983 did not occur as in past years. Landings were above average in April and May, with extremely small shrimp being landed (Table 1, 2).

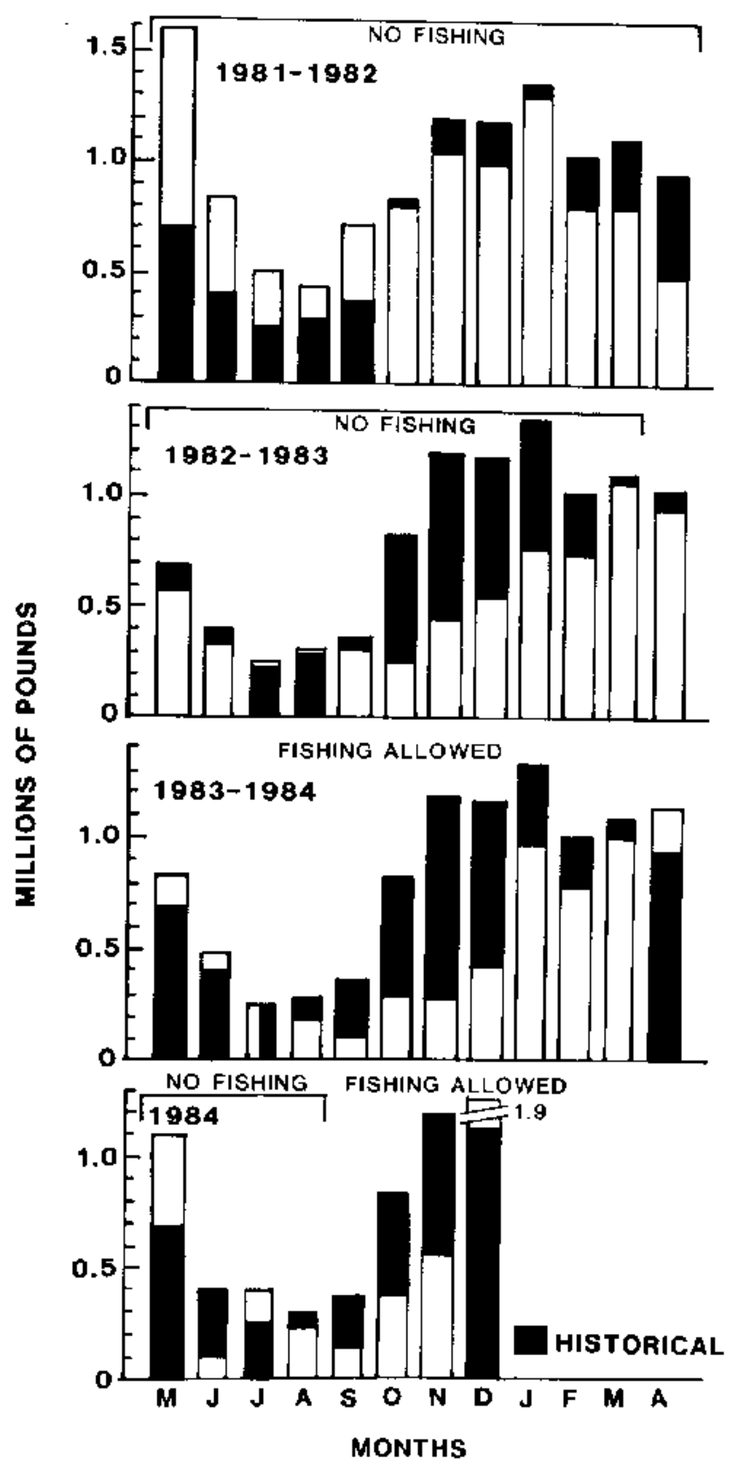

Figure 4.—Average monthly historical catch compared to the catch from May 1981 through December 1984 from the Tortugas grounds (SS 1-3).

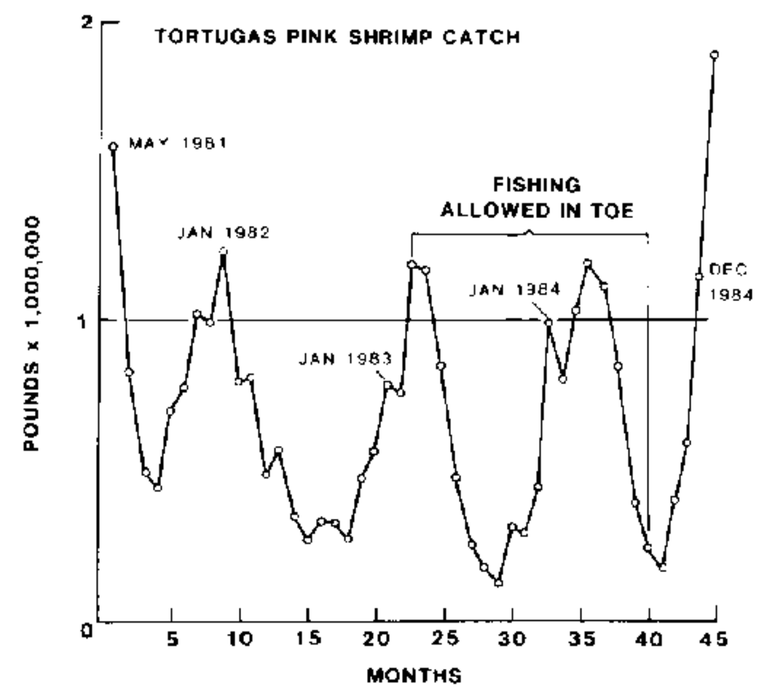

Figure 5.—Monthly landings in pounds from May 1981 through December 1984.

