Potential for Increasing Artisanal Fisheries Production from Floating Artificial Habitats in the Caribbean

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RESUMEN

Estructuras artificiales se han usado con éxito en todo el mundo, desde el lejano Oriente hasta Norte América y Europa, para atraer peces e invertebrados de importancia comercial y recreativos. Estas estructuras tienen éxito porque pueden (1) atraer dichos organismos a regiones donde no han existido previamente, (2) concentrar organismos de áreas ampliamente separadas, (3) reponer recursos agotados, (4) cambiar la presión de un recurso intensamente pescado a otros recursos, (5) reponer los recursos en áreas que estuvieron contaminadas anteriormente, (6) aumentar la sobrevivencia de juveniles, protegiéndolos de los carnívoros, (7) ahorrar en tiempo y costo de conbustible y (8) reducir la incidencia de ciguatera proveyendo hábitats para peces pelágicos, mayormente no ciguatóxicos.

En esta ponencia se examinan las clases más importantes de los peces bentónicos, de media agua o pelágicos y sus respectivos ambientes. Varias clases de estructuras artificiales para el fondo o flotantes y ancladas, son también discutidas desde el punto de vista de su esperado éxito en atraer organismos, (1) costo relativo, (2) construcción con materiales locales, (3) pesqueros en que van a emplearse y (4) observación sistemática con respecto a sus beneficios comparativos, tanto biológicos como económicos.

INTRODUCTION

The term "fish-attracting device" (FAD) has been used for structures that create floating artificial habitats which are suspended at the surface, slightly below the surface, or in midwater between the surface and the bottom. This practice is based upon the concept that pelagic fishes are attracted to floating objects, much in the same way as reef fishes are attracted to artificial benthic habitats (Uda, 1933; Kimura, 1954; Kojima, 1956; Inoue et al., 1963; 1968; Gooding, 1965; Gooding and Magnuson, 1967; Greenblatt, 1979).

It was formerly believed that the FAD merely concentrated pelagic fishes. Now there is evidence that the number of fish and their survival actually increase because of the protection provided by the hiding places. The FAD also acts as a habitat for juvenile fishes which otherwise might have perished (Stone et al., 1979). However, the important practical result of this concentrating concept is that the FAD works in attracting fish, is relatively simple and inexpensive to manufacture, and is easy to install.

Various theories have been proposed to explain exactly why floating artificial habitats generally are successful in attracting fishes (Kojima, 1956; Shojima and Ueki, 1964; Hunter, 1968; Hunter and Mitchell, 1968a, 1968b; Gooding and Magnuson, 1967; Klima and Wickham, 1971; Wickham et al., 1973; Wickham and Russell, 1974; Greenblatt, 1979). Artificial habitats are thought to be successful fish attractants because they function as: (1) places to live for bottom-dwelling organisms; (2) protection against predators; (3) concentrators of bait fish; (4) hiding places for fish or their food; (5) cleaning and scraping stations; (6) reference points for metamorphosing individuals; (7) quiet areas in strong currents; (8) places for upwelling and increased food supply; (9) thigmotropic (touching) devices; (10) dark places where plankton is more visible; (11) drifting schooling companions; (12) visual reference points, or "spatial landmarks" in an otherwise non-dimensional medium.

ECOLOGICAL ASPECTS OF THE FAD

The success of the FAD in attracting different fish species depends on multiple environmental factors. These include: water clarity; water color; water depth; water quality, such as pollution; current speed; closeness of existing coral reefs or benthic artificial reefs; efficiency of the type of FAD used; and length of time in the water.

Water transparency indicates the biological productivity of the water. The clearer the water in unpolluted regions, the poorer will be the catch. Very clear water indicates poor phytoplankton productivity on which zooplankton feed. These, in turn, are eaten by filter-feeding fishes. The latter comprise the diet of large predators such as tunas and dolphins. However, turbid nearshore waters may also indicate sewage, industrial pollution, or dredged or suspended materials. These substances may reduce visibility and productivity. Consequently, the ability of the fish to find their food or the lures of the fishermen is reduced. However, as discussed later, the FAD used to attract some fish species in Indonesian waters work better in more turbid water than in clear water (Westenberg, 1953).

