A Comparison of Fishing Methods Associated with Fish Aggregating Devices (FADs) Off Puerto Rico

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ABSTRACT

Six FADs were deployed off northeast Puerto Rico in June and monitored through December 1986. Emphasis was placed on comparing small-scale fishing gear techniques. There was a significant difference in fishing success among four trolling regimes with 56.3% of the fish taken on natural bait at the surface. Of the fish caught, 64.2% were dolphin (*Coryphaena hippurus*). These were caught close to the FADs with 32 of 34 taken within 50 meters.

During experimental night handlining, catch rates were 50% higher around the FADs than at the control area. A significant difference in the species diversity was found between the FAD and control areas. The FADs were most productive in the early morning and late evening hours while the control site produced best from 8 – 12 pm.

Night handlining was the most profitable method of fishing around the FADs. Trolling was uneconomical around the FADs, but catch rates were higher than around the control areas, and thus, the potential exists to enhance recreational fishing.

INTRODUCTION

Several different methods are employed in harvesting pelagic resources from fish aggregating devices (FADs) around the world. These range from artisanal fishing methods such as trolling and handlining to large-scale commercial fishing operations using purse seines, gill nets, and pole-and-line techniques (Preston, 1982; Floyd and Pauly, 1983). Pole-and-line vessels have been known to average 2000 kg per trip around Hawaiian FADs, and purse seiners in Fiji have recorded single set catches of 60 tons around FADs (Shomura and Matsumoto, 1982). Very little work has been done to quantitatively evaluate the success of the gear and technology involved in fishing around FADs in the Caribbean.

In Puerto Rico most subsistence fishermen participate in an inshore fishery which is highly dependent on reef species (Weiler and Suarez-Caabro, 1980). In the past few years, intensive fishing pressure on a limited shelf has resulted in severe and rapid depletion of the demersal resources (Bohnsack *et al.*, 1986). There are several underutilized pelagic fish stocks in the Caribbean (Hunte, 1986), and many of these species are attracted to FADs (Brock, 1985).

The concentration of these fish may offer an economically viable alternative to existing benthic fish stocks for artisanal fishermen and help reduce fishing pressure on reef fishes. FADs may also assist recreational anglers in catching more fish and save fuel by reducing the time spent searching for fish schools (Bockstael *et al.*, 1985). Improvements in FAD design require that harvesting techniques are quantitatively evaluated. The purpose of this study was to compare the success of several types of fishing methods around FADs in Puerto Rico. Emphasis was placed on techniques which could be used by small-scale commercial fishermen and recreational anglers in the Caribbean.

MATERIALS AND METHODS

This study was done in conjunction with a larger one conducted by Old Dominion University (ODU) in the waters northeast of Puerto Rico. The principal study tested FAD design, durability, and placement. Additional details are contained in Feigenbaum *et al.* (1989).

Six surface FADs consisting of polyurethane filled tractor tires were deployed in two groups of three off the northeast corner of the island. Three inshore FADs were placed just inside the shelfbreak in approximately 90 meters of water. Three offshore FADs were deployed in a depth of 550 m and separated from each other by 2 – 3 km (Figure 1).

Trolling

A number of different lure and bait types were employed during the study. These data were placed in four general categories for most analyses: natural bait trolled at the surface; natural bait trolled deep; artificial lures trolled at the surface; and artificial lures trolled deep.

Natural bait normally consisted of ballyhoo (*Hemiramphus brasiliensis*). Artificial lures were of a variety of different types and colors.

Fishing reels were spooled with either 36 kg test monofilament line or 45 kg test Monel wire. All bait and lures fished with monofilament main line were categorized as surface trolling except for one 0.4 kg pink squid lure which was trolled deep. Baits and lures which used Monel line were considered deep trolling as the wire sinks due to its weight. Approximately 90 m of monel with a 28 g lure will sink about 12 m at 3 knots (Moss, 1976).

