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FISH AGGREGATION DEVICE (FAD) ENHANCEMENT OF OFFSHORE FISHERIES IN AMERICAN SAMOA

Raymond M. Buckley, David G. Itano and Troy W. Buckley

ABSTRACT

Fish Aggregation Devices (FAD's) have become an established part of efforts to enhance catches of offshore fishery resources throughout the Pacific region, even though there has been little scientific evidence which verifies that FAD's meet this objective. Support for FAD programs has usually been based on fishery catch reports providing only sporadic, qualitative, and circumstantial information. Federal funding for a FAD program in American Samoa began in 1979. Troll fishing test fishery analysis of FAD's in American Samoa began in 1980. In 1985, test fishery procedures were standardized to use quantitative troll fishing techniques. This enabled assessment of the effectiveness of FAD's in enhancing offshore fisheries through comparisons with offshore banks and open-water "control" areas. Analysis of test fishery CPUE's showed a significant difference between open-water areas and offshore banks, but no significant difference between FAD's and offshore banks. Catches were always lower in open-water areas. There were significant differences between FAD's, and open-water and bank areas combined, for mean lengths of yellowfin tuna and skipjack tuna. The smaller sizes of yellowfin and skipjack tuna at FAD's are examined for possible size range bias in the test fishery catches.

Fish Aggregation Devices (FAD's) have become an established part of modern efforts to enhance catches of offshore pelagic fishery resources throughout the tropical Pacific Ocean. This current enthusiasm for anchoring buoys in the open ocean to attract and "hold" schools of tuna (Scombridae) and other pelagic fishes, seems to be based on the successful use of "payaos"—anchored and drifting bamboo rafts—in the Philippines in the early 1970's to enhance the purse seine fishery for tuna (Matsumoto et al., 1981). Virtually all of the countries in the south Pacific had, or were planning, FAD programs by 1982 (de San, 1982; Preston, 1982), and there were a number of efforts to improve the physical designs for FAD systems to increase their "attractiveness" to desired fishes, and to increase their durability in the high-energy ocean environment (Shomura and Matsumoto, 1982; Boy and Smith, 1984).

The widespread use of FAD's to enhance catches of pelagic fishes received considerable funding support from various states and nations in the Indopacific region even though there was little, if any, scientific evidence which verified that FAD's met this objective. The support for FAD programs was based on their popularity with fishermen and fishery agencies, as the only practical method for increasing the availability of oceanic fish resources through "controlling" the movements of wandering schools of fish. It had long been known to fishermen and fishery scientists that many valuable pelagic fishes had an affinity for objects floating in the open ocean. Properly sited FAD's would take advantage of this behavioral response and attract pelagic fish, providing the opportunity for increasing catches, while decreasing the searching time and operating costs for fishing vessels (Matsumoto et al., 1981; Brock, 1985; Frusher, 1986).

U.S. government funding for the FAD program in American Samoa began in 1979 with the deployment of ten FAD's that remained on-station for apparently very short periods. From 1981 through 1983, the "second generation" FAD system deployed, and redeployed, six FAD's; deployment times ranged from 0 to 13 months, and the average deployment time was 3.0 months. Deployment of the "third generation" FAD's began in August 1984 under an analysis program to test specific engineering and design criteria for FAD's anchored in depths ranging from 915 to 1,646 m. By January 1985, three FAD's had been deployed; through September 1987 the number of FAD's (and the percent time) on-station fluctuated between three (42%), four (24%) and five (34%). The program goal of six FAD's remaining on-station for one year each was never attained, primarily due to construction and deployment infrastructure problems. The longest deployment times achieved (through 1985) in the third generation of FAD's were 34 and 35 months.

