RECENT USE OF FISH AGGREGATING DEVICES IN THE EASTERN TROPICAL PACIFIC TUNA PURSE-SEINE FISHERY: 1990-1994

(Revised March 1996)

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INTRODUCTION

In the eastern tropical Pacific Ocean (ETP), an area stretching south from Baja California to Peru and west to 160° W longitude, fishermen have capitalized on an association between yellowfin tuna, *Thunnus albacares*, and dolphins, primarily offshore spotted, *Stenella attenuata*, spinner, *Stenella longirostris*, and common, *Delphinus delphis*. Prior to the advent of modern purse-seining (McNeely 1961; Howard 1962), most offshore tuna were caught by longline vessels and baitboats. Modernization of purse-seine fishing gear was facilitated in the early 1960's by the invention of the Puretic power-block, development of nylon net webbing, and improvements in ammonia refrigeration technology (McNeely 1961) that permitted vessels to store their catch for extended periods of time. Gear modifications provided fishermen with the means to encircle dolphin herds with purse-seines and capture premium sized tuna[1] in much greater quantities than when bait fishing (Perrin 1968, Perrin 1969). Since dolphins are surface-breathing mammals and are often found in association with flocks of seabirds (Au and Pitman 1986; 1988), they were relatively easy to locate, and a mode of fishing developed to take advantage of these multispecies aggregations. Throughout the 1970's and 1980's tuna caught in association with dolphins comprised the majority (60-90 %) of the ETP yellowfin tuna catch (Inter-American Tropical Tuna Commission (IATTC) 1989), although tuna caught in free-swimming schools, in association with logs, and by longline fishing also provided substantial tonnage to the total catch of tuna in the ETP.

During the expansion of the ETP tuna purse-seine fleet from the 1960's to the present, a long history of dolphin mortality incidental to fishing operations has been documented and monitored by the National Marine Fisheries Service (NMFS) and IATTC. The problem of dolphin mortality resulted in an escalating interaction between fishing interests, government, and environmental organizations. On November 23, 1988 Congress passed the amended reauthorization of the Marine Mammal Protection Act (MMPA) of 1972. Section 110(a) of the reauthorized MMPA focused on identifying promising new methods of locating and catching yellowfin tuna without incidental capture of dolphins. The NMFS's report, *Strategic Plan To Develop And Evaluate "Dolphin-Safe" Methods Of Fishing For Yellowfin Tuna In The Eastern Tropical Pacific* (DeMaster 1992), focused on evaluating

[1] Yellowfin tuna greater than 9.1 kilograms or 20 pounds (American Tuna Sales Association, 4500 Trias Street, San Diego, CA 92103).

alternative methods of fishing that do not involve the chase or encirclement of dolphins.

In April 1990, U.S. tuna canners conceded to pressure from environmental groups urging a boycott of tuna caught in association with dolphins by announcing that they would no longer purchase yellowfin tuna caught in this manner. This policy eliminated a large segment of the market for tuna caught in association with dolphins by U.S. fishermen. "Dolphin-Safe" canned tuna became the U.S. industry standard. In the wake of this policy change the desire to develop methods of catching yellowfin tuna that were not associated with dolphins became a paramount concern of the U.S. tuna purse-seine fleet. NMFS Dolphin-Safe Program research projects were selected based on their potential to improve understanding of the behavioral association between yellowfin tuna and dolphins and their potential to develop new methods of locating and aggregating large (>9.1 kg) yellowfin tuna not associated with dolphins. One of the avenues of research being explored by the Dolphin-Safe Program is the potential use of Fish Aggregating Devices (FADs).

Although the precise mechanisms involved in the attraction of fish to floating objects are unknown, it occurs with sufficient regularity to justify research that explores the use of FADs to enhance dolphin-safe fishing efforts in the ETP. The focus of NMFS Dolphin-Safe FAD research is to develop methods to build and deploy relatively inexpensive drifting and anchored FADs that will attract mature tuna in sufficient abundance to supplement current harvest levels and to decrease fishing activity associated with dolphins. The purpose of this report is to provide some background on the potential of FADs to aggregate tuna, describe the investigations undertaken by NMFS, and present the results of a cooperative research project.

LOGS

Fishermen and scientists alike have long been aware that objects (ie., "logs") at or near the surface of the ocean attract various species of fish (Hunter and Mitchell 1967). Logs include wood objects such as tree stumps, branches, and milled lumber products, other organic materials such as dead marine mammals, sea turtles, and aquatic vegetation, and man-made objects such as rope, discarded fishing gear, or just about anything that floats. In the ETP logs are widely but not evenly distributed in the pelagic environment.

The presence of logs in the open ocean is correlated with local precipitation patterns, rate of river run-off, and the type and use of vegetation in coastal areas (Hoffman 1975; Hall, Arenas and Miller 1992). The majority of floating objects enter the ocean at the mouths of rivers and eventually aggregate along oceanic fronts. Water circulation patterns and wind patterns affect the rates of distribution and accumulation of these objects. In the ETP, the eastern boundary currents flowing along the coasts of the Americas toward the equator turn west and form the zonal circulation characteristic of the central Pacific. The water circulation pattern is dominated by the eastern and equatorial components of the subtropical wind-driven anticyclonic gyrals (Wooster and Cromwell 1958; Wyrtki 1967). There is considerable variation in the circulation pattern throughout the year (Wyrtki 1967) and the distribution of logs is likely affected. Logs are discharged into the Panama Bight area from several small rivers in Costa Rica, Panama and Colombia during the rainy season (August - November). Riverine transport of debris into the ocean is also very high along the coast of Ecuador throughout the year. The net effect of the origin of natural logs and ocean circulation is to concentrate logs in coastal (out to ˜50-100 nautical miles) waters. Thus, there are fewer natural logs offshore (> 100 nautical miles) in the ETP where much of the large yellowfin tuna are captured in association with schools of tropical dolphins. We hope that FADs deployed in offshore "dolphin-fishing" grounds will aggregate large yellowfin tuna frequently found associated with dolphins.

Association of fishes with logs and other flotsam in inshore waters have been studied in Hawaii (Gooding and Magnuson 1967), California and Central America (Hunter and Mitchell 1967; Greenblatt 1979), and other regions as well. Pelagic fish communities have not been extensively studied because of logistical constraints inherent in their study. Two important tuna fishing grounds that are characterized as logfishing areas in the Pacific are found around the Philippine islands, especially Moro Bay, and the ETP, particularly in the coastal waters off Central America. The coastal waters of Panama, Costa Rica, Guatemala, and northern Ecuador are where the majority of sets on logs are made in the ETP (Hall, Arenas and Miller 1992). This coastal pattern of log sets changes to a more offshore distribution at 10°N and extends out to 145°W along this latitude. Little logfishing occurs along most of the mainland of Mexico or the Baja California peninsula (Hall, Arenas and Miller 1992).

What might attract fish to flotsam? Gooding and Magnuson (1967) offered a review of the following hypotheses proposed by other authors. Food collecting around flotsam attracts fish to floating algae or decaying coconut fronds (Reuter 1938; Soemarto 1960). Fish move away from direct sunlight (negative phototaxis) in response to the shadow cast by the object (Suyehiro 1952). Flotsam provides shelter from predators (Suyehiro 1952; Soemarto 1960). Various species of fish attracted to flotsam use it as a spawning substrate (Besednov 1960). Damant (1921) theorized that the shadow associated with the floating object makes local populations of zooplankton more visible to predators. Hunter and Mitchell (1967) suggested that floating objects provide spacial orientation in the optical void of the pelagic environment and function as schooling companions for pelagic fish species. Floating objects may function as substitutes for reefs or other substrates for species of fish not adapted to pelagic life.

Analysis of fishery effort by IATTC (Hall, Garcia, Lennert and Arenas 1992) suggests that logs may provide sensory evidence to a school of fish that the body of water has received some continental nutrients and the area is potentially rich in prey. Regions of high primary productivity are quite narrow in the ETP (Reilly 1990; Fiedler 1992). Tunas are regarded as visual predators and presumably forage chiefly during the daylight hours or at night when the full moon provides enough light for effective hunting. Random swimming movements to forage at night seem inefficient for tuna because it might cause them to unknowingly move from biologically productive areas to less rich areas. Perhaps it is advantageous for tuna to develop a mechanism to help them remain or orient themselves in productive water masses. Locating a log in the ocean and staying nearby during the night could be one such a mechanism.

It is thought young tunas may develop early associations with logs to avoid predators. Fedoryako (1989) proposed that species at different stages of their life cycles that are associated with flotsam may do so for different reasons at different stages of their development; other species may be attracted to logs because they follow prey species for trophic reasons so that a community of organisms is formed of which only a few species are actually associated with the floating object. This description of the piscovorous component of the "log community" offers one possible explanation of why there is often a high predator biomass (several hundred tons of tuna, dolphinfish, *Coryphaena hippurus*, and sharks) relative to forage fish biomass found associated with logs in the ETP.

FADS

Fish Aggregating Devices (FADs) are free floating or anchored structures constructed and deployed by fishermen to attract schools of fish. The development and use of FADs is not a new concept (Shomura and Matsumoto 1982). In the Philippines fishermen have used bamboo rafts (payaos) since before World War II to aggregate fish for handline fishing (De Jesus 1982). Japanese fishermen have used moored rafts to attract dolphinfish, *Coryphaena hippurus*, in the western portion of the Japan Sea (Chagoma 1960). In the western Pacific Ocean (WPO) tuna fishery, purse-seine vessels make sets on a variety of floating objects that tend to accumulate tuna. FADs have been used for commercial fishing operations in the central and western Pacific Ocean by the Japanese since the mid-1970's. The Japanese high seas tuna purse-seine fleet moved to the central and western Pacific during the seventies in search of an area to conduct year-round fishing operations for tropical pelagic fishes and tunas. Year-round operations were made possible by the discovery of logfishing methodology (Honma and Suzuki 1978). Anchored FADs are used by fishermen of the Philippine and Solomon Islands fleets. FAD sets in the WPO tend to produce catches of mixed species of skipjack and yellowfin (Bailey 1985) as is the case in the ETP.

Typically, sets on FADs are made prior to sunrise and occasional sets are made at dusk. FADs in the WPO are either anchored, broken loose from their moorings and free-floating, or are intentionally deployed as drifting FADs. The surface-platforms of these FADs are constructed from bamboo, plastic pipe, steel pontoons, or empty oil drums (Boy and Smith 1984). Most of these FADs utilize subsurface appendages such as palm fronds, net webbing or other materials believed by fishermen to attract fish to the surface-platform. Anchored and drifting payaos constructed from bamboo are deployed throughout the waters of the Philippines except the eastern regions where the currents are strong. Payao fishing, which in the past had been used by local coastal fishermen to aggregate small and large pelagic fish, has proved to be an effective method for attracting and catching tunas with purse-seines. Since the mid-1970's thousands of payaos were deployed in Moro Gulf (De Jesus 1982; Malig, De Jesus and Dickson 1991) and according the South Pacific Commission, the Philippine fleet fished for tuna associated with drifting and anchored FADs during 76% of their sets between 1984 and 1990 (De Jesus 1982; Lawson 1991). Philippine fishery statistics show a significant increase in landed catch of tunas from 25,000 metric tons (mt) in 1973 to 124,984 mt a year after purse seining with payaos was introduced, to a high of 313,371 mt landed in 1990 (De Jesus 1982). The introduction of purse-seine vessels into these fishing grounds led to the development of more durable surface-platform designs that incorporated cylindrical steel rafts, permitted deep mooring farther offshore, and extended the life of the FAD.

In the WPO the majority of yellowfin tuna caught associated with FADs are juveniles (De Jesus 1982). Juvenile yellowfin tuna are 0-1 year old, have a fork length of 49 cm or less, and weigh 2.3 kg or less (Table 1). Medium size (60-100 cm) tuna that weigh between 4.5 - 20.4 kg are seldom caught in the Philippines (De Jesus 1982). Tuna longer than 100 cm and weighing more than 20.4 kg are caught by handline around payaos at depths of 160-280 meters. Catching tuna of this size with a purse-seiner in the WPO would require a very deep fishing net and possibly acoustic or optical detection devices to locate the fish. Yellowfin tuna caught in association with logs in the ETP are in most cases smaller sized (< 77 cm and <9.1 kg) in comparison with yellowfin tuna caught in association with dolphins (> 77 cm and >9.1 kg) (IATTC 1989).

IATTC analyses have demonstrated that yield-per-recruit is about 34 percent greater when fishing vessels concentrate on larger fish than when they direct their efforts toward smaller fish (IATTC 1991; IATTC 1992). To meet the goal of developing dolphin-safe fishing methods that do not involve the chase or encirclement of dolphins and permit fishermen to sustain current levels of harvest it will be important to find a method(s) to catch or attract the tuna greater than 77 centimeters in length and 9.1 kilograms in weight that are frequently found associated with dolphins. Fishermen may be able to utilize FADs to aggregate tuna in currently productive offshore logfishing areas, dolphin-fishing grounds, and possibly other areas in the ETP and other tropical oceans. The introduction of man-made "logs" into these offshore areas is part of our investigation.

FAD INVESTIGATIONS: 1990-1992

The IATTC, NMFS, and Bumble Bee Seafoods have cooperated on research projects to explore mechanisms of attracting large tuna to FADs (Young and Armstrong 1992). Seven FADs with "sea kite" arrays were deployed by fishermen in the ETP during 1990. Sea kites are pyramidal structures, measuring six feet on a side, and are constructed with a fiberglass pole frame and yellow "rip-stop" nylon. A number of kites were attached at regular intervals to a weighted monofilament mainline suspended in the water from the surface-buoy. These FADs remained in the water from two hours to 19 days. Observations of accumulations of forage fish, barnacles, and crabs were reported by the tuna fishermen, but no tuna were observed around the FADs and no sets were made. In January of 1991 two identical FADs equipped with satellite transmitters were deployed in the ETP to test the durability of the surface-buoys, ARGOS satellite transmitters, longevity of batteries, and the practicality of tracking FADs by satellite to provide more or less continuous position information to fishing vessels. Positions and estimates of drift transmitted to vessels searching for the FADs were accurate and sightings of the FADs by NMFS observers indicated the surface-buoys were in good condition several months after deployment.

Positions of low profile, wave and wind-resistant drifting oceanographic buoys (ie., drifting "FADs") were transmitted to interested purse-seiner skippers and owners on a weekly basis from 21 March 1991 through 5 October 1992. Three sets were made on these buoys and 25 tons of yellowfin plus 92 tons of skipjack tuna were caught (Young and Armstrong 1992). The ability of anchored oceanographic buoys deployed by NOAA's Thermal Array for Ocean project (TAO) to attract fish has been noted by personal observations of NMFS observers and tuna fishermen, but these buoys are not actively promoted as FADs by the Dolphin-Safe Program as fishing near or around these structures could damage them.

