AN ANALYSIS OF CATCH AND EFFORT DATA FROM THE U.S. RECREATIONAL FISHERY FOR BILLFISHES (ISTIOPHORIDAE) IN THE WESTERN NORTH ATLANTIC OCEAN AND GULF OF MEXICO, 1971-78[1]

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ABSTRACT

Catch and effort data from the United States recreational fishery for billfishes in the Atlantic Ocean and Gulf of Mexico were examined to evaluate their usefulness in determining trends in abundance. In the Gulf of Mexico, data were recorded from both organized fishing tournaments and from noncompetitive fishing. A fishing power model was developed and comparisons made between catch per unit effort from tournament data, nontournament data, and Japanese longline data. The results indicate that catch and effort statistics for white marlin, *Tetrapturus albidus*, and sailfish, *Istiophorus platypterus*, in the Gulf of Mexico appear to be reliable and can be aggregated to provide a means of indexing relative abundance of these species. The model did not appear to be appropriate for blue marlin, *Makaira nigricans*, however. The general trend in catch per unit effort from 1972 to 1978 for sailfish and white marlin in the Gulf of Mexico appears to be downward.

Based on catch per unit effort from all fishing areas, there appears to be a single stock of white marlin in the western North Atlantic and Gulf of Mexico.

In 1971, the National Marine Fisheries Service's Southeast Fisheries Center initiated research on the billfish stocks of the western North Atlantic Ocean and Gulf of Mexico. The purpose of this research was to develop and evaluate a method of determining changes in relative abundance of billfish stocks using catch and effort data from the recreational fishery. This report has been prepared to present a description of this research, evaluate the reliability of the sampling techniques, and make a preliminary determination of the validity of catch and effort data from the recreational fishery as an indicator of changes in relative abundance of billfish populations.

THE RECREATIONAL FISHERY

The development of the U.S. recreational fishery for billfishes (families Istiophoridae and Xiphiidae) has been reviewed in detail by de Sylva (1974). The first sailfish caught by rod and reel in the Atlantic was probably taken off Miami, Fla., around the turn of the century. After World War II, increased leisure time and affluence coupled with newer and better fishing gear, vessels, and angling techniques spurred a dramatic expansion of the fishery geographically as well as to a broader segment of the population. In the Atlantic, anglers now fish for billfishes from almost every state along the eastern coast of the United States as well as from the U.S. Virgin Islands, Puerto Rico, and numerous foreign ports.

Species

The billfish species in the Atlantic recreational fishery are the sailfish, *Istiophorus platypterus*, the white marlin, *Tetrapturus albidus*, the blue marlin, *Makaira nigricans*, and to a much lesser extent the swordfish, *Xiphias gladius*, and the longbill spearfish, *Tetrapturus pfluegeri*. Sailfish, the most commonly occurring species in the catch, is more coastal in its habitat than any of the other species and consequently is available to a greater number of anglers. It is also the smallest in average size, with the possible exception of the longbill spearfish, and generally requires less expensive and sophisticated fishing tackle than is commonly used in fishing for marlins. The two marlins are most abundant in oceanic waters, generally far from the coast of the United States, and fishing for marlins usually requires relatively large vessels and expensive fishing gear. Prior to 1976, recreational fishing for swordfish was a specialized type of fishing where the fish was usually sighted before the fishing lines were placed in the water.

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Fishing was done in a fairly restricted area off the northeastern United States. In 1976, however, a new method of fishing for swordfish was developed off the southeast Florida coast. This method involved drifting baited lines at various depths at night. Fishing success using this technique has been substantially higher than by the earlier method, and swordfish are now available to fishermen all along the Gulf of Mexico and Atlantic coasts of the United States, whereas previously the fishery was confined to a relatively small geographical area.

Longbill spearfish are rare in the recreational catch. They are believed to be primarily an open ocean species and generally are not common in the areas where recreational fishing takes place.

Because of the nature of the fishery for swordfish and the scarcity of longbill spearfish in the recreational catch, our study involves only the sailfish and the two marlins, and the following discussions deal only with these species.

Fishing Techniques

Fishing, using rod and reel, is conducted primarily by trolling dead or artificial baits at speeds ranging from 3 to 15 kn. The baits are fished mainly at the surface, although sometimes baits are rigged to troll down to a meter or more beneath the surface. Generally, three to four lines are fished simultaneously, although as many as eight are occasionally used. In some areas the use of live bait has become increasingly popular. Our study does not include catch and effort data involving the use of live bait.

Once a billfish is hooked, the boat operator usually maneuvers the boat so that the effort required by the angler is reduced. Once the fish is brought to the boat it is either gaffed and brought onboard or released alive. More and more frequently, anglers and crews are tagging their fish before releasing them in cooperation with the National Marine Fisheries Service Cooperative Game Fish Tagging Program (formerly the National Marine Fisheries Service-Woods Hole Oceanographic Institution Cooperative Game Fish Tagging Program).

Billfishes are not highly desirable as food in the continental United States, although they are utilized to some extent as a smoked product. However, many fishermen are learning that fresh marlin, in particular, is an excellent food fish. In Puerto Rico and the Virgin Islands there is a great demand for fresh marlin which commands a high price on the local fresh fish markets.

THE LONGLINE FISHERY

The high seas longline fishery for tunas was begun in the Atlantic by the Japanese in 1956. Fishing effort increased rapidly, peaking in 1965 when almost 100 million hooks were set and the fishery included almost all waters between lat. 40° N and 40° S. Effort fell off rapidly, however, in response to declining catch rates and increasing costs, and by the early 1970's the Japanese were averaging only about 40 million hooks annually. In the mid-1960's, Taiwan and South Korea entered the fishery and by the 1970's theirs were the dominant fleets in the Atlantic. An excellent review of the development of the fishery is available in Ueyanagi (1974).

The longline fishery in the Atlantic is directed primarily at tunas, and billfishes are incidental catches, although large numbers are caught. From 1956 through 1976, for example, almost 140,000 t of white marlin, blue marlin, and sailfish/spearfish were caught by longliners in the Atlantic (Table 1). There is some evidence that stocks of white and blue marlin in the North Atlantic and South Atlantic are discrete groups (Mather et al. 1972; Wise and Davis 1973). Longline catch per unit effort (CPUE) values for white and blue marlins within these two areas in the 1970's are for the most part considerably below those in the 1960's (Figure 1).

TABLE 1.—Estimated landings, in metric tons, of blue marlin, white marlin, and sailfish/spearfish by the tuna longline fishery in the Atlantic Ocean, 1956-76. Data from Conser and Beardsley,[1] tables 1 and 4, for blue marlin and white marlin, and Conser,[2] table 1, for sailfish/spearfish.

Year	Blue marlin	White marlin	Sailfish/ spearfish	Year	Blue marlin	White marlin	Sailfish/ spearfish
1956	6	—	1	1967	2,316	1,421	1,421
1957	92	15	39	1968	3,572	2,458	2,281
1958	722	25	50	1969	3,727	2,538	1,586
1959	847	123	72	1970	4,939	2,916	2,758
1960	1,517	206	160	1971	4,316	2,999	1,710
1961	4,004	713	383	1972	3,047	2,452	1,551
1962	7,414	1,984	602	1973	2,925	2,461	1,298
1963	9,034	2,526	841	1974	2,761	2,958	1,413
1964	7,847	3,634	1,240	1975	3,000	1,987	1,122
1965	6,019	4,847	2,587	1976	1,076	2,062	750
1966	3,713	3,296	2,032				

[1]Conser, R. J., and G. L. Beardsley. 1979. An assessment of the status of stocks of blue marlin, *Makaira nigricans*, and white marlin, *Tetrapturus albidus*, in the Atlantic Ocean. Collect. Vol. Sci. Pap. 8(2):461-489. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid, Spain.

[2]Conser, R. 1979. Production model analysis of the sailfish and spearfish stocks in the Atlantic Ocean. Working paper submitted to the Standing Committee on Research and Statistics, Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid, Spain, November 1979.