Most of the studies and reports on the effectiveness of FAD's in improving catches in offshore fisheries have been primarily qualitative, and based on sporadic catch reports from fishermen, or on the results of short-term, non-standardized test fisheries (for example, Pacific Tuna Development Foundation and Pacific Fishery Development Foundation, unpublished reports). The few studies which have attempted to present quantitative analyses of fishery enhancement programs utilizing FAD's have been hampered by relying, to various extents, on voluntary catch reports, short duration and irregular sampling periods, and inadequate information from control areas (Matsumoto et al., 1981; Frusher, 1986). It is the objective of this paper to quantitatively evaluate the effectiveness of FAD's to enhance the catches of pelagic fishes in offshore fisheries in American Samoa. Two areas of interest in this evaluation are the comparisons of FAD's with offshore banks, which are natural fish aggregation "devices," and with open-water (control) areas.

METHODS

Test fisheries were conducted approximately monthly from November 1984 through September 1987, using a research vessel rigged for trolling at a standard fishing power of six lines, and one lure per line. Catches were recorded for the time spent fishing at FAD's—within 1.6 km of the buoy, on offshore banks—at depths ≤183 m, and in open-water areas—at depths >183 m and >1.6 km from a FAD buoy. The area delineation for FAD's was based on the observed behavior of FAD associated schools of tuna to remain relatively close to the buoy during the day. Fishing was conducted in all three areas to maximize catches. A fish was recorded as caught if it was landed, or if it was lost near enough to the vessel to be identified.

The catch data was summarized based on the annual cycle (November through October) of seasonal wind conditions which had the greatest effect on offshore fishing: November through April—calm seas with moderate northerly winds; May through October—moderate seas with strong south east trade winds. Catch-per-unit-of-effort (CPUE) was expressed in $kg \cdot h^{-1}$ for the research vessel.

The Kruskal-Wallis test and nonparametric multiple comparisons (Zar, 1984) were used to test for statistical differences in CPUE's. Normal approximation of the Mann-Whitney *U*-test (Zar, 1984) was used to test for statistical differences in mean lengths of fish.

RESULTS AND DISCUSSION

Test fishery catch data have been available from the offshore waters of Tutuila Island, American Samoa since 1975 (see OMWR Annual Reports, unpublished). Unfortunately, the data from 1975 to 1984 can only be used for relative comparisons within, and between, years due to the irregular sampling periods and the lack of standardization in fishing effort and data recording procedures. This eliminates any accurate estimation of offshore fishing success prior to the introduction of FAD's in 1979, although the relative trends in catch rates provide some information on the impact of FAD's on the accessibility and abundance of the pelagic fish resources.

Test fishery CPUE's for 1975 through 1979 showed a steady decrease from 7.6 $kg \cdot h^{-1}$ to 4.4 $kg \cdot h^{-1}$, but increased to 7.0 $kg \cdot h^{-1}$ in 1980 (Table 1), apparently

Table 1. Catch-per-unit-of-effort (CPUE—kg·h⁻¹) for the 1975–1984 trolling test fisheries in American Samoa

Year	Location	CPUE*	Year	Location	CPUE*
1975	All	7.6	1983	Bank	10.3
1976	All	7.4	1983	Other	4.2
1977	All	6.3	1983	All	8.1
1978	All	5.7			
1979	All	4.4	1984	Bank	11.4
1980	All	7.0	1984	Other	6.6
1981	All	7.3	1984	All	8.3
1982	All	7.4			

* Species caught: Blue marlin (*Makaira nigricans*), Dolphinfish (*Coryphaena hippurus*), Yellowfin tuna (*Thunnus albacares*), Skipjack tuna (*Katsuwonus pelamis*), Kawakawa (*Euthynnus affinis*), Wahoo (*Acanthocybium solandri*), Dogtooth tuna (*Gymnosarda unicolor*) and Rainbow runner (*Elagatis bipinnulatus*).

attributable to trips to three FAD's which accounted for approximately 33% of the total test fishery catch. However, the test fishery in 1981 recorded a slightly increased CPUE of 7.3 $kg \cdot h^{-1}$ when only one, poorly producing FAD was on-station. In 1982, the total test fishery CPUE of 7.4 $kg \cdot h^{-1}$ was comprised of a CPUE of 13.7 $kg \cdot h^{-1}$ for trips that included FAD's and a CPUE of 5.9 $kg \cdot h^{-1}$ for trips that excluded FAD's. These trends seem to indicate that the introduction of FAD's had a positive impact on the accessibility of the pelagic fishes, even during the early years of the program (1979–1982) when the FAD's were on-station for only short periods.