In July of 1991 NMFS, IATTC, and Bumblebee Seafoods Inc. deployed 30 FADs constructed of ten different designs equipped with various tracking and locating devices (Young and Armstrong 1992). The design of the surface-platforms ranged from a simple surface-buoy to surface-buoys with arrays descending to 100 meters in depth. FADs were deployed in ten groups, each group consisting of three identical FADs. One FAD in each group was equipped with a satellite transmitter that communicated positions through the ARGOS satellite system. The satellite transmitters provided positions that were accurate to within a kilometer or less and position data were accessed daily through the Service ARGOS satellite system. The other two buoys in a group were equipped with selective-calling (SELCALL) medium-wave radio-buoys that transmit only when activated by a vessel's signal generator. SELCALL radio-buoys can be interrogated by vessels at distances up to 200 kilometers. These FADs were deployed 1,000 miles west of the Pacific coast of Mexico in an area from 9°N to 11°N between 121°W and 124°W, an area within the traditional fishing grounds for large yellowfin tuna caught in association with dolphins. The IATTC's historical data also indicated adjacent areas, although not especially rich in natural logs, had produced larger than average yellowfin in association with logs (IATTC 1992).

All 30 FADs deployed in July 1991 were launched within a 24-hour period in roughly a 2° x 3° area. The deployment around the 10° N latitude apparently overlapped the north equatorial countercurrent and the north equatorial current, as several of the FADs drifted in a northwesterly direction, while others, positioned a short distance away, drifted to the southeast. Those drifting to the northwest eventually turned to the west. Those drifting to the southeast circled around to the northeast, and then to the west as they encountered a westerly current near 12° N latitude. FADs were tracked for several months by NMFS and IATTC staff at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, and daily positions were provided to vessel managers and IATTC field offices throughout Latin America. This study was judged successful because the FADs remained afloat, eight satellite transmitters functioned for more than 20 months, and, according to limited sighting and catch data, were moderately successful attracting fish. Shortly after the FADs were deployed a series of tropical storms and hurricanes occurred near the deployment site which obstructed access to these FADs and carried them westward of the fishing fleet. Because fishing was "better" to the east of the rapidly westward-moving FADs, the fishing fleet was unable or reluctant to assess the ability of these FADs to aggregate tuna.

The first satellite transmitter failure occurred on November 6, 1991 (11/6/91), 106 days after deployment. It was followed by failure of a second satellite transmitter on November 8, 1991 (11/8/91). The last positions obtained for the eight remaining satellite-equipped FADs were received from Service ARGOS Inc., on April 20, 1993 (4/20/93), and indicated a continued westward movement well outside of the fishing grounds. One of these FADs was recovered by a fisherman from the Province of Southern Leyte in the Republic of the Philippines in May of 1993[2].

FAD INVESTIGATIONS: 1993-1994

In 1993 two U.S. purse-seine captains who were interested in participating in cooperative FAD research contacted NMFS. Skipper-A, Dick Stephenson, approached NMFS with a proposal to deploy anchored FADs constructed of low cost materials that were easy to deploy, recover, and store. NMFS provided Captain Stephenson with 3,500 fathoms of used mooring line and he constructed and deployed surface-platforms and anchors, and maintained a data logbook written by members of the Dolphin-Safe Program (Appendix 1). The logbook was kept

[2] Dave Bratten, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography. La Jolla, California, 92038. Pers. comun., June 1993.

to record specific details about construction, deployment, effort, and catch associated with FADs. In February and March of 1994 Stephenson deployed and fished several drifting FADs in offshore waters off the coast of Ecuador and Peru. In April and May of 1994 he deployed, visited, and documented another vessel's fishing effort associated with two anchored FADs in the Gulf of Panama.

The NMFS purchased five Ryokuseisha SV-CL3B[3] SELCALL radio-buoys in June 1993, and loaned them to Skipper-B (name withheld by request) so he could deploy five "extra" FADs during a fishing trip. He documented construction, deployment, effort, and catch associated with 16 FADs during two fishing trips. Skipper B constructed drifting FADs out of lumber and surplus materials found aboard the vessel including, old net webbing and twine, used corkline, balloon floats, wooden crates, and pallets. He incorporated "seasoned" flotsam such as logs, driftwood, dead marine mammals, billfish, and abandoned or discarded fishing gear, plywood, sheets of plastic, and floating line found at sea into the FAD structure.

Skipper-B's general FAD design employed a wooden board with purse-seine corks laced to the top. This structure functioned as the surface-platform. Black nylon 4.25" mesh purse-seine webbing, stretched as long as the board and hanging several meters deep was connected to the bottom of the surface-platform with net twine. The hanging net webbing created a curtain-like structure in the water. Skipper B believed the hanging webbing attracted fish to FADs. The net webbing could be rolled up around the surface-platform when the FAD was recovered for easy storage and subsequent deployment. Sometimes a plastic, 55-gallon drum filled with discarded fish (from previous sets) was connected to one end of the surface-platform. A SELCALL radio-buoy was attached to the bucket of bait or directly to the surface-platform with a section of nylon line. These radio-buoys can be electronically interrogated and located from the purse-seine vessel or its helicopter. Drifting FADs were deployed within a few miles of each other in areas where "signs"[4] of tuna were detected from the ship or by the ship's helicopter. Skipper B uses the helicopter to check each of his FADs at first light to determine if any have accumulated enough tuna to justify making a set.

DOLPHIN-SAFE QUESTIONNAIRE

A questionnaire was created during 1993 (Appendix 2) in an attempt to seek advice, invite counsel, and offer the opportunity to critique existing and proposed methods to catch large yellowfin tuna without encircling dolphins by experienced tuna fishermen and industry leaders.

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[3] Use of product name does not imply endorsement by the National Marine Fisheries Service.

[4] "Fish signs" are visual cues such as jumping, and breezing tuna, an abundance of seabird feeding behavior, and/or current fronts indicated by drift lines of debris.

The questionnaire was distributed to tuna skippers who attended the IATTC Organizational Meeting of the Scientific Advisory Board in San Diego, California during April of 1993. An additional 85 copies of the questionnaire were mailed to vessel owners and currently active and retired tuna fishermen during mid-1994. The responses are summarized later in this report.

SKIPPER A's FADs:

Drifting FADs: Construction and Deployment

Drifting FADs (Fig. 1) were constructed out of inexpensive materials stored aboard the ship (old net webbing and net twine, used purse-seine corks and floats) or purchased in Manta, Ecuador (bamboo poles). The surface-platforms were square rafts made from bamboo poles that were approximately 15' long and 4-6" in diameter. A 10 fathom wide section of net webbing hanging 10 fathoms deep was suspended with net twine to the middle of the bamboo raft and weighted with 1/2" chain. The net webbing was permeated with "fish solubles" (a sludge by-product produced when fish meal is rendered into fish oil which has no economic value to fish meal processors) prior to deployment. Stephenson stored the sludge in 55-gallon drums and soaked net webbing used to construct FADs in the drums for several weeks. The webbing slowly released the sediments into the water forming a slick he believed attracted fish to his FADs.

Stephenson made 35 deployments of drifting FADs between 2/2/93 and 3/13/93 in an area bounded by 4-11° S latitude and 81-83° W longitude (Fig. 2). The FADs were deployed on different dates in six groups consisting of six to nine FADs each (Table 2a). The FADs in each group were deployed approximately five miles from each other in a circular or linear pattern around a central FAD equipped with a SELCALL radio-buoy (Fig. 3). Each FAD had a numbered red flag tied to the bamboo raft. These deployment patterns permitted Stephenson to use only one rather expensive radio-buoy costing from $900 to $1,500 each to locate several FADs. Stephenson deployed six groups of drifting FADs, but only collected data from the first five groups he deployed. The sixth group was abandoned 60 hours after deployment. When Stephenson moved to a new fishing area he would retrieve the SELCALL radio-buoys and either recover or abandon the bamboo surface-platforms.

FADs in Group No.3 were deployed approximately 60 nautical miles (nm) northwest of Group No.2. FAD Groups 1, 4, 5, and 6 were deployed approximately 420 nm NNW, 240 nm NNW, 300 nm NNW, and 420 nm NW of the FADs in Group 2 respectively. Surface water temperature recorded by Stephenson in the deployment area for Groups 1-3 ranged from 78-81° F and his estimation of turbidity ranged from "clear to slightly green." The water temperature in the area where groups 4-6 were deployed ranged from 73.5 - 74° F and the water was reported as "dirty-green" in color.

Results

Stephenson made three sets on his Group 2 and Group 3 FADs during mid-February, 5 to 8 days after deployment, and loaded 225 tons of yellowfin and skipjack tuna (Table 2a) during these sets. This catch filled his vessel (~500 tons fish carrying capacity), and he headed to port to unload, leaving the Group 2 and Group 3 FADs to be fished by other vessels in the area. While heading to port, Stephenson deployed the Group 4 and Group 5 FADs in areas he thought might be productive when he returned. Unloading delays forced Stephenson to remain in port for two weeks (February 20-March 2), during which time he received regular radio calls from fishermen at sea. Stephenson reported that at least three boats caught a total of 750 tons of tuna in association with his Group 2 Fads and at least six boats caught 1,490 tons of tuna off his Group 3 FADS (Table 2b). Although the tonnages, exact dates, and number of sets were not provided by Stephenson, we confirmed that a large amount of tuna were caught on FADs in the area and period Stephenson reported (IATTC, Rick Lindsay pers. comun., March 1996). Stevenson deployed his Group 6 FADs after leaving port on March 2 and proceeded to locate his Group 4 and Group 5 FADs, which had drifted approximately 125 miles west during the two weeks he was in port. Not finding any fish signs in the area, he retrieved these latter FADs and headed north to search for other productive areas.

All of Stephenson's FADs were essentially identical in design and deployed within approximately 30 days of each other. Stephenson believed that the location of FADs was more important than the appearance of the FAD. The most obvious difference between Stephenson's six "Groups" of FADs was the areas they were deployed (Fig. 3). Differences in surface temperature and water clarity imply that each area exhibited different oceanographic characteristics. These differences suggest that certain areas had higher primary productivity and were possibly more favorable tuna habitat.

Anchored FADs: Construction and Deployment

Captain Stephenson constructed and deployed two anchored FADs in the Gulf of Panama during April and May of 1994. He was interested in determining whether small forage fish (bait) and tuna were capable of maintaining a stable position near a FAD that was anchored in a strong current (> 2 kts), and how the fish oriented themselves to the FAD in relation to the current. Stephenson used the same inexpensive materials to construct the surface-platforms that were used for his drifting FADs (Fig. 4).

Results

One of Stephenson's anchored FADs was deployed on 4/21/94 at 7°46' N and 79°07' W. A second anchored FAD was deployed on 5/19/94 at 7°44' N and 79°00' W. The anchored FAD deployed first remained in position for approximately two weeks until it was cut loose by another tuna vessel during a set. Stephenson reported that this other vessel captured 30 tons of mixed yellowfin and skipjack tuna off the anchored FAD, but did not provide the vessel's name. The second FAD accumulated a very large quantity (estimated > 1,000 tons) of bullet mackerel, *Auxis rochei,* and black skipjack tuna, *Euthynnus lineatus,* which have low commercial value and are not sought by tuna purse-seine operators. No sets were made on this FAD. Stephenson noted that bait accumulated upcurrent of both FADs regardless of the prevailing wind direction. He reported that there were very little school fish and log fish being caught in early 1994 north of the equator and felt that this was why the anchored FADs did not accumulate tuna. Captain Stephenson reported that, during 1995, he planned to investigate the practicality and productivity of using anchored-FADs in the coastal and offshore areas of Central America or the southern equatorial waters in which his drifting FADs were effective during 1994.

SKIPPER B's DRIFTING FADs: TRIP 1

Construction and Deployment: Phases 1- 3

Trip No. 1 logbook information documented fishing efforts made in association with ship-built FADs from 6/6/93 through 9/4/93 (Fig.2). Drifting FADs were deployed in three phases during this fishing trip (Fig. 5). Phase 1 FADs were deployed from 6/10/93 - 6/22/93. Fishing effort and catch made in association with these FADs are shown in Table 3. Three Phase 1 FAD surface-platforms were constructed from wooden beams with 7-10 purse-seine corks attached to increase buoyancy, and the other FAD's surface-platform was fabricated from floating nylon line bundled into a raft (Fig. 6). Each surface-platform had a section of black 4.25" stretched-mesh webbing lashed to it that hung 10-15 fathoms below the FAD. Three FADs had 55-gallon buckets of bait tied to the surface-platform. Every FAD deployed by Skipper B was equipped with a SELCALL radio-buoy.

Phase 2 consisted of five individual FAD deployments on 7/11/93 (FAD2, FAD5, FAD6, FAD7, FAD8). FAD2's design was described in the Phase 1 deployments. FAD5 and FAD6 had the same dimensions and were constructed out of the same materials as FAD3 described in the Phase 1 deployments. The remaining two FADs in this group (FADs 7 and 8) were described in Figure 5.

Phase 3 involved the deployment of seven FADs on 9/4/93. These FADs were deployed after the ship had filled the fish wells and was headed to port to unload the catch. Skipper B observed "signs" that tuna were in the area he was traveling through on 9/4/93 so he planted some FADS and hoped they would aggregate tuna while he unloaded the catch. FADs deployed on 9/4/93 were not visited until the vessel returned to the fishing grounds on 9/23/93 (Trip 2). FAD1 and FAD2 were each described in the Phase 1 deployments. FAD9's surface-platform was assembled from discarded gillnet and longline fishing gear. Three spherical glass "longline" floats were lashed to a bundle of old tangled gillnet webbing. A 15-foot line was attached to the floats and a SELCALL radio-buoy. A 55-gallon bait drum was tethered to this line approximately five feet from the FAD. FAD10 and FAD15 had analogous designs. Their surface-platforms were made of wooden beams with purse-seine corks tied to the top, and net webbing suspended below. FAD11 was fabricated from several different colored floating ropes that were weaved between two 4"x4"x6' wooden beams. A cork was lashed to each end of these boards to enhance buoyancy. A 15-foot long nylon line was tied to a 4x4 and attached to the SELCALL radio-buoy and a plastic, 55-gallon bucket of bait was tethered five feet from the surface float on the radio-buoy line.

Results

FAD1 was visited ten days following deployment and there were no yellowfin tuna within 5 miles of the FAD. The skipper reported two non-yellowfin tuna schools, one estimated to be 2-3 tons of skipjack tuna, within 0.5 miles of the FAD. The other was estimated to be 7-10 tons of skipjack tuna within 2-5 miles of the FAD. An additional two schools of 3-4, and 10-12 tons of bigeye tuna, *Thunnus obesus,* were reported within 0.5 and 2-5 miles of the FAD, respectively. A set was made approximately 2.25 miles from FAD1 which yielded 10 tons of 2.3 - 3.4 kg bigeye tuna.

FAD 2 was visited on two occasions (21-22 days) following the Phase 1 deployments. The ship's side-scanning sonar indicated a 15-20 ton school of bigeye tuna located 15 - 20 fathoms deep. The weather was too rough to make a set so the ship drifted next to the FAD overnight. The following day the side-scan sonar indicated a 20-25 ton school of fish located 15-20 fathoms below the FAD but sea conditions were unsuitable to perform fishing operations. The captain decided to move to a location north of where the Phase 1 FADs had been deployed to take advantage of good fishing being reported there so FAD2 was recovered. FAD2 was visited 11 days after its Phase 2 deployment and "good fish signs" were reported within 0.5 miles of the FAD. A set was made during this visit and about 1/4 ton of 2.7 - 3.6 kg yellowfin tuna was captured.