Water color indicates the kinds of species which may be caught using the FAD. Thus, blue marlin (*Makaira nigricans*), wahoo (*Acanthocybium solanderi*), dolphin (*Coryphaena hippurus*), and most tuna (*Thunnus* spp.) are found in blue water, while green water contains king mackerel (*Scomberomorous cavalla*), cero (*Scomberomorus regalis*), amberjack (*Seriola dumerili*), and little tuna (*Euthynnus alletteratus*).

Water depth also indicates the species of pelagic fishes which may occur there (de Sylva, 1981). This depends upon the slope of the continental shelf. Thus, where this gradient is great, blue-water fishes will be found close to shore. Where the slope is small, even though blue water may be close to shore, it may be necessary to travel farther offshore to find blue-water fishes. Water depth and water color are frequently closely related, and thus the skillful fisherman keeps records of daily changes of water color on his fishing grounds.

Water quality is usually not an important consideration when fishing for blue-water species, unless oil spills are involved. In green coastal waters, sewage, industrial pollution, or pesticides may be toxic either to the fishes or to their food. Thus a productive fishing location may eventually become a poor one.

Current speed is important in determining the kind of FAD to be employed. Drag caused by strong currents may pull any floating object under the surface, where it can no longer be readily located, or may tear it from its mooring. A FAD located in a strong current or over very deep water would be difficult to maintain during periods of stormy weather.

A FAD installed close to existing benthic reefs, either natural or artificial, can increase the catch rate. Experiments with FAD in South Carolina showed that the catch per unit effort obtained at FAD anchored in about 27 m of water was about 80% higher than in control areas (Hammond et al., 1977).

The shape, size, and number of the FAD employed undoubtedly will affect the catch rate. This must be balanced against initial cost and any projected maintenance or monitoring costs.

The length of time a FAD is in the water will also determine the catch rate. In some cases, bait fish are attracted in a matter of hours. In other instances, several days to weeks are required to attract bait fish. These eventually attract the larger predatory species.

The FAD should be carefully placed in regard to the above ecological considerations. This will ensure the best catches with the least loss of gear. Subsequent monitoring of the ecological and economic value of the FAD is mandatory if the device is to prove cost-effective.

EXPERIENCE WITH FAD IN THE GULF AND CARIBBEAN REGION

Only a few experiments have been conducted using the FAD in the Gulf of Mexico. The earliest work was done by the U.S. National Marine Fisheries Service, in the northeastern Gulf of Mexico (Klima and Wickham, 1971). Their initial concept was to use the FAD to attract large numbers of baitfish. These would be concentrated using artificial lights, and would then be pumped on board for rapid processing. The FAD were anchored in shallow green waters rich in phytoplankton and thus herring. Midwater structures were constructed of 2.5-cm by 5.0-cm wood slats and were right prisms, 0.9 by 0.9 by 0.9 by 1.5 m. These were built in the shape of a pup tent, forming an inverted V, and were covered on the upper sides with vinyl cloth painted white (Klima and Wickham, 1971: 90). The structures were anchored 4.9 m beneath the surface.

These FAD were successful in attracting such bait species as round scad (*Decapterus punctatus*) and herring (*Harengula* and *Sardinella*). Predatory species attracted were amberjack, rainbow runner (*Elagatis bipinnulatus*), and blue runner (*Caranx crysos*). Bait species were sometimes estimated at 10,000 individuals, and amberjacks were the most frequently observed. If such structures were used elsewhere in the Gulf and Caribbean, the bait fish thus attracted might be collected with small purse seines, and could be used either as food or as bait for trolling or longline fishing.

Subsequent studies in the northeastern Gulf of Mexico by the U.S. National Marine Fisheries Service involved a pyramidal FAD suspended about 5 m below the surface and anchored in about 24 m of water (Wickham et al., 1973). These were 1.2 m on the sides and comprised a rigid, triangular frame

(Wickham et al., 1973: 565). Experimental trolling was carried out and compared to control areas where no FAD were present. The main species caught were little tuna, king mackerel, Spanish mackerel (*Scomberomorus maculatus*), and dolphin. The catch rate around the FAD was 7 fish per hour as compared to a catch rate of about 1.3 fish per hour in the control area.