Records were kept of effort, strikes, catch, time of day, species and weight of fish caught, lure/bait type (including surface or deep) and distance from FAD at the time of strike. The trolling pattern was a loop which passed all the FADs of an inshore and offshore array and included a control. Areas one to two km away from the FADs (east or west) were designated as control sites. An attempt was made to fish each FAD for an equal amount of time during each trolling period. The start of each trolling trip was alternated between offshore and inshore FADs to avoid bias in time of day.

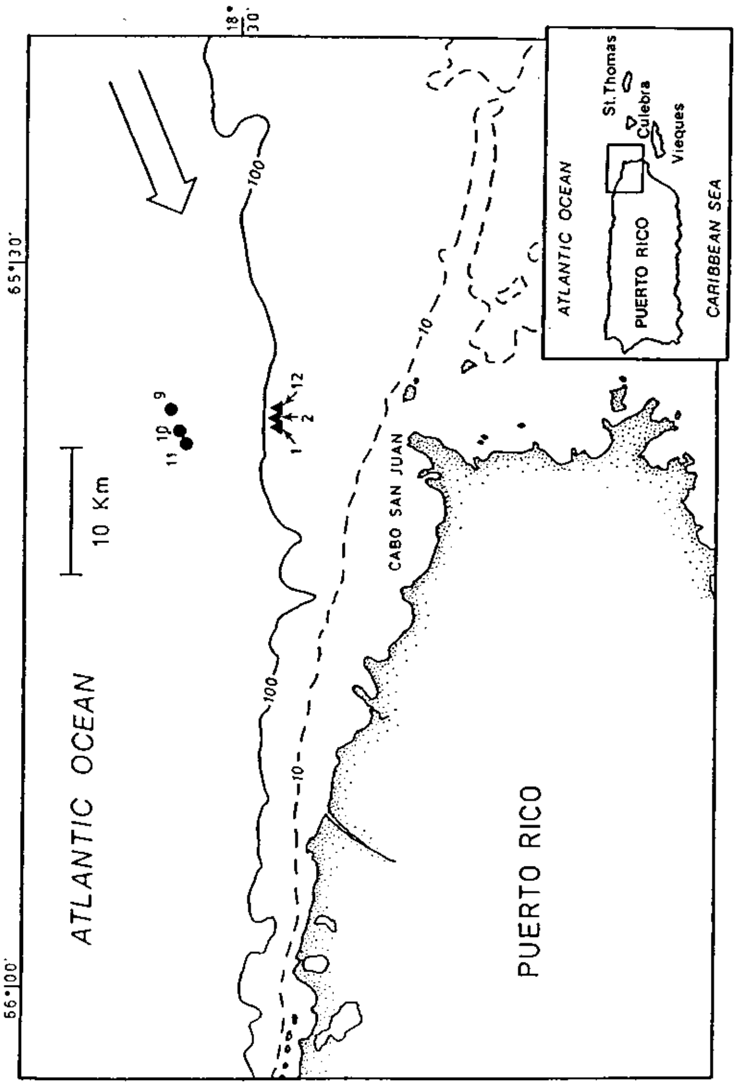

Figure 1. Chart of study area. Depth contours are in fathoms. Arrow shows direction of prevailing current (from Feigenbaum *et al.*, 1989).

Live-bait Handlining

From October through December 1986, the study team fished with the crew of a local commercial vessel for experimental, live-bait, night fishing operations. Two commercial fishermen ran the operations in accordance with study objectives. Bait normally consisted of sardines (*Harengula* sp.) and other carangids. The fishermen set up operations near an inshore FAD in late afternoon and fished throughout the night. Fishing gear in the study consisted of handlines using several hundred meters of 68 kg test monofilament line with No. 4 steel leader and a 4/0 or 5/0 size hook. Live baits were hooked either through the nostrils or just in front of the dorsal fin and then allowed to swim freely behind the boat.

Half of each trip was spent on the FADs while the other portion was spent on a control site several km away at a similar depth. As with trolling, the start of each trip was alternated between FAD and control to avoid bias in time of day. Effort, species caught, weight, and time of capture were recorded.