FAD3 was visited 10 days after its Phase 1 deployment. The vessel made a set on this FAD and twelve 20.4 - 22.7 kg yellowfin tuna were caught. FAD4 was visited three times following its Phase 1 deployment. On the third visit that occurred eight days following its deployment, a school of ten tons of bigeye tuna was reported within 0.5 miles of the FAD. The vessel set and one ton of skipjack and 15 tons of bigeye tuna were caught. FAD5 was visited 41 days following its Phase 2 deployment. "Good fish signs" were reported within 0.5 miles of the FAD, a set was made, and approximately 1/2 a ton of 1.8 - 2.7 kg yellowfin and 1/4 ton of skipjack tuna were caught.

SKIPPER B's DRIFTING FADs: TRIP 2

Construction and Deployment: Phases 4- 5

The logbook information for Trip No. 2 documented fishing effort made in association with ship-built FADs from 9/23/93 through 10/23/93 (Fig. 2). Drifting FADs were deployed in two phases during this trip (Fig. 5). Fishing effort and catch made in association with these FADs are shown in

Table 4. Seven FADs (FAD1, FAD2, FAD9, FAD10, FAD11, FAD15, FAD16) were deployed on 9/4/93 at the end of Trip 1 (Phase 3) and were described during Trip 1 (Fig. 6). These FADs were recovered and redeployed at an unknown date(s) which were designated as the Phase 4 deployments. The authors estimate these deployments occurred sometime between 10/10/93 and 10/15/93. Since the dates of deployments for these FADs were not documented, the values representing the number of days in the water for FADs visited after 10/10/93 were estimated.

Three FADs were deployed during Phase 5 on 10/22/93 (FAD12, FAD13, FAD14). FAD12's surface-platform was made out of a 4"x4"x10' wooden beam with seven purse-seine corks tied to the top with net twine. FAD13's surface-platform consisted of two 2"x4"x12' wooden beams tied together with net twine and ten purse-seine corks tied to the top of the board.. A section of net webbing was fastened to the bottom of each of their surface-platforms and dangled six fathoms below. Each of these FADs had a SELCALL radio and a 55-gallon bucket attached which was filled with bait.

Results

FAD1 was visited seven-to-twelve days after the Phase 4 deployment. The skipper reported an estimated 50-60 ton school of yellowfin, 50-60 ton school of skipjack, and at least a 300 ton school of bigeye tuna within 0.5 miles of the FAD prior to making a set. Two sets were made on this FAD on the same day. The FAD was not encircled during the first set because there were more tons of tuna associated with the FAD than needed to fill the vessel's remaining empty fish wells. An estimated 10-15 tons of yellowfin (weight not reported), five tons of 4.5 - 6.8 kg skipjack, and 20 tons of > 9.1 kg bigeye tuna were captured. A second set was made that encircled the FAD and resulted in the capture of more tuna than was necessary to fill the remaining wells. There was so much tuna captured in the seine that the captain ordered the deckboss to "cut some purse-cable rings" to release the surplus tuna. Cutting purse-cable rings created an opening in the seine below the purse-cable davits where the rings were secured after the net was pursed. The skipper, from his vantage point in the crows nest, watched as tuna escaped through the opening. He estimated between 150 - 200 tons of tuna were released before he ordered the opening to be closed. Fifteen tons of 4.5 - 6.8 kg skipjack and 140 tons of 18.1 - 27.2 kg bigeye tuna were loaded (Table 4). He estimated 50-60 tons of tuna remained in the sack after the fish wells were full. There were no other purse-seiners in the area so the excess tuna was dumped by releasing the seines bow ortza[5].

FAD2 was visited 35 days after its Phase 3 deployment. A set ensued that captured three tons of 3.4 - 9.1 kg and 17 tons of > 9.1 kg lb yellowfin plus 17 tons of 4.5 - 5.4 kg skipjack tuna. FAD9 was visited 36 days following its Phase 3 deployment and a set was made that captured a 30 ton school

[5] A stainless steel triangle to which the end of the net is attached. A typical tuna purse-seine tapers up gradually from its maximum depth (generally 12-18 strips [each strip is approximately 6 fathoms]) to the ortzas. The bow ortza is located at the end of the net rolled aboard last, so if it is released the sack opens and fish in the sack are dumped.

of 4.5 - 6.8 kg skipjack tuna. FAD10 was visited on 10/11/93, "good fish signs" were observed, and a set was made. The resulting catch included one ton of 1.8 - 3.2 kg yellowfin, 99 tons of 4.5 - 6.8 kg skipjack, and 20 tons of 22.7 - 31.8 kg bigeye tuna. This FAD was visited again on 10/15/93 and a set was made. A 25 ton school of 6.8 - 9.1 kg skipjack tuna was captured.

FAD15 was visited twice on 10/21/93. "Good fish signs" were reported within 0.5 miles of the FAD and two sets were made during the visit. The catch from the first set included 20 tons of 1.8 - 3.2 kg yellowfin, 30 tons of 6.8 - 9.1 kg skipjack, and 100 tons of bigeye tuna. The skipper noted in the logbook that there was a strong surface current that caused the fish to ball up at one end of the net. The combination of the strong current and several hundred tons of swirling tuna concentrated at one end of the net caused the corkline to sink and spilled an estimated 100 tons of tuna. The second set produced five tons of 1.8 - 3.2 kg yellowfin, 10 tons of 6.8 - 9.1 kg skipjack, and 10 tons of 27.2 - 36.3 kg bigeye tuna. FAD16 was visited on 10/22/93 as the ship headed to port to unload. The skipper reported seeing a school estimated to be over 400 tons of yellowfin, skipjack, and bigeye tuna within 0.5 miles of this FAD. This FAD's position was provided to another vessel.

Effort and Catch Summary

Skipper B documented 17 drifting FAD deployments between 6/10/93 and 9/4/93 (Trip 1), seven of which were made after the ship had filled its wells and was headed to port to unload. The ship made 13 visits including five sets on these FADs (Table 3). These FADs produced a total catch of one ton of yellowfin , 1.25 tons of skipjack, and 25 tons of bigeye tuna during Trip 1 (Table 5).

Skipper B recorded the deployment of three drifting FADs during his second trip (Trip 2). However, FAD positions from his logbook imply that several FADs were recovered and redeployed in the middle of the trip (Phase 4 deployments) and not recorded in the logbook. This assumption was based on the fact the FADs could not have traveled (via surface currents alone) the distances recorded between deployment position and set positions during the time period represented in the logbook data (Fig. 5). The logbook documented 14 visits to FADs that included eight sets during Trip 2. The resulting sets on FADs produced a total catch of 677 tons of tuna. The catch consisted of 56 tons of yellowfin with a mean value of seven tons per set, 231 tons of skipjack with a mean value of 28.9 tons per set, and 390 tons of bigeye tuna with a mean value of 48.8 tons per set (Table 5). Sets made on FADs filled approximately half of this vessels carrying capacity of 1,400 tons. It is significant that during one set the skipper estimated 150 - 200 tons of tuna were deliberately released by "cutting purse-rings" and an additional 50 tons of tuna were dumped from the sack because the ship inadvertently captured more fish than was needed to fill its holds. The skipper also observed over 400 tons of tuna within 0.5 miles of FAD16 when he visited this FAD on the way to port to unload a full boat.

FLOTSAM INFORMATION RECORD (FIR) DATA

Anecdotal evidence received via conversations with fishermen and debriefing NMFS observers at SWFSC indicate that several of the vessels in Skipper B's code group made sets on his FADs after he departed to unload his catch. This prompted interest in examining the IATTC Flotsam Information Records (FIR) database for fishing vessels operating at the same time and in the same general area as Skipper A and Skipper B. Examination of FIR data suggested the possibility of tracking sets made in association with each skipper's FADs while they were unloading their catch. The effort to track individual FADs met with limited success because of variability in the quantity of documentation of fishing effort associated with flotsam and FADs by observers, but it did show that FADs are used frequently and over a wide area by skippers in the US tuna purse-seine fleet (Fig. 8).

IATTC FIR data were reviewed for a specific set of nine cruises by U.S. purse-seine vessels. The FIRs were filled out by scientific technicians working for either the NMFS or the IATTC Tuna-Dolphin Observer Programs during trips aboard U.S. purse-seine vessels from October, 1993 into March, 1994. These data were reviewed because the vessels made sets on FADs in the time and region of the ETP where FADs were deployed by Skipper A, Skipper B, or were built and deployed by other fishermen. A summary of the visits and sets made on FADs by these vessels during the period are presented in Table 6.

Results

The FIR data from these nine fishing trips describe 94 visits which included 69 sets associated with FADs made by four purse-seine vessels (nine trips) during the time period October 24, 1993 to March 12, 1994 (Table 6). Sets associated with these FADs produced total catches of 2,601.5 tons of skipjack tuna with 312.5 tons discarded, 432 tons of yellowfin tuna with 36 tons discarded, and 1,743 tons of bigeye tuna with 69 tons discarded. The total combined catch for these sets was 4,210.5 tons of tuna with 417.5 tons discarded. In addition to the sets made on inexpensive FADs, three of the four vessels encountered anchored NOAA Atlas weather buoys in the area, and during four sets captured 144 tons of skipjack tuna and 602 tons of bigeye tuna, all of which was retained (0 tons discarded). Although the ships were also making sets on tuna associated with logs and schooling tuna, the data suggests that FAD-fishing was an important element of fishing strategy for all of these vessels.

DOLPHIN-SAFE QUESTIONNAIRE

We created a questionnaire and sent copies to currently active and retired tuna fishermen in an attempt to solicit advice, stimulate suggestions, and offer critiques of existing and proposed methods to catch mature yellowfin tuna without encircling dolphins (Appendix 2). We inquired about the types of support NMFS/IATTC could provide fishermen in terms of equipment, gear research projects, and data that would assist the industry to develop "Dolphin-Safe" fishing techniques. Several questionnaires were distributed to tuna purse-seine skippers who attended the IATTC Organizational Meeting of the Scientific Advisory Board in San Diego in April of 1993, and 85 copies were mailed to tuna vessel owners and skippers in the U.S. and Mexican fleets on June 20, 1994. We have received responses from six fishing captains to date.

Results

The six respondents to the Dolphin-Safe Questionnaire had differing opinions about almost all of the questions asked. Concerning the effect of seasons on log fishing their responses varied from: (1) there were no seasons for logfishing (logfishing is good all year long but some areas are inaccessible because of prevailing weather conditions), to (2) there are seasons for specific areas such as April - May for the Gulf of Panama, October - January for Central American waters, and October - December for Peruvian and Ecuadorian waters. The "best" areas to fish logs were listed as coastal waters of Costa Rica, Colombia, Peru and Ecuador, the Gulf of Tehuantepec, the Gulf of Fonseco, south and west of the Galapagos Islands, and west of the 110° W longitude between the 3° N and 3° S latitude if logs were available. Agreement was unanimous that schoolfish are most commonly found in coastal waters or around seamounts and banks. Schoolfish are found in the Gulf of Panama in April and May and then they tend to move north into Costa Rican and Mexican waters in May and June and can be found during most years from December to February in the Gulf of California and the Gulf of Tehuantepec.

The respondents agreed that 70-86° F, turbid or off color water located in an area with cyclical current fronts had the most favorable oceanographic conditions for logfishing. They were equally divided on their feelings about seamounts or banks enhancing logfishing areas. Some felt that seamounts or banks were more attractive to tuna than flotsam and thus made flotsam unproductive while others felt that areas around seamounts and banks were good for log fishing because they made the region richer biologically and would attract more fish to the area.

We were interested in the type of "signs" experienced fishermen look for when searching for logs and schoolfish. Various "fish signs" provide fishermen with cues that areas may be productive logfishing grounds. Seabirds such as frigate birds, storm petrels, and booby birds will direct fishermen towards flotsam and schools of jumping tuna can indicate there may be a larger biomass of tuna in the area. Although different species of forage fish are found around logs in different regions of the ETP, each of the skippers felt that the amount of bait found associated with flotsam was more important as an attractant than the kind of bait associated with the log. Most of the skippers interviewed indicated that they tie up to flotsam at night in order to use the ships' lights to attract more fish to the log. One interviewed skipper declared that he never ties up to logs at night because the lights from his ship attract bait and tuna to the seiner and this makes it difficult to set in the morning. Another skipper said he did not tie up to logs in areas with strong currents because in those conditions the vessel's faster drift would make the log drift too quickly and cause it to loose its bait and tuna.

Five of the six skippers felt that dead whales were the most "attractive" form of flotsam for larger schools of tuna. These were followed in level of effectiveness by trees and branches, old fishing gear, and man-made objects such as pallets, floating rope, and crates. Five felt that location of flotsam was more important than the composition of the flotsam in regard to producing large catches of tuna.

The sixth felt that the amount of time the log spent in the water "seasoning" and attracting a "log community" was the most important factor involved in the production of large catches associated with logs. All believed that "good logs" usually have subsurface structure that attracts bait and holds tuna.

Some of the skippers had deployed FADs in the ETP and others had not. The skippers that had deployed FADs believed that surface-platforms constructed from wooden pallets with plywood nailed to the top or bamboo rafts made the best surface-platforms. All felt that the most important element of FAD design was to hang some sort of material (net webbing, rope) several fathoms below the surface-platform to attract bait and tuna. The skippers were evenly split in their opinions about whether FADs deployed in traditional dolphin-fishing areas would be effective attracting large yellowfin tuna.

As to the types of research and support that NMFS/IATTC could provide, there is interest in development of FADs that are easily deployed, recovered, and stored aboard fishing vessels. One skipper stated his interest in deploying FADs in areas potentially rich in large yellowfin tuna if materials to build, or prefabricated FADs, were provided to him. Another thinks that FADs could be constructed from polyethylene foam which could be made into shapes that resemble whales or "balls of bait." He believed this type of FAD would be lightweight and simple to deploy and recover. One of the skippers stated that he had personally observed several thousand tons of large (> 9.1 kg) yellowfin tuna that were not associated with dolphins within the 200-mile limit of several coastal nations in Central and South America. He advocated reducing the 200-mile limit to 50 miles to provide coastal access to the international purse-seine fleet. The interviewed skippers, who continue to set on tuna associated with dolphins, would like to see continued improvements in purse-seine gear that help to further reduce incidental dolphin mortality associated with purse-seine fishing operations. All of the respondents were concerned about the future effects of log and FAD-fishing efforts on ETP tuna resources. They feel that the capture of small tuna and bycatch species that are commonly associated with logs may effect the health and future productivity of the ETP tuna fishery.