Table 2.—Index of recruitment on Tortugas fishery grounds using weight average, size count, and commercial landings. A + symbol indicates better than average recruitment, a blank indicates less than average recruitment.

	Biological year																								
Mo.	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
May	+										+								+			+		+	+
Aug.	+	+			+	+	+													+			+		
Sept.	+	+			+	+	+		+					+		+				+	+				
Oct.	+	+				+	+																		
Nov.		+				+	+																		
Mar.	+		+							+								+			+		+		N.d.
Apr.			+							+							+	+			+		+	+	N.d.

[1]N.d. = No data.

From May through November 1984, landings were well below the average historical landings. But, landings peaked in December 1984 with a catch of 1.9 million pounds, significantly above the historical landings for December. We noted differences in both 1981, 1982, and 1983 monthly landings compared with the historical monthly landings from 1960 to 1979, as well as the differences in the monthly landings between 1981, 1982, and 1983 (Fig. 4, 5; Table 1).

Fishing Effort

Fishing effort from 1960 to 1982 averaged about 16,000 days per year with a standard deviation of ±2,500 days and a 15.6 percent coefficient of variation. Highest fishing effort was 22,000 days expended in 1960 (Fig. 6). The lowest effort was 10,900 days expended in 1980. Fishing effort did not fluctuate greatly throughout the 24-year time period.

Fishing effort during the closed period was lower than the historical average by 12,800, 14,700 and 13,700 days in 1981, 1982, and 1983, respectively.