Data Analysis

In an attempt to reduce some of the variability, data were grouped into two week periods. These statistical periods became the basis for all further comparisons. Fishing success was normalized by considering the number of rod-hours expended during each fishing activity.

For trolling analysis, catches and strikes were combined to make a total value of success (H). This total was then divided by the number of rod-hours to obtain HPUE (hookups per unit effort) (Pristas and Fable, 1984).

RESULTS

Trolling

There were 55 trolling trips performed between June 6 and December 31, 1986. Fifty-three fish were caught and 66 additional strikes recorded around the FADs in 198.61 rod-hours of effort (Table 1). Two different fishing vessels were used during experimental trolling. There was no significant difference in the

Table 1. Trolling bait type and success rates. SPUE = strikes per rod-hr, CPUE = catch per rod-hr, HPUE = hook-ups per rod hour.

Bait Type	Effort	Strikes	Catch	SPUE	CPUE	HPUE
Natural/Surface	47.14	33	31	0.70	0.66	1.36
Natural/Deep	60.63	15	16	0.25	0.26	0.51
Artificial/Surface	69.71	12	6	0.17	0.09	0.26
Artificial/Deep	21.13	6	0	0.28	0.00	0.28
Total	198.61	66	53	0.33	0.27	0.60

trolling success between the two boats ($t = 1.35$, $p = 0.21$, $df = 10$). As a result all trolling data were combined for further comparisons. The overall HPUE for the study was 0.60 (hook-ups per rod hour).

Twenty-eight of the fish caught (52.8%) and 35 of the strikes recorded (53.0%) were associated with the inshore FADs. The total weight of fish caught inshore was 152.0 kg, an average of 5.43 kg per fish. Offshore FADs contributed 25 fish (47.2%) and 31 strikes (47.0%). A total of 137.2 kg were caught on these units, an average weight of 5.49 kg per fish. Fish were caught on 30 (54.5%) trolling trips with an average of just under one fish (0.963) per visit.

Species Composition. There were seven species of fish taken during trolling operations (Table 2). The predominant species landed was dolphin (*Coryphaena hippurus*) which accounted for 64.2% of the catch by number and 52.2% by weight (Figure 2). They were also the most common gamefish sighted around the FADs.

There were seven different species of fish caught inshore while only four different species were taken offshore (Table 2). The inshore FADs were situated at the shelf break which may account for their higher diversity. FADs placed close to shore can be expected to have a mixed assemblage of oceanic and inshore fish (Brock, 1985).

Bait/Lure Preference. There were 28 different bait/lure configurations used during trolling operations. Ballyhoo fished at the surface was the most successful gear type for both strikes and catches. There was a highly significant difference between the fishing success of the four major categories of trolling gear employed in the study ($\chi^2 = 63.08$, $p = 0.001$, $df = 3$) (Figure 3). Natural bait trolled at the surface was the most successful gear type and accounted for more than half (56.3%) of the catches and strikes recorded when effort was taken into account. For dolphin, fishing success was significantly different between the four different gear configurations ($\chi^2 = 59.05$, $p = 0.001$, $df = 3$). Of the 34 dolphin caught on the FADs, 27 (79.4%) were landed using natural bait at the surface (Table 2).

Species Orientation to FADs. The various species of fish were hooked at different distances from the FADs (Figure 4). Twenty-two of the 34 (64.7%) dolphin struck the lure or bait within 10 meters of the FADs with an additional 10 (29.4%) being caught between 10^+ and 50 meters. There was a significant difference in the distribution of fish relative to their distance from the FADs [Kolmogorov-Smirnov test for goodness of fit for continuous data ($D = 0.698$, $P < 0.001$)]. Over 94% of the dolphin struck the lure/bait within 50 meters of the FADs.