DISCUSSION

Drifting FADs were successfully utilized by both participating skippers (A and B) to catch tuna in the ETP (Tables 2- 5). Although Stephenson's (Skipper A) tuna catch associated with his Group 2 and Group 3 drifting FADs was limited to 225 tons in three sets before he headed to port to unload, the unverified (by us) reports he received from other fishermen after his departure indicate that these FAD-Groups were very productive with tuna catches by three vessels totaling 750 tons on Group 2 FADs and catches from six vessels totaling 1,490 tons on Group 3 FADs. Skipper B's fishing effort on FADs during his second trip was significantly more productive than the first trip. The total tuna catch associated with Trip 1 drifting FADs ranged from 0.25 to 16 tons per set with a mean value of 5.4 tons per set. The total tuna catch associated with drifting FADs during Trip 2 ranged from 30 - 190 tons per set with a mean value of 84.6 tons per set. Both skippers utilized a basic design for their drifting FADs that employed a surface-platform constructed entirely with buoyant materials. Each suspended net webbing or other available materials to their FADs' surface-platform that hangs below the water surface and is believed to attract fish. Both reported that location of deployment, ease of deployment, recovery, and storage of the units were more important than focusing an extraordinary effort on "gizmos" that make FADs "more attractive" to tuna. While more elaborate FAD designs have been used by these skippers, they believe the simpler designs using relatively inexpensive materials are equally effective and reduce their monetary losses associated with the disappearance, vandalism or piracy of unattended fishing gear.

Because each skipper's FADs were reasonably similar in design (Figs. 1 and 6), catch data should be similar for each FAD if there was not some other factor involved, such as a correlation between oceanographic conditions and catch. Determination of this relationship was well beyond the scope of this investigation. However, a cursory examination of logbook deployment and set position data, compared with the summaries of effort and catch, suggests the area fished played a more notable role than structural design of the FAD in terms of total tuna catch associated with these FADs. Skipper A loaded 40 tons of tuna during one set on a Group 2 FAD and 185 tons from two sets on Group 3 FADs, but he provided information which indicates that other fishermen captured 4,210.5 tons of tuna in association with these two FAD-Groups. No tuna were reported caught associated with any of his other groups of FADs. FADs fished by Skipper B during his second trip produced significantly more tuna than they did during the first trip. Some FADs, such as FAD1 and FAD2, were unproductive in one area during Trip 1 and productive in another area during Trip 2, which may suggest a temporal and/or a spatial effect on fishing success associated with FADs.

FADS were deployed in regions where skippers felt there were good fish signs. Most skippers base these decisions on detailed records of past fishing effort recorded on navigation charts, computers, and from information received on a daily basis at sea from other fishermen. Skippers will check an area for "signs of fish" prior to deploying FADs and when FADs are visited. Tuna observed jumping, creating a "shiner" (reflection off the side of a tuna), or a surface disturbance known as a "breezer" are regarded as good fish signs. Large numbers of seabirds, especially frigate birds, *Fregetta sp*., and booby birds, *Sula sp.*, flying above a log are generally a reliable clue that tuna may be in the area, as are large numbers of baitfish, dolphin fish, and sharks swimming near flotsam. These methods of assessment are effective at a very local level, but the ETP tuna fishing grounds encompass a huge area. Therefore, it would be desirable for fishermen to obtain larger scale assessments of oceanographic conditions and trends that could allow them to become more efficient and achieve higher productivity fishing FADs. It would be useful for fishermen working with FADs to have access to real-time global atmospheric and oceanographic information that would assist with their choice of fishing area during various times of the year. Data from satellites and remote sensing instruments that provide images of sea surface temperature, frontal zones, salinity, productivity, and possibly other oceanographic data would be highly valued by the industry.

FADs constructed and fished by fishermen who responded to our questionnaire tended to also be similar in design. They were all constructed from low cost or surplus materials that are commonly carried aboard ships, or found at sea. Each design included a simple surface-platform constructed from wooden boards, pallets, sheets of floating material, bundled and tangled line, or other discarded fishing gear. Corks or floats were attached to the surface-platform to enhance buoyancy. Most had net webbing or some other material attached to the surface-platform that hung a few to several fathoms below the surface. Skippers reported that the ease of deployment, recovery, and storage of the FADS were important to the safety of their crew.

These FADs were deployed in regions where skippers felt there were good fish signs. Selective calling radio-buoys were attached to FADs to insure that they could be relocated after deployment. SELCALL radio-buoys are expensive and their cost becomes a financial burden for companies that deploy a large number of drifting FADs. The cost can be offset in many cases by increasing the efficiency of the FAD-fishing operation. A skipper who has a helicopter and SELCALL-equipped FADs can deploy groups of FADs many miles apart, rapidly check each FAD during the morning, and choose the FAD with the most fish for a set. Finally, the importance of the ease of deployment and recovery of FADs cannot be understated. A FAD that can be easily deployed, retrieved, and stored is desirable because it saves time and is safer for crewmembers to use.

An informal inquiry was made concerning the possibility of an interrogation of the IATTC (FIR) data base for trips made by the international fleet of tuna purse-seine vessels operating in the same region and time as Skippers A and B. The purpose of this inquiry was to obtain a larger picture of how the international fleet fared on FADs in equatorial waters during this time period. Most of the requested data had not been entered into the data base and time constraints dictated that this data search could not be made for inclusion in this paper. If further interest in FAD-fishing is generated by this report, an analysis of the total tonnage and proportion of the international fleets catch made on FADs in equatorial waters during the northern winters between 1988 (the first year of "Dolphin-Safe" labeling of tuna) and the present, is suggested.

It is clear that FADS constructed of inexpensive materials can quickly aggregate large amounts of tuna as evidenced by the catch of 225 tons of tuna in 3 sets made by Skipper-A on drifting FADS within 5-8 days after deployment, and the 365 tons captured by Skipper-B during four sets made 6-12 days after deployment. While yellowfin and skipjack tuna weights varied greatly in the reported catches (1.8 - 22.7 kg), most of the reported bigeye tuna catch involved fish weighing more than 20 kg. Historically, annual bigeye tuna catches in the purse-seine fishery have been small, averaging 5,738 tons for the period 1979-1993 (IATTC 1995). However, during 1994 purse-seiners fishing on FADS captured 30,000 tons of bigeye tuna, primarily in the area bounded by latitudes 5N - 10S and longitudes 85W - 110W (IATTC 1995). Utilization of drifting FADS in areas generally categorized by fishermen as "dolphin-fishing areas" could potentially aggregate commercial quantities of the larger (>9.1 kg) tunas normally found in association with dolphins.

If FADs are going to be used effectively to eliminate some of the effort on tuna caught in association with dolphins, a means will be needed for determining which regions contain large biomasses of tuna at various times of the year. The area that makes up the traditional tuna purse-seine fishery in the ETP is vast. It is possible there are biologically rich areas that are underutilized because distance and weather constraints make it impossible for the tuna fleet to check all of the potentially good tuna habitat in a fishing year. The use of remote sensing technologies and satellite imagery has the potential to provide fishermen with a wider appraisal of the fishing grounds. It would be useful to determine whether unique regional and local variations in oceanographic conditions are detectable in the regions where FADs have been productive.

We contacted a NMFS oceanographer[6] (Paul Fiedler) and asked whether he had noted any seasonal characteristics or anomalies in the regions that Stephenson's and Skipper B's FADs were deployed that would have made these habitats more attractive to tuna than other areas within few hundred miles. Fiedler remarked that both skipper's FADs had been deployed in equatorial waters. He stated that these waters can be fished only during the northern winter because trade winds are too strong during the northern summer to operate fishing vessels safely along and south of the equator. The unpublished analysis of 1980-1990 large yellowfin catch data by Punsley and Fiedler (1994) suggests that the region south of the equator should produce high catch rates of tuna that are not associated with dolphins. Only a small part of the historical variability that leads to that conclusion can be explained by the environmental conditions (cool sea surface temperature, and a shallow but not very strong thermocline).

Data from the Climate Diagnostics Bulletins for November 1993 and February 1994 indicated that surface temperature, thermocline depth, and winds were all near normal in the areas that the FADs discussed above were deployed. Based on climatological data, the catches on FADs may not have been anomalous for those areas at that time of year and one might conclude that during this time of the year these regions could produce successful FAD-fishing on a regular basis. Other areas may be identified by examining data collected via satellite imagery, remote sensing, and by research vessels collecting oceanographic data. The catch data presented during this investigation indicates FADs were used successfully by some of the vessels in the ETP tuna purse-seine fleet in 1993 and 1994. The magnitude of success documented by these experienced captains was the result of many hours of trial and error to make their dolphin-safe fishing operations competitive and profitable. FAD-fishing has potential to supplement other forms of dolphin-safe fishing methods if it is supported by organized scientific and technological effort. Further investigations are warranted.

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[6]Paul Fiedler, Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. Pers. comun., October 1994.

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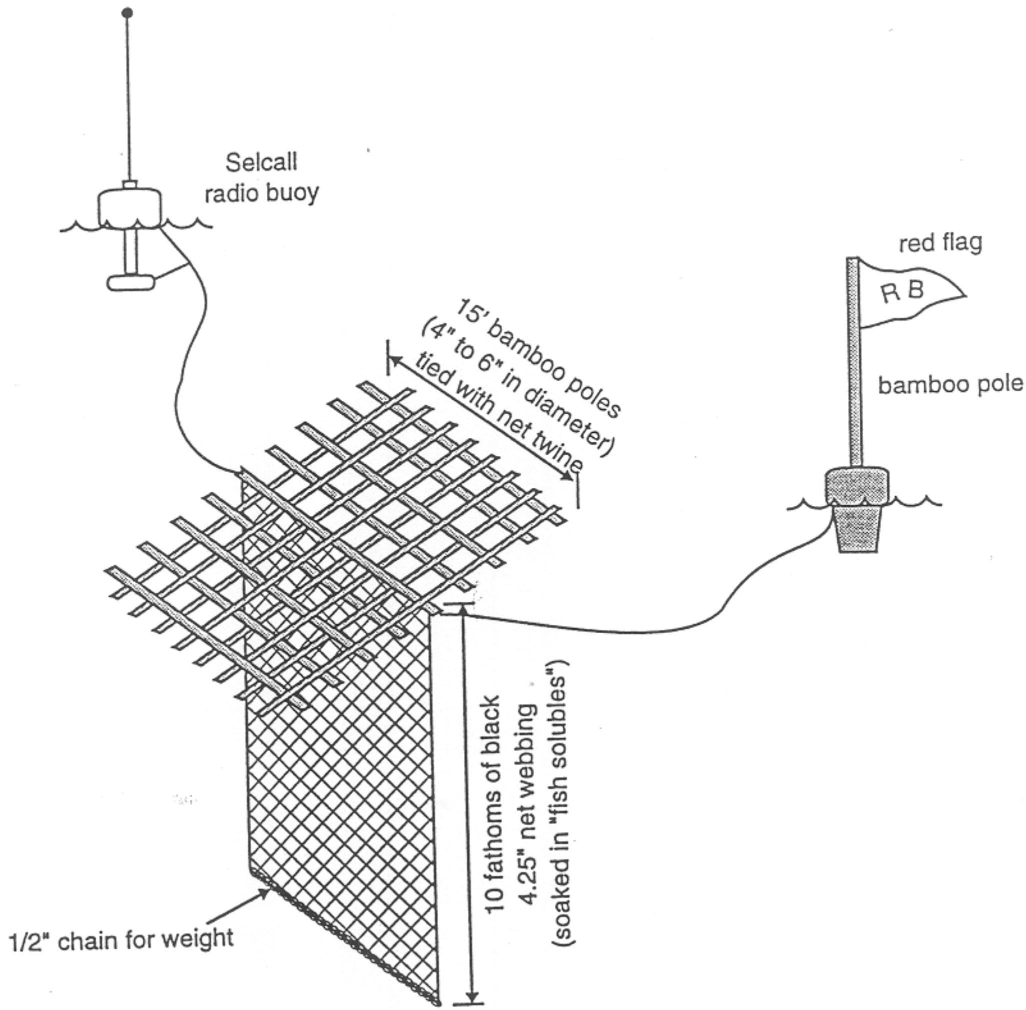
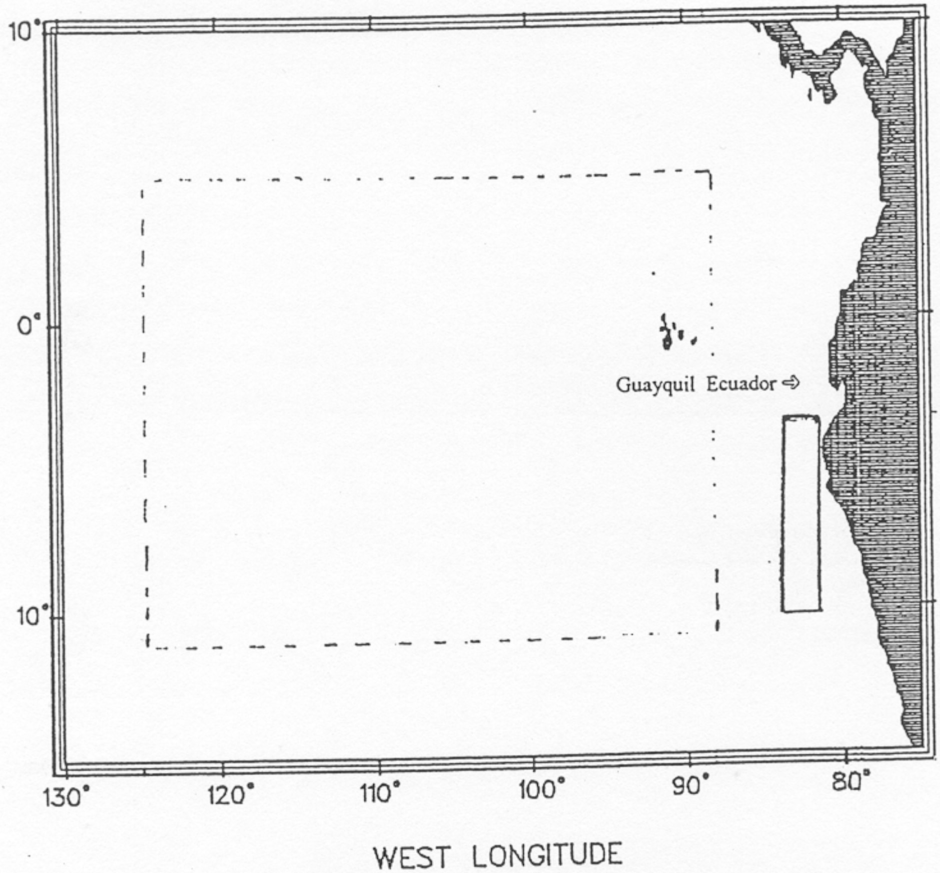


Figure 1. Skipper A's Drifting FAD Design



KEY

Skipper A ____________

Skipper B - - - - - - - - - - - -

Figure 2. Area of Operations.