Experiments were also carried out in this area by Wickham et al. (1973: 566) using multiple structures which were conical, with a 1.5-m diameter, semi-rigid frame, and a height of 1.5 m. Multiple structures consisted of five buoyant, inverted cones spaced at 20-m intervals and tethered 5 m beneath the surface by weighted lines attached to an anchored ground line.

Larger schools of coastal bait fish were attracted to the multiple structures and produced larger catches of pelagic game fish than the single-structure FAD. Catch rates by charterboats around multiple structures were reported to be at least double those made at the single structures or in the control areas.

Midwater FAD have been successfully used in the coastal waters of South Carolina, at an existing artificial benthic reef (Hammond et al., 1977). Thirty midwater structures (Hammond et al., 1977: 4–5) were deployed in a straight line at 27-m intervals over a distance of about 823 m, with a buoy at each end. Each midwater FAD consisted of six automobile tires lashed together with polypropylene rope, fastened to a 136-kg block of concrete. The uppermost tire was buoyed by a flotation device, which was an empty 22.2-*l* steel freon canister. Trolling for pelagic fishes was done at the midwater FAD, an artificial benthic reef, and at two control areas. Within 2 months, an extremely large school of bait fish (*Decapterus*), estimated to contain more than 100,000 individuals, gathered about the midwater structures. Of the 14 fish species caught during the entire survey, only two (Spanish mackerel and king mackerel) were common. The catch per unit effort at the midwater structures was 22.1% higher than that at the existing benthic reef, and 80.3% higher than that at the control areas.

Guy Harvey (personal communication) of the Zoology Department, University of the West Indies, Kingston, Jamaica, informs me that Caribbean-type z-traps made of reed are used as midwater FAD. Buoyed at the surface and anchored along the Jamaican coast, they are very successful in attracting barracuda, amberjack, rainbow runner, and bar jack (*Caranx ruber*) to the traps where they aggregate and are caught by trolling.

EXPERIMENTS WITH FAD IN OTHER AREAS

FAD of various designs have been historically used to attract sport and commercial fishes (Hunter, 1968) in various parts of the world. In the Mediterranean Sea, the kannizzati fishery is unique to the island of Malta (Galea, 1961). The main fishes taken are the dolphin and the pilotfish (*Naucrates ductor*). These species are caught by fishermen using modified purse seines which do not have pursing rings, and also by longlines baited with squid. The kannizzati (Galea, 1961: 86) is a float consisting of two large flat masses of cork slabs which are several layers thick. A marker float is attached to the cork. In the Gulf and Caribbean, sheets of plywood or styrofoam could be substituted for the cork. In Malta, an anchor stone is connected to the raft, formerly using treated sisal rope, but now monofilament nylon is being used. Each unit is about 1.5 km long between floats, and is anchored in depths of about 140 to 730 m or more. Annual catches of the 50 fishing boats (about 21 m long) average approximately 950,000 kg.

Similar rafts are used in Japanese waters to attract dolphin (Kojima, 1956: 1050). These bamboo rafts are 7 m long and are either drifted or anchored, depending on depth. A few amberjack and clupeoids are taken as well and these are captured using purse seines (Imamura et al., 1965: 82).

A tree found in the Philippines called "lauan" (Dipterocarpaceae) is used to make logs of about 3 to 6 m long and 1 m in diameter to attract skipjack (*Euthynnus pelamis*) and other tunas. These are both anchored and drifted and work very successfully in the troll fishery.

In Indonesian waters, simple midwater structures (*roempons*) are made of palm fronds inserted into rope made from coconut fibers (Van Pel, 1938, 1941; Hardenberg, 1950; Westenberg, 1953; Soemarto, 1958; von Brandt, 1960). The FAD is weighted by a stone and buoyed by a single bamboo pole, on which a frond is fastened vertically to act as a marker buoy. Sardines (*Sardinella fimbriata*), oil mackerel (*Rastrelliger kanagurta*) and jacks (*Decapterus* spp.) are the primary species attracted to these. They are taken in purse seines, lampara nets and cast nets at dawn and dusk. Because of the very clear water, only poor catches are made during the day.

Such frond rafts should be feasible in the Caribbean, since lethal yellowing disease in some areas has resulted in an abundance of dead and dying fronds. Plastic strips have been substituted for the fronds in the Philippines, but their high cost has caused fishermen to revert to using palm fronds.