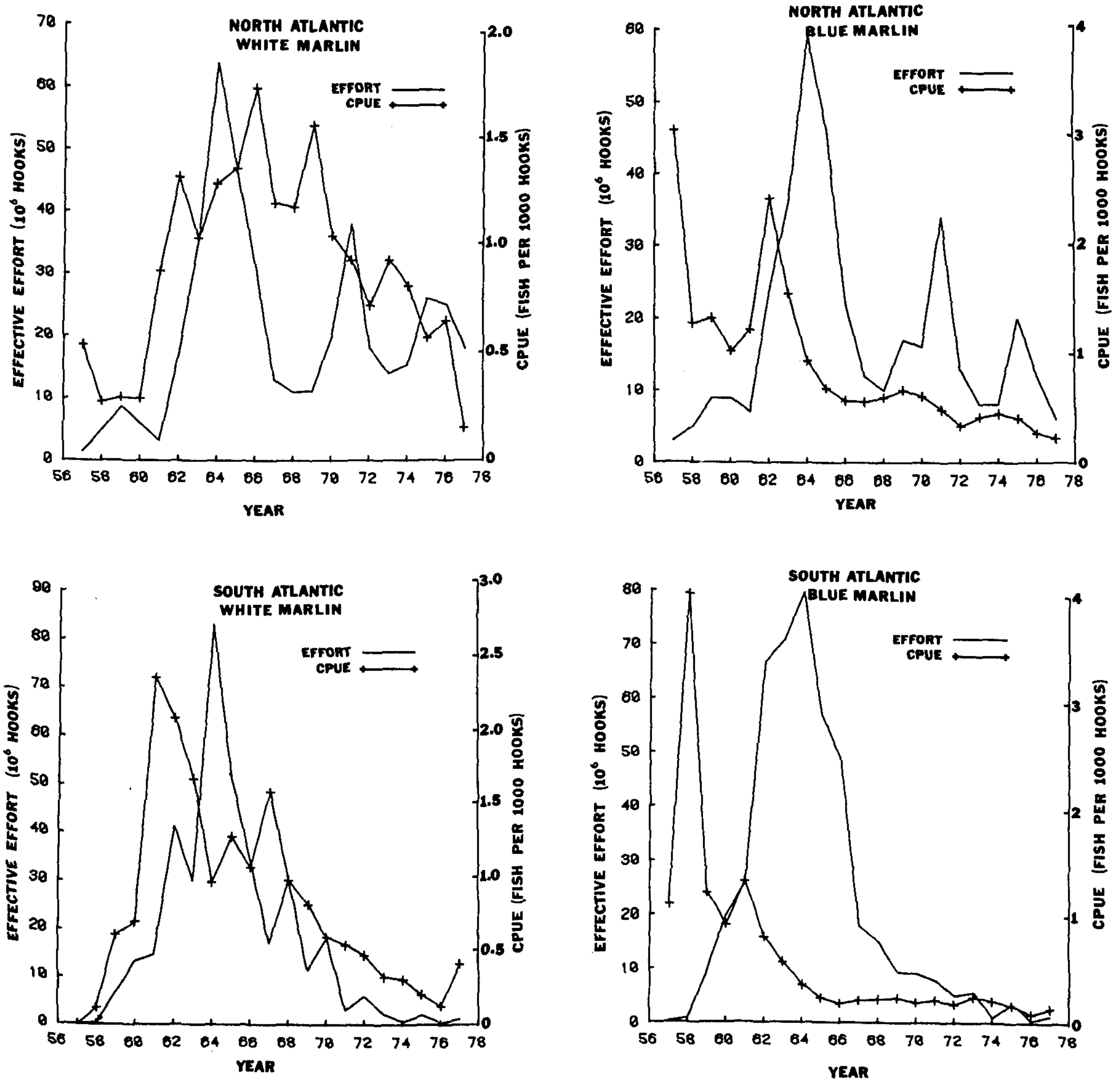

FIGURE 1.—Effective effort in millions of hooks and catch per unit effort (CPUE) in numbers of fish caught per 1,000 hooks for blue marlin and white marlin in the North and South Atlantic Oceans, 1956-77. Data on the Japanese longline fishery are reported by the Fisheries Agency of Japan, Annual report of effort and catch statistics by area on Japanese tuna longline fisheries, 1962-77.

THE SAMPLING PROGRAM

Prior to 1970 almost no data are available from the U.S. recreational fishery for billfishes on fishing effort, although a considerable amount of information exists on catch. Because of the large number of big-game fishing tournaments taking place throughout much of the range of the billfishes, and the fairly continuous and often intensive fishing effort at various fishing centers along the U.S. coast, it seemed feasible that catch and effort from the recreational fishery could be used to detect changes in relative abundance from year to year as well as short-term changes in availability. As a consequence, the Oceanic Game Fish Investigations Program was organized at the Southeast Fisheries Center Miami Laboratory in 1972 to develop an effective system for the collection of billfish catch and effort data in the Gulf of Mexico, Caribbean Sea, and western North Atlantic

Ocean, and to analyze these data to provide information on temporal and spatial changes in relative abundance.

The program is directed primarily at sailfish, white marlin, and blue marlin, although data on recreational catches of yellowfin and bluefin tunas are also recorded. Swordfish and longbill spearfish are rare in the recreational catch, but some data have been obtained.

Much preliminary work had already been accomplished in the Gulf of Mexico by the Southeast Fisheries Center Panama City Laboratory, NMFS, NOAA, in cooperation with various big-game fishing clubs and charterboat associations along the coast. Sampling sites were established and coverage of fishing effort during the fishing season in the gulf was estimated to be as high as 90% (Nakamura and Rivas 1974).

Initial contact with big-game fishing clubs, tournament managers, and others associated with big-game fishing tournaments produced a list of about 40-50 tournaments scheduled throughout the Bahamas, Caribbean, Gulf of Mexico, and along the eastern coast of the United States. Contact with various state marine research agencies provided cooperative sampling agreements for tournaments within their states. In addition to tournament sampling, port samplers were stationed in the Gulf of Mexico to maintain day-to-day coverage of nontournament fishing activity at major fishing areas along the coast. At present, coverage includes Port Aransas, Tex.; Grand Isle and South Pass, La.; Orange Beach, Ala.; and Pensacola, Destin, and Panama City, Fla. The fishing season in the Gulf of Mexico usually runs from April through October.

Data Acquisition

Sampling procedures at tournaments are reasonably uniform regardless of locality or season. At the end of each fishing day, program samplers interview the angler or a member of the crew of each boat participating in the tournament. Information on environmental conditions, number and species of fish hooked, and other activities are recorded. At most tournaments all of the participating boats are located at a single marina, and sampling coverage is usually 100%. Tournament sampling is further simplified in that most tournaments have rigidly controlled fishing hours, and all boats in the tournament fish the same amount of time. After the statistical information is collected, the sampler obtains biological data from each billfish landed.

Daily port sampling is more difficult than tournament sampling. Fishing frequently takes place from a variety of locations, the boats return to the dock at different times, and fishing effort is frequently not as consistent as during tournaments. Much of the success of daily sampling is attributable to the samplers' knowledge of the area and their persistence and resourcefulness in obtaining the data.

Sampling Problems

There are numerous sampling problems that appear to be unique to the recreational fishery for billfishes. The first is the determination of what constitutes the catch portion of the CPUE ratio. When trolling for billfishes there are three distinct levels of activity that feasibly could be associated with effort and provide an estimate of relative abundance. The first is commonly known as a fish "raised." This term refers to the visual observation of a billfish behind the trolling baits whether it ultimately strikes the baits or not. The inherent problem in using this measure is species identification. In addition, it is apparently not uncommon for a single billfish to be raised more than once during a given day's fishing, occasionally by the same boat. There is also the possibility that two or more billfishes are raised in rapid succession, but the observer may interpret this as a single fish. The second level of activity, and the one used in this study, is fish "hooked." Disadvantages of this criterion are differences in the skills of anglers in hooking fish, and the fewer data obtained since many fish that are raised are not hooked. Its advantages are that identification reliability is considerably increased since billfishes almost always jump when hooked and positive identification is usually possible. The third level of activity is a billfish "boated" (or caught and released). The biggest difficulty with this measure of catch is that different tournaments use different categories of line-test; comparing CPUE on 9 kg test line with CPUE on 36 kg test line is not reasonable. Another drawback is that the number of data points available from "boated" fish decreases significantly. The value of this measure is that species identification is no longer a problem. We decided to use fish hooked as our measure of catch, and all subsequent references to CPUE in the recreational fishery refer to number of billfishes hooked per hour of trolling.

Another problem was the determination of which tournaments were suitable for use in the analysis of any given species. Billfish tournaments may be classified as "all billfish" or restricted to a single species or combination of species. In examining CPUE of white marlin in the Bahamas, for example, it is unreasonable to include data from tournaments that are exclusively blue marlin tournaments, because when fishing for blue marlin many boats troll large baits, and white marlin, considerably smaller in average size than blue marlin, either refuse to strike at such baits or are unusually difficult to hook. Accordingly, any analysis of a given species used only data from tournaments that were specifically directed at that species or that were designated as "all billfish."

An additional sampling problem, encountered in almost any kind of fisheries survey, is reliability of recall. We believe that, in general, the respondents are able to recall accurately their fishing activity during the day; however, it may occasionally be difficult for the angler or crew to recall each species of billfish hooked if fishing was good and several billfishes were hooked during the day. When possible, more than one member of the fishing party was consulted if there was some doubt expressed in the original interview. Tournament and port samplers have received excellent cooperation at every level, and most of the anglers and crew members make every effort to assist our data collection activities. Consequently, we do not believe that errors in recall significantly affect the results of our analyses.

Sampling Coverage

Tournament sampling extends along the east and gulf coasts of the United States from Long Island, N.Y., to Port Isabel, Tex. (Figure 2). Additional tournament sampling has been or is being conducted in the Bahamas, Jamaica, Mexico, Puerto Rico, and the Virgin Islands. Tournaments are scheduled throughout the year to coincide with the presence of seasonal concentrations of billfishes. In the Bahamas, for example, the tournament season extends from March through July. In southeast Florida, most tournaments are scheduled from November through January. Most of the tournaments sampled are annual events and occur at approximately the same time each year. Tournament scheduling is also arranged so that

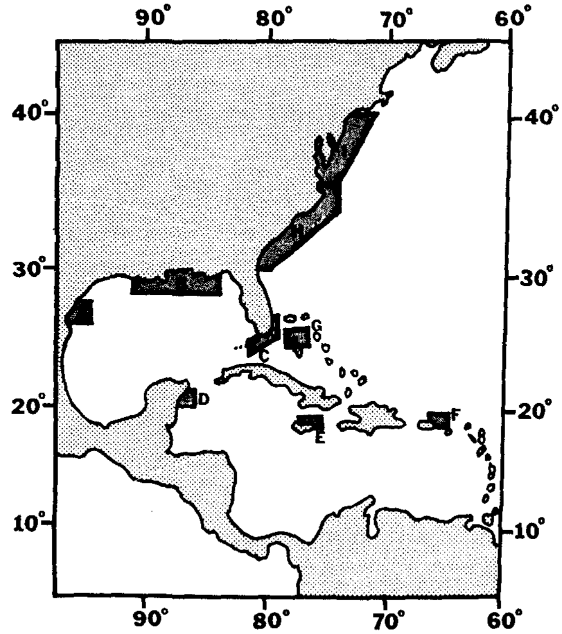

FIGURE 2.—Areas in the western North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico where the recreational fishery for billfishes is sampled. Primary species available by area are: A—blue marlin, sailfish; B—blue marlin, white marlin, sailfish; C—sailfish; D—sailfish; E—blue marlin; F—blue marlin; G—blue marlin, white marlin, sailfish; H—blue marlin; I—white marlin.

there are few instances where two or more tournaments are held at the same time in the same area.

Seasonal port sampling on a daily basis is conducted in the gulf beginning in April and extending through October. The amount of effort measured and the recorded number of fish hooked from daily dock sampling from 1971 through 1978 and from tournament sampling, 1972 through 1978, are shown in Table 2.