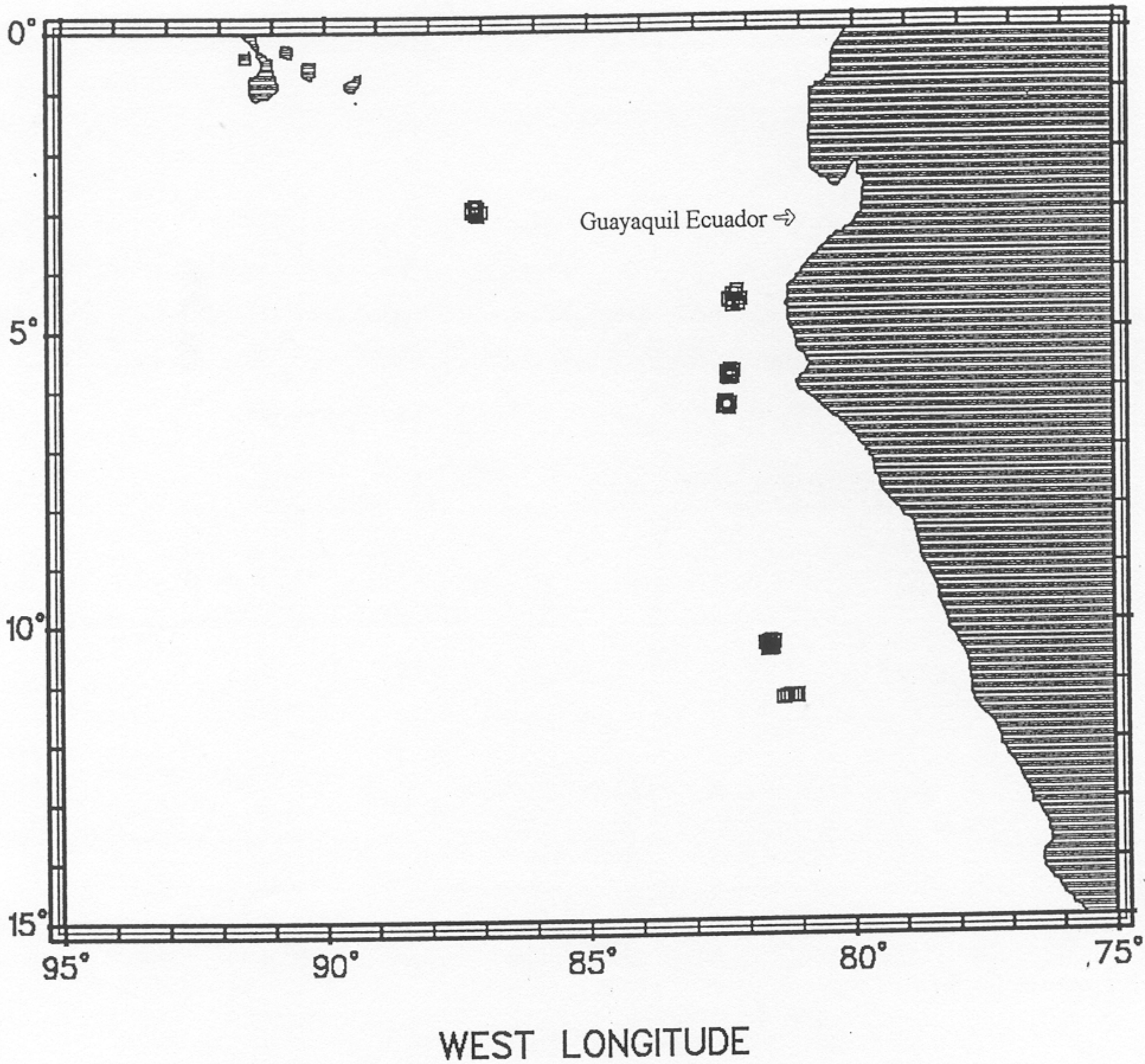


Figure 3. Plotted Positions of Skipper A's FAD Deployments (Groups 1-6)

