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SUMMARY OF PERTINENT INFORMATION ON THE ATTRACTIVE EFFECTS OF ARTIFICIAL STRUCTURES IN TROPICAL AND SUBTROPICAL WATERS

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I. INTRODUCTION

In the search for renewable alternate energy sources, solar seapower or ocean thermal energy conversion (OTEC), as an alternate technology, has emerged as one of the promising options. This technology would utilize a resource that is the world's largest solar collector and one which comprises 70% of the Earth's surface--the sea.

In the OTEC Act of 1980, the National Oceanic and Atmospheric Administration (NOAA) was mandated the responsibility for the establishment of a program which would help foster the development of OTEC as a commercial energy technology. In the process, provisions for the protection of the marine environments at the potential OTEC sites and considerations in minimizing adverse impacts on other users of the ocean must be emphasized.

The program was formally established when NOAA issued the environmental regulations for licensing commercial OTEC plants in July 1981 (Federal Register 1981). The regulations rely predominantly on the existing regulatory framework, such as the Clean Water Act, the Clean Air Act, the Endangered Species Act, and the Fish and Wildlife Coordination Act.

In accordance with the regulations, NOAA prepared an environmental impact statement which expressed the need for further investigation into the uncertainties of environmental effects (NOAA 1981), culminating in an environmental effects research plan (NOAA 1982).

The research plan identified two areas of research that are critical to NOAA's immediate responsibilities: the direct licensing requirements and the effects upon fisheries. This report summarizes the pertinent information of the effects upon fisheries--those of biota attraction and avoidance due to the presence of the OTEC plants.

Biota attraction and avoidance due to the presence of an OTEC plant will be highly dependent upon the plant's structural design. The proposed OTEC plant designs have been classified into two general categories: oceanic plant ships and land-based facilities.

The oceanic plant ships could be free-floating or moving slowly under their own power as they follow optimum thermal gradient conditions. Included among these designs are the experimental OTEC plant ships, "Mini-OTEC" and "OTEC-1," which were moored off Keahole Point, Hawaii (Figure 1). These plant ships are anticipated to exhibit the attractive properties characteristic of flotsam and fish aggregating devices (FAD's) employed throughout the Pacific.

As the name implies, land-based facilities include plant designs that are land-based or shelf-mounted such as man-made islands and towers (Figure 2) and would serve as artificial reefs. The towers in particular should exhibit attractive properties very similar to those of offshore drilling platforms in the Gulf of Mexico where the structures have proved instrumental in the development of a recreational fishery. It appears that whatever OTEC plant design is used, attraction of marine organisms to the structures would be inevitable. As indicated by Yuen (1981), long-term effects on the local population in the environment will depend upon the types, sizes, and numbers of organisms attracted to the structure. There may also be possible effects on populations such as interference with or modification of breeding habits or migration routes. Some potential environmental impacts and mitigating measures related to biota attraction and avoidance are presented in Table 1.

In addition, Sullivan et al. (1981) also speculated that the increased population near the plant would compound environmental impacts, increase the difficulty of monitoring environmental effects resulting from plant operation, and potentially increase the risk of diver-related accidents due to the attraction of sharks.

II. ATTRACTION OF MARINE ORGANISMS

A. Open Ocean Plant Ships

1. Observations of attraction to floating objects

As previously mentioned, an oceanic plant ship is anticipated to exhibit attractive properties characteristic of flotsam. Many pelagic fish species have long been known to aggregate around natural and man-made objects and structures in the sea. This phenomenon is evident for all objects and structures occupying the water column and thus has provided potentially good fishing areas for sport and commercial fishermen. Throughout the Pacific, an understanding of fish aggregation has proved instrumental in the development of the pelagic fishery around FAD's and in the evolution of the man-made FAD's.

The attraction of fishes to free-floating and anchored objects or structures has been studied throughout the world's tropical and subtropical waters. The objects to which fishes have been observed to associate with include drifting seaweed (Senta 1966), driftwood (Yabe and Mori 1950; Inoue et al. 1963; Hunter and Mitchell 1967; Inoue et al. 1968), man-made rafts (Kojma 1960; Gooding and Magnuson 1967), and artificial surface or midwater structures, including the commercial FAD's (Hunter and Mitchell 1968; Klima and Wickham 1971; Wickham et al. 1973; Wickham and Russell 1974; Matsumoto et al. 1981).