DATA ANALYSIS—GULF OF MEXICO

Methodology

There are several areas along the Atlantic and Gulf of Mexico coasts of the United States where recreational and commercial fishermen compete for billfishes. This interaction occurs most frequently in the northern Gulf of Mexico where intensive recreational fishing for billfishes takes place from a number of ports from Florida to Texas during April through October. During the same

TABLE 2.—Data on effort and catch for billfishes recorded by tournament and dock sampling, 1971-78, in the western North Atlantic and Gulf of Mexico.

Year	Hours fished	No. fish hooked		
		Blue marlin	White marlin	Sailfish
	Tournaments			
1972	23,090.4	365	170	399
1973	17,864.0	512	233	684
1974	18,473.6	537	368	768
1975	26,858.4	684	1,088	1,664
1976	27,368.4	655	750	1,062
1977	35,333.9	772	781	1,989
1978	40,601.0	801	992	1,752
	Dock sampling			
1971	11,609.9	266	491	482
1972	13,298.2	306	517	528
1973	7,859.5	176	414	140
1974	10,462.8	290	487	197
1975	8,852.5	196	684	434
1976	8,174.5	177	434	577
1977	8,575.0	225	398	232
1978	12,522.7	251	402	200

period of the year, Japanese longliners fish in the same area for yellowfin and bluefin tunas but frequently catch billfishes as well. Detailed and consistent catch and effort data are available from both the recreational and longline fisheries in this area over the period 1971-78. These attributes make the northern Gulf of Mexico fishery unique when compared with other billfish fisheries in that more than one type of gear is operating at significant effort levels in the same time and place, and consistent catch and effort statistics are available from both types of fishing operations for a reasonably long time series. In this analysis we attempt to: 1) determine the utility and consistency of catch and effort data from the recreational and longline fisheries for indexing changes in abundance of billfish populations, 2) obtain species- and area-specific indices of abundance that incorporate both recreational and longline data, and 3) gain a better understanding of the dynamics of the fishery by modeling the general characteristics of recreational and longline fishing for billfishes.

The northern Gulf of Mexico was divided into three areas based on the general distribution of recreational fishing (shaded areas in Figure 3). The easternmost, Panhandle, groups fishing effort from Panama City, Destin, and Pensacola, Fla., and Orange Beach and Mobile, Ala. The center, New Orleans, combines effort from South Pass and Grand Isle, La., and the westernmost, Texas, encompasses all fishing from Texas. Recreational catch and effort data are acquired in each of these areas by sampling both daily, noncompetitive recreational fishing as well as fishing conducted during organized big-game fishing tournaments. From 1971 through 1978 over 136,000 h of tournament and nontournament fishing for billfishes in these three areas were recorded (Table 3). Tournament and dock data were processed and monthly total catch and total effort were compiled by species, area, and type of fishing. CPUE was computed for those months in which 60 h or more of fishing effort had been sampled. The 60-h minimum effort criterion was chosen by making two series of calculations of the variance of monthly CPUE using various minimum effort criteria, and then subjectively selecting a minimum effort level which provided a balance between the variance and sample size considerations. Using the 60-h minimum effort criterion produced more reliable statistics without causing the sample size to become unacceptably small. It represents approxi-

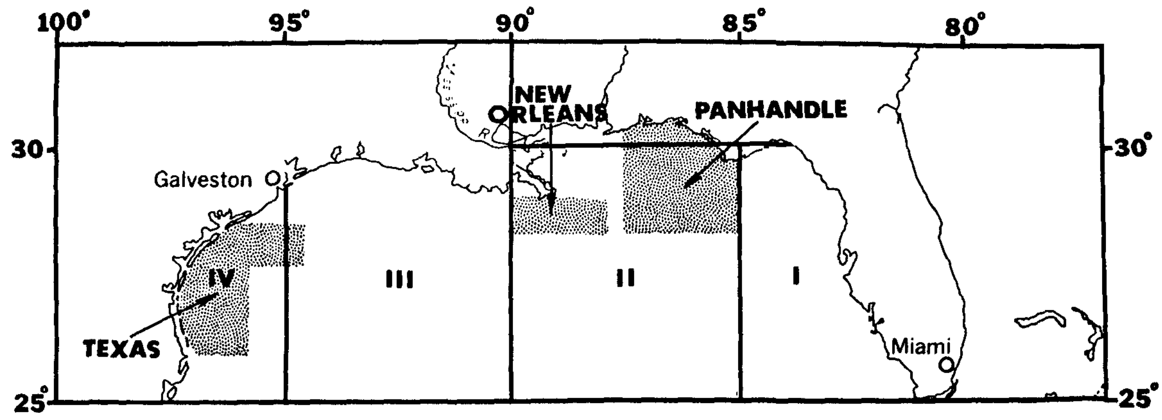

FIGURE 3.—The shaded areas, Panhandle, New Orleans, and Texas, are major recreational fishing areas for billfishes. The larger areas, I, II, III, and IV, are 5° squares from which Japanese longline catch and effort data are available.

TABLE 3.—Number of fishing hours recorded from tournament (tourn.) and dock sampling at three major fishing areas for billfishes in the Gulf of Mexico, 1971-78. See Figure 3 for location of areas.

Year	Panhandle		New Orleans		Texas	
	Tourn.	Dock	Tourn.	Dock	Tourn.	Dock
1971	—	8,287.7	—	3,322.2	—	—
1972	143.5	4,225.2	355.2	3,380.0	462.0	254.3
1973	703.6	8,605.2	—	3,730.0	52.7	963.0
1974	584.2	5,618.1	—	3,395.0	—	1,449.7
1975	2,020.0	5,587.1	2,441.3	2,034.3	1,767.8	1,230.1
1976	4,279.7	4,619.3	3,552.3	1,762.4	2,314.3	1,792.8
1977	6,088.3	5,516.2	5,981.0	2,412.6	4,496.0	646.2
1978	6,983.4	7,410.8	7,576.1	3,966.2	4,999.4	1,145.7

mately 10 boat-days of fishing and occurs in a region of the effort distribution where moderate changes in the minimum effort criterion would have little effect on the number of months used. The resulting CPUE values by area and type of fishing are displayed in Figure 4 for blue marlin, Figure 5 for white marlin, and Figure 6 for sailfish.

Monthly catch and effort statistics by 5° area for the Japanese longline fleet are reported by the Fisheries Agency of Japan in the *Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fisheries* for the period 1962-77. Japanese longliners fish all four of the 5° areas that compose the northern Gulf of Mexico (Areas I through IV, Figure 3). However, 52% of their fishing effort in the northern gulf during 1971-77 occurred in area II and 39% in area III. Only 1% occurred in area I and 8% in area IV. Since nearly all recreational fishing for billfishes in the northern gulf occurs in areas II and IV, only longline data from these two areas were used in this comparative analysis. Although no data on the distribution of longline effort within 5° areas are given in the Japanese annual reports, data supplied by Honma[3] on the distribution of catch and effort during 1971-75 show that most longline effort in areas II and IV occurred in the more coastal regions which coincides fairly well with the location of recreational fishing grounds as displayed in Figure 3. Catch and effort statistics by species for areas II and IV were compiled from the Japanese annual reports for 1971-77 (Table 4). Comparable statistics for 1978 were compiled from the quarterly reports submitted to the Southeast Fisheries Center by Japanese longliners fishing in the U.S. Fishery Conservation Zone. CPUE was then computed for those months in which 2,000 hooks or more of fishing effort occurred. As with

[3]Misao Honma, Far Seas Fisheries Research Laboratory, Shimizu, Japan, pers. commun. July 1977.

TABLE 4.—Japanese catch (in numbers of fish) and effort (in numbers of hooks) from the two 5° areas (longline areas II and IV in Figure 3) in the northern Gulf of Mexico which coincide with recreational fishing areas, 1971-78. BM = blue marlin, WM = white marlin, and SF = sailfish.

Year	Area II				Area IV			
	Effort (hooks)	Catch			Effort (hooks)	Catch		
		BM	WM	SF		BM	WM	SF
1971	413,941	220	1,273	853	227,552	114	2,627	1,402
1972	664,295	181	2,280	571	—	—	—	—
1973	237,092	93	998	204	64,787	28	533	797
1974	53,632	34	213	42	104,298	120	635	505
1975	712,659	149	546	313	220,337	140	1,174	878
1976	2,999,552	269	3,100	850	309,118	97	622	937
1977	2,206,500	181	993	272	54,407	8	64	87
1978	1,454,447	100	719	62	36,355	6	90	29

the recreational data, using a minimum effort criterion produced more reliable statistics and the number of months accepted was not sensitive to moderate changes in the threshold level. The Japanese longline CPUE values by species and comparable recreational fishing area are also shown in Figures 4-6.

Murphy (1960), Rothschild (1977), and others have discussed some of the important aspects involved in using longline statistics to estimate changes in abundance. One of the demonstrated functional relationships, which may be pertinent in this analysis, is that the average amount of effective effort per hook is a function of the amount of "soaking time" the gear is in the water. Although the Japanese annual reports do not provide time in the water data, NMFS observers aboard Japanese vessels in the northern gulf report a consistency in the time the gear is in the water during recent years (Lopez et al. 1979). Although no data are available from earlier years of the analysis period, soaking times tend to remain more or less constant in most tuna longline fisheries and consequently, fishing time can be measured by the number of hooks set (Food and Agriculture Organization 1976). The lack of data on time in the water should, therefore, not contribute significantly to any bias in the estimates of relative abundance. Another aspect of the longline data which is also pertinent to this analysis is that sailfish and spearfish catches are combined in the Japanese annual reports. This problem may be minimal in coastal areas, however, since Ueyanagi et al. (1970) demonstrated that sailfish are found primarily in coastal areas and spearfish tend to inhabit more oceanic waters. In this analysis all catches from areas II and IV that were reported as sailfish/spearfish in the annual reports were assumed to be sailfish.