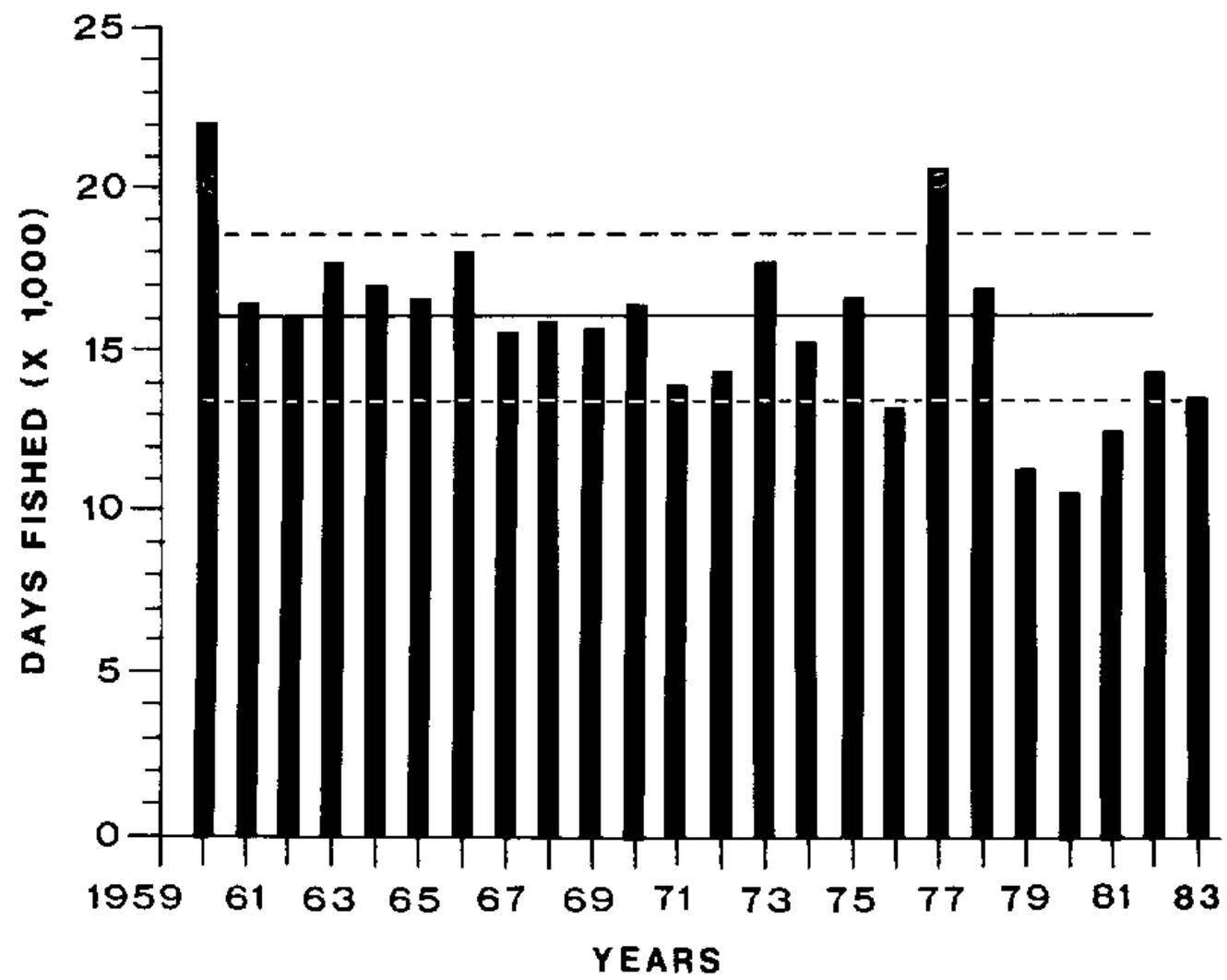

Figure 6.—Pink shrimp fishing effort on the Tortugas grounds (SS 1-3) by biological years for 1960-83. Solid line is the mean fishing effort, broken lines are at ± one standard deviation.

Relative Abundance

The relative abundance of pink shrimp, as expressed by catch per unit of effort (CPUE), is reported as pounds caught per 24-hour fishing day (pounds/day). For the Tortugas fishing grounds the annual CPUE (the mean of 12 monthly CPUE's) has been a remarkably stable parameter from 1960 through 1982 (Fig. 7). CPUE averaged 600 pounds/day with a standard deviation of ±79 pounds and a 13 percent coefficient of variation. The highest annual CPUE was 797 pounds/day recorded for 1981, and the lowest was 479 pounds/day recorded for 1982 and 505 pounds/day in 1983.

The uniformity of the annual average CPUE's for these 24 years is somewhat misleading as there are large differences in the monthly CPUE's between months (Fig. 8). Measures of monthly CPUE from 1960 to 1979 reveal low CPUE's of around 500 pounds/day in May and June. They increase to 650 pounds/day in July and August, and increase to 800 pounds/day in September. A peak is reached at about 940 pounds/day in October, after which there is a steady decline to a low of about 450 pounds/day in February. In March and April, CPUE's increase slightly to about 500 pounds/day.

With the closure of the sanctuary area to trawling in May 1981, the monthly CPUE dropped from the May figure of >1,200 pounds/day to around 700 pounds/day in June and remained at that level through September. A spike occurred in October at 1,400 pounds/day,