Experiments conducted off the Pacific coast of Costa Rica (Hunter and Mitchell, 1968) have used simple structures made of black plastic sheets attached to frames of PVC pipe, formed in various configurations. The greatest number of pelagic fishes were taken under a tent-shaped object, the next largest number by a flat rectangle. In Florida, anglers have scattered newspapers at the surface to attract sailfish and in Japan, fishermen use bundles of wood to attract wahoo (Kishinouye, 1923).

A successful fishery for flyingfish in the Makassar Strait between Borneo and Celebes uses bamboo bow-net-shaped baskets tied behind the drifting boat (Hardenberg, 1950). Pieces of seaweed are attached to the front of the basket. When the female fish swims into the basket to spawn, it is trapped.

Several kinds of Fad have been used in American Samoa, Palau, Guam, the Marianas and Hawaii (Matsumoto et al., 1981; Anonymous, 1981; Pacific Tuna Development Foundation, 1980). Two types of buoys were used in the experiments. The first type (Matsumoto et al., 1981: 3) consists of three foam-filled, 208-*l* drums anchored by chain in depths of over 900 m. A drape made of polypropylene rope was suspended directly from the buoy and this was successful in attracting dolphin, wahoo, schools of yellowfin (*Thunnus albacares*) and skipjack tunas, and kawakawa (*Euthynnus affinis*). The second type was a raft (Matsumoto et al., 1981: 4), 1.2 by 3.6 m, filled with polyurethane foam, from which a drape of nylon netting was hung. The FAD were anchored in depths of 442 to 2286 m. A variety of pelagic fishes appeared around the FAD within 1 to 5 weeks after their installation. Commercial tuna pole-and-line boats benefitted greatly by taking large catches of tunas from around the FAD, and fishing around the FAD resulted in reduced fuel and baitfish expenses.