In 1983, the total test fishery CPUE increased to 8.1 $kg \cdot h^{-1}$, but included catches from offshore banks which had not been fished in previous test fisheries. The 1983 test fishery recorded a bank trip CPUE of 10.3 $kg \cdot h^{-1}$ and an "other area" CPUE of 4.2 $kg \cdot h^{-1}$. This trend followed in 1984, with a bank trip CPUE of 11.4 $kg \cdot h^{-1}$ and an "other area" CPUE of 6.6 $kg \cdot h^{-1}$ (Table 1). In both 1983 and 1984, the test fishing effort expended around FAD's was included in the "other area" data. However, the similarity between the CPUE's for the bank trips and the 1982 trips that included FAD's, provides an indication that FAD's had the potential to "create" target fishing locations that were more accessible than offshore banks, and to produce catches of the same relative magnitude.

Complete standardization of the test fishery procedures in 1985 enabled quantitative comparisons between the catches of pelagic fishes made around FAD's,

Table 2. Catch-per-unit-of-effort (CPUE—kg·h⁻¹), by seasonal periods, for the Year 1, Year 2, and Year 3 trolling test fisheries in American Samoa

	CPUE*		
Period	Open-water	FAD	Bank
Nov. 1984–Apr. 1985	2.9	13.2	36.7
May 1985–Oct. 1985	5.0	19.5	34.0
Year 1 total	3.8	16.1	36.0
Nov. 1985–Apr. 1986	7.9	32.7	35.8
May 1986–Oct. 1986	7.4	17.3	16.9
Year 2 total	7.5	24.2	26.1
Nov. 1986–Apr. 1987	7.5	—	29.1
May 1986–Oct. 1987	5.7	29.7	17.0
Year 3 total	6.3	29.7	27.6

* See Table 1 for species caught.