Behavioral observations of fish fauna around flotsam by Hunter (1968) revealed that all species and all individuals, large or small, aggregated near the object in the presence of a fright stimulus. In addition, fishes appeared to prefer the object of their original association (also observed by Hunter and Mitchell (1967)). This was evident when in his studies, Hunter attached a second object to an object which had an existing population, and separated the two objects after a 24-hour waiting period. The result was a continued association with the original object, unless the object was completely removed from the water. Fishes were also found to be attracted to anything that drifted, and on occasion in addition to the numerous resident juveniles, schools of transient species were also observed to aggregate. As time progressed, larger fishes appeared to dominate the flotsam population, although occasional transient schools sometimes mixed with the resident population of juveniles.

Other investigators have made various observations on fish populations around flotsam. Hunter and Mitchell (1967) found that the coloration of fishes was related to their association behavior. The darker colored species were found to remain closer to the floating object than the lighter, silvery fishes. Wickham et al. (1973) provided evidence that the distance offshore or the depth of the structures may have affected the species and number of fishes attracted and caught.

2. Theories associated with flotsam attraction

Whereas fish attraction to flotsam is well documented, theories as to why they are attracted to flotsam are still speculative. Several hypotheses have been proposed. Gooding and Magnuson (1967) suggested that floating objects served as cleaning stations where external parasites of pelagic fishes were removed by other fishes. It has been suggested that flotsam provides shade for fishes (Suyehiro 1952), produces shadows to make zooplankton more visible for fishes to feed upon (Damant 1921), and serves as a substrate for fishes to lay their eggs (Besednov 1960). Other hypotheses have suggested that fishes are attracted to flotsam because the drifting objects functioned as schooling companions (Hunter and Mitchell 1967) and that floating materials provided spatial references around which fishes could orient in an otherwise unstructured pelagic environment (Klima and Wickham 1971). Suyehiro (1952) proposed that fishes utilize floating objects as a means of seeking shelter from predators, especially for the smaller fishes which would be more susceptible to predation. In turn, Kojima (1956) suggested that larger fishes aggregate around floating objects to prey upon the smaller fishes.

It appears that although some hypotheses are valid, no single biological association or adaptive advantage can explain the aggregation of fishes around flotsam. In a given environment the association of fishes to flotsam may be species-dependent.

3. Impact upon fisheries

Fish aggregating devices have thus become instrumental in oceanic fishery development. Although fishing around FAD's has been practiced in Japan and in the Philippines for many years, it wasn't until recently that the use of FAD's for large-scale commercial fishing was first developed in the Philippines (Chikuni 1978). Since then, 23 countries have deployed or anticipate deployment of FAD's to assist the local artisanal fisheries as well as the commercial fisheries (Figure 3; Shomura and Matsumoto 1982).

Not all of the FAD's being utilized in the various areas are of the same design. Table 2 summarizes the various types, number, and longevity of the FAD's presently being used and those planned for future deployment. The early FAD's were simple bamboo rafts (not necessarily equipped with suspended midwater attractants) anchored in more protected water. The use of FAD's then extended into deeper waters and eventually to the open ocean where adverse conditions demanded sturdier construction. Developmental studies to achieve this at the National Marine Fisheries Service, Southwest Fisheries Center Honolulu Laboratory (HL) produced a buoy-type FAD utilizing two 55-gallon steel drums. Later improvements to this model resulted in the substitution of a raft in place of the 55-gallon drums (Figure 4; Matsumoto et al. 1981). The success of the HL's designs prompted the Hawaii Department of Land and Natural Resources (DLNR) to initiate a full-scale FAD system. Initially, the DLNR's 26 FAD's were constructed of large tractor tires filled with polyurethane. This design has since undergone modifications to a pentasphere design and presently, a single sphere design (Figure 5; [Hawaii.] DLNR 1983). Other Pacific countries have since implemented their own FAD system utilizing the DLNR design, the HL design, or one of their own.