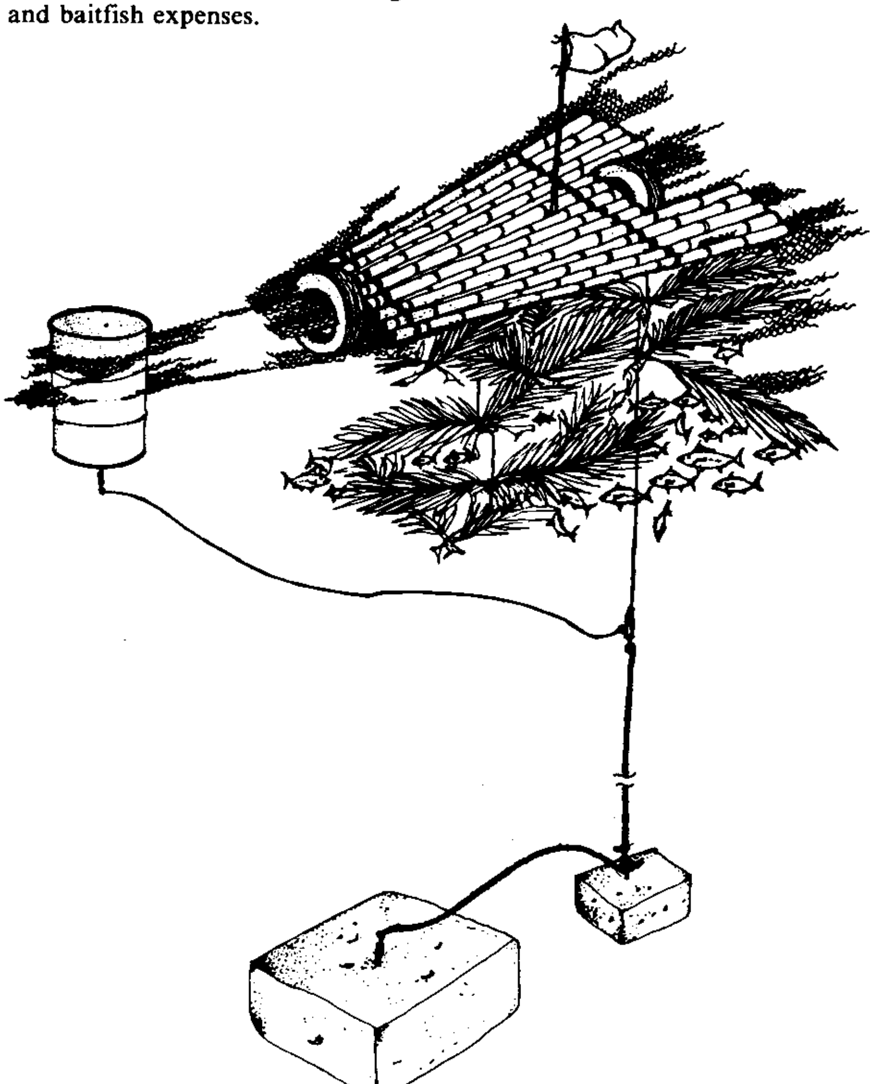

Figure 1. The payao, a raft made of two layers of bamboo lashed together in a V-shape, is used by tuna fishermen off certain islands of the Philippines to attract schools of yellowfin, skipjack, and little tuna. The payaos studied were each about 4 m long, and 1.5 m at the widest end.

FAD have been constructed in the Hawaiian Islands using truck tires filled with polyurethane foam (Schlais, 1981; Tanoue, 1981), which were successful in attracting dolphin, tunas and wahoo.

In the Philippines, FAD made of anchored bamboo rafts (*payaos*) have been used successfully to attract yellowfin, skipjack and little tuna (Murdy, 1980). Two layers of bamboo are lashed together in a V-shape, about 4 m long, and about 1.5 m at the widest end (Fig. 1). These represent a variation on the Japanese bamboo raft, but entail the use of a combination of anchored bamboo rafts, palm fronds, netting, lights and purse seines. These were anchored at about 2000 m and were left in place for about 1 month. At night, 500-w lights are turned on, and at about 0430 hours or just before sunrise a purse seine of 168 to 183 m deep is set. The net is lifted gradually into the boat. The first haul yielded 36.3 tons of mostly skipjack and some yellowfin tuna. The success of using purse seines for tuna has been documented by McNeely (1961).

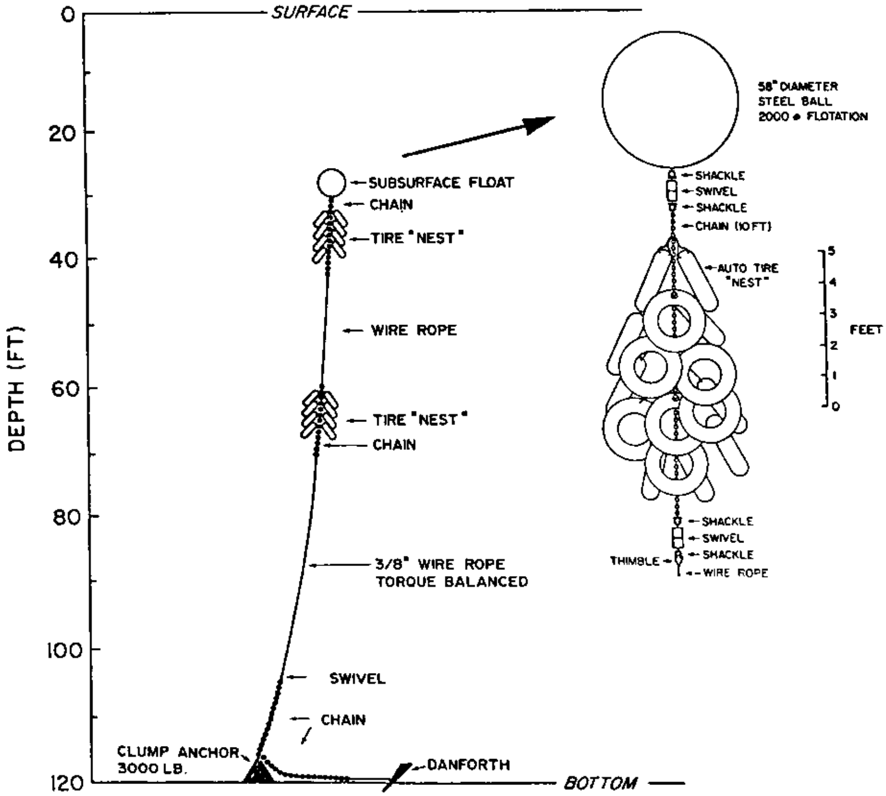

Figure 2. Diagram of proposed fish-aggregating device (FAD) and tire "nest" as anchored in the Straits of Florida off Miami.