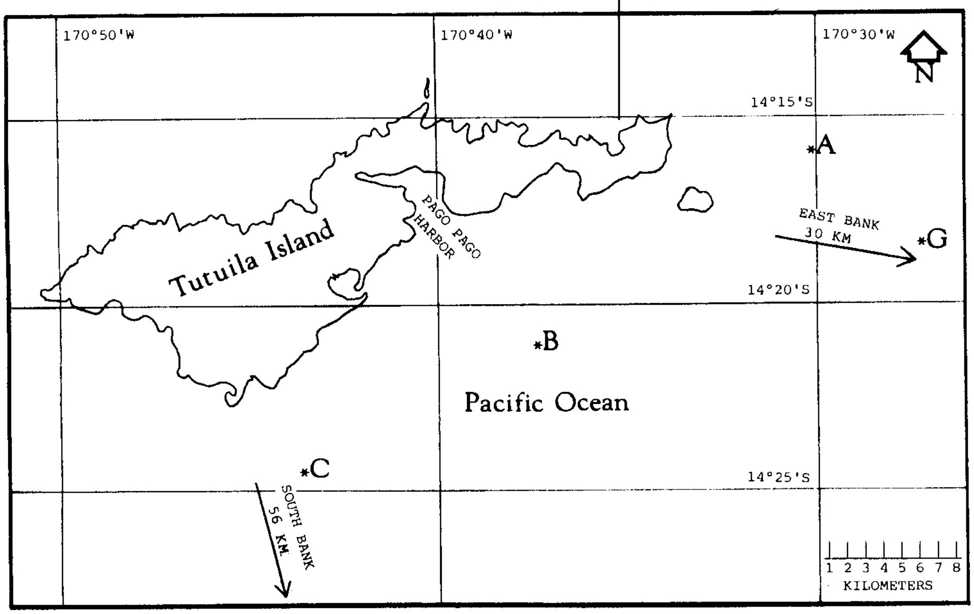
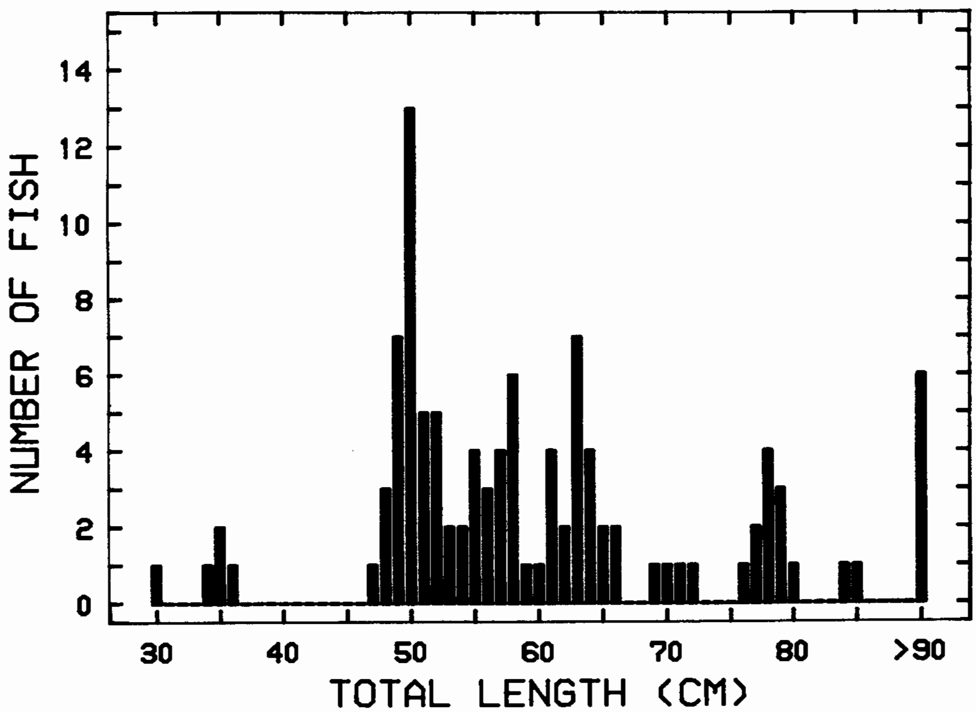


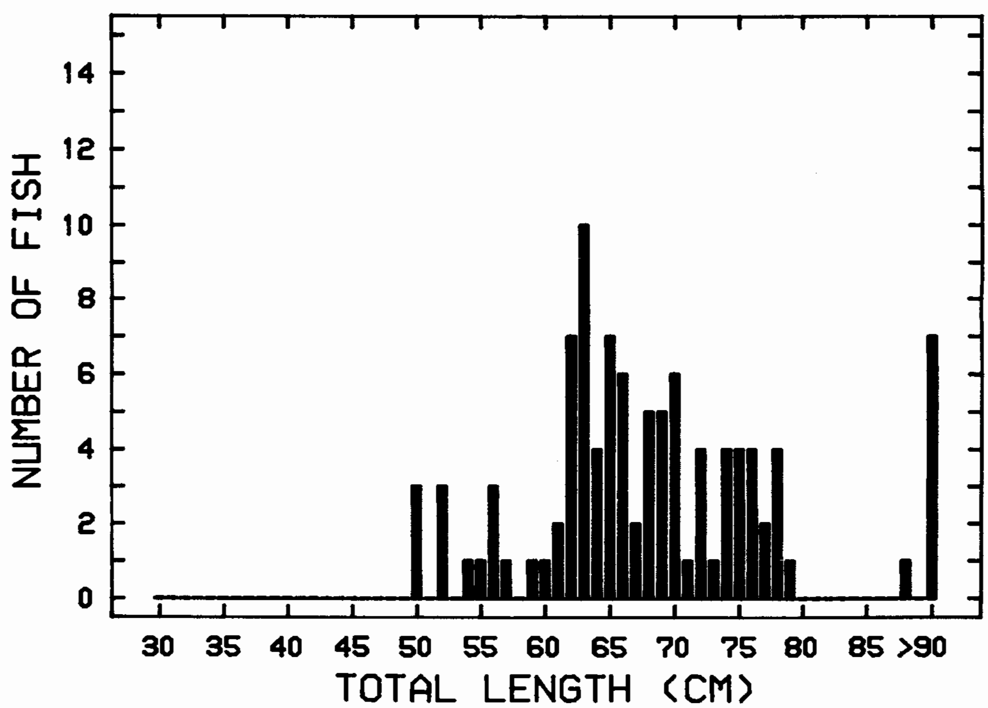
Figure 1. Locations of FAD's A, B, C and G and offshore banks in American Samoa.