Stevenson's Anchored FADs

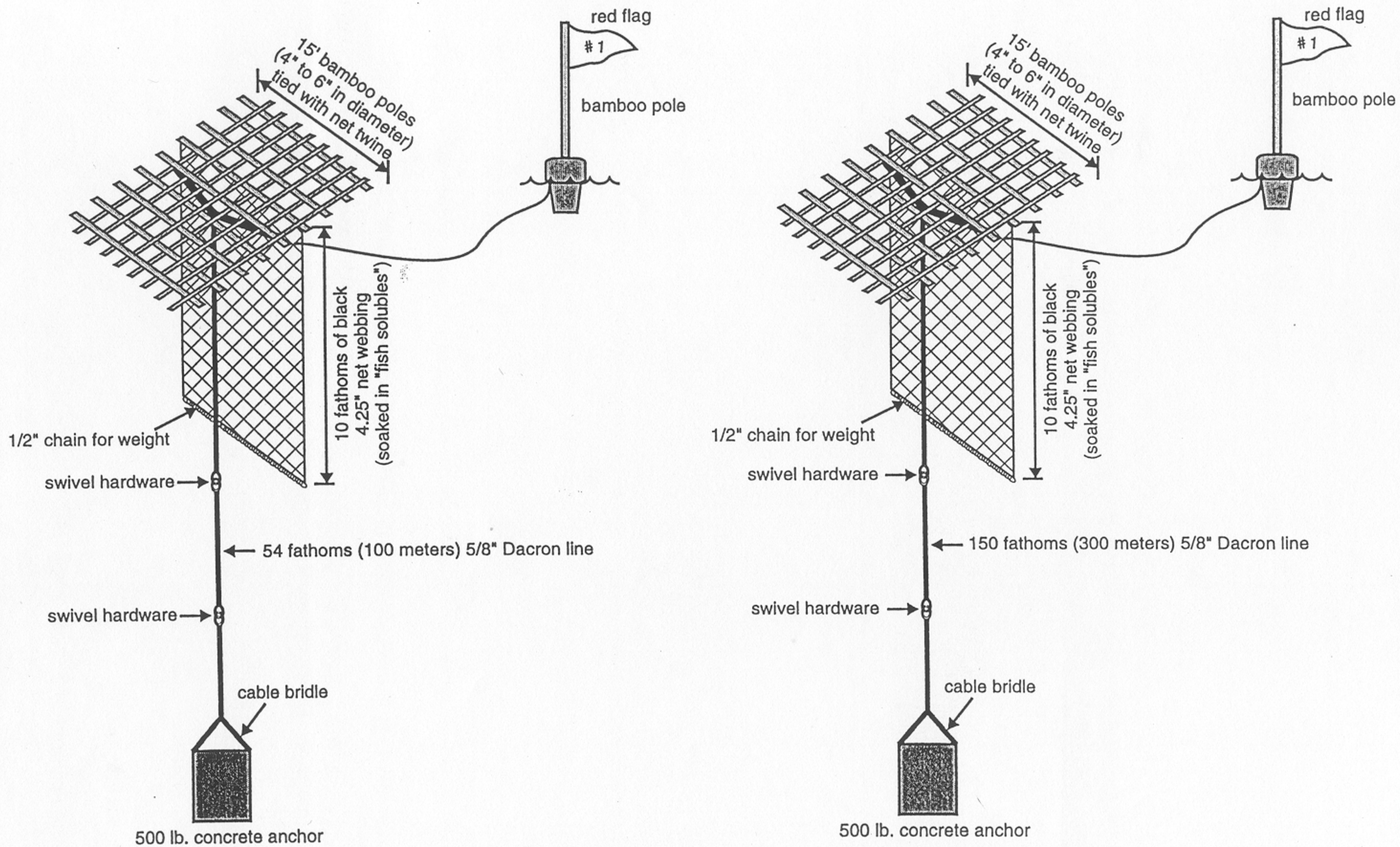


Figure 4. Skipper A's Anchored FAD Designs

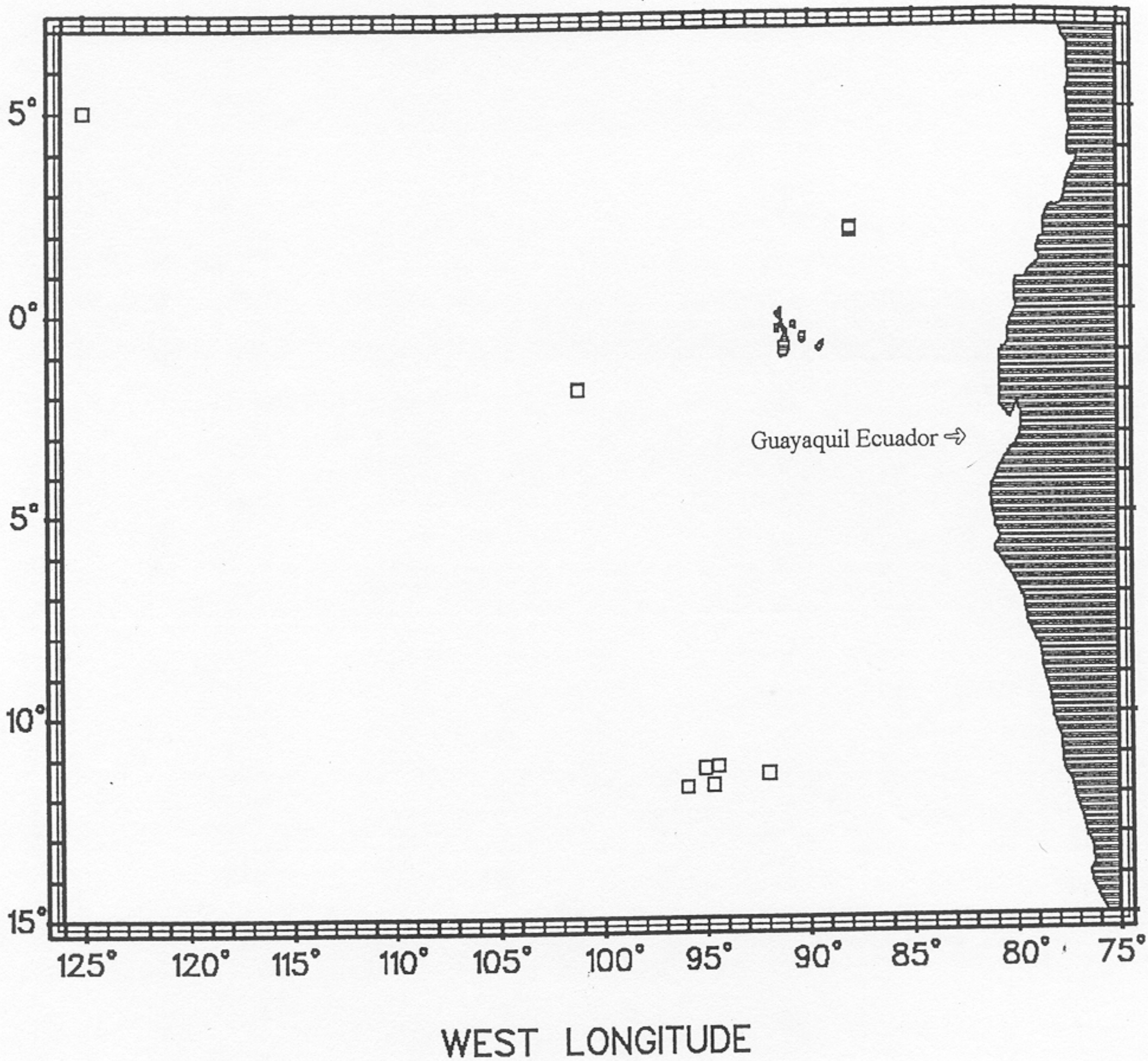


Figure 5. Plotted Positions of Skipper B's FADs

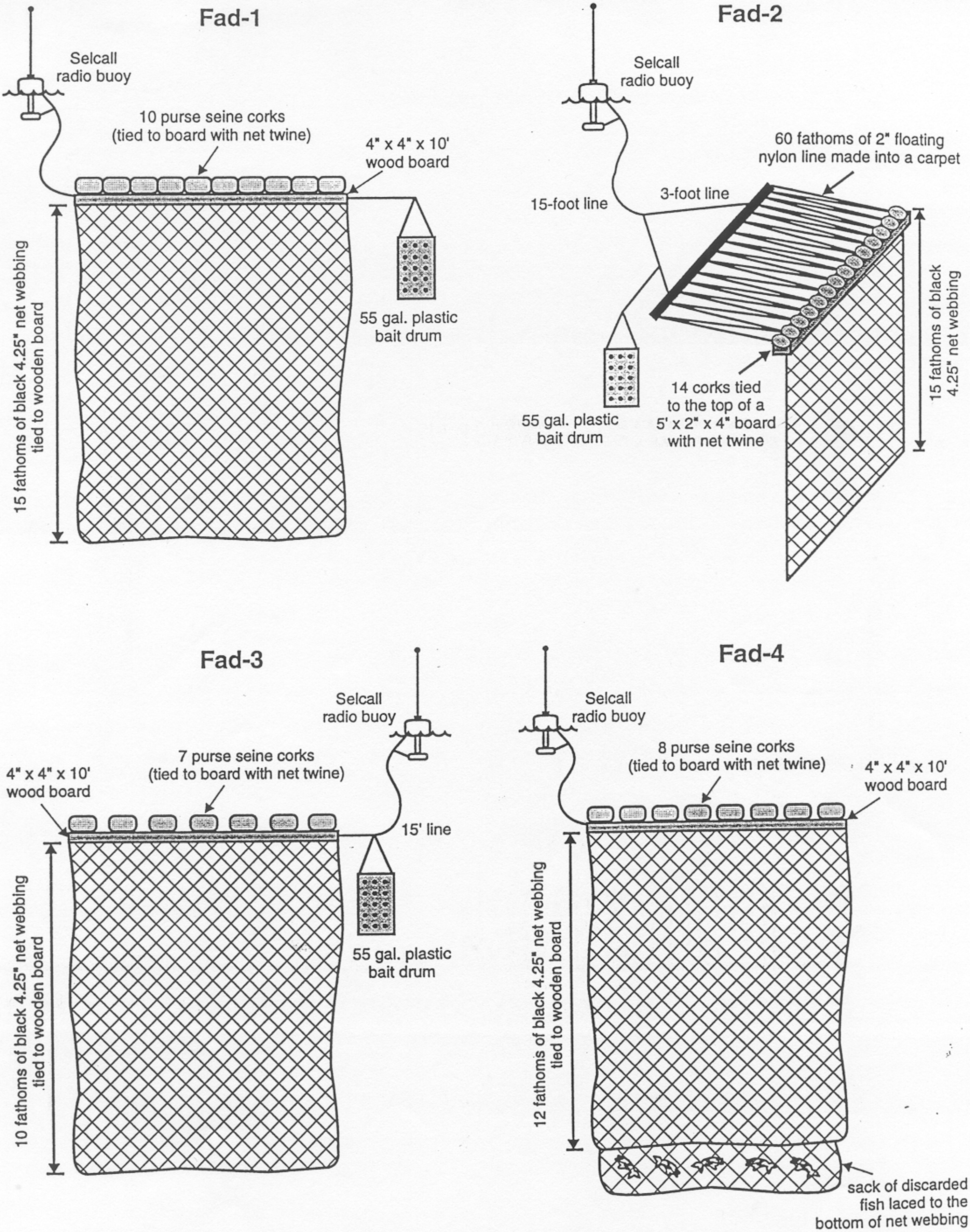


Figure 6. Skipper B's FAD Designs

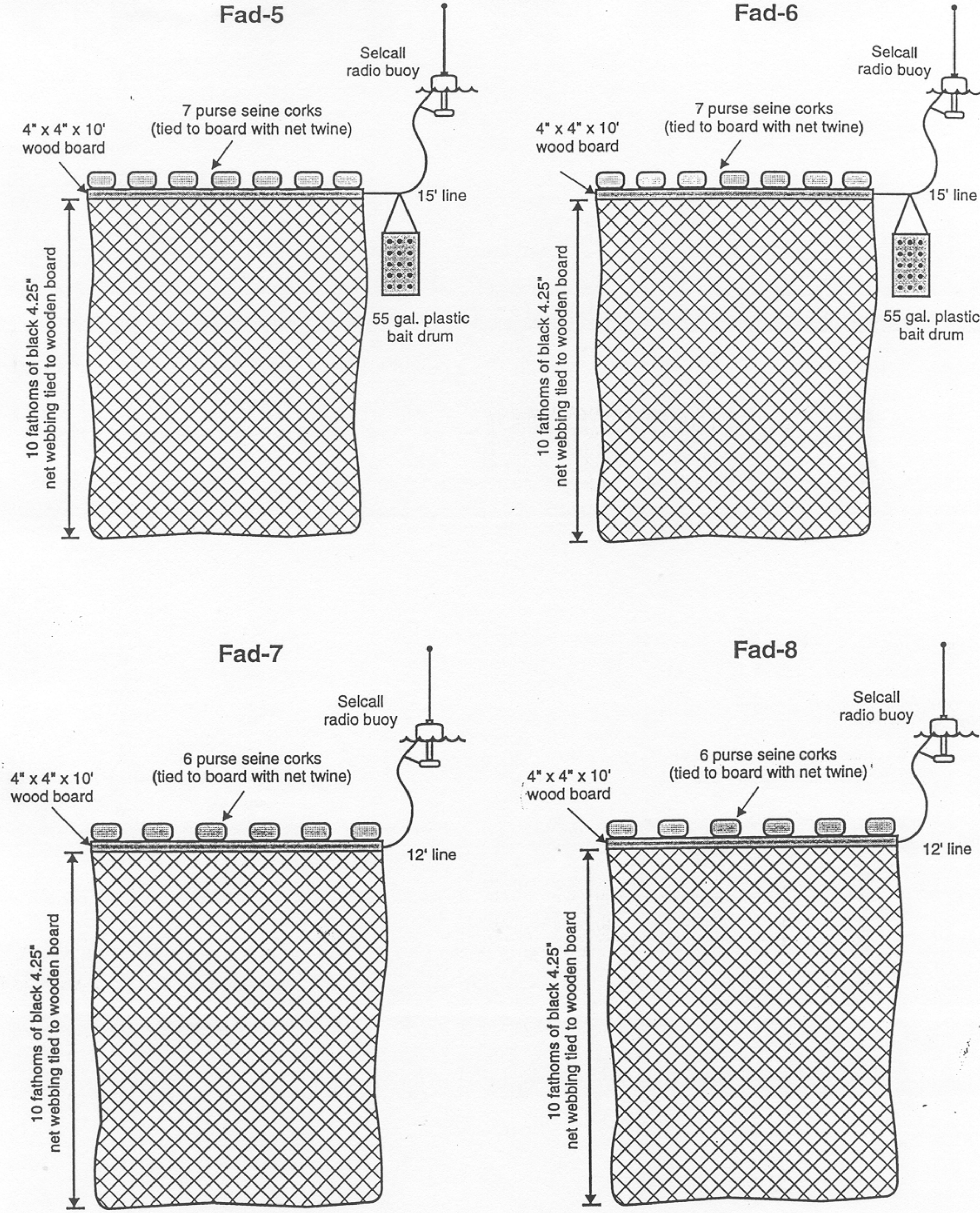
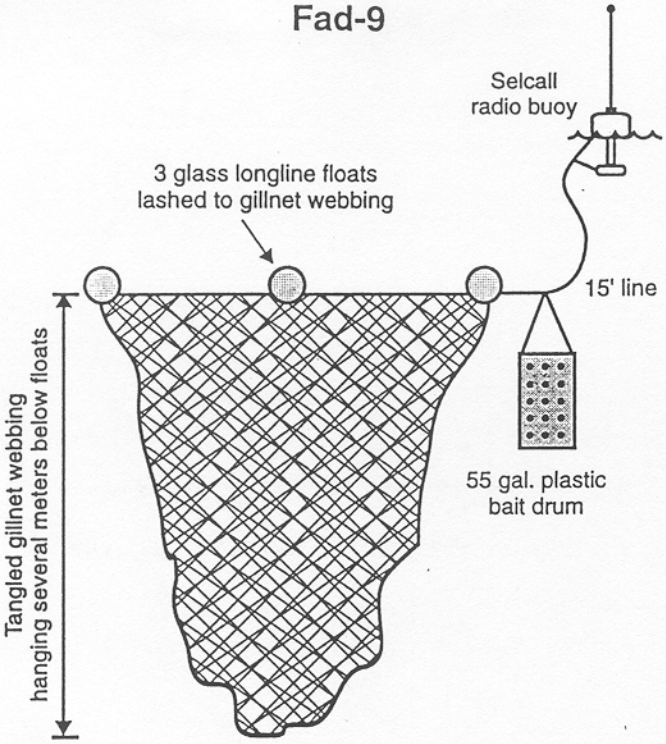
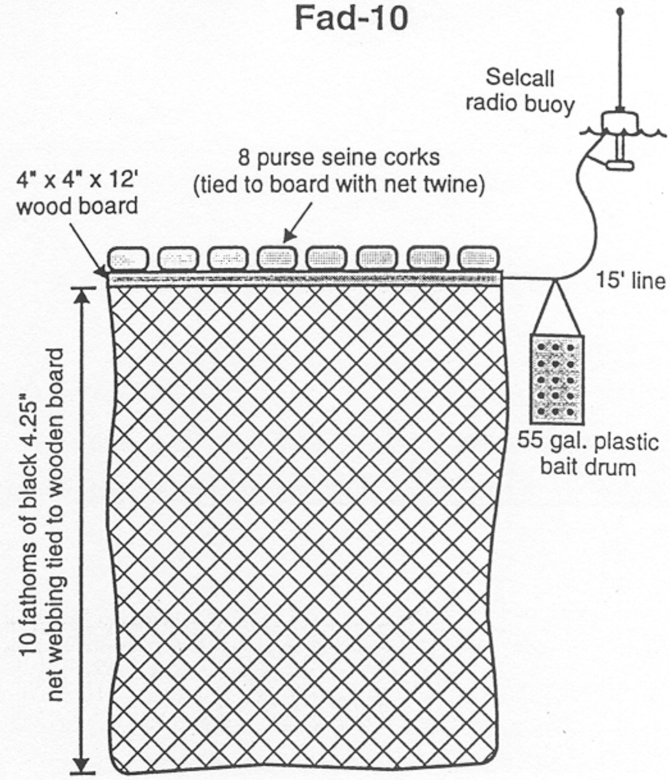


Figure 6. Skipper B's FAD Designs

Fad-9

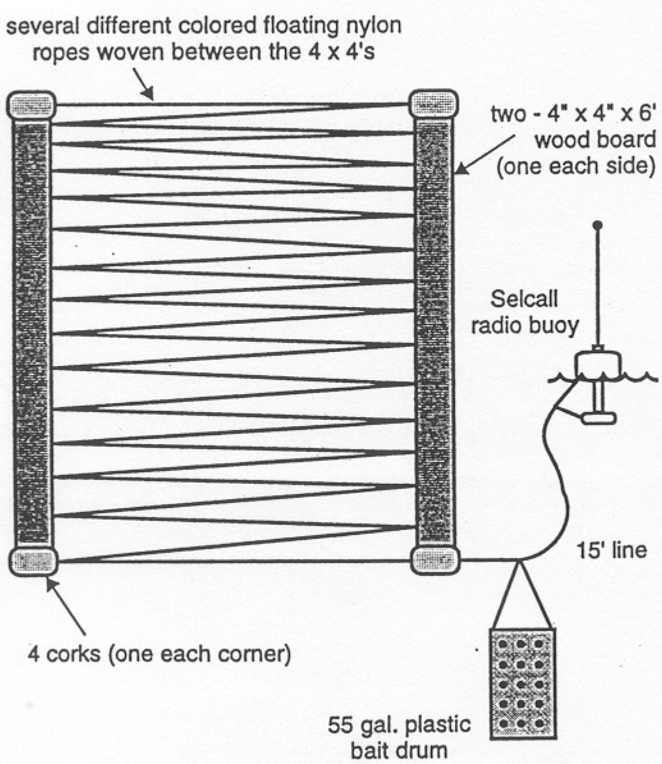


Fad-10



Fad-11

Surface platform, viewed from above



Fad-12

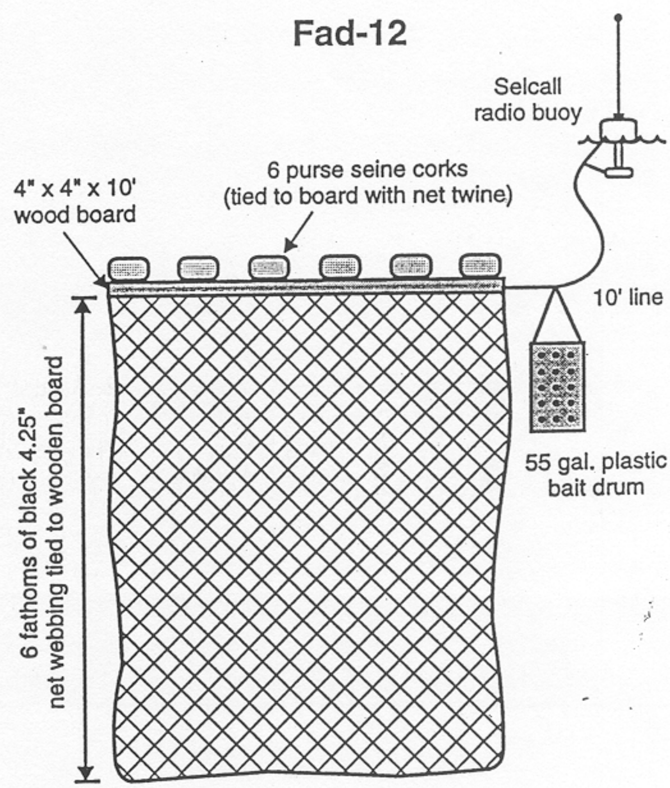
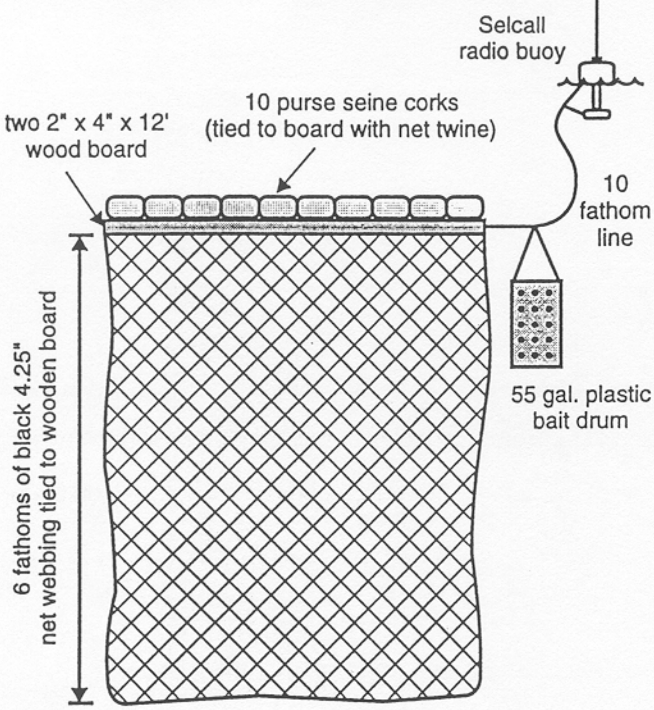