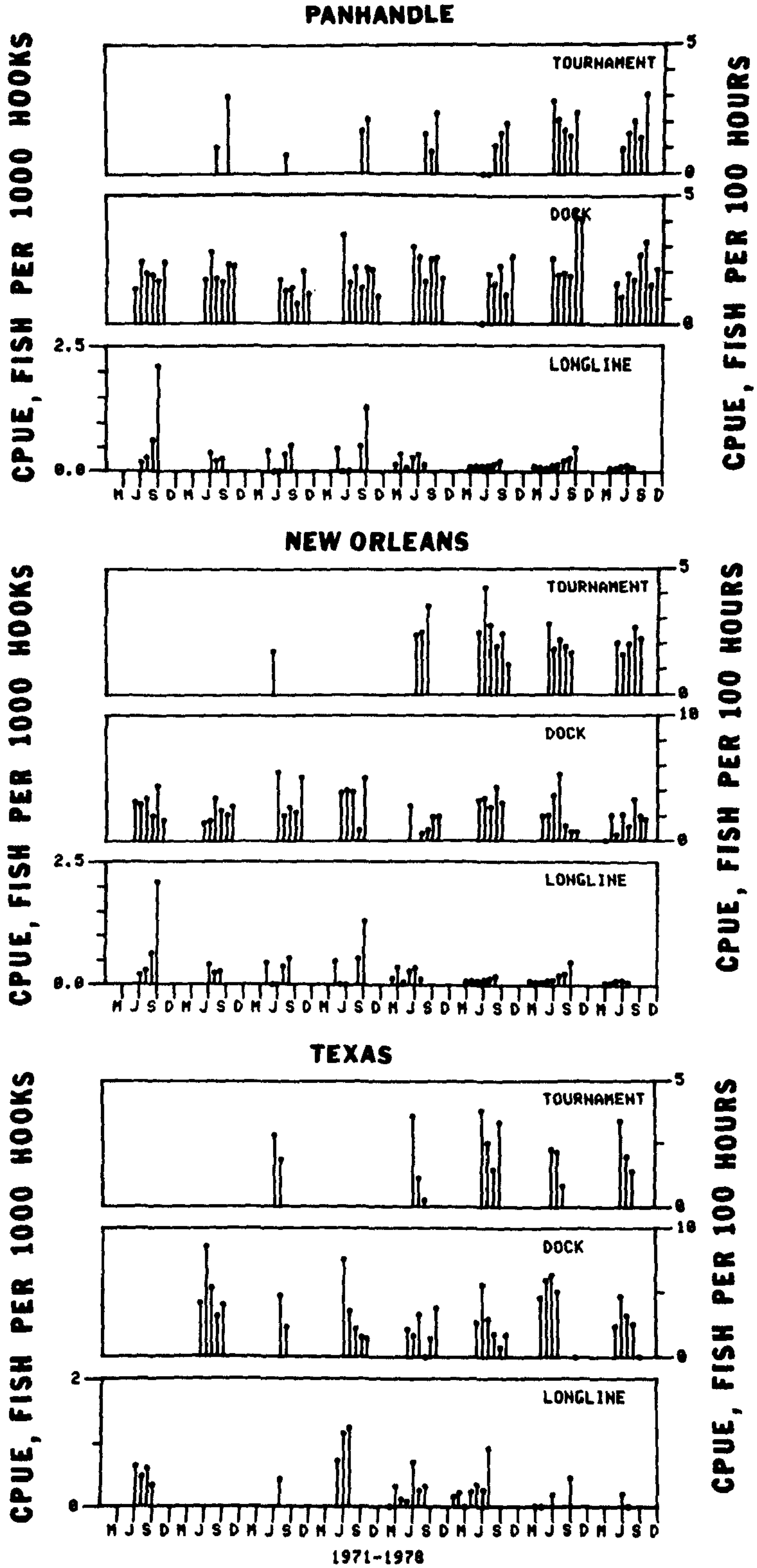

FIGURE 4.—Monthly CPUE for blue marlin from the longline fishery and the recreational fishery in the three major fishing areas in the northern Gulf of Mexico, 1971-78. Longline CPUE depicted for Panhandle and New Orleans were derived from data taken from the 5° square labeled II in Figure 3. CPUE for Texas was taken from the 5° square labeled IV in Figure 3. The first month depicted on the abscissa is March (M) 1971. CPUE is in numbers of fish caught per 1,000 hooks in the longline fishery and numbers of fish hooked per 100 hours fished in the recreational fishery. The Tournament panel displays CPUE calculated from billfish fishing tournaments while the panel labeled Dock shows CPUE derived from noncompetitive fishing.

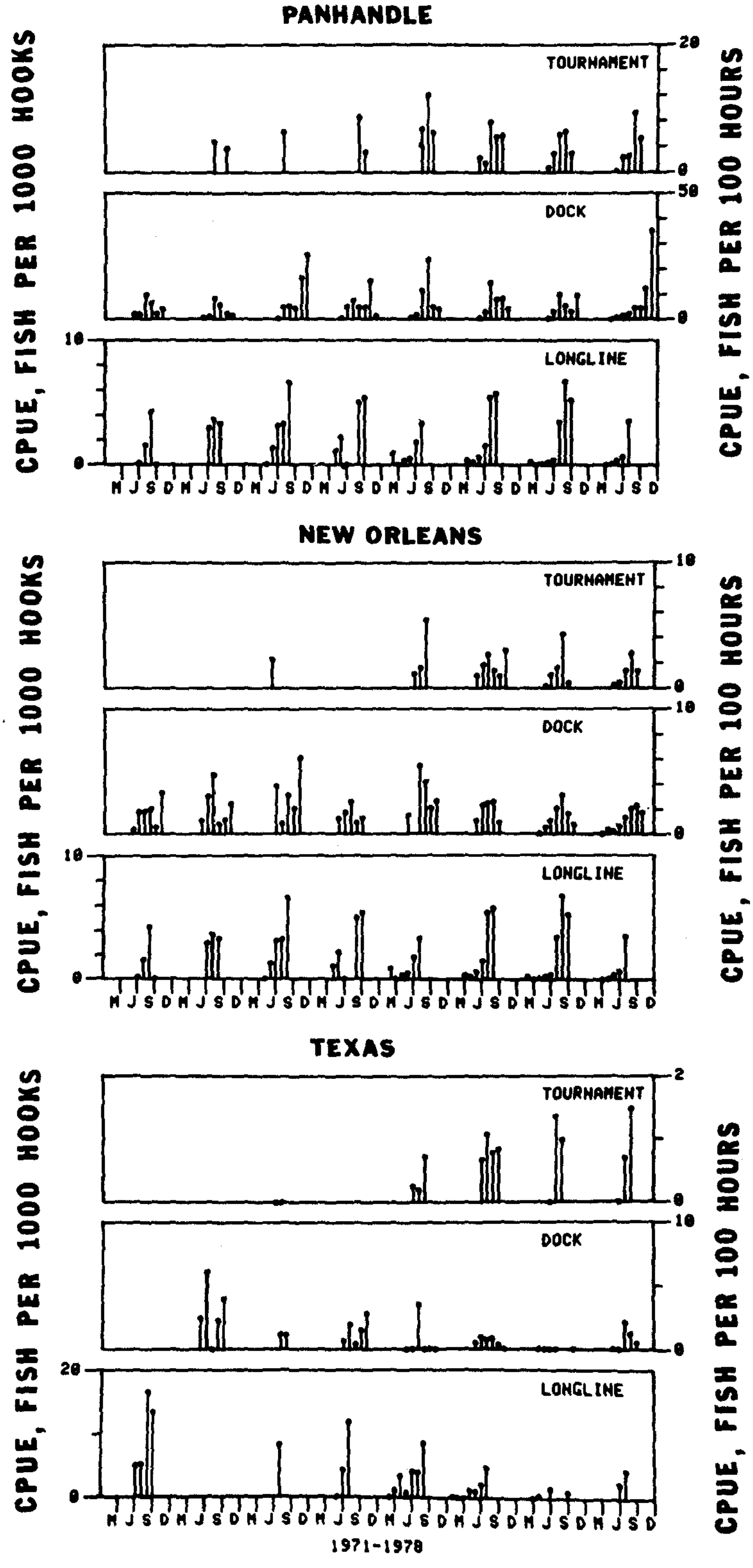

FIGURE 5.—Monthly CPUE for white marlin from the longline fishery and the recreational fishery in the three major fishing areas in the northern Gulf of Mexico, 1971-78. Longline CPUE depicted for Panhandle and New Orleans were derived from data taken from the 5° square labeled II in Figure 3. CPUE for Texas was taken from the 5° labeled IV in Figure 3. The first month depicted on the abscissa is March (M) 1971. CPUE is in numbers of fish caught per 1,000 hooks in the longline fishery and numbers of fish hooked per 100 hours fished in the recreational fishery. The Tournament panel displays CPUE calculated from billfish fishing tournaments while the panel labeled Dock shows CPUE derived from noncompetitive fishing.