on offshore banks, and in open-water areas. It was possible to make standardization corrections in the test fishery data taken in November and December 1984, which provided comparative catch rate data for three annual cycles of the seasonal winds that affect the offshore fisheries. These annual cycles are hereafter referred to as Year 1, Year 2, and Year 3 (Table 2). This data is presented for the eight species of pelagic fish commonly caught on troll fishing gear in the offshore waters of American Samoa. All of these species are acceptable catches in the subsistence, recreational, or commercial fisheries and, with two exceptions, they were caught in all three areas; blue marlin were not caught on the offshore banks, and dogtooth tuna were not caught around FAD's. However, these species were retained in the analysis because the primary objective was to examine FAD enhancement of the offshore fisheries in relation to the total complex of species.

There were significant differences between open-water areas, FAD's, and offshore banks for seasonal test fishery CPUE's for Years 1, 2, and 3 ($P = 0.05$, $H = 11.0$). The total test fishery CPUE's for Years 1, 2, and 3 were 3.8, 7.5 and 6.3 $kg \cdot h^{-1}$ for open-water "control" areas, 16.1, 24.2 and 29.7 $kg \cdot h^{-1}$ for FAD's, and 36.0, 26.1 and 27.6 $kg \cdot h^{-1}$ for offshore banks, respectively (Table 2). These figures indicate that catch rates were always lower in the open-water "control" areas, but the only appreciable difference between the FAD's and offshore banks occurred during the Year 1 test fisheries.

There was a significant difference between the total seasonal test fishery CPUE's for open-water areas and offshore banks ($P = 0.05$, $Q = 3.2$), but no significant difference between the CPUE's for FAD's and offshore banks ($P = 0.05$, $Q = 0.6$). The offshore banks were the most productive "natural fish aggregation devices" available in American Samoa for comparison with the enhancement effectiveness of FAD's. These banks are highly desirable target fishing locations, but they are located well beyond the cruising range of most of the fishing fleet (Fig. 1) and they are often difficult to locate.


14
12
10
8
6
4
2
0
NUMBER OF FISH
30
40
50
60
70
80
>90
TOTAL LENGTH (CM)


14
12
10
8
6
4
2
0
NUMBER OF FISH
30 35 40 45 50 55 60 65 70 75 80 85 >90
TOTAL LENGTH (CM)

There were significant differences between FAD's, and open-water and bank areas combined ("non-FAD" areas), for the mean lengths of yellowfin tuna ($P = 0.05$, $Z = 5.6$) and skipjack tuna ($P = 0.05$, $Z = 7.6$) caught in the test fisheries for Years 1, 2, and 3 combined. However, the range of the sizes of the tuna caught at FAD and non-FAD areas were nearly the same for both yellowfin and skipjack (Figs. 2, 3). This indicates that the smaller average sizes of the yellowfin tuna and skipjack tuna caught at the FAD's may not represent biological differences based on aggregation of select groups of fish. Comparable size ranges of both species seem to have been present at both areas, but they were apparently caught at different rates. This could have been caused by either a disproportional abundance by size, or a disproportional recruitment to the test fishery trolling gear by size.

Baited hook-and-line test fishing in Years 1, 2, and 3 at various depths at the FAD's often caught larger yellowfin tuna than were taken in concurrent test fishing with the standardized trolling gear. This indicates that the larger fish were not fully recruited to the surface trolling methods at the FAD's. There was no comparable baited hook-and-line test fishing conducted in non-FAD areas. Therefore, the available information is insufficient to determine if the differential in the sizes of the yellowfin tuna is related to the abundance of specific sizes, or possible size-related recruitment to the troll fishing methods, or a combination of both factors. It has been shown that yellowfin tuna feed on deep dwelling oplophorid shrimp around FAD's (Brock, 1985), but there is not an indication that there is a depth distribution by size.