Live-bait Handlining

There were eight nightfishing trips performed between October 10 and December 18, 1986 (Table 3). Half of the effort was spent around the FADs and

Table 2. Trolling bait/lure preference on the FADs by species. Numbers in parentheses are identified strikes.

	Natural		Artificial		Total
	Surface	Deep	Surface	Deep	
Dolphin	27	5	2(1)	0	34(1)
Wahoo	0	5(1)	0	0	5(1)
Barracuda	1	2	2	0	5
Shark	1	0	0	0	1
Yellowfin	1	1(1)	2	0	4(1)
Blackfin	1	2	0	0	3
Skipjack	0	1	0	0	1
Total	31	16(2)	6(1)	0	53(3)

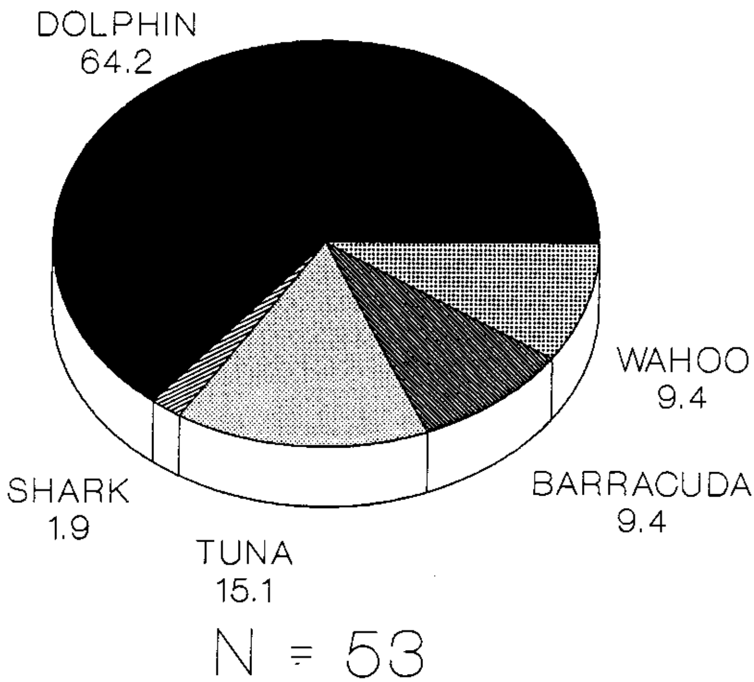

Figure 2. Species composition (%) of trolling catch around the FADs based on number of fish.

Table 3. Catch results of night fishing (live bait at anchor or tied to FAD).

Date (1986)	Location	Weight (Kg.)	Effort (rod-hrs)	CPUE (kg/rod-hr)
10-Oct	FAD	5.9	14	1.26
	Control	15.7	12	1.31
13-Oct	FAD	34.8	14	2.49
	Control	0.0	12	0.00
15-Oct	FAD	25.4	13	1.95
	Control	3.3	12	0.28
20-Oct	FAD	4.8	13	0.37
	Control	8.2	11	0.75
27-Oct	FAD	11.0	14.5	0.76
	Control	26.7	9.5	2.81
21-Nov	FAD	2.27	15.6	0.15
	Control	0.0	13	0.0
06-Dec	FAD	9.5	11.3	0.84
	Control	8.5	12.3	0.69
18-Dec	FAD	5.7	15	0.38
	Control	0.0	12	0.0
Total	FAD	111.1	110.4	1.025
8 Trips	Control	62.4	93.8	0.730