Figure 6. Skipper B's FAD Designs

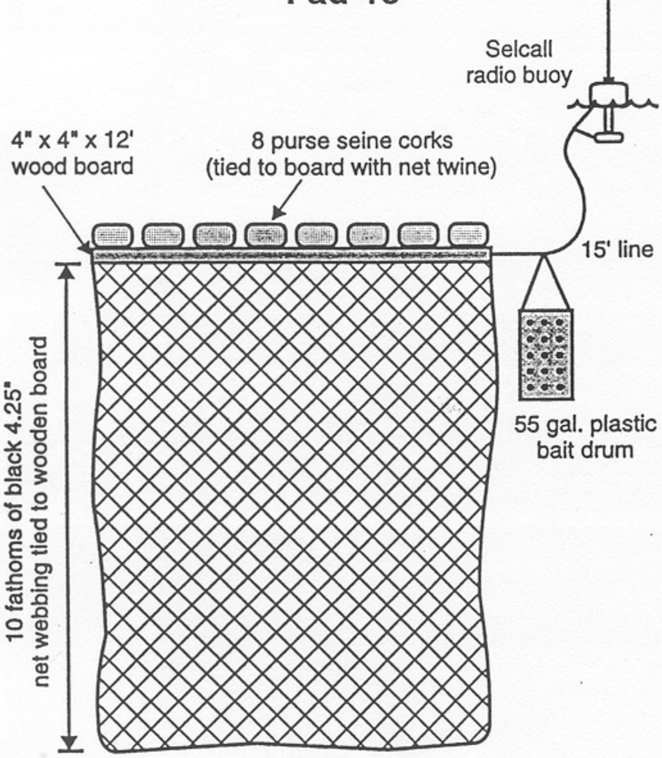
Fad-13



Fad-14

(No documentation on the construction of FAD-14 was provided

Fad-15



Fad-16

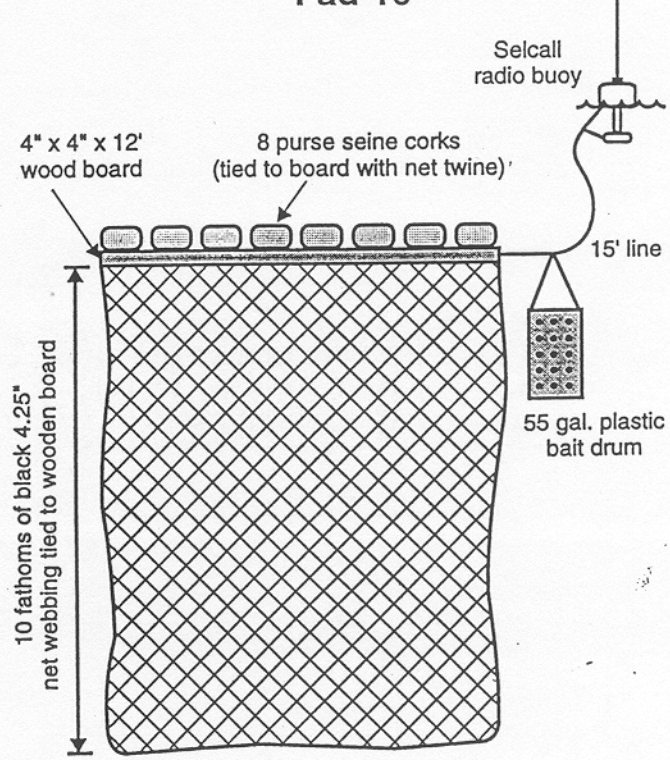


Figure 6. Skipper B's FAD Designs

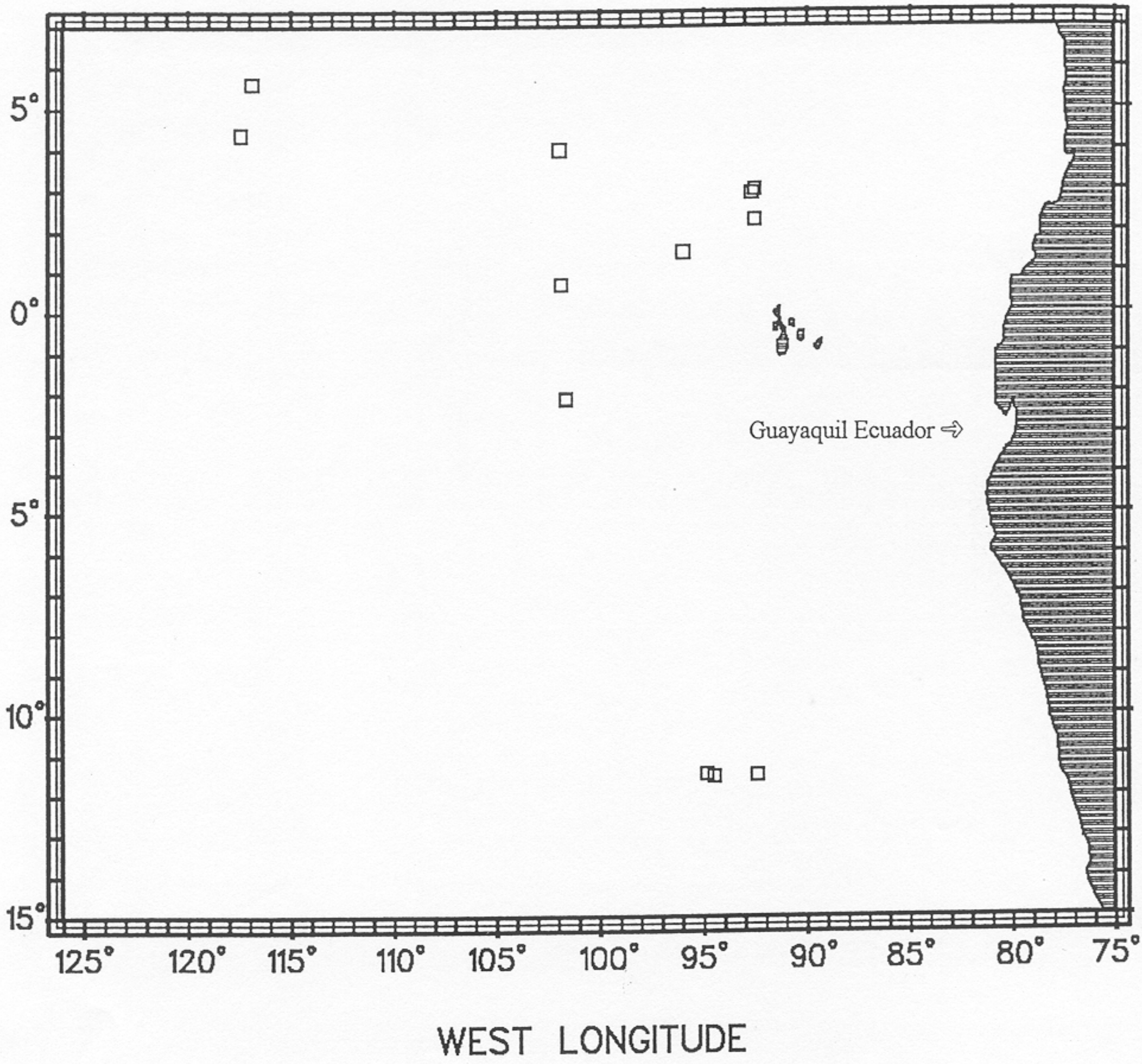


Figure 7. Plotted Positions of All Sets Made on Skipper B's Drifting FADs

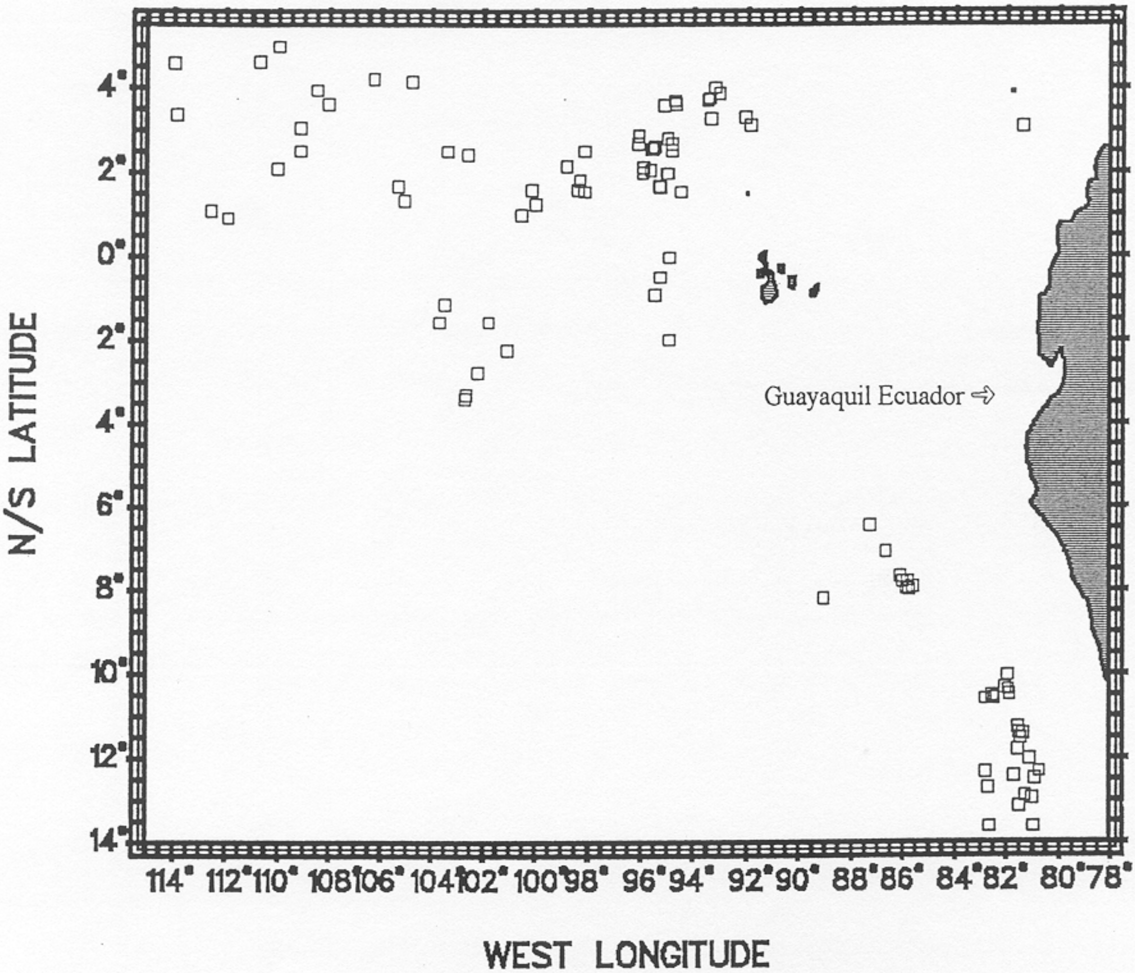


Figure 8. Plotted Positions of Sets and Visits associated with IATTC Flotsam Information Records October 24, 1993- March 12, 1994

Table 1. Length to weight relationship for yellowfin tuna in the eastern tropical Pacific. Values were calculated using equation 11: ln WEIGHT = a + b ln FORK LENGTH, and parameters for sexed and unsexed, inshore and offshore samples: a = -11.186; b = 3.086 (Wild 1986).

Fork Length (cm)	Weight (lbs)	Weight (kg)	Fork Length (cm)	Weight (lbs)	Weight (kg)
20	0.32	0.14	100	45.43	20.61
22	0.42	0.19	102	48.29	21.90
24	0.56	0.25	104	51.27	23.26
26	0.71	0.32	106	54.38	24.66
28	0.89	0.41	108	57.61	26.13
30	1.11	0.50	110	60.96	27.65
32	1.35	0.61	112	64.45	29.23
34	1.63	0.74	114	68.07	30.87
36	1.94	0.88	116	71.82	32.58
38	2.29	1.04	118	75.71	34.34
40	2.69	1.22	120	79.74	36.17
42	3.12	1.42	122	83.91	38.06
44	3.61	1.64	124	88.23	40.02
46	4.14	1.88	126	92.70	42.05
48	4.72	2.14	128	97.31	44.14
50	5.35	2.43	130	102.08	46.30
52	6.04	2.74	132	107.01	48.54
54	6.78	3.08	134	112.09	50.84
56	7.59	3.44	136	117.33	53.22
58	8.46	3.84	138	122.74	55.67
60	9.39	4.26	140	128.31	58.20
62	10.39	4.71	142	134.05	60.81
64	11.46	5.20	144	139.97	63.49
66	12.60	5.72	146	146.05	66.25
68	13.82	6.27	148	152.32	69.09
70	15.11	6.85	150	158.76	72.01
72	16.48	7.48	152	165.38	75.02
74	17.94	8.14	154	172.19	78.10
76	19.48	8.83	156	179.18	81.28
78	21.10	9.57	158	186.37	84.54
80	22.82	10.35	160	193.75	87.88
82	24.62	11.17	162	201.32	91.32
84	26.52	12.03	164	209.09	94.84
86	28.52	12.94	166	217.06	98.45
88	30.62	13.89	168	225.23	102.16
90	32.82	14.89	170	233.60	105.96
92	35.12	15.93			
94	37.53	17.02			
96	40.05	18.17			
98	42.68	19.36			

Table 2a. Skipper A's effort and tuna catch on Skipper A's FADs (2/02/94 - 3/15/94).

Group	**FAD ID**	**Date (yy/mm/dd)**	**(D)eploy. (S)et (R)etrieval**	**# Days**	**Total Catch (in Tons) YF**	**SJ**	**MIX**
1	1-7,RB	94/02/02	D	0	(FADs Stolen)		
2	8-11,RB	94/02/09	D	0	-	-	-
2	RB	94/02/16	S	7	15	25	-
3	12-17,38-39,RB	94/02/10	D	0	-	-	-
3	RB	94/02/17	S	7	-	-	160
3	RB	94/02/18	S	8	20	5	-
3	RB	94/02/19	R	9	-	-	-
4	9b,16b,19,20,14,RB	94/02/19	D	0	-	-	-
4	9b,14,16b,19,RB	94/03/07	R	16	-	-	-
5	17b,18,21-24,RB	94/02/19	D	0	-	-	-
5	17b,21,23,RB	94/03/07	R	16	-	-	-
6	9b,17b, 25-29,RB	94/03/13	D	0	-	-	-
6	RB	94/03/15	R	2	-	-	-

Table 2b. Unverified radio reports of tuna catch by other boats on Skipper A's FADs (2/14/94 - 2/25/94). Dates were provided by Skipper A from radio calls. The number of sets generating each reported catch is unknown.

Group	**FAD ID**	**Date (yy/mm/dd)**	**# Days**	**Total Catch (in Tons) YF**	**SJ**	**MIX**
2	9	94/02/14	5	100	-	-
2	10	94/02/15	6	-	-	250
2	11	94/02/16	7	-	-	400
3	12	94/02/18	8	-	-	190
3	15	94/02/19	9	275	-	-
3	RB	94/02/19	9	-	-	100
3	13	94/02/20	10	-	-	450
3	14	94/02/20	10	-	-	300
3	16	94/02/22	12	-	-	90
3	17	94/02/22	12	-	-	150
3	38	94/02/25	15	-	-	160
3	39	94/02/25	15	-	-	150
			Totals =	***375***	**-**	***2240***

Table 3. Fishing Effort and Total Tuna Catch made in association with Skipper B's Ship-Built FADs 6/6/93 - 9/4/93: (**TRIP 1**)

FAD ID	**Date (yy/mm/dd)**	**(D)eployment (V)isit (S)et (R)ecovery**	**# Days in water**	**Catch Data (Tons) YF**	**SJ**	**BE**
FAD1	93/06/10	D	0	-	-	-
FAD1	93/06/20	V	10	-	-	-
FAD1	93/06/20	S	10	0	0	10 '
FAD1	93/06/20	D	0	-	-	-
FAD1	unknown	R	-	-	-	-
FAD2	93/06/12	D	0	-	-	-
FAD2	93/07/03	V	21	-	-	-
FAD2	93/07/04	V	22	-	-	-
FAD2	93/07/04	R	22	-	-	-
FAD3	93/06/15	D	0	-	-	-
FAD3	93/06/25	V	10	-	-	-
FAD3	93/06/25	S	10	0.25	0	0 **4**
FAD3	93/06/25	R	10	-	-	-
FAD4	93/06/22	D	0	-	-	-
FAD4	93/06/23	V	1	-	-	-
FAD4	93/06/28	V	6	-	-	-
FAD4	93/06/30	V	8	-	-	-
FAD4	93/06/30	S	8	0	1	15
FAD4	93/06/30	R	8	-	-	-
FAD2	93/07/11	D	0	-	-	-
FAD2	93/08/22	V	11	-	-	-
FAD2	93/08/22	S	11	0.25 '	0	0
FAD2	93/08/22	R	11	-	-	-
FAD5	93/07/11	D	0	-	-	-
FAD5	93/08/21	V	41	-	-	-
FAD5	93/08/21	S	41	0.5 '	0.25	0
FAD5	93/08/21	R	41	-	-	-
FAD6	93/07/11	D	0	-	-	-
FAD6	93/08/21	V	41	-	-	-
FAD6	93/08/21	R	41	-	-	-
FAD7	93/07/11	D	0	-	-	-
FAD7	93/08/03	V	23	-	-	-
FAD7	93/08/21	R	41	-	-	-
FAD8	93/07/11	D	0	-	-	-
FAD8	93/08/03	V	23	-	-	-
FAD8	93/08/22	V	42	-	-	-
FAD8	93/08/22	R	42	-	-	-
FAD1	93/09/04	D	0	-	-	-
FAD2	93/09/04	D	0	-	-	-
FAD9	93/09/04	D	0	-	-	-
FAD10	93/09/04	D	0	-	-	-
FAD11	93/09/04	D	0	-	-	-
FAD15	93/09/04	D	0	-	-	-
FAD16	93/09/04	D	0	-	-	-
' = 4-8 lb	**4 = 45 - 50 lb**					

Table 4. Fishing Effort and Total Tuna Catch made in association with Skipper B's Ship-Built FADs (**TRIP 2**: 9/23/93 - 10/22/93).