Most FAD work well when currents are not too strong. In southeast Florida, with strong currents, we have proposed to install 1.5-m stainless steel spheres which float about 9.1 m below the surface (Fig. 2) to avoid navigational hazards from deep-draft vessels (de Sylva and De Ferrari, unpublished ms.). These would be moored off South Florida at various depths to attract tunas, dolphin and billfish (Istiophoridae). Current-powered lights would be used to attract fish for night-time fishing. The cost of these midwater spheres, their emplacement, monitoring and, especially, location in strong currents (up to 450 cm/sec) suggest that this kind of FAD may not be economically feasible for use in artisanal fisheries, although it augurs well for recreational fisheries development.

In Fort Lauderdale, Florida, the Macent Corporation has proposed (Gregory MacIntosh, pers. comm.) and recently installed a series of subsurface FAD and parasol nets which expand and collapse with current strength. Their cost-effectiveness relating to construction, installation and monitoring is presently being evaluated. Cost-effectiveness will have to be evaluated in the Caribbean before some kinds of the FAD can be shown to produce fish economically for the artisanal fisherman.

CONCLUSIONS

I believe that some kinds of FAD can be an economical, effective way to attract and concentrate fish for the artisanal fisherman or for the recreational angler. For both kinds of fishermen, the FAD is a fuel-saving device because it decreases the time spent in searching for fish schools. Instead, the fish come to the FAD. Also, trolling around the FAD can be done using sail power. However, the FAD concept has not been used widely in the Caribbean. Pelagic commercial and recreational fish stocks which could be attracted to artisanal FAD are known to exist in the Caribbean (Bane, 1964a; 1964b; Bird, 1960; de Sylva, 1963; Erdman, 1962; Erdman and Roman, 1959; Fiedler et al., 1947; Iñigo and Juhl, 1968; Juhl, 1971; Kawaguchi, 1974; Naranjo, 1956; Sanchez and Maza, 1952; Suarez-Caabro, 1970; 1979; Wagner and Wolf, 1974; Wolf and Rathjen, 1974). Methods applied elsewhere may or may not be applicable here because of ecological factors such as water clarity and depth. Nevertheless, the FAD offers a great opportunity for the governments in the Caribbean to use cheap, expendable materials such as palm fronds, used freon containers, tires, and other unwanted refuse to construct habitats to replace those which are increasingly difficult for our marine creatures to find.

Finally, the problem of ciguatera—tropical fish poisoning—is posing increasing problems in the marketing and consumption of Caribbean reef fishes (Schaeffers, 1970; Brody, 1974; de Sylva and Higman, 1980). The FAD should attract fish species which are mostly non-ciguatoxic, except for barracuda, amberjack, and king mackerel. Thus, the FAD will help to promote the development of a fishery for wholesome, non-ciguatoxic fishes, and will at the same time reduce fishing pressure on reef fish stocks which may be under heavy fishing pressure.

LITERATURE CITED

Anon.
1981. Japanese rafts attract tuna. Austral. Fish. 40: 21.

Bane, G.W.
1964a. Notes on exploratory fishing and biology of the blackfin tuna around Puerto Rico. Proc. 9th Internat. Game Fish Conf., Miami, Florida, pp. 12–16.

____
1964b. Exploratory fishing for tunas in the Mona Passage. Proc. Gulf Carib. Fish. Inst. 17: 55–61.

Bird, E.A.
1960. Fishing off Puerto Rico. A.S. Barnes, N.Y.

Brody, R.
1974. Ciguatera fish poisoning goes unchecked in Caribbean. Natl. Fisherman, Jan., pp. 12-C and 13-C.

de Sylva, D.P.
1963. Preliminary report on the blue marlin sport fishery of Port Antonio, Jamaica. Inst. of Mar. Sci., University of Miami, Florida. 13 pp.

____
1981. Fish habitats in Dade County, Florida. *In*: Metro-Dade County Artificial Reef Workshop, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida, 14 January 1981, 10 pp., 16 figs. In press.