This possibility of a size range bias in the test fishing catches does not invalidate the assessment of FAD enhancement because trolling is the standard fishing method for the offshore pelagic fishery in American Samoa. It does indicate, however, that care should be taken in extrapolating this length frequency information to possible effects that FAD enhancement may have on the stocks of fish. It does not appear from the sizes of yellowfin tuna and skipjack tuna caught at the FAD's, that the FAD's in American Samoa are selectively aggregating juveniles of these species. This has been reported for catches from FAD areas in Papua New Guinea (primarily yellowfin from 21 to 35 cm, and skipjack 19 to 39 cm; Frusher, 1986), and suspected for yellowfin catches around FAD's in Hawaii (R. E. Brock, University of Hawaii, personal communication). However, in American Samoa the majority of the yellowfin tuna caught in FAD areas (93.7% to 96.6%) are smaller than the 91 to 100 cm length-at-first-spawning reported for eastern central Pacific yellowfin tuna (Cole, 1980); the majority of the skipjack tuna (81.0% to 90.6%) are larger than the 40 to 43 cm length-at-first-spawning reported for this species in the same area (Forsbergh, 1980).

The quantitative information in this study on differential catch rates between open-water areas, FAD's, and offshore banks, conclusively shows that FAD's are an effective method for enhancing the troll fishery catches of commonly caught pelagic fishes in American Samoa. It is not possible to make a concise extrapolation of this result to the "total value" of FAD enhancement, because accurate quantitative information is not available on the variety of other factors that would be part of this analysis; for example, FAD deployment costs, fish resource status, vessel operation costs, fishery market demands, etc. However, it is general knowl-