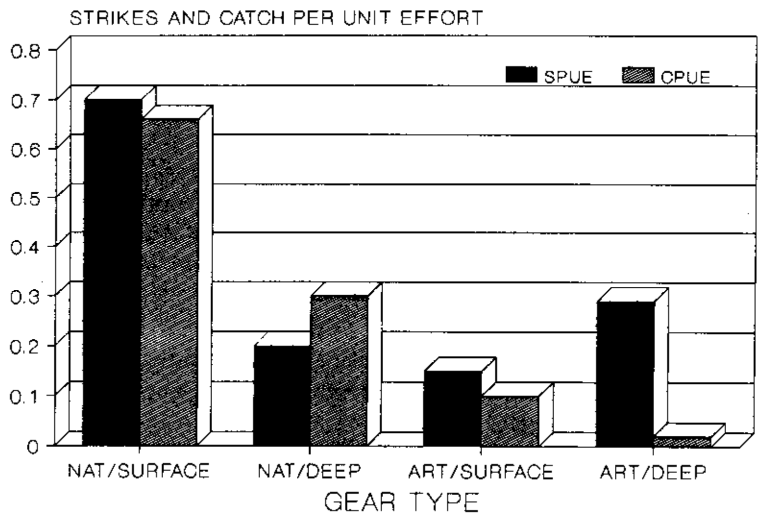

Figure 3. Trolling strike per unit effort (SPUE) and catch per unit effort (CPUE) by bait/lure type around the FADS. NAT = natural; ART = artificial.

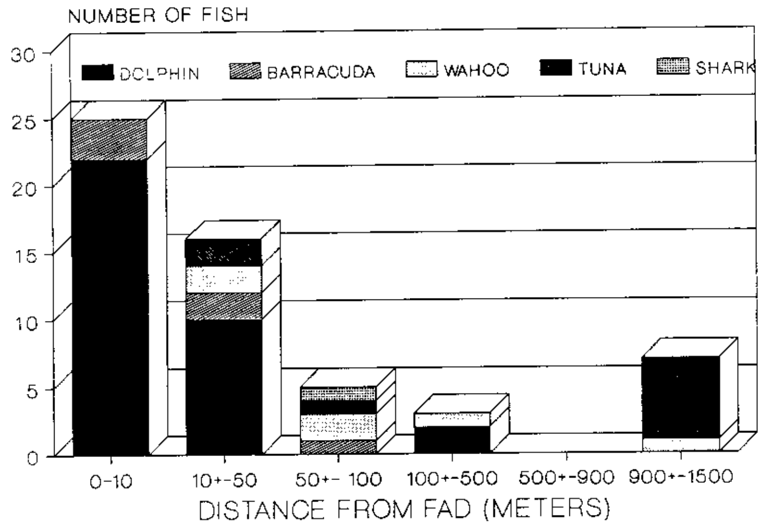

Figure 4. Species orientation to FADs. Distance from FAD where fish were caught while trolling.

half around a control site several kilometers to the east or west of the FADs. A total of 111.17 kg (mean = 13.90 kg) of fish per trip were landed around the FADs with 62.4 kg (mean = 7.8 kg) taken from the control areas. Catch rates varied from 0.146 to 2.486 kg per rod-hour around the FADs (mean = 1.007) and from 0 to 2.811 kg/rod-hr around the control (mean = 0.666). There was no significant difference in CPUE between the two sites ($t = 0.66$, $p = 0.52$, $df = 14$). However, the FADs did catch more fish by weight per rod-hour than the control areas (1.007 vs. 0.666 kg/per rod-hour). One reason for a lack of statistical difference between the two locations was the high degree of variability in these data and the low number of trips attempted.

Commercial landings experienced a sharp seasonal decline after early September due to the absence of kingfish (*Scomberomorus cavalla*) from the catch. Both the experimental and commercial segments of the fishery experienced poor catch rates after this period. During the eight study trips, only four kingfish were landed around the FADs and nine around the control sites. As a result, these data may not be a good indication of the fishing success for these two locations over the course of a year.