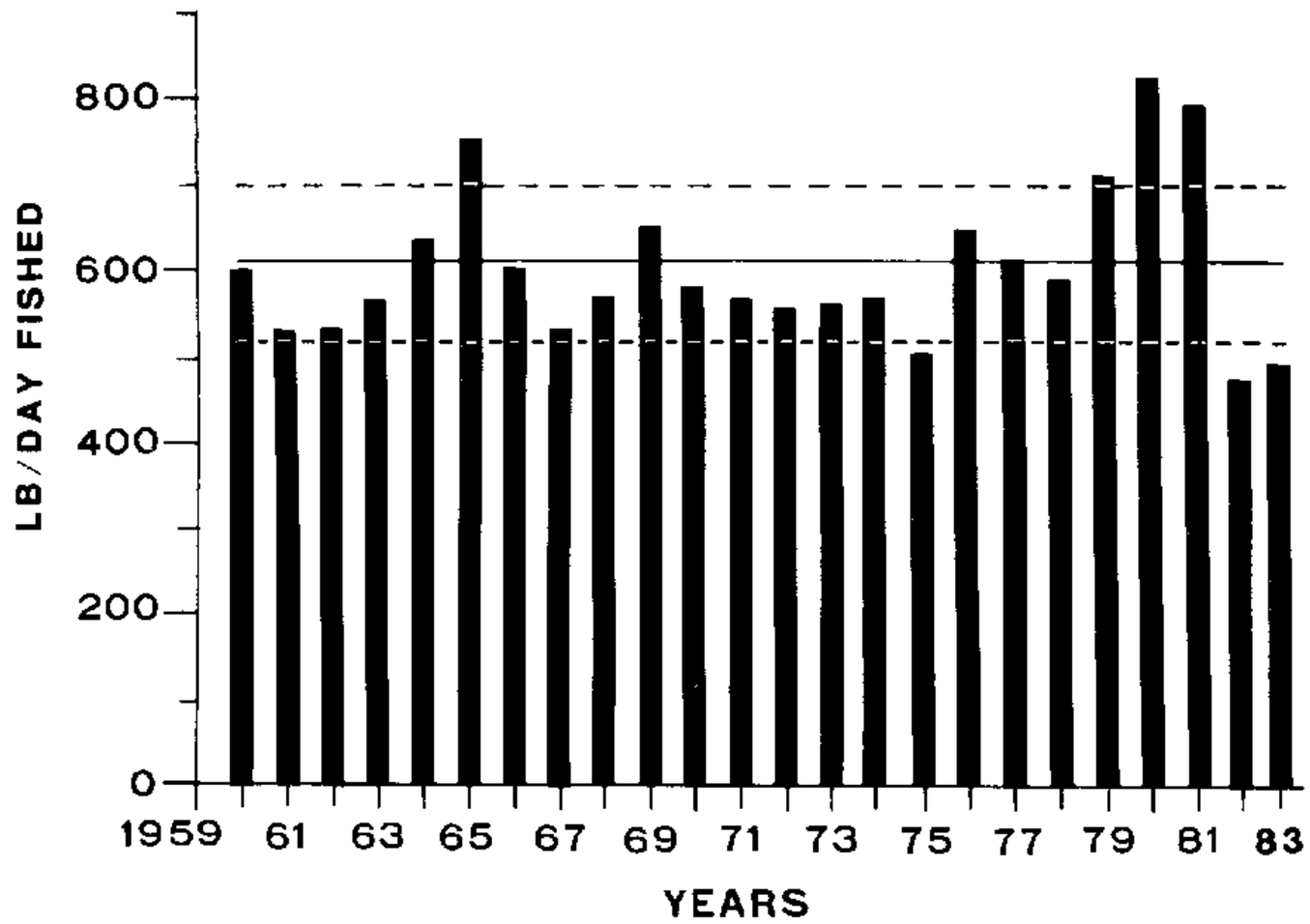

Figure 7.—Catch per unit effort by biological years for 1960-83 in statistical subareas 1, 2, and 3. Solid line is the mean, broken lines are ± one standard deviation away.

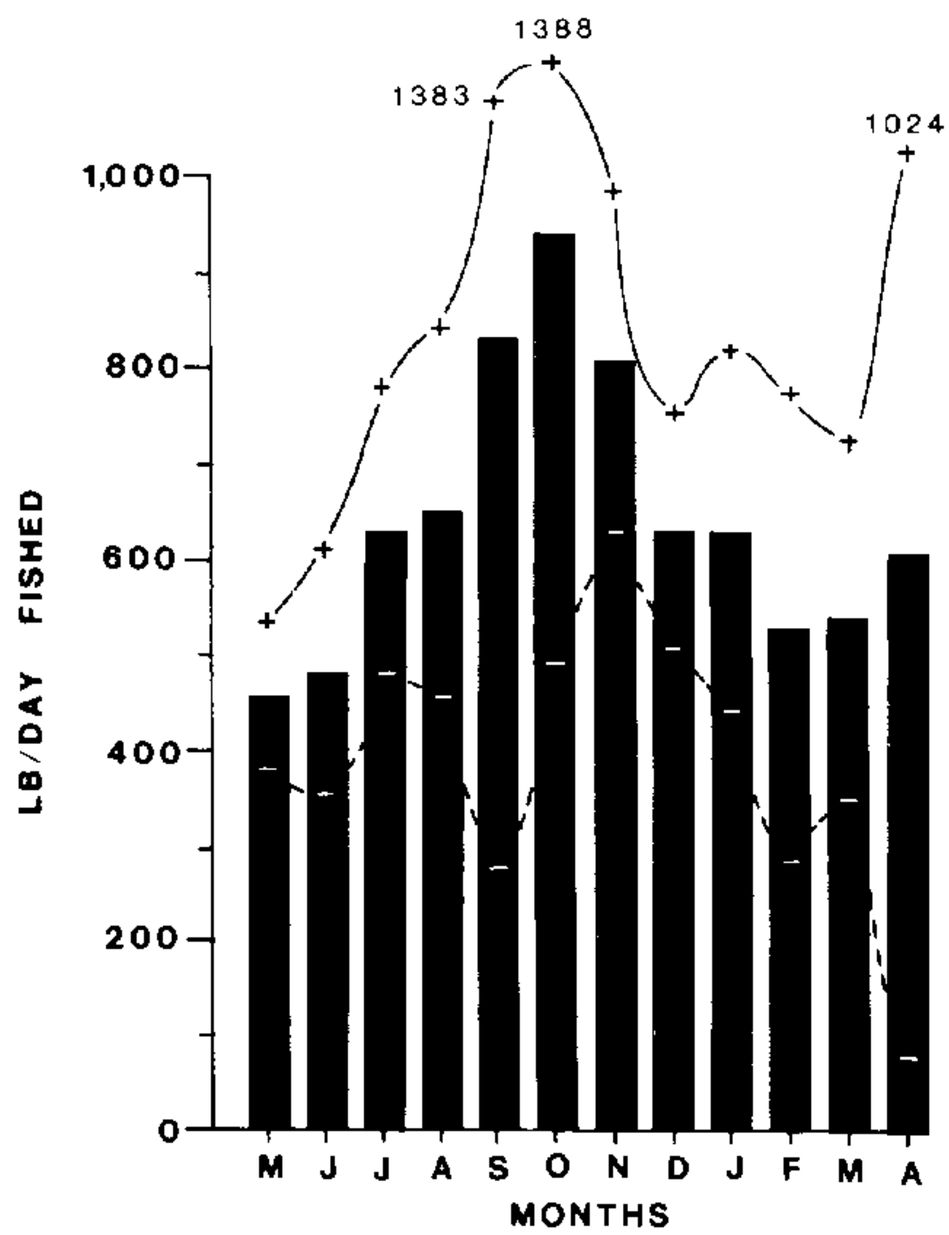

Figure 8.—Monthly CPUE means for shrimping on the Tortugas grounds (SS 1-3) for the biological years 1960-79. Each + is one standard deviation from its mean.

