Long-Term Trends in Abundance of the Dolphin (*Coryphaena hippurus*) near Barbados

HAZEL A. OXENFORD[1] AND WAYNE HUNTE[2]
[1]Biology Department
University of the West Indies
Barbados
[2]Bellairs Research Institute
of McGill University
Barbados

ABSTRACT

In terms of weight and revenue, the dolphin (*Coryphaena hippurus*) is the most important of the large pelagic fish landed by the Barbadian fishery. Accurate catch records are collected by the Fisheries Division and indicate that the total weight of dolphin landed annually has increased between 1958 and 1983 by 4,322 kg per year. Over this period, catch per trip has increased at a rate of 0.72 kg per trip, the number of fishing trips made annually has decreased by 246 trips per year, and mean launch size has increased by 0.09 meters per year. Larger launches catch more per trip than smaller launches; the increase occurring at a rate of 7.44 kg per meter of launch. When effect of increasing launch size is removed, average catch per unit effort recorded at the largest market (Oistins) still increases at an annual rate of 1.66 kg over the period 1961 to 1982. This suggests either that the increased fishing efficiency of larger launches has not been adequately corrected, or that dolphin abundance has increased, or that dolphin catchability has increased. These alternatives are discussed in the context of an observed long-term increase in Amazon River outflow. There is no evidence to date that fishing mortality in the eastern Caribbean is affecting dolphin stock abundance.

INTRODUCTION

The dolphin (*Coryphaena hippurus*) is a large, oceanic, epipelagic species found worldwide in tropical and subtropical waters (Palko et al., 1982). In the eastern Caribbean it supports important commercial fisheries in all the Windward Islands (Hunte, in press), and in Barbados it is the most important of the large pelagic species landed in terms of weight and revenue (Mahon et al., 1981; Chakalall, 1982; McConney, 1983).

Monitoring numerical changes in a population with time is essential to an understanding of population dynamics, of production and yield to the fishery, of the responses of the population to fishing mortality and hence ultimately to the rational management of the fishery. Fluctuations in catch are characteristic of all fisheries and usually reflect fluctuations in recruitment to the stock, which may be determined by environmental variations and/or the effects of fishing mortality on the breeding stock. These processes can lead to recruitment failure and collapse of the fishery (Cushing, 1977; Murphy, 1982) and this may be particularly true of pelagic stocks (Saville, 1979).

In this study we investigate long-term changes in abundance of dolphin near Barbados by analyzing 26 years of catch and effort data from the commercial fishery at Barbados. To ensure that this approach would be meaningful, it was necessary to examine the methods of recording catch data at all major landing sites on the island, and to investigate the validity of using catch per trip as synonymous with catch per unit effort and hence as an index of dolphin abundance. Once the data were standardized as above, between-year variation in abundance could be examined, and an attempt could be made to identify correlations between dolphin year class strength and environmental factors. More specifically, a possible correlation between year class strength and Amazon River outflow, which is known to affect productivity in the eastern Caribbean waters (Lewis and Fish, 1969; Kidd and Sander, 1979; Borstad, 1982a, b), was investigated.

METHODS

The Barbados Fisheries Division of the Ministry of Agriculture, Food and Consumer Affairs has been recording catch and effort data since 1957. At each major market on the island, dolphin catch by weight and number of fishing launches are recorded daily (except for Sundays and bank holidays). Records of the sizes of named launches have been kept by the Fisheries Division since 1961. Information on the weight of dolphin landed by individual named launches of known size was obtained at the major market (Oistins) from 1974. These data could therefore be used to investigate the effects of launch size on catch per launch, and on frequency of fishing trips.

Catch records from the sport fishery in Barbados are kept by the Barbados Game Fish Association (BGFA), and are available from 1978 to the present. The records include the individual weights of 1,543 dolphin landed in competitions over the six years, and are the only long-term records of individual fish weights for the Barbados stock.

Personal observations of the number of hours spent at sea per trip, the number of launches fishing daily, and the quantity of dolphin landed per launch were made at Oistins 2 to 5 days a week from February 1981 to May 1982. These data were then used as a check for the reliability of the data recorded by the Fisheries Division over the corresponding period.

All catch and effort data in this study are presented by 'fishing years' or 'fishing seasons.' A 'fishing year' runs from September to August of the next calendar year and is labelled by the latter year. A 'fishing season' refers to the months of peak dolphin catch, which are January to May inclusively. Long-term trends in annual total dolphin catch by weight, in annual total number of fishing trips and in annual dolphin catch per fishing trip by weight were identified from slopes of standard linear regressions of catch vs years; number of trips vs years; and catch per trip vs years respectively. The catching success of different sized launches each year at Oistins was assessed using standard linear regressions of average catch per trip over the fishing season vs launch length for the years 1974 to 1982. Differences between years in correlations of average catch per trip with launch length were tested using a Newman-Keuls multiple range test for unequal sizes (Zar, 1974).

The relationship between launch length and the frequency of fishing trips made per season was investigated in each of the 9 years from 1974 to 1982 using standard linear regressions of trips vs launch size. Differences between years in the rate of increase in trips per season with launch length were investigated using an analysis of covariance (Zar, 1974).