Species Composition. Seven different pelagic species were landed around the FADs while only four were taken around the control areas during

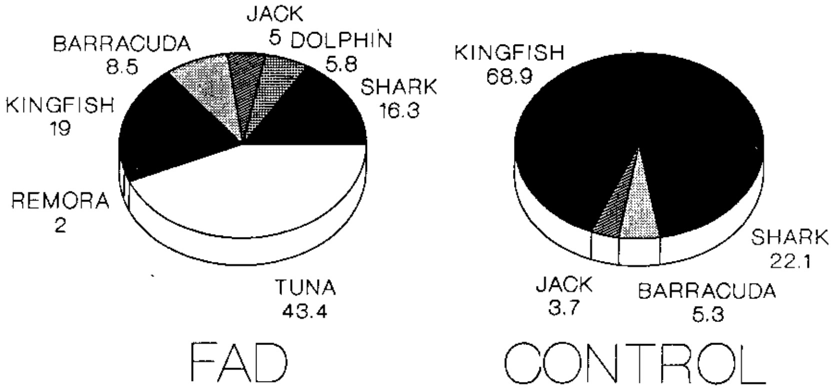

Figure 5. Species composition of FAD and control areas for experimental live-bait night handlining based on weight.

experimental, night handlining (Figure 5). There were significant statistical differences found between the species mix of these two locations using a chi square contingency test ($\chi^2 = 20.65$, $p = 0.002$, $df = 6$). Tuna (Scombridae) made up 43.4% of the FAD catch by weight but were not caught at all on the control sites. As previously mentioned, the presence of these fish around the FADs may help to expand the resources available to the fishermen in this fishery. The next most abundant species taken on the FADs was kingfish (19.0%) which was followed by shark (Chondrichthyes) (16.3%). The remainder of the catch consisted of dolphins, jacks (Carangidae), barracudas (*Sphyraena barracuda*), and remoras (*Remora remora*), but none of these amounted to more than 10% of the catch by weight.

The control sites were dominated by kingfish which accounted for 68.9% of the catch by weight. Sharks comprised 22.1% with the remainder consisting of barracudas and jacks.

Time of Capture. Fish caught around the FAD and control were grouped into four different periods, depending on the time of capture (Figure 6). There was a significant difference in the time in which fish were taken on both the FAD and the control (FAD – $\chi^2 = 52.29$, $p < 0.001$, $df = 3$); Control -$\chi^2 = 73.674$, $p < 0.001$, $df = 3$). The FADs were generally more productive in the

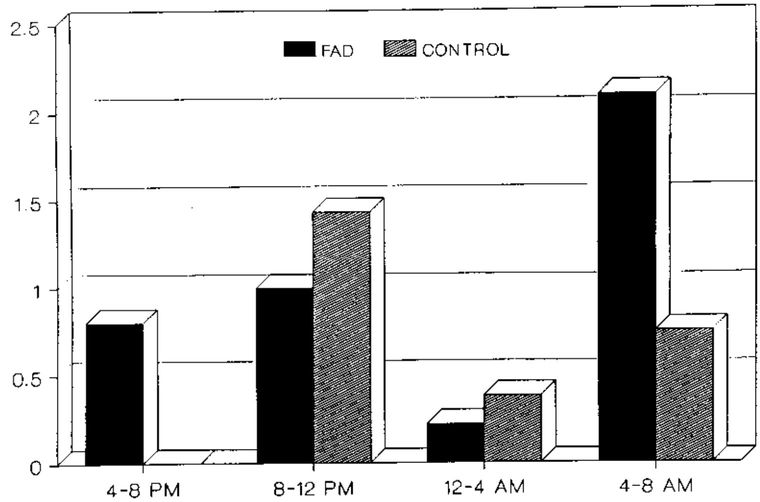

Figure 6. Time of capture for FAD and control sites during experimental live-bait night handlining.

morning and early evening, but the control produced best from 8 – 12 PM. The most successful period of FAD fishing based on kg/rod-hr occurred between the hours of four and eight in the morning. The greatest diversity in catch was also observed during this time.

Numerous schools of tuna were observed around the FADs in the early morning and late evening hours. The majority of the tuna were landed between the hours of eight and twelve in the evening and in several cases, schools of tuna were observed to pass close to the inshore units as they migrated through the area in the late evening.