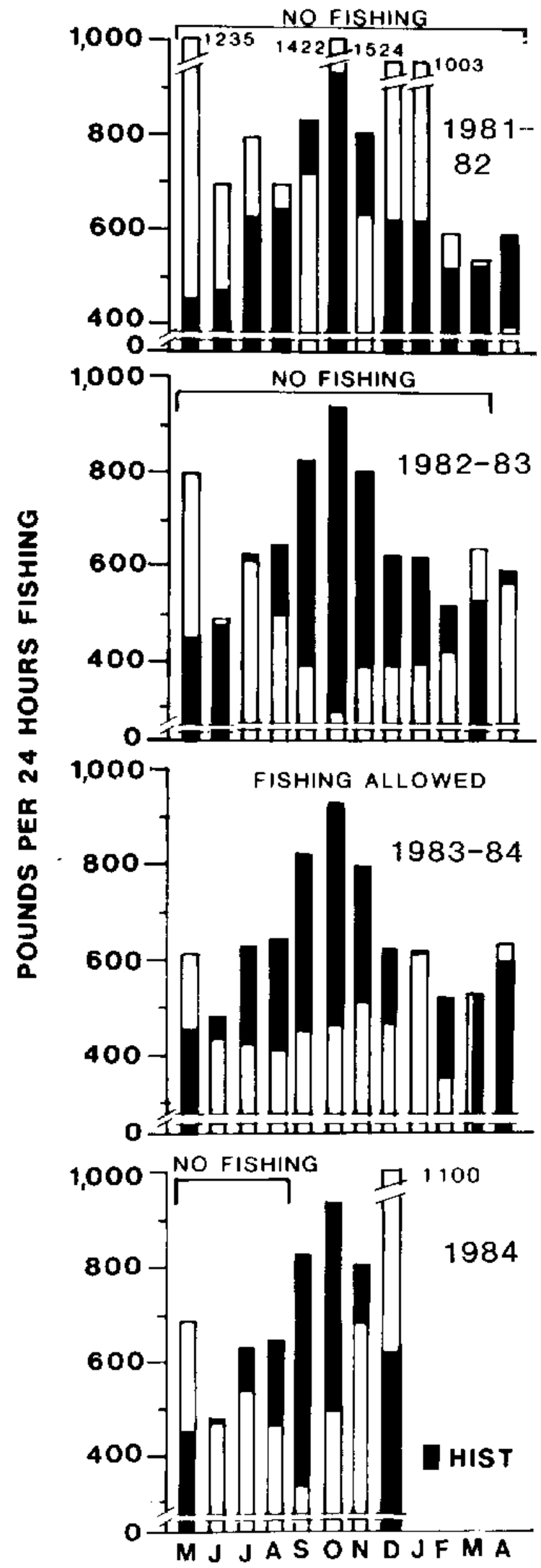

Figure 9.—Average monthly historical CPUE compared with the CPUE from may 1981 through December 1984.

but in November the CPUE dropped to about 600 pounds/day, rose in December to about 1,500 pounds/day, followed by a gradual decline to about 400 pounds/day by April (Fig. 9). The CPUE during the 1981 biological year fluctuated radically, whereas in the 1982 biological year the CPUE was much steadier, averaging about 478 pounds (Fig. 9 and Table 1), and from September 1982 through February 1983 CPUE was ≤400 pounds per day.

With the opening of the toe area of the boot to fishing in March 1983, CPUE rose to 638 pounds/day and stayed at that level through May. From June through December 1983 the CPUE was extremely low, and well below the historical monthly average (Fig. 8). With the exception of April and May 1984 the CPUE was well below the monthly historical average through November 1984. The toe of the boot area was again closed to fishing in August 1984 and in December the CPUE was almost double the December historical average.

In comparing the monthly CPUE's with the historical data, we plotted a ratio of the monthly CPUE from January 1981 through December 1984 over the historical CPUE for 1960-79. These data revealed a higher relative abundance of shrimp on the grounds in 1981 than the historical norm. In 1982 the shrimp abundance was below the historical norm except in May (Fig. 10). With the opening of the toe to fishing in April 1983, the abundance on the Tortugas grounds was less than during the 1960-79 period except for April and May 1984. After the close of fishing in the toe in August 1984, abundance remained low until December 1984.