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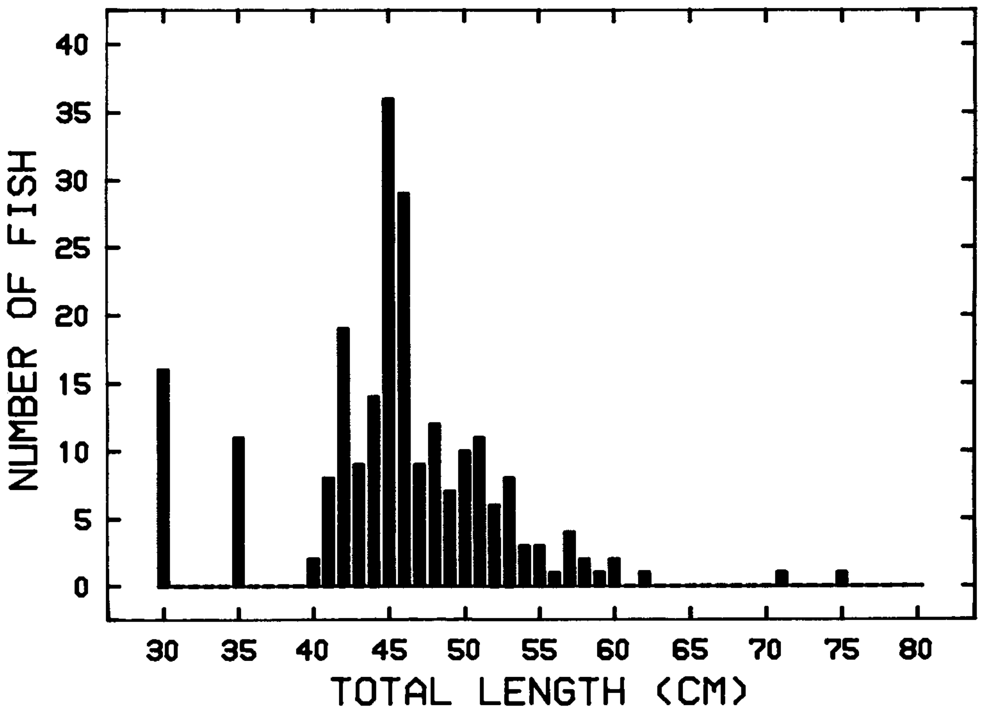
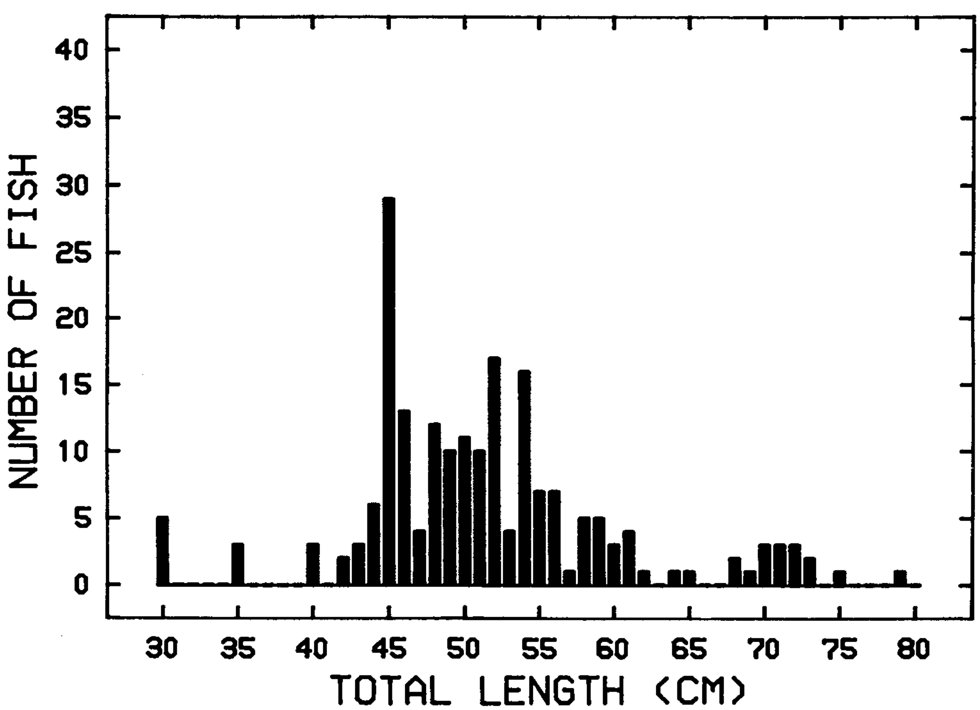
Figure 2. Length frequency distributions of yellowfin tuna caught at FAD's (top, N = 106), and open-water and bank areas combined (bottom, N = 101), during the November 1984–October 1987 trolling test fisheries in American Samoa.


NUMBER OF FISH
40
35
30
25
20
15
10
5
0
30 35 40 45 50 55 60 65 70 75 80
TOTAL LENGTH (CM)


NUMBER OF FISH
40
35
30
25
20
15
10
5
0
30 35 40 45 50 55 60 65 70 75 80
TOTAL LENGTH (CM)

edge that there is a demand for fresh fish for local retail markets, subsistence, and some export, and that the present local fishing fleet is not technologically capable, or economically motivated, to fulfill these demands without some assistance. Considering the present biological information on FAD related catches (no apparent excess harvest of juveniles) and the present success in FAD design and engineering (the potential for over 2.5 years on-station), it seems both desirable and practical to use FAD's to create productive target fishing locations within practical distances from harbors in American Samoa.

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Addresses: *(R.M.B.) Washington State Department of Fisheries, 115 General Administration Building, Olympia, Washington 98504; (D.G.I. and T.W.B.) Office of Marine and Wildlife Resources, Government of American Samoa, P.O. Box 3730, Pago Pago, American Samoa 96799.*

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Figure 3. Length frequency distributions of skipjack tuna caught at FAD's (top, N = 226), and open-water and bank areas combined (bottom, N = 200), during the November 1984–October 1987 trolling test fisheries in American Samoa.