Given that there is a correlation between launch size and catching success, and between launch size and the frequency of fishing trips per year; and that there has been an increase in average size of launches in the Barbados fleet over the 26 years under study, it is clear that investigating between-year variation in abundance by using total annual catch divided by total number of launches fishing in that year could give seriously misleading results. In short, it is necessary to quantify the rates of catch improvement associated with these parameters and then compensate for them in the long-term catch per trip data. For the years prior to 1974, although total number of fishing trips is known, the data do not allow one to determine the number of trips made by individual launches. The determination of long-term trends in the size of 'actively fishing' launches therefore took several steps. The precise number of trips made by named launches of known size each season was available for the years 1974 to 1982. From these data, a correlation between launch size and frequency of fishing trips made per season was quantified. This was then used, together with the known sizes of launches and the total number of trips made that year, to assess how many trips were made by launches of each size in the years prior to 1974. Thus, the mean size of 'actively fishing' launches could be calculated for 1961-1973.

The rate of catch improvement as a function of launch length was calculated using the seasonal average catch per trip and launch size data for the 9 years (1974-1982). This was then used to compensate for the increasing size of 'actively fishing' launches in the fleet and thereby transforming observed catch per trip data to a more valid index of catch per effort over the 26 years of catch data (subsequently referred to as catch per unit of standard effort or CPUE). This was achieved by using mean 'actively fishing' launch size in 1961 as a baseline and then rating the mean size of 'actively fishing' launches in all subsequent years by a positive or negative increment of length increase compared with 1961. The rating gives a quantitative estimate of the size advantage in kg per trip (using the slope of the overall regression of catch/trip vs length) which could then be added to or subtracted from the observed mean catch per trip recorded over the year 1961 to 1982 by the Fisheries Division.

Finally, annual fluctuations in the average catch per unit of standard effort in each year from 1961 to 1978 were compared with the annual average height of the River Negro (a major tributary of the Amazon River, and hence an index of Amazon outflow) in the same and preceding years. This necessitated that both data sets be detrended. Linear regressions of CPUE vs years from 1961 to 1978 and from 1962 to 1979, and of Negro River heights vs years from 1961 to 1978 were done, and the residuals of each in the same years were subsequently plotted against each other to investigate correlations between CPUE and Amazon outflow.

RESULTS

Our own records of the weight of dolphin landed by the commercial fishing fleet at Oistins over the 1982 fishing season from January to May compared closely with data collected there over the same period by the Fisheries Division (Table 1). This, together with personal observations of the Fisheries Division's data recording procedure during the 1981, 1982 and 1983 fishing seasons, confirmed that their data were accurate. Note that the same procedures have been followed since the onset of data collection at this market, and under the supervision of the same government employee.

Table 1. Comparisons of independent estimates of the weight of the dolphin (Coryphaena hippurus) landed by the commercial fleet at Oistins, Barbados, with Fisheries Division catch records for the same fish market during the 1982 fishing season

Month	Estimated total landings kg	Fisheries Division records of total landings (kg)	Differences between estimates (%)
January	9,189	8,800	- 3.36
February	16,771	16,876	+ 0.63
March	32,824	31,765	- 3.23
April	32,311	33,609	+ 4.02
May	11,104	10,500	- 5.44

The total weight of dolphin landed by the commercial fleet each fishing year, the number of daily fishing trips per year and the annual average catch per trip recorded for all major markets in Barbados from 1958 to 1983, are illustrated in Figure 1. Over the last 26 years, there has been a significant increase in the annual weight of dolphin landed, at a rate of 4,322 kg a year (linear regression, total weight vs years: $r = 0.623$, $v = 24$, $P < 0.05$); a slight, but significant decrease in the total number of daily fishing trips, at a rate of 264 trips a year (linear regression, trips vs years: $r = 0.679$, $v = 24$, $P < 0.05$; but note the sharp increase in 1983); and a significant increase in the average catch per trip at an annual rate of 0.72 kg per trip (linear regression, annual average catch/trip vs years: $r = 0.835$, $v = 24$, $P < 0.05$).

Table 2. Linear regression analyses of launch size (m) versus catching success, i.e., the average weight of the dolphin (Coryphaena hippurus) caught per trip each season (Jan.-May), at Oistins, Barbados

Year	Seasonal aver.catch/ trip (kg)	Linear regression slope (b)	Correlation coefficient (r)	Number of launches (n)	Significance of correlation (P< 0.05)
1974	44.09	2.19	0.110	71	No
1975	47.73	6.98	0.664	91	Yes
1976	50.18	14.15	0.502	94	Yes
1977	56.83	9.11	0.401	93	Yes
1978	50.11	7.44	0.434	83	Yes
1979	34.34	4.22	0.286	93	Yes
1980	63.59	11.04	0.437	101	Yes
1981	58.17	7.37	0.420	93	Yes
1982	50.77	8.75	0.427	96	Yes

The average size of launches in the registered fleet at Oistins has increased from 7.26 m in 1961 to 8.68 m in 1982 (Figure 2). Launch size was consistently positively correlated with catching success. Throughout 1981, using individual days in an attempt to control for variation in dolphin abundance, catch was positively correlated with launch size on each day. However, given the small sample sizes (only 10-28 launches fishing on any one day), and the considerable chance element in locating 'dolphin-rich' rafts, none of the correlation coefficients were significant. An analysis of average daily catch per launch throughout the fishing season vs launch size was conducted for all launches at Oistins separately for the 9 years between 1974 and 1982. Catch was significantly correlated with launch size in 8 of the years (1975-1982), and was positively, but not significantly, correlated with launch size in the remaining year (1974) (Table 2). Note that in 'good' years, when the average catch per trip is high, the data fit the regression line more closely and the slope tends to be steeper than in 'bad' years with lower catch per trip values. In short, in 'good' years there is less variation in the data and the increased success of large over small boats is greater than in 'bad' years. A multiple comparison of the slopes of the linear regressions for each of the 9 years showed that they were not all the same (analysis of covariance: $F = 2.3$, numerator d.f. = 8, denominator d.f. = 801, $P < 0.05$). However, a Newman-Keuls multiple range test indicated that only 2 of 36 pair-wise slope