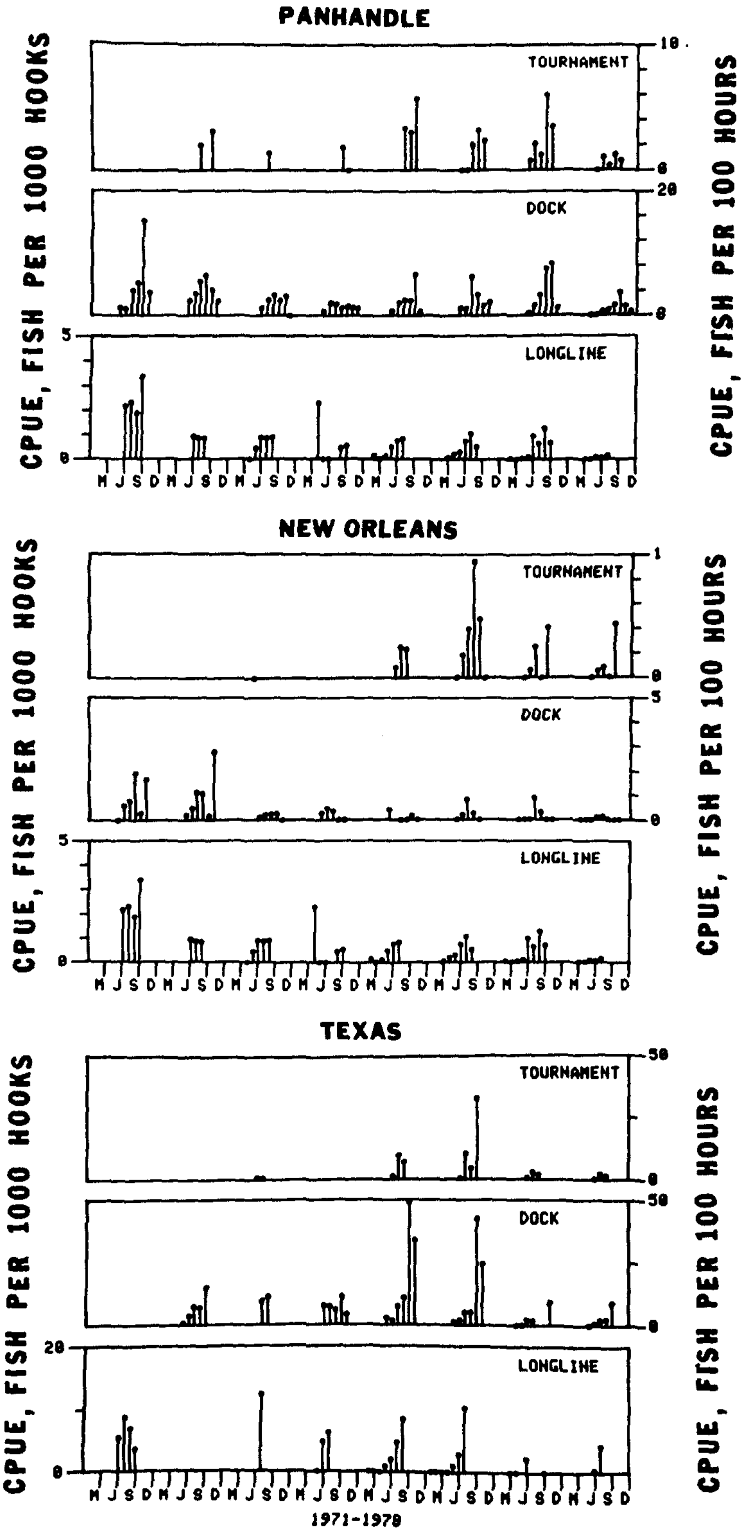

FIGURE 6.—Monthly CPUE for sailfish from the longline fishery and recreational fishery in the three major fishing areas in the northern Gulf of Mexico, 1971-78. Longline CPUE depicted for Panhandle and New Orleans were derived from data taken from the 5° square labeled II in Figure 3. CPUE for Texas was taken from the 5° square labeled IV in Figure 3. The first month depicted on the abscissa is March (M) 1971. CPUE is in numbers of fish caught per 1,000 hooks in the longline fishery. The Tournament panel displays CPUE calculated from billfish fishing tournaments while the panel labeled Dock shows CPUE derived from noncompetitive fishing.

Catch Model

A basic catch model was used for dock, tournament, and longline fishing in the northern Gulf of Mexico:

$$C_{ijk} = q_{ik} f_{ij} \overline{N}_{jk} \epsilon_{ijk} \tag{1}$$

where C_{ijk} is the catch of species k from the ith type of fishing during month j, q_{ik} is the catchability coefficient of the ith type of fishing on species k, f_{ij} is the amount of fishing effort expended by the ith type of fishing during month j, $\overline{N}_{jk}$ is the average population size of species k in month j, and ϵ_{ijk} is a log-normally distributed error term. Note that no k index appears on the f_{ij} since effort is not generally directed at any particular billfish species in the recreational fishery in the northern Gulf of Mexico. This basic catch model has been used by many authors to study fisheries in which more than one type of fishing was employed (Gulland 1956; Beverton and Holt 1957; Robson 1966). Equation (1) can be written as a linear, two factor analysis of variance (ANOVA) model by dividing through by f_{ij}, taking natural logarithms, and obtaining

$$Y_{ijk} = \alpha_{ik} + \beta_{jk} + \epsilon'_{ijk} \tag{2}$$

where $Y_{ijk} = \ln (C_{ijk}/f_{ij})$,
$\alpha_{ik} = \ln q_{ik}$,
$\beta_{jk} = \ln \overline{N}_{jk}$, and
$\epsilon'_{ijk} = \ln \epsilon_{ijk}$.

The ANOVA can be used to test for significant differences in the catchability of various types of fishing and in population density over time. The ANOVA model cannot, however, be used to estimate catchability or population densities, but it can be reparameterized to obtain estimates of relative catchability (P_{ik}) and relative population density (D_{jk}), where

$$P_{ik} = q_{ik}/q_{sk} \tag{3}$$

$$D_{jk} = \overline{N}_{jk}/\overline{N}_{sk} \tag{4}$$

in which s refers to the type of fishing and month designated as standard. After reparameterization, Equation (2) becomes

$$Y_{ijk} = u_k + \alpha'_{ik} + \beta'_{jk} + \epsilon'_{ijk} \tag{5}$$

where $u_k = \alpha_{sk} + \beta_{sk}$,
$\alpha' = (\alpha_{ik} - \alpha_{sk})$, and
$\beta'_{jk} = (\beta_{jk} - \beta_{sk})$.

The parameters u_k, α'_{ik}, and β'_{jk} can be estimated by solving the usual normal equations and estimates of relative fishing power and relative population density can be obtained from [$P_{ik} = \exp(\hat{\alpha}_{ik})$ and $\hat{D}_{jk} = \exp(\hat{\beta}'_{jk})$].

To apply the basic catch model to the billfish fishery in the northern gulf, it is necessary to assume that for each type of fishing (i.e., dock, tournament, and longline) catchability is constant throughout the analysis period, there is no interaction between catchability and density, and units of effort operate independently. The first two assumptions may be tenuous for this fishery and will be investigated in the analysis. The third assumption appears to be reasonable.

The basic catch model was used initially to determine what relationship existed between catch and effort data from dock and tournament data. Figure 7 presents a flow diagram for the determi-

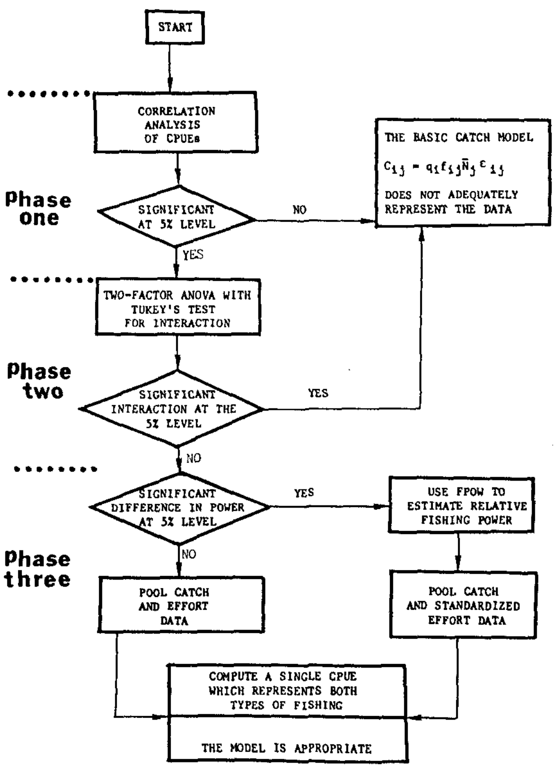

FIGURE 7.—Flow diagram for determining the appropriateness of using the basic catch model to represent data from the two different kinds of fishing methods.

nation of the appropriateness of the basic catch model for a single species-area case. Separate analyses were performed for blue marlin, white marlin, and sailfish in each of the three recreational areas.

Since the model assumes that the catchability coefficients of dock and tournament fishing are proportional [Equation (3)], correlation analysis was performed on the dock and tournament CPUE values (Phase 1, Figure 7) and the model was considered appropriate for estimating fishing power only when the CPUE's were significantly correlated at the 5% level. Data used in the correlation analysis were from all months in which dock and tournament fishing met the minimum effort threshold concurrently.

The two factor ANOVA model [Equation (2)] was then used to test for significant differences in fishing power and density, and Tukey's (1949) test was used to test for significant interaction. The data used in the ANOVA were from all months in the 1971-78 period for which dock and tournament sampling met the minimum effort threshold concurrently and for which CPUE's were >0 for both types of fishing. The positive CPUE constraint was necessary because of the log transformation used in obtaining Equation (2). Because the model requires that there be no interaction between power and density, the model was not considered appropriate when interaction was significant at the 5% level.

For all cases in which the model was deemed appropriate and the ANOVA test for difference in power was not significant at the 5% level, the catch and effort data were pooled and a single recreational CPUE was calculated for those species-area combinations. Where the model was appropriate and the power was significantly different, dock sampling was designated as the standard and the relative fishing power of tournament fishing was estimated from Equation (5). The computer program FPOW (Berude and Abramson 1972) was used to estimate the relative fishing power. FPOW solves the normal equations like Equation (5) and corrects for the logarithmic bias using a Taylor series expansion of the estimate about its true value (Laurent 1963). The FPOW program was modified to perform the usual F-test for the significance of the overall regression and to compute the coefficient of determination. As in the ANOVA test, the data used in the fishing power estimation were from all months for which dock and tournament fishing met the minimum effort threshold concurrently, and for which both CPUE's were >0. For those species-area combinations in which the model adequately represented the recreational data, the entire procedure was then repeated in an analogous manner to compare the recreational and longline data.

Results

The results of the correlation, ANOVA, and regression analyses for blue marlin, white marlin, and sailfish from the Panhandle, New Orleans, and Texas areas are summarized in Table 5.

Blue Marlin

In the Panhandle area, dock and tournament CPUE data are fairly consistent and it appears that fishing power is greater for dock data than for tournament data. When the dock and tournament data were pooled and compared with the longline data, no correlation was found and interaction between power and density was apparent. In the New Orleans and Texas areas, no significant difference in the power of dock and tournament data was found, but the CPUE's were not correlated and interaction was significant in the New Orleans data.

The blue marlin results generally indicate that the basic catch model does not adequately represent the blue marlin data in the northern Gulf of Mexico. While it may be possible to obtain adequate indices of abundance from recreational or longline data, the two types of fishing appear to be providing very different indices in the same local areas, and it cannot be determined which, if either, provides a valid measure of relative abundance. It appears that until the dynamics of the blue marlin fishery are better understood, the use of nominal catch and effort data to index relative abundance may produce inconsistent and misleading results.