__________ and J.B. Higman
1980. A plan to reduce ciguatera in the tropical western Atlantic region. Proc. Gulf Carib. Fish. Inst. 32: 139–153.

Erdman, D.S.
1962. The sport fishery for blue marlin off Puerto Rico. Trans. Am. Fish. Soc. 91: 225-227.

__________ and E. Roman
1959. Puerto Rico game fishing. Sea Frontiers 5: 114–122.

Fiedler, R.H., M.J. Lobell, and C. R. Lucas
1947. The fisheries and fishery resources of the Caribbean area. U.S. Fish Wild. Serv., Fish. Leafl. (259): 210 pp.

Galea, J.A.
1961. The "kannizzati" fishery. Proc. Gen. Fish. Coun. Medit. (6): 85–91.

Gooding, R.M.
1965. A raft for direct subsurface observation at sea. U.S. Fish Wildl. Serv., Spec. Sci. Rept.—Fish. (517): 5 pp.

__________ and J.J. Magnuson
1967. Ecological significance of a drifting object to pelagic fishes. Pacific Sci. 21: 486–497.

Greenblatt, P.R.
1979. Associations of tuna with flotsam in the eastern tropical Pacific. Fish. Bull. U.S. 71: 147–155.

Hammond, D.L., D.O. Myatt, and D.M. Cupka
1977. Evaluation of midwater structures as a potential tool in the management of the fisheries resources on South Carolina's artificial fishing reefs. South Carolina Mar. Res. Cent. Tech. Rep. Ser. (15): iii + 19 pp.

Hardenberg, J.D.F.
1950. Development of pelagic fisheries. Proc. Indo-Pacific Fish. Counc. (1): 138–143.

Hunter, J.R.
1968. Fishes beneath flotsam. Sea Frontiers 14: 280–288.

__________ and C.T. Mitchell
1968a. Field experiments on the attraction of pelagic fish to floating objects. J. du Conseil 31: 427–434.

__________ and C.T. Mitchell
1968b. Association of fishes with flotsam in the offshore waters of Central America. Fish. Bull. U.S. 66: 13–29.

Imamura, Y., M. Inoue, M. Ogura, and S. Takeuchi
1965. Fishing of dolphin [sic], *Coryphaena hippurus,* by bamboo raft in southwest coast of Japan Sea. J. Tokyo Univ. Fish. 51: 81–86.

Inigo, F. and R. Juhl
1968. An outlook of Puerto Rico's commercial fisheries. Proc. Gulf Carib. Fish. Inst. 20: 128–132.

Inoue, M., R. Amano, and Y. Iwasaki
1963. Studies on environments alluring skipjack and other tunas. I. On the oceanographical conditions of Japan and adjacent waters and the drifting substances accompanied by skipjack and other tunas. Rep. Fish. Res. Lab., Tokai Univ. 1: 12–23.

__________, R. Amano, Y. Iwasaki, and M. Yamauti
1968. Studies on environments alluring skipjack and other tunas—II. On the driftwoods accompanied by skipjack and tunas. Bull. Japan. Soc. Sci. Fish. 34: 283–287.

Juhl, R.
1971. Status and potential of the fishery in the Caribbean. Proc. Gulf Carib. Fish. Inst. 23: 175–183.

Kawaguchi, K.
1974. Exploratory tuna longline fishing in the Caribbean and adjacent waters. Mar. Fish. Rev. 36(9): 61–66.

Kimura, K.
1954. Analysis of skipjack (*Katsuwonus pelamis*) shoals in the water of "Tohoku Kaiku" by its association with other animals and objects based on the records of fishing boats. Bull. Tohoku Reg. Fish. Res. Lab. (3): 87 pp.

Kishinouye, K.
1923. Contributions to the comparative study on the so-called scombroid fishes. J. Coll. Agric. Univ. Tokyo 8: 293–475 + 34 pls.

Klima, E.F. and D.A. Wickham
1971. Attraction of coastal pelagic fishes with artificial structures. Trans. Am. Fish. Soc. 100: 86–99.

Kojima, A.
1956. Fishing for dolphins in the western part of the Japan. Sea—II. Why do the fish take shelter under floating materials? Bull. Japan Soc. Sci. Fish. 21: 1049–1052.