4. Organisms attracted to flotsam

From the studies by Gooding and Magnuson (1967), Hunter and Mitchell (1967), and Matsumoto et al. (1981), it seems apparent that the dominant species of fishes which are attracted to structured flotsam are pelagic or nondemersal. A list of the animals observed by Gooding and Magnuson (1967) from the observation chamber of a drifting raft serves as an index to the general nektonic faunal composition at a floating structure (Table 3). A broad classification of the behavior category (resident, visitor, and transient) of the animals in relation to the raft is also presented in the table. By definition, the transients were animals that did not appear to react to the raft but were briefly visible as they swam by; the visitors would remain near the raft for several minutes to an hour but did not aggregate; and the residents aggregated and formed an association with the raft. Some commercial species which were considered resident such as mahimahi, Coryphaena hippurus, bigeye trevally, Caranx sexfasciatus, and kahala, Seriola dumerili, were observed and captured in 2 days of fishing at the experimental plant ship, "Mini-OTEC" (once labeled the "world's largest fish aggregation buoy") (Field 1979), off Keahole Point (Johnston and Hicks 1979).

Target species for the various fisheries which capitalize on the presence of the buoys are similar. Tunas dominate the catch of the pole-and-line, trolling, handline, and purse seine boats fishing around FAD's, as evidenced by some catch data obtained from Kiribati, Western Samoa, Fiji, and Hawaii (Shomura and Matsumoto 1982). The experimental study by Matsumoto et al. (1981) provided the most detailed records of catches around FAD's in the Pacific. Table 4 presents the 1978 catch of the commercial pole-and-line boats around the Hawaiian FAD's and Table 5 presents the catch of trolling boats around the FAD's from May 1977 through July 1979. Matsumoto reported that skipjack tuna, Katsuwonus pelamis, which represented nearly 90% of the catch, dominated the catch by the pole-and-line boats. These fish ranged from 0.9 to 5.4 kg and sometimes over 9.1 kg. Unlike pole-and-line boats, trolling boats had a much more diversified catch. Tunas (mostly yellowfin tuna, Thunnus albacares, and skipjack tuna) still dominated the catch although mahimahi constituted the largest percentage of single species caught.

Another tuna fishery which utilizes FAD's (in conjunction with an artificial light source) in Hawaii is the ika-shibi or the night handline fishery for tuna. Although this rapidly growing fishery utilizes extremely simple gear (a single hook and a line) as compared with the longliners and large purse seiners, it is an extremely effective method as indicated by the mean catch rate of approximately two fish per hook per night (Yuen 1979). From 1973 to 1975, the catch and value of tuna has shown a consistent growth from 89,000 kg, valued at $131,000, in 1973 to 155,000 kg, valued at $328,000, in 1975 (Table 6).

B. Land-Based Facilities

1. Platforms and artificial reefs

The land-based tower and man-made island designs of OTEC pilot plants are expected to function as artificial reefs. Stone (1974) defined artificial reefs as "...man-made or natural objects intentionally placed in selected areas of the environment to duplicate those conditions that cause concentrations of fishes and invertebrates on natural reefs and rough bottom areas." As stated by Dugas et al. (1979), because offshore oil drilling platforms are constructed solely for oil and gas production, they may not fit Stone's definition of an artificial reef; however, the platforms do function as artificial reefs and the structures produced a new marine ecosystem that was instrumental in the development of an offshore sport fishery. The attractive effects of a tower OTEC facility would appear to mirror those of an offshore drilling rig. For this summary, therefore, offshore platforms and artificial reefs will be treated together and will be referred to generally as structures.

2. Theories associated with artificial reefs

The attraction of fishes to artificial reefs may be attributed to many of the same reasons given for their attraction to floating objects, including orientation, food, shelter, and energy conservation (Stone 1978). The theory that fishes aggregate as a means of energy conservation was advanced by Stone et al. (1974) in Florida. It appeared that fishes used protected or favorable areas created by the presence of a structure which in turn dampened or deflected the strong Gulf Stream. When the current was strong, the fishes crowded inside the sheltered area whereas they scattered around or above it when the current was weak.

Depending on the structural design, attraction hypotheses such as providing shade for fishes (Suyehiro 1952), producing shadows to make zooplankton more visible for fishes to feed upon (Damant 1921), providing a substrate for fishes to lay their eggs (Besednov 1960), providing spatial references around which fishes could orient in an otherwise unstructured environment (Klima and Wickham 1971), and seeking shelter from predators (Suyehiro 1952) would appear to be valid. However, a combination of the various hypotheses would still be required to explain why such structures are attractive, thus indicating that the reasons may be species specific.