White Marlin

In the Panhandle and New Orleans areas, the CPUE's were well correlated, no significant difference in the power of dock and tournament data was found, and no interaction was apparent. When dock and tournament data were pooled and compared with longline data, the CPUE's were well correlated, and a significant difference in power was found, but significant interaction was found in

TABLE 5.—Summary of the results from the correlation, ANOVA, and regression analyses for blue marlin, white marlin, and sailfish from the Panhandle, New Orleans, and Texas areas. See text for use of these test statistics in determining the appropriateness of the basic catch model.

					Two Factor ANOVA with Tukey's Test[1]			Regression (FPOW)[2]			
Species	Area	Standard fishing	Other fishing	Correlation	Power	Density	Interaction	Significance	Degree of fit	Estimate of power	95% C.I.
Blue marlin	Panhandle	Dock	Tournament	$r_{21} = 0.58^{**}$	$F_{1,20} = 5.19^{*}$	$F_{20,20} = 2.98^{**}$	$F_{1,19} = 0.90$	$F_{21,20} = 3.09^{**}$	$R^2 = 0.76$	0.82	0.70-0.97
		Longline	Recreational	$r_{28} = 0.01$	$F_{1,24} = 1{,}527^{***}$	$F_{25,24} = 2.83^{**}$	$F_{1,24} = 39^{***}$	—	—	—	
	New Orleans	Dock	Tournament	$r_{15} = 0.07$	$F_{1,15} = 2.35$	$F_{16,15} = 2.59^{*}$	$F_{1,15} = 21^{***}$	—	—	—	
	Texas	Dock	Tournament	$r_{11} = 0.32$	$F_{1,11} = 1.78$	$F_{11,11} = 0.88$	$F_{1,10} = 2.23$	—	—	—	
White marlin	Panhandle	Dock	Tournament	$r_{21} = 0.78^{***}$	$F_{1,22} = 0.04$	$F_{22,22} = 9.32^{***}$	$F_{1,21} = 1.85$	—	—	1.00	
		Longline	Recreational	$r_{28} = 0.55^{**}$	$F_{1,26} = 132^{***}$	$F_{26,26} = 2.92^{**}$	$F_{1,25} = 0.005$	$F_{27,26} = 7.77^{***}$	$R^2 = 0.89$	13.01	8.6-20.7
	New Orleans	Dock	Tournament	$r_{15} = 0.66^{**}$	$F_{1,16} = 3.59$	$F_{16,16} = 9.31^{***}$	$F_{1,15} = 0.76$	—	—	1.00	
		Longline	Recreational	$r_{31} = 0.54^{**}$	$F_{1,27} = 155^{***}$	$F_{28,27} = 4.37^{***}$	$F_{1,27} = 11.49^{**}$	$F_{29,28} = 7.06^{***}$	$R^2 = 0.88$	7.74	5.4-11.5
	Texas	Dock	Tournament	$r_{11} = -0.07$	$F_{1,6} = 0.83$	$F_{6,6} = 0.23$	$F_{1,5} = 0.14$	—	—	—	
Sailfish	Panhandle	Dock	Tournament	$r_{21} = 0.74^{***}$	$F_{1,18} = 2.71$	$F_{18,18} = 4.91^{***}$	$F_{1,17} = 1.62$	—	—	1.00	
		Longline	Recreational	$r_{28} = 0.76^{***}$	$F_{1,25} = 674^{***}$	$F_{25,25} = 6.14^{***}$	$F_{1,24} = 0.22$	$F_{26,25} = 31.6^{***}$	$R^2 = 0.97$	31.76	24.6-41.7
	New Orleans	Dock	Tournament	$r_{15} = 0.22$	$F_{1,5} = 1.00$	$F_{5,5} = 3.75$	$F_{1,4} = 0.17$	—	—	—	
		Longline	Dock	$r_{29} = 0.44^{*}$	$F_{1,17} = 57^{***}$	$F_{17,17} = 2.92^{*}$	$F_{1,16} = 0.18$	$F_{18,17} = 5.90^{***}$	$R^2 = 0.86$	4.89	3.3-7.6
	Texas	Dock	Tournament	$r_{11} = 0.94^{***}$	$F_{1,12} = 3.11$	$F_{12,12} = 5.39^{**}$	$F_{1,11} = 1.86$	—	—	1.00	
		Longline	Recreational	$r_{12} = 0.65^{*}$	$F_{1,12} = 113^{***}$	$F_{12,12} = 7.27^{***}$	$F_{1,11} = .09$	$F_{13,12} = 15.4^{***}$	$R^2 = 0.94$	8.64	5.9-13.2

$^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.

[1]Tukey's test for interaction was used in the ANOVA. When interaction was not significant, the interaction sum of squares was pooled into the error sum of squares and the test statistics shown for power and density were calculated using the pooled error term.

[2]FPOW was used to estimate relative fishing power only when the ANOVA showed a significant difference in power and the CPUE's were significantly correlated.

the New Orleans area. The interaction implies that a better model exists for representing the data, probably one with a cross product term, but since the data were well correlated, we believe a reasonable power estimate could be obtained using the simpler basic catch model. The degree of fit of the regression model used to estimate power is good in both areas, accounting for nearly 90% of the variation in the data, and despite the interaction found in the New Orleans area the power estimates appear to be reasonable. So few white marlin are caught in the Texas area that sample size was not adequate to make similar determinations. The correlation and ANOVA analyses produced nonsignificant results.

The results generally indicate that the basic catch model adequately represents the white marlin data in the northern Gulf of Mexico. It appears that any one of the data types (dock, tournament, and longline) can be used to index relative abundance for local areas but more reliable indices will result if all three are aggregated as was done here and displayed in Figure 8.

Sailfish

No significant differences were found in the fishing power of dock and tournament data and no interactions were apparent in any of the three areas. CPUE's were significantly correlated in the Panhandle and Texas areas but not in the New Orleans area. Relatively few sailfish are caught in the New Orleans area, especially in tournament fishing during the early years, and sample size was inadequate for comparison of dock and tournament data. Sample size was better from dock data, so dock and longline data were compared in the New Orleans area while dock and tournament data were pooled and compared with longline data in the Panhandle and Texas areas. In all three areas, the CPUE's were significantly correlated, significant differences in power were found between recreational and longline fishing, and no interactions were apparent. The regression model used for estimating power is highly significant, and the degree of fit is good in all three areas, but the recreational fishing power estimate may be somewhat inflated in the Panhandle area because

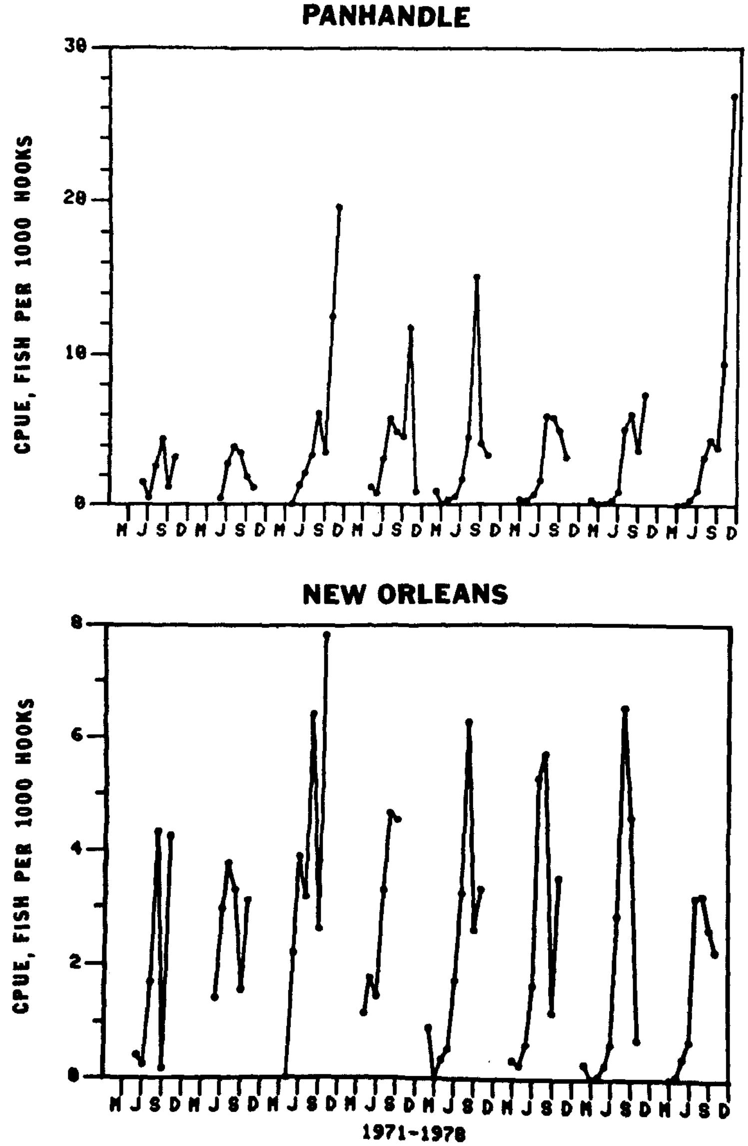

FIGURE 8.—Monthly CPUE for white marlin from the Panhandle and New Orleans areas, 1971-78. CPUE is derived from standardized recreational (both dock and tournament fishing) and longline effort. The first month depicted on the abscissa is March (M) 1971.

part of the comparable longline effort probably occurred in the western portion of area II where few sailfish are caught. Recreational and longline data were pooled, and the aggregate indices of abundance are shown in Figure 9. The results indicate that the basic catch model is adequate for representing the sailfish data in the northern Gulf of Mexico.

In view of these results, it then seems appropriate to examine white marlin and sailfish catch data from the Gulf of Mexico to see if any trends in relative abundance are apparent. Figure 8 presents CPUE for white marlin from the Panhandle and New Orleans areas and suggests that a general decline in white marlin abundance has taken place since 1973. There was a peak in 1975 in both areas (also seen in the yearly average of CPUE shown below) and two good months in 1978 in the Panhandle area, but the overall trend would appear to be downward.