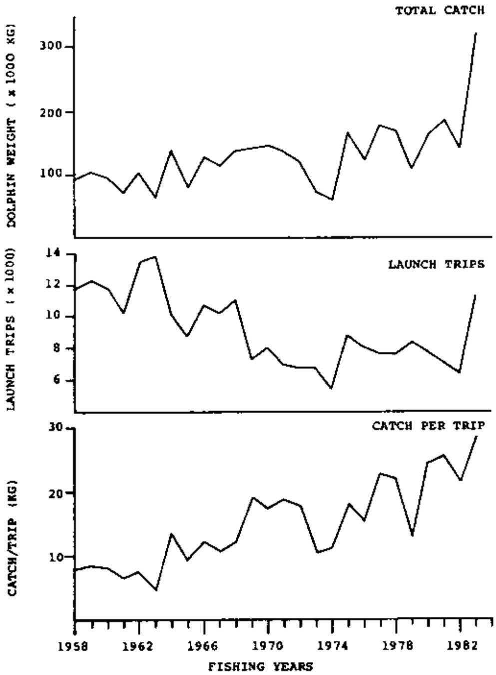

Figure 1. Annual total catches by weight of the dolphin (Coryphaena hippurus), annual total numbers of launch fishing trips, and annual average catches of dolphin per fishing trip recorded at the four major fish markets in Barbados.

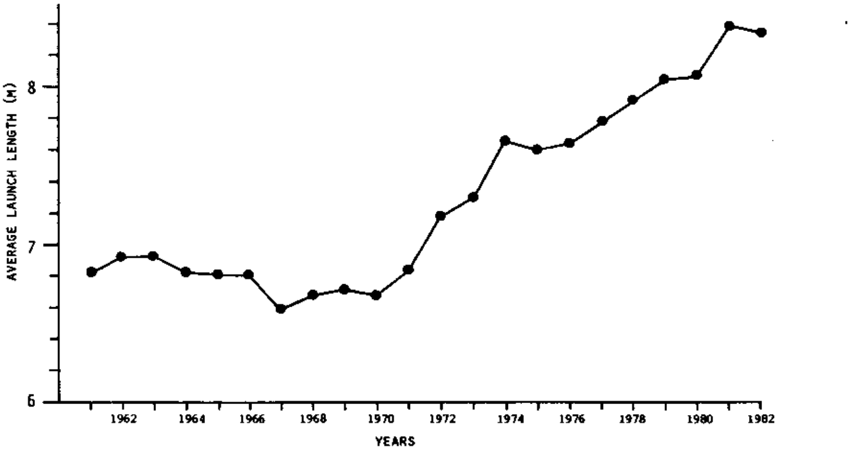

Figure 2. The average length of registered launches in the fishing fleet at Oistins, Barbados, each year, showing a gradual increase in launch size over the last 23 years.

Table 3. Summary of the results and conclusions of a Newman-Keuls multiple range test to investigate differences between years, in the degree of increased average catching success with launch length over nine fishing seasons. The data refer to the average catch of dolphin (Coryphaena hippurus) per trip by launches of known size, fishing from Oistins, Barbados.

		CONCLUSIONS							
RANK (year)	1 1974	2 1979	3 1975	4 1981	5 1978	6 1982	7 1977	8 1980	9 1976
RESULTS: 1 (1974)	-	β1979 = β1974	β1975 = β1974	β1981 = β1974	β1978 = β1974	β1982 = β1974	β1977 = β1974	β1980 = β1974	β1976 ≠ β1974
2 (1979)	q=1.047 p=2 v=801 P>0.05	-	β1975 = β1979	β1981 = β1979	β1978 = β1979	β1982 = β1979	β1977 = β1979	β1980 = β1979	β1976 ≠ β1979
3 (1975)	q=1.794 p=3 v=801 P>0.05	-	-	β1981 = β1975	β1978 = β1975	β1982 = β1975	β1977 = β1975	β1980 = β1975	β1976 = β1975
4 (1981)	q=2.461 p=4 v=801 P>0.05	-	-	-	β1978 = β1981	β1982 = β1981	β1977 = β1981	β1980 = β1981	β1976 = β1981
5 (1978)	q=1.856 p=5 v=801 P>0.05	-	-	-	-	β1982 = β1978	β1977 = β1978	β1980 = β1978	β1976 = β1978
6 (1982)	q=2.820 p=6 v=801 P>0.05	-	-	-	-	-	β1977 = β1982	β1980 = β1982	β1976 = β1982
7 (1977)	q=2.923 p=7 v=801 P>0.05	-	-	-	-	-	-	β1980 = β1977	β1976 = β1977
8 (1980)	q=3.352 p=8 v=801 P>0.05	-	-	-	-	-	-	-	β1976 = β1980
9 (1976)	q=4.632 p=9 v=801 P<0.05	q=4.913 p=8 v=801 P<0.05	q=2.732 p=7 v=801 P>0.05	-	-	-	-	-	-

comparisons were significantly different, i.e., differed in degree of increased catching success with launch size. Slope differences were found between 1976 and 1974, and between 1976 and 1979 (Table 3). Note that 1974 and 1979 are the two worst years (lowest average catch/trip; Table 2); and 1976, although not the best year, has the steepest slope. Using data from all 9 years combined, the effect of launch size on catch rate is given by the linear relationship: Average catch/trip (kg) = 13.29 + 7.44 launch lengths(m) ($r = 0.34$, $v = 813$, $P < 0.05$). This indicates that, for every 1 meter increase in length over the range 5.2 to 11.5 meters, a launch will catch an average of 7.44 kg more dolphin per trip during the peak fishing months.