Unlike flotsam, artificial reefs are known to be prolific producers of food at the lower trophic levels. Algae, the basis of ocean life, thrive offshore on hard surfaces such as rock or concrete, provided sufficient light is present. Consequently, algal growth is most prolific near the surface. Although the proposed structure would occupy the full water column, algal growth would be limited to the areas of the structure within the euphotic zone. As reported by Gunter and Geyer (1955), various encrusting and serpulid worms were among the organisms that took advantage of the artificial habitat created by an oil platform. A detailed description of the fauna at an artificial reef in Santa Monica Bay, California is given by Turner et al. (1969). The artificial reefs were constructed of quarry rock, concrete shelters, automobile bodies, and a streetcar. Table 7 presents the invertebrate fauna of the concrete shelter portions of the reef.

Although attraction of fish to man-made structures is well documented, questions still arise regarding the relationship between artificial structures and fish production. Mallory (1965) believed that a structure concentrated the fishes which constantly migrated in and out, thus serving as an orientation point. This was true for a number of species (primarily the game fishes) associated with flotsam. Stroud (1965) felt that since the artificial habitat provides food and shelter, reproduction will be enhanced resulting in an increase in production and yield of fishes. A third hypothesis discussed by Carlisle et al. (1964), Turner et al. (1969), and Dugas et al. (1979), combines both viewpoints: fishes are concentrated by recruitment, and, as the colonization progresses on the structures, a reproducing resident fish community may evolve. Although this may hold true for many of the reef fishes, this hypothesis falls short of accounting for overall fish attraction as evidenced primarily for such species as the deeper water pelagic scombrids and billfishes.

3. Artificial reefs and fisheries

The knowledge that artificial structures can turn barren, nonproductive areas into productive fishing habitats has been applied all over the world. The most advanced artificial reef program is in Japan, where various structural designs have been used to enhance the Japanese fishing grounds for more than 200 years (Sheehy 1981). The early artificial structures were deployed by individual fishermen using stone, wood, and scrap boats. Since then, artificial reef programs have expanded and the Japanese Government has supported programs for the past 50 years.

In 1976, the Japanese Government began its current billion dollar reef program. In essence, the structures deployed in this program are of two categories: the low-profiled tsukiiso in shallow waters and the high-profiled gyosho in deeper waters (Unger 1966; Sheehy 1981; Ogawa 1982).

The tsukiiso, meaning "bank building" or "constructed beach," is designed with the intent to improve the nearshore bottom conditions for such invertebrates as abalone, lobster, sea urchin, sea cucumber, and seaweed. Examples of these structures are shown in Figure 6.

The gyosho or "fish reef" is designed to expand natural reefs. These not only include the bottom structures but also moored midwater attractants and surface FAD's. Figure 7 presents some variations of the gyosho. Some of the Japanese designs have since been deployed in United States' waters where, although it was evident that the prefabricated reefs were not "tailormade" for North American fisheries, they could be modified. As indicated by Sheehy (1982), the concepts developed for the units may be applied to the improvement efforts in scrap-material reefs, especially the continued use of tires, concrete rubble, ships, and offshore drilling platforms.

The Japanese programs have shown that seaweeds grow well on small, low objects; invertebrates are best attracted to structures with many holes or crevices; and the higher and larger the structure, the more fishes are attracted to it (Unger 1966; Sheehy 1981).

4. Organisms attracted to artificial reefs

Numerous studies have described the variety of fishes which have been attracted to artificial reefs at various sites. In all studies, the many different species found generally represent similar basic broad behavioral classes (such as the Turner et al. (1969) reef or nonreef associations; the former further split into resident or semiresident). Presented in Table 8 is a list of fishes observed at an artificial reef project in Hawaii, which is in close proximity to a proposed OTEC site.

Four reefs were established at various sites in Hawaii between 1960 and 1973, using primarily car bodies, damaged concrete pipes, and old car tires filled with mortar. The southern boundary of a reef created at one of these sites (Waianae) on the western coast of the Island of Oahu is at lat. 21°25.1'N, long. 158°11.6'W (Kanayama and Onizuka 1973). This site is only 3 miles from the present OTEC benchmark survey site at lat. 21°19.5'N, long. 158°12.5'W (Figure 8; Jones 1981).