Figure 9 presents similar data for sailfish from all three gulf areas. For this species, too, the general trend in relative abundance, at least in the Panhandle and New Orleans areas, appears to be

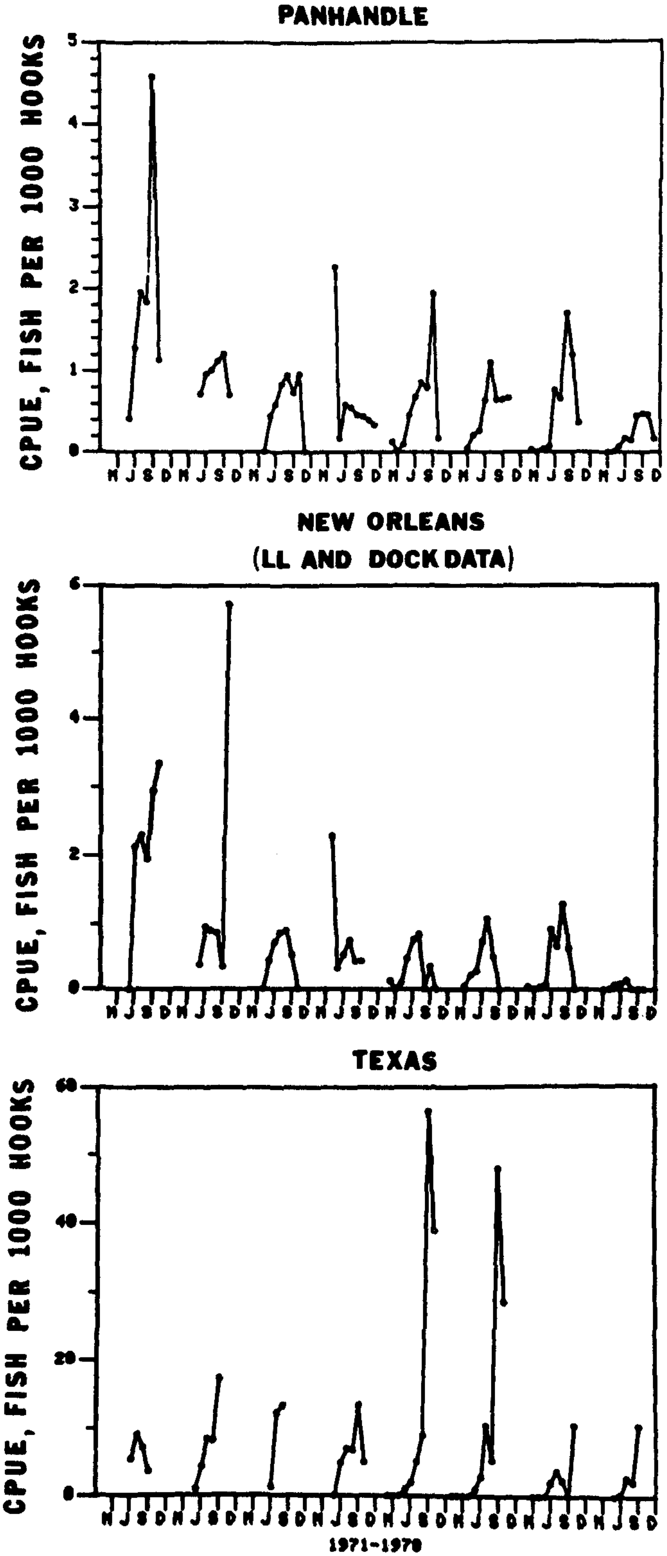

FIGURE 9.—Monthly CPUE for sailfish from the Panhandle, New Orleans, and Texas areas, 1971-78. CPUE is derived from standardized recreational (both dock and tournament except for New Orleans) and longline effort. The first month depicted on the abscissa is March (M) 1971.

clearly downward. In the Texas area, 1975 and 1976 were years when CPUE was unusually high, but in 1977 and 1978 CPUE dropped back to levels more consistent with earlier years.

DATA ANALYSIS—ALL AREAS

Only tournament data are available from the recreational fishery in areas other than the Gulf of Mexico, hence a fishing power analysis similar to the one conducted for the gulf is not presented. It is informative, nevertheless, to examine CPUE data from all sources throughout the western Atlantic and Gulf of Mexico in view of the results of the analysis presented for the gulf.

Blue Marlin

Data on blue marlin were divided into two areas: the Gulf of Mexico and the Atlantic and Caribbean (Figure 10). Both tournament and dock sampling were combined for the gulf. This division does not necessarily mean we support a separate stock theory for these areas, but merely that the geographical separation of fishing effort indicates that this is a logical division for comparative purposes. If, however, trends in CPUE from the two areas are similar, one might conclude that there is at least prima facie evidence of a single stock. Figure 10 shows that trends between the two areas are similar only from 1973 to 1976, which is obviously inconclusive. It should also be noted that there is little fluctuation in CPUE over the time series presented, particularly when compared with white marlin (Figure 11) and sailfish (discussed below). Normally one would expect CPUE for a long-lived species with numerous age groups contributing to the fishery to fluctuate much less than that for a species with a relatively short life span where the impact of a large or small incoming year class would be much greater on the fishery. Although no reliable age and growth data are available on blue and white marlins, the Atlantic blue marlin grows to a much larger size than either the white marlin or the sailfish, occasionally reaching weights of over 580 kg (International Game Fish Association 1979) and would therefore appear to be the longest lived of the three species. The trends in CPUE for the three species appear to conform to the general pattern one might expect based on their presumed relative life span and the length of time they would be expected to contribute to the recreational fishery.

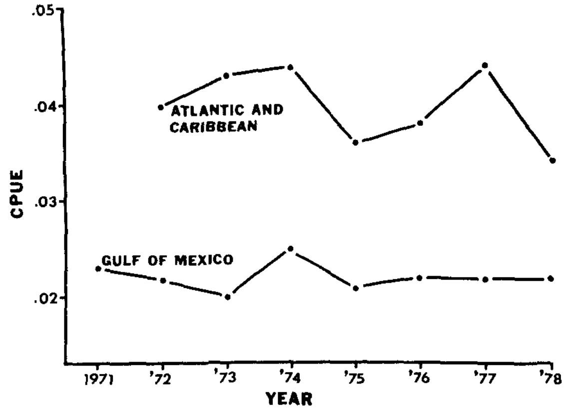

FIGURE 10.—CPUE, in number of fish hooked per hour of fishing, from the recreational fishery for blue marlin in the two major fishing areas, 1971-78.

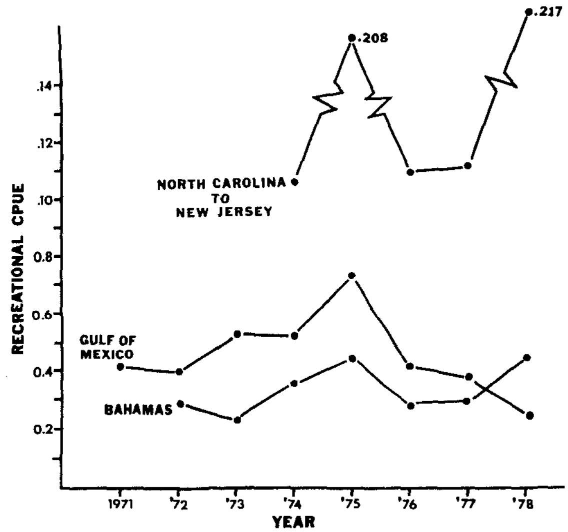

FIGURE 11.—CPUE, in number of fish hooked per hour of fishing, from the recreational fishery for white marlin in three major fishing areas, 1971-78.

White Marlin

Data on catch and effort for white marlin were divided into three areas (Figure 11). Mather et al. (1972) hypothesized that the gulf and Atlantic stocks of white marlin were separate based on tag return data and the distribution of CPUE in the Japanese longline fishery. More recent tag return data, however, indicate that there may be considerable mixing of white marlin between the Gulf of Mexico and the Atlantic Ocean.[4] There is rather

[4]Chester C. Buchanan, U.S. Fish and Wildlife Service, Anchorage, AK 99503, pers. commun. June 1977.

clear evidence (Mather et al. 1972) that the group of white marlin available to the recreational fishery in the Florida Straits and Bahamas in late winter and early spring (labeled Bahamas in Figure 11) is the same group that concentrates off the northeastern coast of the United States in late summer and early fall (labeled North Carolina to New Jersey in Figure 11). If CPUE from the recreational fishery is adequately measuring the relative abundance of white marlin stocks, one would expect a high degree of correlation between CPUE from a single stock from three widely separated areas assuming a constant percentage of the total stock was available in each area, each year. By inspection, it is clear that for the time series available a close relationship appears to exist between CPUE from the three areas sampled. It is also interesting to note that 1975 was a good year in all three areas. Although availability obviously plays an important role in affecting CPUE, it seems unlikely that it is the dominant factor in this case since the three fishing areas are widely separated geographically, and conditions affecting availability would not likely be optimal in all three areas in the same year. Correlation coefficients were calculated for all three areas (5 yr) and for the Gulf of Mexico and the Bahamas (7 yr). The multiple correlation coefficient for all three areas was significant at the 95% level (R = 0.925) and the simple correlation coefficient for the Bahamas and the Gulf of Mexico was significant at the 99% level (r = 0.865). If we are indeed measuring relative abundance, then the similarities in all three sets of data support the hypothesis that the three general fishing areas harbor a single stock of white marlin.

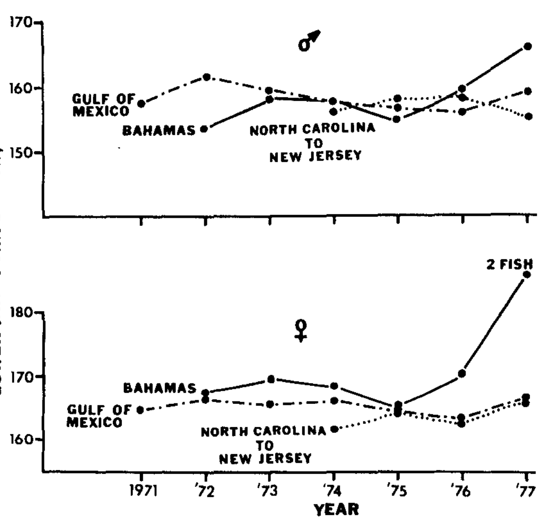

FIGURE 12.—Length frequencies of white marlin from three major fishing areas, 1971-77.