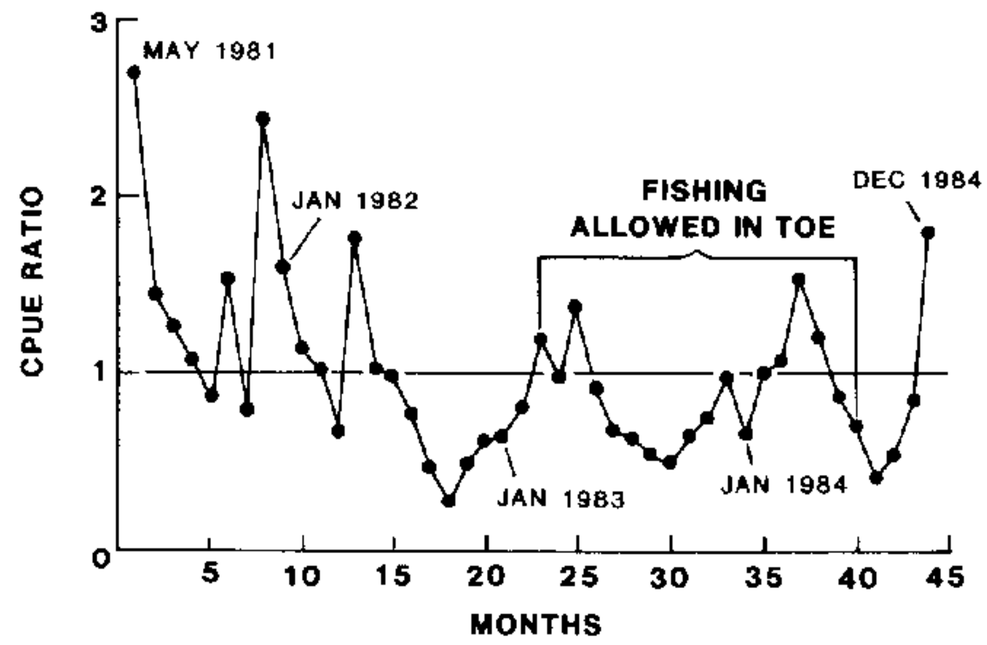

Figure 10.—Ratios of current monthly CPUE's to their corresponding historical means for the Tortugas pink shrimp fishery (SS 1-3).

Size

Recruitment into the Tortugas shrimping grounds occurs during two periods of the year. The first recruitment occurs usually from August through October, with a second recruitment from March through May. The average size of shrimp measured by size categories of the FIMD has been used as an indicator of recruitment on the Tortugas grounds (Klima et al., In press). These data show large fluctuations within the 1960-79 period.

However, to provide a better measure of recruitment, we have examined the pounds of shrimp landed during these critical months (Table 2). If the landings for a given month exceeded the historical average for the data set 1960-79, and if the average weighted mean size for that month was greater than the historical average, we called recruitment "good" or "better than average" for that month. The pluses on Table 2 indicate periods when recruitment was strong according to these criteria. Good recruitment in two consecutive months occurred in 1960, 1961, 1962, 1964, 1965, 1966, 1969, 1977, 1979, 1980, and 1982.

In March and April 1981, before the closure, there was a major recruitment of small shrimp onto the Tortugas grounds. Apparently there was no major movement of small shrimp onto the fishery grounds during the remainder of 1981. Not until March, April, and May of 1983 was there major recruitment again onto the Tortugas fishing grounds.

No detectable major recruitment was observed during the fall of 1983. Good recruitment was observed in April and May 1984. The commercial landings did not show large concentration of small shrimp entering the fishery from August to November 1984. This may be due to prohibition of fishing in the sanctuary and especially in the toe area from August to December 1984. Fishing increased dramatically in December 1984, with the large catches of 21-30 count shrimp composing over 50 percent of the landings. The ratio of mean monthly sizes from May 1981-December 1984 to the historical mean sizes showed some increase through December 1982 in size as would be expected if the management measures were effective (Fig. 11, Table 3). However, with the opening of the tow area to fishing in April 1983, the average monthly size of shrimp landed was consistently smaller than the historical monthly sizes (Fig. 11, Table 3). When the toe area was again closed to fishing in August 1984 the size of shrimp increased dramatically.

Klima et al. (In press) have shown, using G-tests, significant differences in the monthly composition of size categories between 1981 and 1982 and between 1981 as well as 1982 and the monthly historical size compositions. Although we have not gone through the rigors of statistical testing of the data from April 1983 to August 1984, we feel the size composition is clearly different from that of the closed fishing time from May 1981 to February 1983 (Fig. 10, Table 3).

Fishing Effort and Catch

We examined the landings in millions of pounds versus total projected fishery effort for 1960 through 1982 (Fig. 12). These data indicate the condition of the fishery, and a few years stand out: 1960, 1965, 1977, and 1980. These data points show high landings at various levels of fishing effort. The 1981 landings were high with relatively low fishing effort, whereas 1982 and 1983 landings were low with moderate levels of fishing effort.

Discussion

The permanent closure of the Tortugas Sanctuary was established in May 1981, but a small and extremely important part of the extremely southern end