In the study at the Waianae artificial reef, sampling along a fish transect established before the reef construction indicated the presence of 32 different species and a standing crop density of 103 pounds of fish per acre. Kanayama and Onizuka (1973) used the change in the density between the pre- and post-reef construction transects as an index to rate the reef's effectiveness in increasing fish life. The reef was constructed in two sections, one composed of car bodies and the other of damaged concrete pipes. Thirty species of fishes (standing crop estimated at 1,271 pounds per acre) were present at the car body section. This was a tenfold increase over the pre-reef count. The concrete pipe section showed a fivefold increase of 45 fish species and a standing crop estimated at 496 pounds per acre. The results of the surveys conducted at the Waianae reef as well as at three other sites are presented in Table 9.

Since offshore platforms occupy the entire water column, they have additional attraction potentials. Epipelagic fish species which occupy the water column near commercial FAD's have been observed at platforms. The fish fauna at an offshore platform and the use of the water column near the structure as a habitat were discussed by Hastings et al. (1976), in their study of two offshore platforms (one 32 m deep and the other 18 m deep) in the northeastern Gulf of Mexico (Table 10).

In addition, Dugas et al. (1979) summarized the major game fish species which were attracted to and caught at platforms in the Gulf of Mexico off the Louisiana coast (Table 11). It was emphasized that the profileration of offshore oil and gas platforms has contributed immensely to the development of the state's offshore sport fishery.

C. Attraction to Night Illumination

The attraction of various marine organisms to light is a phenomenon that has been used in the harvesting of fish for many years. Mackerel scad, Decapterus macarellus, and bigeye scad, Selar crumenophthalmus (Yamaguchi 1953; Powell 1968), various species of tuna (Yuen 1979), and squid (Ogura and Nasumi 1976), are caught by the use of night lights. As indicated by Sullivan et al. (1981) and Yuen (1981), the impact upon both planktonic and nektonic organisms attracted to light from an OTEC facility is a major concern.

In the recent survey of the fishery resources in the Northwestern Hawaiian Islands conducted by the HL, night-light fishing was used as one of the sampling methods. The light (a 1,500-W bulb) was initially submersed to 21.3 m (the maximum amount of wire out). After an hour, the light would be raised to about 10 m below the surface and to within 2 m about an hour after that. The purpose for the lowering and raising was to attract the organisms farther down and draw them to the surface with the light. The intensity of the light was controlled with a rheostat. Dimming the light concentrated the organisms and facilitated observation and collection.

Generally, the first organisms to appear around the light were zooplankton. This was also observed by Powell (1968). Soon after the zooplankton have collected within the radius of the light, larger organisms appear.

Among the positively phototactic species are the baitfish, such as the silversides (Atherinidae) and small round herrings (Clupeidae). Flyingfishes (Exocoetidae), halfbeaks (Hemiramphidae), filefishes (Monacanthidae), and lanternfishes (Myctophidae) are also commonly seen around night lights.

In addition to the mackerel scad, bigeye scad, squids, and tunas, other marketable fishes taken at the night light were the squirrelfishes, Myripristis spp., and the red bigeyes, Priacanthus spp.

How much an effect the lights from an OTEC facility will have on the fauna is not presently known. As indicated by Laevastu and Hayes (1981), every species has a particular optimum light intensity in which its activity is at a maximum. It is probable that the lux of the artificial lights would fall within the thresholds of some species.

D. Seasonal and Diurnal Variations

The fish community attracted to artificial structures varies with the season. In a study of two platforms off the Florida Gulf coast, differences in faunal composition with seasonal changes were obvious. Hastings et al. (1976) found that changes in fish fauna were correlated with temperature and that larger numbers of species were present during the warmer months of summer and fall, whereas the least were observed through the winter and spring. The seasonal estimates of abundance (Table 10) indicated that most species leave the area in the winter and gradually return in the spring or summer.

Among the fishes which may exhibit seasonal variation and those most apt to be affected by the presence of offshore structures are the game fishes. These include the billfishes, mahimahi, and tunas.

The occurrence of adult male blue marlin, Makaira nigricans, appears to be seasonal throughout its range (Rivas 1975). In Hawaii, blue marlin catches are highest in summer and lowest in winter. Similarly, the largest catches in Puerto Rico are made in August, September, and October, and the lowest in December. In their study of billfish caught by longline in the eastern Pacific, Kume and Joseph (1969) suggested that blue marlin segregated into distinct areal groups according to sex.