Separately in each of 9 years (1974-1982), launch size is also positively correlated with the frequency of fishing trips made within a season (Table 4). The slopes of the relationships did not differ between any of the 9 years (analysis of covariance: $F = 0.937$, numerator d.f. = 8, denominator d.f. = 880, $P < 0.05$). Using data for all nine years combined, the effect of launch size on frequency of fishing trips is given by the linear relationship: Average number of trips per season = 17.71 + 4.30-launch lengths(m) ($r = 0.392$, $v = 896$, $P < 0.05$). This indicates that for every 1 meter increase in launch length over the range 5.2 to 11.5 meters, the average number of trips made by that launch in a fishing season increases by 4.3.

Table 4. Linear regression analyses of launch length (m) against frequency of fishing trips each season (Jan.-May) at Oistins, Barbados

Year	Linear regression slope (b)	Correlation coefficient (r)	Number of launches (n)	Significance of correlation (P< 0.05)
1974	3.99	0.402	81	Yes
1975	3.89	0.359	102	Yes
1976	3.53	0.345	100	Yes
1977	4.42	0.433	101	Yes
1978	5.16	0.429	92	Yes
1979	5.60	0.537	103	Yes
1980	4.78	0.388	110	Yes
1981	3.10	0.287	107	Yes
1982	2.90	0.255	102	Yes

Since larger launches make more trips per season than smaller ones, average launch size of the registered fleet will necessarily be smaller than the average size of 'actively fishing' launches. The average sizes of 'actively fishing' launches are shown in Table 5. Note that, for 1974 to 1982, this information was taken directly from Market records; for 1961 to 1973, it was calculated from the list of registered launches

Table 5. Changes in launch length (m), catch per trip (kg) and catch per unit of fishing effort, recorded for the dolphin (Coryphaena hippurus) fishery at Oistins, Barbados

Year	Average size of "actively fishing" Launches (m)	Increment of size increase from 1961	Average catch/trip (kg)	Catch/unit effort (CPUE) (kg)
1961	7.26	-	12.12	12.12
1962	7.09	-0.17	13.92	15.18
1963	7.00	-0.26	6.30	8.23
1964	6.96	-0.30	24.18	26.41
1965	6.88	-0.38	10.92	13.75
1966	7.08	-0.18	14.10	15.44
1967	6.63	-0.63	13.87	18.56
1968	6.79	-0.47	23.47	26.97
1969	7.01	-0.25	47.16	49.02
1970	7.04	-0.22	38.22	39.86
1971	7.10	-0.16	29.65	30.84
1972	7.48	+0.22	40.04	38.40
1973	7.82	+0.56	29.14	24.97
1974	8.06	+0.80	44.09	38.14
1975	7.96	+0.70	47.73	42.52
1976	7.91	+0.65	50.43	45.59
1977	8.23	+0.97	56.83	49.61
1978	8.37	+1.11	50.11	41.85
1979	8.63	+1.37	34.34	24.15
1980	8.56	+1.30	63.59	53.92
1981	8.71	+1.45	58.17	47.38
1982	8.68	+1.42	50.77	40.21

using the relationship between launch size and fishing trips. Fixed from 1961, a 'standard unit of fishing effort' is a single fishing trip (of 10.15 hours duration - the past and present mean trip duration) in a 7.26 meter launch. Values of average catch per trip, corrected for launch size advantage using the average size of 'actively fishing' launches and the relationship between catch and launch size, thus represent values of catch per standard unit of effort (CPUE). These are given over the 22 years 1961 to 1982 in Table 5, and CPUE is also shown in Figure 3. These data support a long-term increase in dolphin catch per standard unit effort at an annual rate of 1.66 kg (linear regression, CPUE vs years $b = 1.66$, $r = 0.772$, $v = 20$, $P < 0.05$).

There is no conspicuous periodicity in the long-term fluctuations in catch per standard unit of effort of dolphin at Oistins, but peaks may be identified at alternating three and five year intervals in 1964, 1969, 1972, 1977 and 1980 (Figure 3). The index of Amazon River discharge and CPUE data from Oistins are shown together from 1961 to 1978 in Figure 4. Both variables appear to be increasing. However, there is no apparent correlation between CPUE in a given year with Amazon River discharge in that year (linear regression, detrended Negro River height (1961-1978) vs detrended CPUE (1961-1978): $r = 0.013$, $v = 16$, $P < 0.05$), nor between CPUE in a given year with Amazon River discharge in the preceding year (linear regression, detrended Negro River height (1961-1978) vs detrended CPUE (1962-1979): $r = 0.134$, $v = 16$, $P < 0.05$). Also there were no apparent correlations between the month of peak dolphin abundance in any year and Amazon River discharge in the same year (linear regression, detrended Negro River height (1961-1978) vs month of peak dolphin abundance (1961-1978): $r = 0.101$, $v = 16$, $P < 0.05$) nor in the preceding year (linear regression, detrended Negro River height (1961-1978) vs month of peak dolphin abundance (1962-1979): $r = 0.378$, $v = 16$, $P < 0.05$). These preliminary analyses therefore suggest that annual variation in the volume of Amazon discharge is apparently not affecting annual variation in dolphin abundance near Barbados, nor their time of arrival at Barbados.