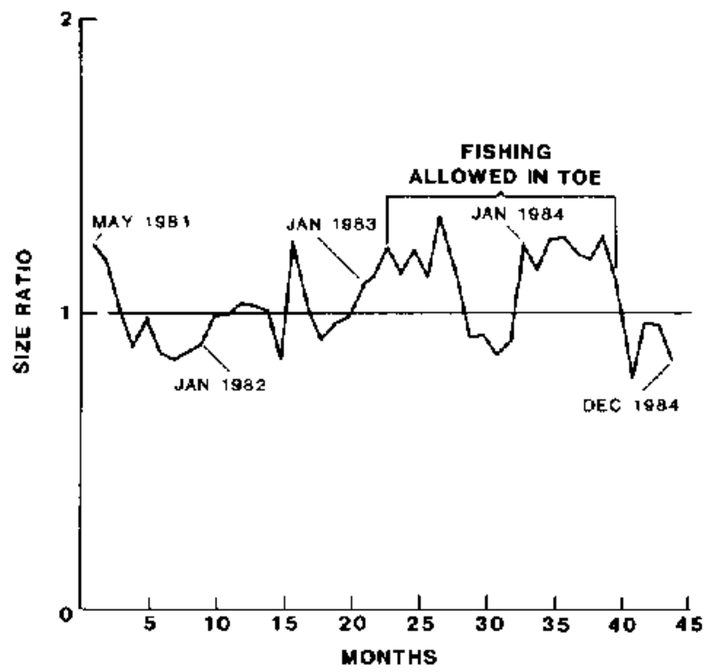

Figure 11.—Ratios of monthly mean number of pink shrimp per pound from May 1981-December 1984 to monthly mean number of pink shrimp per pound for 1960-79.

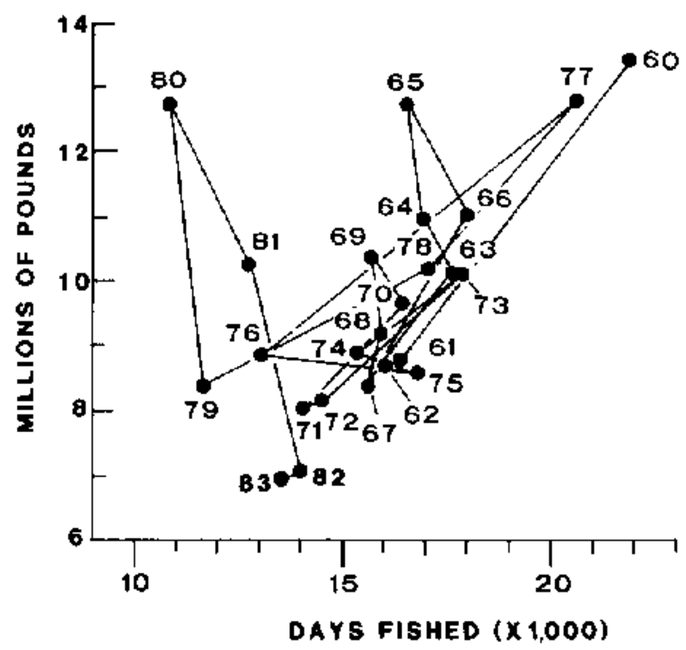

Figure 12.—Catch versus fishing effort for biological years 1960-82 from the Tortugas grounds (SS 1-3).

Table 3.—Monthly average weighted number of pink shrimp per pound for 1960-79, 1981, 1982, 1983, and 1984 (+ indicates larger size group and – indicates smaller size group than historical average; bracketed portion indicates open fishing in toe of the boot).

Month	1960-79 Average number/lb.	1960-79 Standard deviation	1981 Average number/lb.	1982 Average number/lb.	1983 Average number/lb.	1984 Average number/lb.
May	46.8	5.1	57.4 +	48.4 +	56.8 +	55.9 +
June	45.2	4.5	52.7 +	45.7 +	50.2 +	53.1 +
July	44.0	4.7	44.2 +	36.6 –	58.0 +	55.0 +
August	44.0	7.7	38.9 –	55.0 +	49.6 +	46.9 +
September	48.7	7.9	47.5 –	49.0 +	44.2 –	36.9 –
October	47.9	4.8	41.4 –	43.3 –	44.0 –	45.8 –
November	43.1	3.3	36.4 –	41.3 –	36.6 –	41.0 –
December	40.2	2.8	34.9 –	39.3 –	36.1 –	35.2 –
January	40.2	3.1	35.6 –	43.6 +	49.4 +	
February	42.7	3.1	42.1 –	48.0 +	48.1 +	
March	47.5	4.4	46.8 –	57.5 +	58.7 +	
April	48.3	5.8	49.8 +	[54.1 +]	60.5 +	

of the sanctuary was open to fishing from April 1983 through August 1984. In evaluating the management regulations, we have specifically looked at landings, effort, CPUE, and size composition from May 1981 through December 1984 and have compared these catch statistics with the historical data from 1960 through 1979, using the biological year of May through the following April.

The Tortugas fishery has been very stable, with average annual production of about 9.9 million pounds; it does not fluctuate greatly from year to year. The fishery is bounded naturally by trawable bottoms of loggerhead sponges and coral reefs where pink shrimp are protected from trawling even though they may be present in high concentrations. The large area of untrawlable bottom surrounding the fishery grounds may be the reason why this fishery has been so stable since 1960.

Historically, the recruitment of small shrimp onto the Tortugas grounds occurs between September and November, and in certain years there is also a major spring recruitment. In March and April 1981 (prior to the closure of the sanctuary), there was good recruitment of small shrimp onto the Tortugas grounds. That recruitment continued through May 1981, the closure period, and sustained the fishery through the remainder of 1981. The 1981 catch amounted to 10.2 million pounds. However, there was no strong recruitment onto the Tortugas grounds again until March, April, and May of 1983. Consequently, the fishery from May 1982 through April 1983 produced an all-time low of about 7 million pounds of shrimp. It would appear that the fishery had collapsed, but the drop was due primarily to limited recruitment of small juveniles onto the grounds.