Size data from 1971 through 1977 separated by sex do not reveal any substantial differences among fish in the three areas (Figure 12). Average size has remained fairly stable over the period with females averaging larger than males for all areas. Earlier size data from the recreational fishery, not differentiated by sex, and with the Atlantic and gulf areas combined, suggest that a moderate reduction in average size has occurred since the late 1950's and early 1960's (Figure 13), but that size may have stabilized since 1970.

Sailfish

CPUE data for sailfish were separated into three areas (Figure 14). These are the major fish-

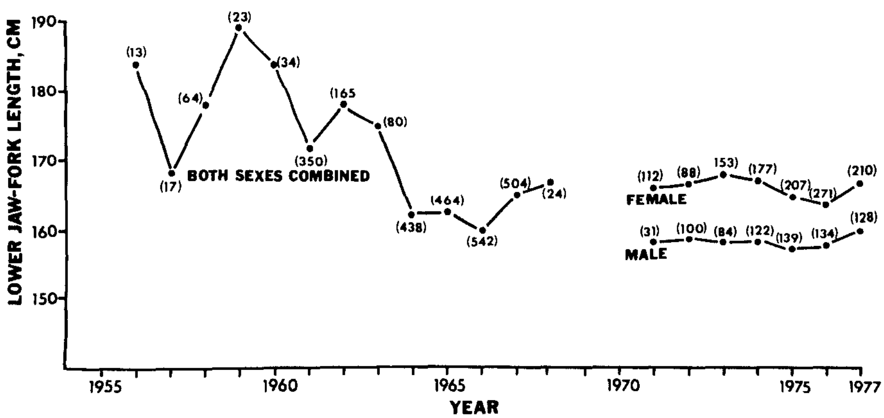

FIGURE 13.—Length frequencies of white marlin from the recreational fishery in the western North Atlantic and Gulf of Mexico. The number of specimens measured is shown in parentheses.

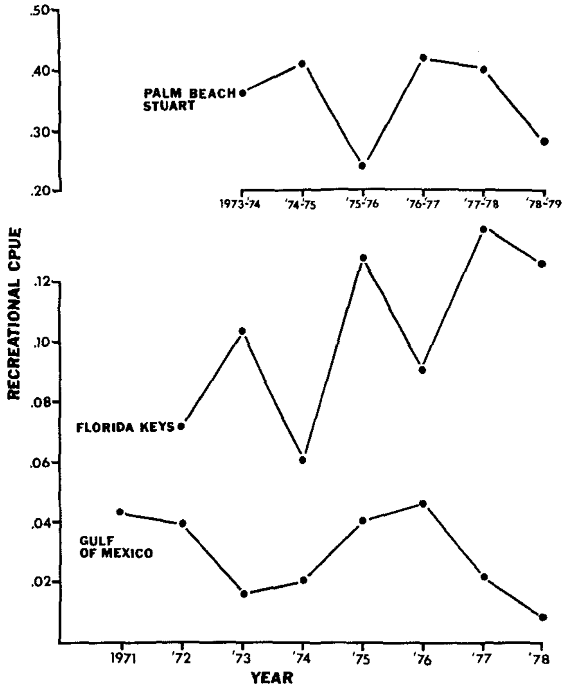

FIGURE 14.—CPUE, in number of fish hooked per hour of fishing, from the recreational fishery for sailfish, 1971-78. The panel labeled Palm Beach-Stuart is an area along the southeast Florida coast about 40 nautical miles long and fishing is concentrated at the end of one year and the beginning of the next.

ing areas for sailfish in the continental United States. Although fishing effort for sailfish is fairly intensive all year long along the southeast Florida coast, we divided the area into two specific locations: the Florida Keys and the Palm Beach-Stuart area. Our sampling at these two areas was concentrated into two separate time periods and we believe that different groups of fish are exploited in each area.

CPUE fluctuates widely in all three areas. One might expect this from a relatively short-lived species where the effect of year-class strength on the fishery is pronounced. In addition, the sailfish is more coastal in its habitat than the marlins and availability may be more strongly influenced by environmental conditions (Jolley 1979). CPUE fell sharply in the gulf in 1977 and again in 1978. This overall decline was strongly influenced by a large decline off the coast of Texas where fishing for sailfish is usually better than in any other area of the gulf (Figure 15). CPUE in 1977 and 1978 was the lowest since we began sampling and 80% below the average of the previous 3 yr. There was also a sharp decline in the northern gulf in 1978 when CPUE fell to the lowest level of the 8-yr time series.

By inspection of Figure 14, it can be seen that there is an inverse relationship between CPUE in the Florida Keys and the Palm Beach-Stuart area except for the 1978 Keys point and the 1978-79 Palm Beach-Stuart point. It is also interesting to note that if we shift the CPUE data from the Florida Keys forward by 1 yr, we obtain a strong positive correlation, significant at the 99% level, between the two areas. Our sampling in the Keys occurred in November and early December and much of the catch consists of very small sailfish, often averaging only 4-7 kg. Our sampling in the Palm Beach-Stuart area was in late December and January and the average size of sailfish in this area during those months was about 14-18 kg. Jolley (1977) concluded as a result of his studies of growth by analysis of dorsal spines that age-2 sailfish averaged about 7 kg and age-3 sailfish about 14 kg. This approximates the difference in size of sailfish caught at the two areas. We believe that tournament sampling in the Keys is providing a measure of the strength of the incoming year class (age 2) and that this strength is reflected in CPUE from the Palm Beach-Stuart area (mostly age-3 fish) some 12-14 mo later.

DISCUSSION

Catch and effort statistics for white marlin and sailfish from the northern Gulf of Mexico appear to be reliable. With the exception of cases where sample size was inadequate, the data from three nearly independent sources, i.e., dock, tournament, and longline fishing, were consistent over an 8-yr period. It seems likely that if significant biases were present in the data sources, they would have behaved differently over the time series and inconsistencies would have resulted. This consistency over time provides greater confidence in each of the individual data sources and enables the pooling of data to form reliable indices of abundance. Although only tournament data are available from areas outside the gulf, a comparison of these data for white marlin indicates a consistency in trends among areas and suggests that catch and effort statistics are providing a reliable means of indexing abundance. We also believe that they provide some evidence that a single stock of white marlin exists throughout the sampling area.

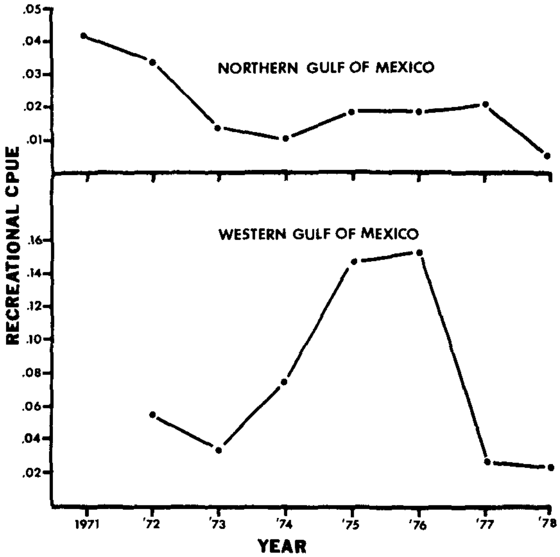

FIGURE 15.—CPUE, in number of fish hooked per hour of fishing, from the recreational fishery for sailfish in the northern and western Gulf of Mexico, 1971-78.

Although trends in CPUE for blue marlin in the Gulf of Mexico and in the Atlantic are similar for some years, the detailed analysis of data from the gulf indicates that caution should be exercised in interpreting catch and effort statistics for blue marlin. In the gulf, little agreement or consistency could be found among the three data sources, and it appears that the basic catch model is not appropriate. Some of the competition effect models discussed by Rothschild (1977), in which catchability decreases as effort increases, may be more appropriate for these data. Rothschild et al. (1970) also demonstrated that the fishing power of various gear types, relative to one another, can change as a function of stock abundance. Declining blue marlin abundance during the analysis period (Conser and Beardsley[5]; Kikawa and Honma[6]) may have caused this situation to occur in the northern gulf. It must be pointed out, however, that white marlin abundance was declining during the same period, but this change in relative fishing power did not occur.

In the analysis of Gulf of Mexico data, the proportionality of catchability over time for the various data sets was examined using correlation analysis of the CPUE's, but the available data did not allow testing the constancy of catchability over time. The results show that the catchability was proportional for all data sets with white marlin and sailfish. Therefore, if any change in catchability occurred, it would have been in the same direction for all data sets. This appears unlikely, however, since any change in catchability for the recreational fishery would probably have been an increase due to improvements in gear and equipment, but an increase in catchability for the longline fishery is unlikely because the fishery has been targeting more on bluefin tuna in recent years, and joint occurrences of billfishes and the tropical tunas tend to be more frequent than joint occurrences of billfishes and the temperate tunas, i.e., bluefin (Fox[7]). It appears reasonable, therefore, to assume that catchability has been constant for white marlin and sailfish, but this assumption would be tenuous for blue marlin in the northern Gulf of Mexico.

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[5]Conser, R. J., and G. L. Beardsley. 1979. An assessment of the status of stocks of blue marlin, *Makaira nigricans*, and white marlin, *Tetrapturus albidus*, in the Atlantic Ocean. Collect. Vol. Sci. Pap. 8(2):461-489. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid, Spain.

[6]Kikawa, S., and M. Honma. 1979. Status of white and blue marlins caught by the longline fisheries in the North Atlantic Ocean. Collect. Vol. Sci. Pap. 8(2):513-515. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid, Spain.

[7]Fox, W. W. 1971. Temporal-spatial relationships among tunas and billfishes based on the Japanese longline fishery in the Atlantic Ocean, 1956-65. Univ. Miami Sea Grant Program, Sea Grant Tech. Bull. 12, 78 p.

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