The mean size of dolphin landed in Barbados changes with each month of the fishing season. Hence, mean size of dolphin landed by the sport fishery in any year would necessarily be affected by the months in which the fish were caught. Comparisons of mean dolphin size between years have therefore been made by month. Average sizes of fish landed by the sport fishery in each calendar month for which data were available are shown for 1978 to 1983 in Figure 5. The month of peak dolphin abundance at Barbados fluctuates between years suggesting that the timing of annual recruitment to the fishery and/or migration to Barbados may vary. Monthly average fish size may therefore vary with the month of peak abundance rather than with the calendar month. Comparisons between years of the average size of fish have therefore also been made according to the months of peak dolphin abundance (Figure 6). No net change in the mean size of dolphin caught around Barbados is apparent over the six years examined. In most calendar months (Figure 5), and also in equivalent

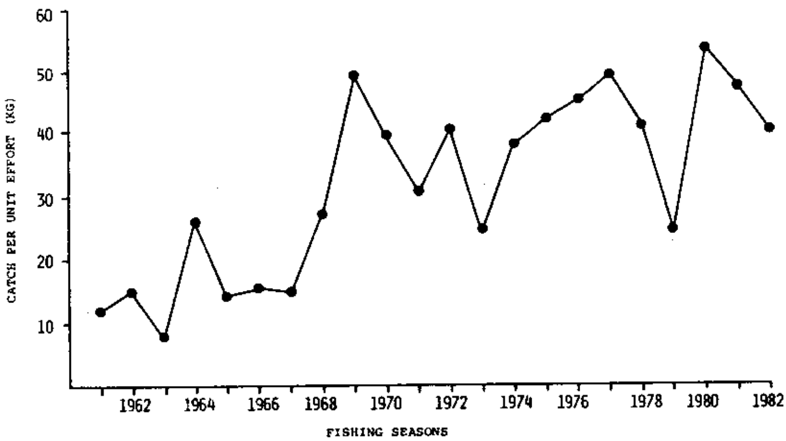

Figure 3. Annual average catch by weight of the dolphin (Coryphaena hippurus) per standard unit of fishing effort, recorded at Oistins, Barbados, each year. A unit of effort is a 10.15 hour fishing trip in a 7.26 meter launch. Fishing seasons run from January to May inclusive.

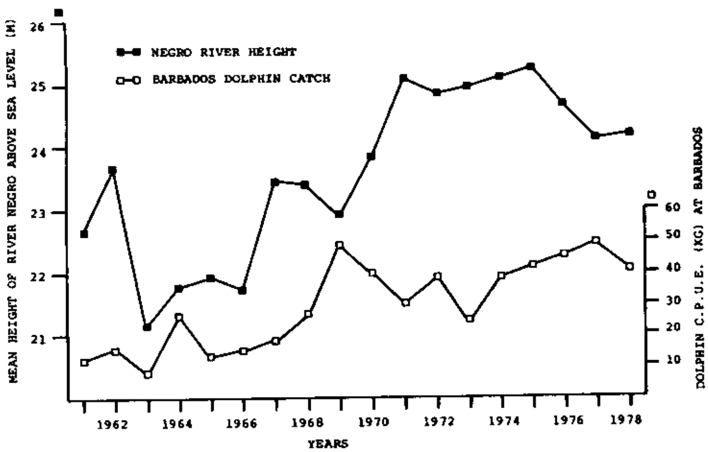

Figure 4. Annual average catch by weight of the dolphin (Coryphaena hippurus) per standard unit of effort at Oistins, Barbados, together with annual average heights above sea level, of the River Negro recorded at Manaus in the same years. Note that the River Negro is a major tributary of the River Amazon which affects salinity and productivity in the eastern Caribbean (Borstad, 1982a, b).

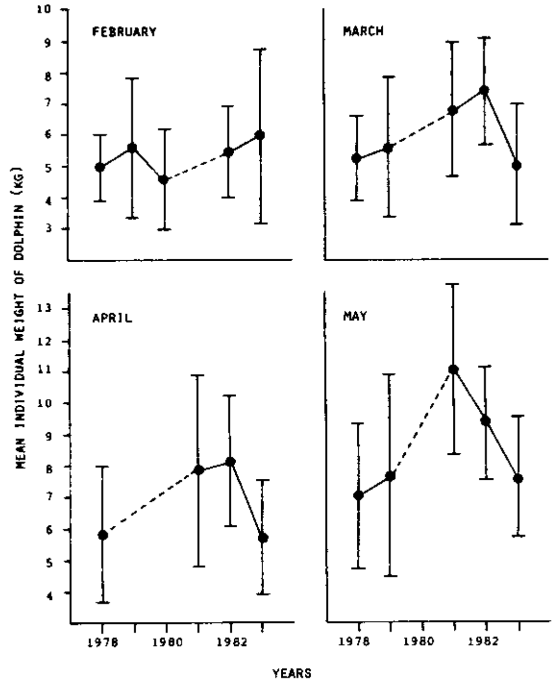

Figure 5. Monthly mean weights of individuals of the dolphin (Coryphaena hippurus) recorded by the Barbados Game Fish Association from competition catches. Data were collected over 6 years and are presented by calendar months. Standard deviations are given by (⊢—⊣) and years with no data by (---).