In April of 1983 the toe of the boot area of the sanctuary was open to fishing and the fleet took advantage of this opening and concentrated their effort on the extremely small and abundant shrimp, which was reflected in an increase of the average size of shrimp landed as well as landings of over 1.0 million pounds per month. Recruitment was poor in the fall of 1983. Above average recruitment was again observed in both April and May 1984. This peak spring 1984 recruitment was again rapidly harvested since the toe area was open to fishing, with a catch of over 1.0 million pounds per month of extremely small shrimp (Fig. 5, 11). After the closure of the toe area to fishing in August 1984, the average size increased to a much larger size than the respective monthly historical size.

The fishery from May 1982 through April 1984 produced an all-time low of about 7 and 6.9 million pounds for the biological years 1982 and 1983, respectively. Production from May to December 1984 was relatively low with a total yield of only 3.0 million pounds. The only exceptional month was December 1984, in which 1.94 million pounds of large shrimp (33/pound average) were landed.

We believe that the high production of large shrimp during December was due to the spring recruitment of shrimp that did not move onto the fishing grounds in August and September, but stayed either in the loggerhead sponge area north of the fishery or in the sanctuary. This stock apparently moved onto the grounds in November-December 1984. They were basically protected from the fishery either by the sanctuary or by the loggerhead sponges. However, this remains purely conjecture. For example, 150-200 count shrimp would take about 6 months to reach a size of 20 count; therefore, shrimp of this size recruited to the sanctuary area from the Everglades during May, would take

about 6 months before they reach a size of 20 count shrimp (Berry, 1967). Further, the December 1984 fishery was basically concentrated in the extreme northern and northeastern part of the Tortugas fishery.

The tone of the fishery from 1981 to 1984 was set by the amount of recruitment and the opening and closing of fishing in the toe area. With good recruitment in the March through April 1981 period, the stage was set for a good fishery, whereas the lack of recruitment in 1982 and 1983 resulted in devastatingly low production. Good recruitment in the spring of 1983 coincided with the opening of the toe area to fishing, which we believe reduced the total yield because of the excessive harvest of small shrimp.

Summary

Commercial pink shrimp landings from the Tortugas fishery were relatively stable from 1960 to 1979 and deviated very little from the mean of 9.9 million pounds with a standard deviation of about 1.7 million pounds and a 17 percent coefficient variation. This indicates a very stable fishery throughout this period.

The Tortugas Sanctuary was closed to all trawling from May 1981 through 15 April 1983. Commercial landing statistics from May 1981 through March 1983, during the two closure years, were dramatically different. Production in 1981 amounted to 10.2 million pounds, but it dropped to about 7 million pounds in 1982.

In April 1983 the toe of the boot was open to fishing through August 1984. Landings during the 1983 biological year were 6.9 million pounds, again well below the annual historical average of 9.9 million pounds. Annual production from April 1983 to March 1984 amounted to 7.1 million pounds. Annual production from January to December 1984 amounted to 8.1 million pounds. Monthly landings of over 1 million pounds were recorded in March, April, and May, a period of open fishing in the toe. After closing the toe area to fishing in August 1984, monthly landings remained lower than their historical average until December when they peaked at 1.9 million pounds, well above the December historical average.

Annual fishing effort from 1960 to 1979 averaged about 16,000 days/year and did not fluctuate greatly. Fishing effort during the closed period was 12,800, 14,700, and 13,700 days in 1981, 1982, and 1983, respectively, less than the historical average.

The relative abundance of shrimp on the Tortugas grounds as measured by the annual CPUE was remarkably stable from 1960 through 1982, with an average of 619 pounds per day and a standard deviation of ±79 pounds. The highest historical CPUE was 829 pounds/day recorded in 1980, the lowest figures were 479 pounds/day recorded in 1982 and 505 pounds/day in 1983. Both figures were significantly different than the historical CPUE during the period 1960-79.

The size distributions of shrimp landed in 1981, 1982, and 1983 were different from each other, and were also different than the period between 1960 and 1964 and the period between 1975 and 1979.

The yield in the Tortugas fishery is based on recruitment and amount of fishing effort expended on small shrimp in the sanctuary and/or toe of the boot area.

Excellent recruitment was observed in March, April, and May 1981, with little observed recruitment in the fall of 1981, and little recruitment in the spring and fall of 1982. In the spring of 1983, good recruitment was noted in March, April and May, with below average recruitment in the fall of 1983. Again, excellent recruitment was noted in April and May 1984, with little observed recruitment in the fall of 1984.

Landings as well as relative abundance as measured by CPUE were low throughout 1982 as well as in January and February 1983 and from April 1983 to November 1984. The only exception to low landings and low levels of abundance was the high CPUE in May 1983 and April and May 1984 associated with the harvesting of small shrimp as they moved into the toe area of the boot and onto the fishing grounds.

Fishing within the toe area of the boot from April 1983 to August 1984 allowed the fishery to exploit small shrimp, resulting in an increase in the average size groups harvested and reducing overall yield to the fishery. Large, predominantly 21-30 count, shrimp were caught in great abundance in December 1984, presumably a result of protecting emigrating juvenile shrimp.

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