Matsumoto, W.M., T.K. Kazama, and D.C. Aasted
1981. Anchored fish aggregating devices in Hawaiian waters. Mar. Fish. Rev. 43(9): 1–13.

McNeely, R.L.
1961. The purse seine revolution in tuna fishing. Pacific Fish. 59: 27–58.

Murdy, Edward O.
1980. The commercial harvesting of tuna-attracting payaos: a possible boon to small-scale fishermen. ICLARM Newsletter, Manila 3(1): 10–13.

Naranjo Betancourt, A.
1956. Cordel y anzuelo. Banfaic, Div. Agricola, Habana, Cuba. 253 pp.

Pacific Tuna Development Foundation
1980. Quarterly Report—PTDF, January–March 1980. PTDF, Honolulu. 30 pp.

Sanchez Roig, M. and F. Gomez de la Maza
1952. La pesca en Cuba. Ministerio de Agricultura, Habana, Cuba. 272 pp.

Schaeffers, E.
1970. Problems in eastern Caribbean fisheries development: ciguatera fish poisoning. Pages 193–196 *in* H.W. Youngken, Jr., ed. Food and Drugs from the Sea. Proc. of the 1969 Symposium, Marine Technology Society, Washington, D.C. 396 pp.

Schlais, J.F.
1981. Fish aggregating buoys. Sea Frontiers 27: 49–53.

Shojima, Y. and K. Ueki
1964. Studies on the larvae and juveniles of fishes accompanying floating algae—II. Research in the vicinity of Tsuyazaki, during April 1958–March 1969. Bull. Japan. Soc. Sci. Fish. 30: 248–254.

Soemarto
1958. Fish behavior with reference to pelagic shoaling species: lajang (*Decapterus* spp.). Proc. Indo-Pacific Fish. Coun. (3): 89–93.

Stone, R.B., H.L. Pratt, R.O. Parker, Jr., and G.E. Davis
1979. A comparison of fish populations on an artificial and natural reef in the Florida Keys. Mar. Fish. Rev. 41(9): 1–11.

Suarez-Caabro, J.A.
1970. Puerto Rico's commercial marine fisheries. Comm. Fish. Rev. 32(3): 31–36.

———
1979. El mar de Puerto Rico—una introduccion a las pesquerías de la isla. Editorial Universitaria, Univ. Puerto Rico, Rio Piedras. 259 pp.

Tanoue, K.Y.
1981. FADs for fishermen. Sea Grant Today, Univ. Hawaii 11(3): 17.

Uda, M.
1933. Types of skipjack schools and their fishing qualities. Bull. Jap. Soc. Sci. Fish. 2: 107–111. Translation by W.G. Van Campen, 1952, Five Japanese papers on skipjack. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. (83): 68–78.

van Pel, H.
1938. De beoefening van de majang zeevisscherij langs de noordkust van Java. Meded. Inst. Zeevissch., Batavia (2B): 101–113.

———
1941. Mededeeling van het Instituut voor de Zeevisscherij, Station Makassar, over 1940. Inst. van den Zeevisscherij. Mimeogr., Batavia. 50 pp.

von Brandt, A.
1960. Fishing methods in world sardine fisheries. Pages 563–623 *in* H. Rosa, Jr. and G. Murphy, eds. Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species. FAO, Rome. Vol. 2, Subject Synopsis No. 3.

Wagner, D.P. and R.S. Wolf
1974. Results of troll fishing explorations in the Caribbean. Mar. Fish. Rev. 36(9): 35–43.

Westenberg, J.
1953. Acoustical aspects of some Indonesian fisheries. J. du Conseil 18: 311–325.

Wickham, D.A. and G.M. Russell
1974. On evaluation of mid-water artificial structures for attracting coastal pelagic fishes. Fish. Bull. U.S. 72: 181–191.

———, J.W. Watson, Jr., and L.H. Ogren
1973. The efficacy of midwater artificial structures for attracting sport fish. Trans. Am. Fish. Soc. 102: 563–572.

Wolf, R.S. and W.F. Rathjen
1974. Exploratory fishing activities of the UNDP/FAO Caribbean Fishery Development Project, 1965–1971: a summary. Mar. Fish. Rev. 36(9): 1–8.