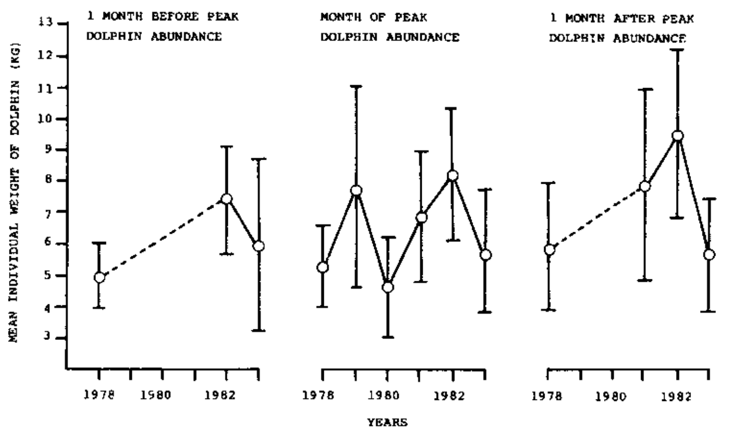

Figure 6. Monthly mean weights of individuals of the dolphin (Coryphaena hippurus) recorded by the Barbados Game Fish Association from competition catches. Data were collected over 6 years and are presented according to the months of peak dolphin abundance in each year. Standard deviations are given by (⊢—⊣) and years with no data by (---).

months by dolphin abundance (Figure 6), fish were larger in 1981 and 1982 than in other years. No explanation for this is presently offered.

DISCUSSION

Catch and catch per trip of dolphin in Barbados have increased over the past 26 years, in spite of a slight decrease in the number of fishing trips made per year up until 1982. An increase in catch per trip as number of trips decreases could theoretically suggest local overfishing (gear competition); a factor which could become less important as fleet range expands. However, given that total catch has been rising, it is more likely that the increase in catch per trip results primarily from an increase in catching efficiency per trip.

The observed increase in catching efficiency of larger launches is probably because larger launches, which typically have more powerful engines, can travel faster. Hence, they can cover greater distances per day in search of dolphin-rich rafts, they can reach sighted 'rafts' faster than small boats and they can spend more time per day fishing rather than travelling from and to their landing sites. It is of interest that launch size is more closely correlated with catch per trip, and that increase in launch size results in a greater increase in catch per trip, in 'good' years than in 'bad' years. This suggests that in 'bad' years, when dolphin-rich rafts are scarce, whether or not one is found may be increasingly a matter of chance than of boat speed. In short, the greater distances covered by larger launches may not greatly improve their catch rate. However, in 'good' years, when dolphin-rich rafts are abundant, speed in moving from raft to raft may become increasingly important to catching success.

The increased fishing efficiency with launch size was quantified and catch per trip data from 1961 to 1982 corrected to obtain a more realistic unit of fishing effort. Note that even with this correction, CPUE at Oistins has tended to increase. This suggests that (a) the increased fishing efficiency per trip resulting from a change in fleet structure has not been adequately corrected for; (b) dolphin catchability has been increasing; (c) the center of distribution of dolphin during the fishing season has been shifting closer towards Barbados; (d) dolphin are genuinely becoming more abundant in the eastern Caribbean. If the first (a) is true, it may be because the increasing use of compasses, charts and VHF radios has improved catching success of launches of all sizes by permitting them to range farther offshore. However, the latter three suggestions (b-d)are at least plausible. Given the increasing Amazon discharge, dolphin distribution may be shifting away from the Amazon mouth and hence closer to Barbados, if adults avoid areas of reduced salinity. This hypothesis could be tested by investigating trends in dolphin abundance near Trinidad and Tobago. Alternatively, given the increasing Amazon discharge, dolphin abundance could have increased through an increase in nutrient input, and hence primary and secondary productivity in eastern Caribbean waters. Amazon outflow is known to reach Barbados waters via the Guiana Current (Starkey, 1939; Wust, 1964; Lewis et al., 1962; Froelich et al., 1978) and to affect not only salinity and silicate content of surface waters, but the whole primary production system in the eastern Caribbean (Lewis and Fish, 1969; Ryther et al., 1967; Hulburt and Corwin, 1969; Beers et al., 1970; Steven, 1971; Sander and Steven, 1973; Borstad, 1978, 1982a, b; Kidd and Sander, 1979). This could in turn affect the survival of pelagic fish larvae and hence recruitment to commercial fish stocks. Note that Powles (1975) did find that fluctuations in fish larvae abundance at Barbados were correlated with surface salinities, which are largely determined by the Amazon outflow. Finally, the increased Amazon outflow could have increased the amount of floating debris near Barbados. The importance of floating objects in attracting fish is well documented (Yabe and Mori, 1950; Kojima, 1956, 1960a, b; Murchison and Magnuson, 1966; Ida et al., 1967a, b; Inoue et al., 1968; Mitchell and Hunter, 1970), and the primary method of dolphin capture in the eastern Caribbean is from around flotsam (Morice and Cadenat, 1952; Wolf, 1974; Mahon et al., 1981; Oxenford and Hunte, in press). Hence, increased flotsam may increase the frequency with which launches locate 'dolphin-rich rafts,' and thus increase dolphin catchability and thereby catch per trip, independently of actual stock abundance. Note too, that if dolphin spawn under flotsam, and flotsam availability limits the number of spawning aggregates, increased flotsam could increase spawning success, thereby leading to an increase in actual stock abundance. None of these explanations for a correlation between CPUE and Amazon discharge are mutually exclusive.