The control area showed a peak in fishing activity from ten in the evening to one in the morning. The catch at this time was made up exclusively of kingfish. Although they were taken during most periods, kingfish were most commonly caught in the middle of the night.

DISCUSSION

Trolling

The fishing success of natural bait trolled at the surface seems to be due to dolphin being the predominant species in the trolling catch. Ballyhoo and other natural baits trolled at the surface are recognized as the best method for catching these fish (Meyer, 1971; McClane, 1974; Earp and Wildeman, 1986).

While artificial lures accounted for 32.5% of the total strikes recorded around the FADs, only 8.5% of the fish were caught on them. Lures have a taste and mouth texture different from that of natural bait, and many fish will reject them unless the hook is set quickly (Moss, 1976).

Dolphin was the most commonly caught fish around the FADs. They have long been known to have an affinity for floating objects in the sea (Kojima, 1956). For years, West Indies fishermen have avidly sought free-drifting items which usually had dolphin associated with them (Wolf, 1974).

Five wahoo (*Acanthocybium solanderi*) were caught and one additional fish was hooked but not landed during the study. All six were hooked on natural bait trolled deep. Earp and Wildeman (1986) note that a deep swimming bait is recommended over a skipping one when fishing for wahoo.

The low number of tuna found around the FADs in Puerto Rico is in stark contrast to the sightings and landings of these fish in various areas of the Pacific (Preston, 1982; Anon., 1981; Matsumoto *et al.*, 1981; Sproul, 1984). However, study results are consistent with the report of Wolf (1974) who found that schools of tuna were generally small in the Caribbean, and the potential for commercial fisheries was limited.

Trolling was the least cost effective fishing method around the FADs. Low catch rates, high trip costs, and wear on the boat and engine makes this an unprofitable commercial venture in the area. The northwest corner of Puerto Rico is the only area of the island which supports an active commercial troll fishery for tuna (Lopez *et al.*, 1980). Implementation of FADs in that area may prove helpful in increasing catch rates, shortening search time, and saving fuel.

For recreational anglers, Hawaiian FADs generated a variety of benefits including cost savings for fuel, oil, and bait, increased profits from catch, and increased fishing satisfaction (Samples, 1986). Trolling typically produces a high number of no catch days (Moss, 1971), and the presence of FADs in Hawaiian waters has helped recreational anglers reduce the number of no-catch trips (Shomura and Matsumoto, 1982).

Live-Bait Handlining

During this study live-bait handlining at night proved to be the most successful method of fishing the FADs. This method has very simple and inexpensive gear which is already in use in the area. The FADs serve as a point of reference and several other boats fishing the same area makes it safer for small vessels to be offshore at night. The FADs help cut down on search time and also allow one or two vessels to tie up to it, eliminating the need for costly and bulky anchor line. No control for the night fishery was conducted until late in the study by which time commercial kingfish landings had experienced a seasonal decline. Future work should incorporate a control during the summer months to determine whether the FADs actually are more productive than the adjacent shelf areas. The catch of tuna is important since it is not traditionally landed in Puerto Rico while handlining at night.

Between the years 1971 – 1975, nearly 100% of the dolphin and approximately 90% of the mackerels and tuna commercially caught in Puerto Rico were taken by troll line fishermen (Centaur Associates, 1983). A shift to more cost-efficient harvesting techniques such as handlining may help to improve the economics of commercial fishing for pelagics on the island.

CONCLUSIONS

Marine recreational fisheries have become increasingly more important in the Caribbean in recent years (Schmied, 1983). There are many charter boats and numerous fishing tournaments in this region (McIntosh, 1983). FADs may help to focus attention on recreational activities since they seem to improve overall trolling success compared to non-FAD areas. Reducing the number of zero catch days can increase angler satisfaction aboard charter vessels.

The live-bait handline fishery around the FADs at night was very effective in catching pelagics. This method had very low operating costs and was consistent with existing fishing techniques in the area. The presence of species other than kingfish around the FADs is important in helping to exploit fish which are underutilized in this area.

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