FAD ID	**Date (yy/mm/dd)**	**(Deployment (V)isit (S)et (R)etrieval**	**# Days in water**	**Catch Data (Tons) YF**	**SJ**	**BE**
FAD1	93/09/23	V	19	-	-	-
FAD1	unknown	R	-	-	-	-
FAD1	unknown	D	0	-	-	-
FAD1	93/10/22	V	7-12*	-	-	-
FAD1	93/10/22	S	7-12*	10	5	20
FAD1	93/10/22	S	7-12*	0	15	140
FAD2	93/09/23	V	19	-	-	-
FAD2	93/10/10	V	36	-	-	-
FAD2	93/10/10	S	36	3!	17"	0
				17#	-	-
FAD2	unknown	R	-	-	-	-
FAD2	unknown	D	0	-	-	-
FAD2	93/10/22	V	7-12*	-	-	-
FAD9	93/09/23	V	19	-	-	-
FAD9	93/10/10	V	36	-	-	-
FAD9	93/10/10	S	36	0	30$	0
FAD10	93/09/23	V	19	-	-	-
FAD10	unknown	R	-	-	-	-
FAD10	unknown	D	0	-	-	-
FAD10	93/10/1 1	V	unk*	-	-	-
FAD10	93/10/11	S	unk*	1)	99$	20(
FAD10	93/10/15	V	unk*	-	-	-
FAD10	93/10/15	S	unk*	0	25*	0
FAD11	93/09/23	V	19	-	-	-
FAD12	93/10/22	D	0	-	-	-
FAD14	93/10/22	D	0	-	-	-
FAD15	unknown	R	-	-	-	-
FAD15	unknown	D	-	-	-	-
FAD15	93/10/21	V	6-11*	-	-	-
FAD15	93/10/21	S	6-11*	20)	30*	100(
FAD15	93/10/21	V	6-11*	-	-	-
FAD15	93/10/21	S	6-11*	5)	10*	10(
FAD16	93/10/22	V	6-12*	-	-	-

) = 4 - 7 lb **!** = 7.5 - 20 lb **"** = > 20 lb **#** = 10-12 lb **$** = 10-15 lb
***** = 15-20 lb **(** = >50 lb

* Seven Phase 3 FADs (FADs 1-2, FADs 9-11, FADs 15-16) were deployed on 9/4/93 at the end of a fishing trip. These FADs were picked up and redeployed at an unknown date estimated by the author to be between 10/10/93 and 10/15/93.

Table 5. Summaries of Fishing Effort and Total Tuna Catch associated with Skipper B's Drifting FADs (**TRIP 1**: 6/6/93 - 9/4/93 and **TRIP 2**: 9/23/93 - 10/23/93).

TRIP 1

FAD Identification	#Visits	#Sets	(Total Tuna Catch in Tons) Yellowfin	Skipjack	Bigeye
FAD1	1	1	0	0	10
FAD2	3	1	0.25	0	0
FAD3	1	1	0.25	0	0
FAD4	3	1	0	1	15
FAD5	1	1	0.5	0.25	0
FAD6	1	0	-	-	-
FAD7	1	0	-	-	-
FAD8	2	0	-	-	-
Sum =	*13*	*5*	*1.0*	*1.25*	*25*
Mean =			*0.2*	*0.25*	*5*
Standard Error (SE) =			*0.09*	*0.19*	*3.16*

TRIP 2

FAD Identification	#Visits	#Sets	(Total Tuna Catch in Tons) Yellowfin	Skipjack	Bigeye
FAD1	2	2	10	20	160
FAD2	3	1	20	17	0
FAD9	2	1	0	30	0
FAD10	3	2	1	124	20
FAD11	1	0	-	-	-
FAD12	0	0	-	-	-
FAD13	0	0	-	-	-
FAD14	0	0	-	-	-
FAD15	2	2	25	40	110
FAD16	1	0	-	-	-
Sum =	*14*	*8*	*56*	*231*	*390*
Mean =			*7*	*28.9*	*36.3*
Standard Error (SE) =			*3.1*	*10.5*	*18.9*

Table 6. Summary of Effort and Total Tuna Catch, by trip, for four vessels (> 1,000 gross tons carrying capacity) fishing on FADs during the period 10/22/93 - 3/12/94 (source: IATTC Flotsam Information Records). Data do not include visits and sets made on NOAA Atlas weather buoys by these vessels during the time period (6 visits and 4 sets produced 144 tons of skipjack tuna and 602 tons of bigeye tuna loaded on vessels).

Vessel	#Visits	#Sets	Skipjack Tons Loaded	Skipjack Tons Discarded	Yellowfin Tons Loaded	Yellowfin Tons Discarded	Bigeye Tons Loaded	Bigeye Tons Discarded
B	16	14	431	126	35	3	384	11
B	6	6	444	23	15	4	0	0
Subtotal:	22	20	875	149	50	7	384	11
C	3	3	190	0	0	0	100	0
C	6	5	155	17	85	0	0	0
C	10	7	91	16.5	137	5	0	0
Subtotal:	19	15	436	33.5	222	5	100	0
D	21	17	371	122	25	20	557	57
D	7	4	74	8	18	4	30	1
D	19	7	259	0	99	0	1	0
Subtotal:	47	28	704	130	142	24	588	58
E	6	6	274	0	18	0	0	0
Subtotal:	6	6	274	0	18	0	0	0

(Tuna Catch In Short Tons)

	#Visits	#Sets	Skipjack Loaded	Skipjack Discarded	Yellowfin Loaded	Yellowfin Discarded	Bigeye Loaded	Bigeye Discarded
Sum	*94*	*69*	*2289*	*312.5*	*432*	*36*	*1072*	*69*
Mean Tons/Set			*33.2*	*4.5*	*6.3*	*0.5*	*15.5*	*1.0*

Dolphin-Safe FAD Logbook

General Instructions:

A. Start each fishing trip with a new logbook. Vessel Owners/Fleet Managers will be provided with spare copies of logbooks by members of the NMFS Dolphin-Safe Program. If you need additional logbooks or data forms contact:

< Dolphin-Safe Program
Attn: Wes Armstrong, Charles Oliver, Liz Edwards
Southwest Fisheries Science Center (SWFSC)
P.O. Box 271
La Jolla, CA. 92038-0271
Phone: (619) 546-5616 (Wes)
(619) 546-7172 (Chuck)
(619) 546-7099 (Liz)
FAX : (619) 546-7003 (All)

B. At the conclusion of each fishing trip, mail the logbook to the address listed above or send it back to San Diego with a responsible crewmember or the NMFS observer.

C. All questions should be directed to:

< Dolphin-Safe Program
Attn: Wes Armstrong, Charles Oliver, Liz Edwards
Southwest Fisheries Science Center (SWFSC)
P.O. Box 271
La Jolla, CA. 92038-0271
Phone: (619) 546-5616 (Wes)
(619) 546-7172 (Chuck)
(619) 546-7099 (Liz)
FAX : (619) 546-7003 (All)

FAD CONSTRUCTION FORM
General Instructions:
Be as accurate and descriptive as possible when filling out the logbook. Sketches are very useful and we encourage you to make them. We will provide you with a camera and film to take photos of the FADS during their construction and deployment aboard your vessel. The rolls of film are numbered. When you take a picture, record the roll number and the frame number(s) (ie. roll #3, frames 5-9) so we can accurately correlate specific photos with your notes about a particular FAD. Please record your thoughts and ideas on any aspect of this project and don't feel restricted to writing notes within the confines of each page of the logbook (use the back of the page or additional sheets if necessary).

Surface Float Construction

1. Describe the surface float and include what materials were used (ie. wooden pallets, floating rope, old net webbing, Jap balls etc..) to construct it. Draw a simple sketch and include the dimensions of the FAD.

Photographs taken: Yes or No (circle one)
Roll #___ Frame(s)_____________
Did you use a bait bucket? Yes or No (circle one)

ANCHORED FAD MOORING FORM

When an anchored FAD is deployed, please write a detailed description of how the surface float was attached to the anchor line (cable, chain-line, hardware, splicing, nylon timble, etc.), and ultimately to the anchor. Include how much and what type of line was used for each component of the mooring? What types, and sizes of hardware were used.

What materials were used to construct the anchor and estimate its weight?

Make a detailed sketch of the FAD mooring.

FAD DEPLOYMENT FORM

Name of FAD:_______________________________________

Date of Deployment:__________________________________

Time of Deployment:__________________________________

Position of Deployment:________________________________

Oceanographic conditions:
1. Current ____________________________________

2. Water temperature ____________________________

3. Water color _________________________________
4. Water depth__________________________________

Photographs taken: Yes or No (circle one)
Roll #___ Frame(s)___________________

Comments:
Why did you deploy the FAD(s) in this area (ie. evidence of current fronts, drift lines, water color, water

temperature, bird life, fish signs, a gut feeling etc..)

FAD VISITATION FORM

Name of FAD:___________________________

Date of visit:______________________________

Position of FAD:__________________________

FAD observed from helicopter, ship, both? (circle one)

Observations:
Direction of drift:_________________________

Oceanographic conditions:
1. Current:_________________________
2. Water temperature:_______________
3. Water color:_____________________

Did you see any yellowfin tuna within (circle most appropriate answer(s)) You can circle more than one response if applicable.
1. 1/2 mile of the FAD? How much?_________________
2. 1/2-2.0 miles of the FAD? How much?_________________
3. 2-5 miles of the FAD? How much?_________________
4. >5 miles of the FAD? How much?_________________

Did you see any skipjack tuna within (circle most appropriate answer(s)) You can circle more than one response if applicable.
1. 1/2 mile of the FAD? How much?_________________
2. 1/2-2.0 miles of the FAD? How much?_________________
3. 2-5 miles of the FAD? How much?_________________
4. >5 miles of the FAD? How much?_________________

Did you see any bigeye tuna within (circle most appropriate answer(s)) You can circle more than one response if applicable.
1. 1/2 mile of the FAD? How much?_________________
2. 1/2-2.0 miles of the FAD? How much?_________________
3. 2-5 miles of the FAD? How much?_________________
4. >5 miles of the FAD? How much?_________________

Did you see birds, bait, dorado, sharks, marlin, black porpoise etc..) within (circle most appropriate answer(s)) You can circle more than one response if applicable.
1. 1/2 mile of the FAD? How much?_________________
2 1/2-2 miles of the FAD? How much?_________________
3. 2-5 miles of the FAD? How much?_________________
4. >5 miles of the FAD? How much?_________________

Did you make a set? Yes or No (circle one)

* **Please fill out a Set/Catch description form if you made a set on or within 5 miles of a FAD.**

1. Set Number:__________

Did you pick up the gear to move it to another area? Yes or No (circle one)
Additional Comments:

SETS ON FADS FORM

Name of FAD:____________________________

Date:___________________________________

Set Number:_____________________________

Set Position:____________________________

Time of Set:_____________________________

Pick up FAD: Yes or No (circle one)

Catch Data:
Please describe as best you can the size of most of the yellowfin, skipjack, and bigeye tuna (ie. 10-15 lbs, 7.5-12 lbs etc.)

Yellowfin	Skipjack	Bigeye
_________	________	______

Estimate the tons of fish loaded:

	7.5 - 20 lbs	>20 lbs
Tons of Yellowfin:	____________	__________
Tons of Skipjack:	____________	__________
Tons of Bigeye:	____________	__________

Additional Comments about the set.

Appendix 2

Dolphin-Safe Questionnaire

NMFS DOLPHIN-SAFE PROGRAM
TUNA PURSE-SEINE FISHING QUESTIONNAIRE

YOUR NAME:____

LOGS AND FLOTSAM

1. When is(are) the best time(s) of the year to find and make sets on logs/flotsam?
   a. Are there seasons?
   b. In your opinion does the phase of the moon make a difference?
2. Where in general terms are the best areas to fish logs/flotsam?
   a. Are some areas better than others during particular months of the year and if so why?
3. What oceanographic conditions are considered best for fishing on logs?
   a. water temperature range:
   b. turbidity (water color):
   c. currents:
   d. bottom topography (banks, sea-mounts etc.):
4. What sorts of "fish signs" are indicative of a potentially good log-fishing area?
5. What species of birds are indicative of a potentially good log-fishing area?
6. When you check a log for tuna, what species of bait-fish do you look for?
   a. In your opinion which of the following is most important for aggregating tuna
      - the kind of bait
      - the amount of bait
7. Do you tie up to a log at the end of the day (yes or no)?
   a. Why or Why not?
8. Do you attach a bait bucket to the log?
9. Do you turn on your lights when tied to a log all night?
   a. Why or Why not?
10. In your opinion, what types of structures make the best logs?
11. In your opinion, what type of logs/flotsam produce the greatest quantity of harvestable fish?
   a. natural logs such as trees and branches
   b. dead whales
   c. man-made materials such as ropes, pallets, crates etc.
   d. old fishing gear (Japanese balls, gillnets, etc.)
   e. other
12. In your opinion, which of the following is more important to successful log fishing?
   a. composition of flotsam (material and/or structure)
   b. location of the flotsam

FREE SWIMMING TUNA (SCHOOLFISH)

1. When is(are) the best time(s) of the year to find and make sets of schoolfish?
   a. are there seasons?
   b. is lunar phase important?
2. Where in general are the best areas to find schoolfish runs?
   a. are some areas better than others at particular times of the year and if so why?
3. What oceanographic conditions are considered best for schoolfishing?

a. water temperature range:
b. turbidity (water color):
c. currents:
d. bottom topography (banks, sea-mounts etc.):

4. What sorts of "fish signs" are indicative of a potentially good school fishing area?
5. What method(s) do you use to stop or slowdown schoolfish so you can make a set?

FISH AGGREGATING DEVICES (FADS)

1. Have you ever constructed and deployed drifting FADs?
2. Have you ever deployed drifting FADs in logfishing areas?
    a. were they successful?
3. Have you ever deployed drifting FADs in schoolfishing areas?
    a. were they successful?
4. Have you ever deployed drifting FADs in dolphin fishing areas?
    a. were they successful?
5. How do you decide if an area is suitable for deployment of FADs?
6. What is the most important element in the design of a drifting FAD?
    a. surface platform
    b. subsurface array (materials below the surface)
    c. amount of time in the water (seasoning)
    d. attachment of the radio buoy
7. In your opinion, would anchored FADs be effective if they were deployed in schoolfishing and/or dolphin fishing areas?
8. Do you attach bait buckets to FADs?
    a. always
    b. never
    c. sometimes
    d. why or why not?
9. What types of materials work best as surface platforms?
10. How do you tie up to a FAD or a log? How much and what kind of line do you use? Please make a simple sketch on the back of this sheet.

GENERAL

1. What type of support could NMFS/IATTC provide to tuna fishermen in terms of equipment, gear research projects, and data that would assist the fishing industry to find cost effective methods of catching mature yellowfin tuna without encircling dolphins?
2. Do you have any projects or ideas that you would like to see the NMFS Dolphin-Safe Program pursue?