Although dolphin CPUE and Amazon River discharge have both been increasing in the long-term, preliminary analyses suggest that annual variation in the average CPUE and in month of peak dolphin abundance are not correlated with annual variation in Amazon outflow in the same year. This would have been expected if effects of salinity differences on dolphin migration, and/or of increased flotsam on dolphin catchability, were particularly marked. Moreover, the analyses suggest that CPUE is not correlated with Amazon outflow in the preceding year, as may be expected if the latter partly determines recruitment strength in the following year. Annual fluctuations in CPUE are characteristic of fisheries worldwide (Sissenwine, 1984), and are thought to be determined largely during a critical phase of the larval stage (Gulland, 1965). Attempts have been made for several fisheries to correlate this variation with environmental parameters, commonly temperature, wind or river discharge (Carruthers, 1951; Gulland, 1965; Dickson and Lee, 1972; Iles, 1973; Southward et al., 1975; Lett and Kohler, 1976; Sutcliffe et al., 1977), so that it might ultimately be possible to forecast the variation. However, as Gulland (1953; 1965) points out, such correlations with any one environmental variable are likely to be weak. Thus, the lack of a correlation between annual variation in dolphin CPUE and annual variation in Amazon outflow does not preclude the possibility that the Amazon affects the fishery. It may merely indicate that annual stock abundance is simultaneously affected by several factors. Likely additional influences include annual variation in Orinoco outflow and in abundance of flyingfish, a major component of the dolphin diet (Oxenford, 1985).

Exploitation of a stock frequently leads to a change in stock size structure such that the mean size of fish in the catch is reduced. This is aggravated by the fact that fishing tends to be selective against larger fish, and at extremes it becomes synonymous with growth overfishing (Cushing, 1968, 1972; Ricker, 1975; Gulland, 1983). This removal of larger fish, continued over generations, can act as an agent of 'natural' selection favoring fish with slower growth and/or smaller maximum size (Borisov, 1978). No net change in the mean size of dolphin in Barbados is apparent over the six years for which data were available. This is consistent with the results of the catch data analyses, suggesting that present levels of exploitation are apparently not yet having adverse effects on the dolphin stock in the eastern Caribbean.

ACKNOWLEDGMENTS

This study was supported by an I.U.C. Scholarship to H.O. and a U.W.I. Postgraduate Awards Grant to W.H. We are grateful for the cooperation afforded us by the Assistant Market Superintendent, the fishermen and the hawkers at Oistins Fish Market. We acknowledge the Fisheries Division and the Barbados Game Fish Association for providing data.

LITERATURE CITED

Beers, J.R., D.M. Steven and J.B. Lewis. 1970. Primary productivity in the Caribbean Sea off Jamaica and the tropical North Atlantic off Barbados. Bull. Mar. Sci. 18: 87-104.

Borisov, V.M. 1978. The selective effect of fishing on the population structure of species with a long life cycle. J. Ichthyol. 18: 896-904.

Borstad, G.A. 1978. Some aspects of the occurrence and biology of Trichodesmium (Cyanophyta) in the western tropical Atlantic near Barbados, West Indies. Ph.D. Thesis, McGill Univ., Montreal. 234 p.

_____ 1982a. The influence of the meandering Guiana Current and Amazon River discharge on surface salinity near Barbados. J. Mar. Res. 40: 421-434.

_____ 1982b. The influence of the meandering Guiana Current on surface conditions near Barbados - temporal variations of Trichodesmium (Cyanophyta) and other plankton. J. Mar. Res. 40: 435-452.

Carruthers, J.N. 1951. An attitude on fishery hydrography. J. Mar. Res. 10: 101-118.

Chakalall, B. 1982. The fishing industry of Barbados. Report for Inter-American Inst. for cooperation on Agriculture.

Cushing, D. 1968. Fisheries biology. A study in population dynamics. Univ. Wisconsin Press, Madison. 200 p.

_____ 1972. The production cycle and numbers of marine fish. Symp. Zool. Soc. Lond. 29: 213-232.

_____ 1977. Marine ecology and fisheries. Cambridge Univ. Press, London. 278 p.

Dickson, R. and A. Lee. 1972. Recent hydrometeorological trends on the North Atlantic fishing grounds. Fish. Int. Rev. 2: 4-11.

Froelich, P.J., Jr., D.K. Atwood and G.S. Glese. 1978. Influence of Amazon River discharge on surface salinity and dissolved silicate concentration in the Caribbean Sea. Deep Sea Res. 25: 735-744.

Gulland, J.A. 1953. Correlations on fisheries hydrography. J. Cons. Int. Explor. Mer. 18: 351-353.

_____ 1965. Survival of the youngest stages of fish, and its relation to year-class strength. Int. Comm. North West Atl. Fish. Environ. Symp. Spec. Publ. (6): 363-371.

_____ 1983. Fish stock assessment. A manual of basic methods. J. Wiley and Sons, New York. 223 p.

Hulburt, E.M. and N. Corwin. 1969. Influence of the Amazon River outflow on the ecology of the western tropical Atlantic. III. The planktonic flora between the Amazon River and the Windward Islands. J. Mar. Res. 27: 54-71.

Hunte, W. In press. Summary of available data base on oceanic pelagic fisheries in the Lesser Antilles. FAO Fish. Rep.

Ida, H., Y. Hiyama and T. Kusaka. 1967a. Study on fishes gathering around floating seaweed - I. Abundance and species composition. Bull. Jpn. Soc. Sci. Fish. 33: 923-929.

_____, _____ and _____ 1967b. Study on fishes gathering around floating seaweed - II. Behaviour and feeding habit. Bull. Jpn. Soc. Sci. Fish. 33: 930=936.

Iles, T.D. 1973. Interaction of environment and parent stocksize in determining recruitment in the Pacific sardine as revealed by analysis of density-dependent O-group growth. pp 228-240 in B.B.Parrish (ed.) Fish stocks and recruitment symposium. Rep. P.-v. Reun. Cons. Int. Explor. Mer. 164.

Inoue, M., R. Amano, Y. Iwasaki and M. Yamauti. 1968. Studies on environments alluring skipjack and other tunas - II. On the driftwoods accompanied by skipjack and tunas. Bull. Jpn. Soc. Sci. Fish. 34: 283-294.

Kidd, R. and F. Sander. 1979. Influence of Amazon River discharge on the marine production system off Barbados, West Indies. J. Mar. Res. 37: 669-681.

Kojima, S. 1956. Studies of dolphin fishing conditions in the Western Sea of Japan - II. "Tsuke" Rafts and their attraction for the fish. Bull. Jap. Soc. Sci. Fish. 21: 1049-1052.

_____ 1960a. Fishing for dolphins in the western part of the Japan Sea. - VI. Behaviours of fish gathering around bamboo rafts. Bull. Jpn. Soc. Sci. Fish. 26: 383-388.

_____ 1960b. Studies of dolphin fishing conditions in the Western Sea of Japan - V. On the species of fish attracted to "Tsuke" Rafts. Bull Jpn. Soc. Sci. Fish. 26: 379-382.

Lett, P.F. and A.C. Kohler. 1976. Recruitment: a problem of multispecies interaction and environmental perturbations, with specific reference to the Gulf of St. Lawrence Atlantic herring (Clupea harengus harengus). J. Fish. Res. Bd. Can. 33: 1351-1371.

Lewis, J.B. and A.G. Fish. 1969. Seasonal variation of the zooplankton fauna of surface waters entering the Caribbean Sea at Barbados. Carib. J. Sci. 9: 1-24.

_____, J.K. Brundritt and A.G. Fish. 1962. The biology of the flyingfish Hirundichthys affinis (Gunther). Bull. Mar. Sci. Gulf Caribb. 12: 73-94.

Mahon, R., W. Hunte, H. Oxenford, K. Storey and R.E. Hastings. 1981. Seasonality in the commercial marine fisheries of Barbados. Proc. Gulf Caribb. Fish Inst. 34: 28-37.

McConney, P.A. 1983. A review of catch statistics in Barbados - an examination of methodology and records. Min. Agr. Food Consum. Aff. 57 p.

Mitchell, C.T. and J.R. Hunter. 1970. Fishes associated with drifting kelp, Macrocystis pyrifera, off the coast of southern California and northern Baja California. Calif. Fish Game. 56: 288-297.

Morice, J. and J. Cadenat. 1952. Distribution of fish species in the French West Indies. pp 102-122 in Fisheries in the Caribbean. Carib. Commn. Port-of-Spain, Trinidad. Kent House.

Murchison, A.E. and J.J. Magnuson. 1966. Notes on the coloration and behaviour of the common dolphin Coryphaena hippurus. Pac. Sci. 20: 515-517.

Murphy, G.I. 1982. Recruitment of tropical fishes. pp 141-148 in D. Pauly and G.I. Murphy (eds.) Theory and management of tropical fisheries. ICLARM, Philipp.

Oxenford, H.A. 1985. Biology of the dolphin Coryphaena hippurus and its implications for the Barbadian fishery. Ph.D. Thesis, Univ. West Indies. 366 pp.

_____ and W. Hunte. In press. Migration of the dolphin (Coryphaena hippurus) and its implications for fisheries management in the western central Atlantic. Proc. Gulf Caribb. Fish. Inst. 37.

Palko, B.J., G.L. Beardsley and W.J. Richards. 1982. Synopsis of the biological data on dolphin-fishes, Coryphaena hippurus Linneaus and Coryphaena equiselis Linneaus. NOAA Tech. Rep. NMFS Circ. (433): 28 p.

Powles, H. 1975. Abundance, seasonality, distribution and aspects of the ecology of some larval fishes off Barbados. Ph.D. Thesis. McGill Univ., Montreal. 227 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191: 1-382.

Ryther, J.H., D.W. Menzel and N. Corwin. 1967. Influence of the Amazon outflow on the ecology of the western tropical Atlantic. I. Hydrography and nutrient chemistry. J. Mar. Res. 25: 69-83.

Sander, F. and D.M. Steven. 1973. Organic productivity of inshore and offshore waters of Barbados: a study of the

island mass effect. Bull. Mar. Sci. 23: 771-792.
Saville, A. 1979. Discussion and conclusions of the symposium on the biological basis of pelagic fish stock management. Rapp. P. -v. Reun. Cons. Int. Mer. 177: 513-517.
Sissenwine, M.P. 1984. The uncertain environment of fishery scientists and managers. Mar. Resource Econ. 1: 1-30.
Southward, A.J., E.I. Butler and L. Pennycuick. 1975. Recent cyclic changes in climate and in abundance of marine life. Nature. 253: 714-717.
Starkey, D.P 1939. The economic geography of Barbados. Columbia Univ. Press, New York. 118 p.
Steven, D.M. 1971. Primary productivity of the tropical western Atlantic Ocean near Barbados. Mar. Biol. 10: 261-264.
Sutcliffe, W.H., Jr., K. Drinkwater and B.S. Muir. 1977. Correlations of fish catch and environmental factors in the Gulf of Maine. J. Fish. Res. Bd. Can. 34: 19-30.
Wolf, R.S. 1974. Minor miscellaneous exploratory/experimental fishing activities in the Caribbean and adjacent waters. Mar. Fish. Rev. 36: 78-87.
Wust, G. 1964. Stratification and circulation in the Antillean-Caribbean basins. Columbia Univ. Press. 201 p.
Yabe, H. and T. Mori. 1950. An observation on a school of skipjack and kimeji, young yellowfin tuna Neothunnus macropterus, accompanying a drift log. J. Jpn. Soc. Sci. Fish. 16: 35-39.
Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, New Jersey. 602 p.