In Hawaii, striped marlin, Tetrapterus audax, occurs from fall through spring and is abundant mainly in the summer months, in complement to the blue marlin (Strasburg 1970). The distribution of the striped marlin in its range throughout the rest of the world is also seasonal (Ueyanagi and Wares 1975).

The abundance of mahimahi is seasonal throughout its range although the season of peak abundance varies greatly (Palko et al. 1982). It was also reported that because many environmental factors are interlinked and dependent upon the prevailing oceanographic conditions, it was probable that the various factors contributed in varying degrees to the seasonal abundance of the species.

The two major commercial tunas in Hawaii, the skipjack and yellowfin, are usually available during the entire year although a marked increase is evident during the warmer months of May to September (Schaefer et al. 1963; Waldron 1963). Most if not all of the other game fishes in the world also exhibit seasonal variation. Generally, oceanographic (temperature and salinity) and environmental influences determine all the seasonal distributions of the species.

Although numerous marine organisms exhibit diel vertical migrations, the largest community, the vertically migrating deep scattering layer is too deep to pose a realistic attraction problem. The migratory behavior is influenced by the occurrence of natural light (Boden and Kampa 1967) but no evidence exists that the community responds to any attractive effect posed by a structure or artificial light source.

III. AVOIDANCE OF STRUCTURES BY MARINE ORGANISMS

Among the major concerns regarding the presence of an OTEC facility is the impact upon the marine species that are classified as being endangered or threatened. At the present time, not much is known about attraction or avoidance responses of these animals to the facilities; therefore, impact assessments have been mainly speculative. Yuen (1981) indicated that the endangered and threatened species would probably avoid the area due to human presence and to the noise emitted from the plant. Sullivan et al. (1981) presented a list of these species and their distribution at the candidate OTEC sites (Table 12).

Research on fishing gear and methods in the past have concentrated on developing fishing techniques which utilize the understanding of fish behavior to achieve better catches per unit of effort. Thus, emphasis has been placed on attraction rather than avoidance of organisms. Among the few studies that address avoidance was one on the negative phototactic behavior of fish. Dragesund (1958) found that herring would sometimes display a shock response. That is, when the light was turned on, the fish would make a sudden upward movement towards the light only to latter disperse or school and descend.

Studies on other aspects of avoidance, such as of the physical structures, are nonexistent in published literature. Future studies should be directed in this area.

IV. SUMMARY AND CONCLUSIONS

The environmental considerations for deployment of an OTEC facility would depend to a large extent upon the benefits and adverse effects produced by the attraction of marine organisms to such a structure. As stated by Sullivan et al. (1981), "...because of the synergistic effect attraction has on impacts, attraction is the most important environmental effect associated with platform deployment."

The obvious benefit from the construction of an OTEC facility is the possibility for fishery enhancement. If the results obtained by the use of FAD's and offshore platforms are any indication of what could be expected by the presence of an OTEC facility, commercial and recreational fishermen would benefit greatly by its deployment. It would be a further plus if the artificial reef created by the facility not only aggregate organisms but serves as the substrate and habitat to enhance the production of the marine community.

Along with the benefits to fishery development are man-made disturbances to the environment. Combined with the noise from the plant, the increased activity and presence of man may affect the larger marine animals (in particular the endangered and the threatened species) from the area. In recent years, these animals have become the subject of much public concern and thus, any OTEC deployment must seriously consider any potential impacts upon them.

Much research is still needed in the study of the attraction and avoidance effects upon marine organisms because of the alteration of their natural environment. The effects of other possible nonstructural attractants, such nutrients which are added to the environment by a coexisting aquaculture farm or chlorine or other biocides discharged from the facility, have not been tested. Research is continuing on the possible use of cold water effluent from a coexisting OTEC plant by the Natural Energy Laboratory of Hawaii aquaculture farm. Thus, the study of the attraction effects of the farm's nutrient-rich effluent may be advised. Practically no information is presently available on the avoidance by marine organisms of artificial changes in the environment.

It is evident from what is known about attraction, that the design and location of structures will prove extremely important with respect to the severity of any environmental impact.

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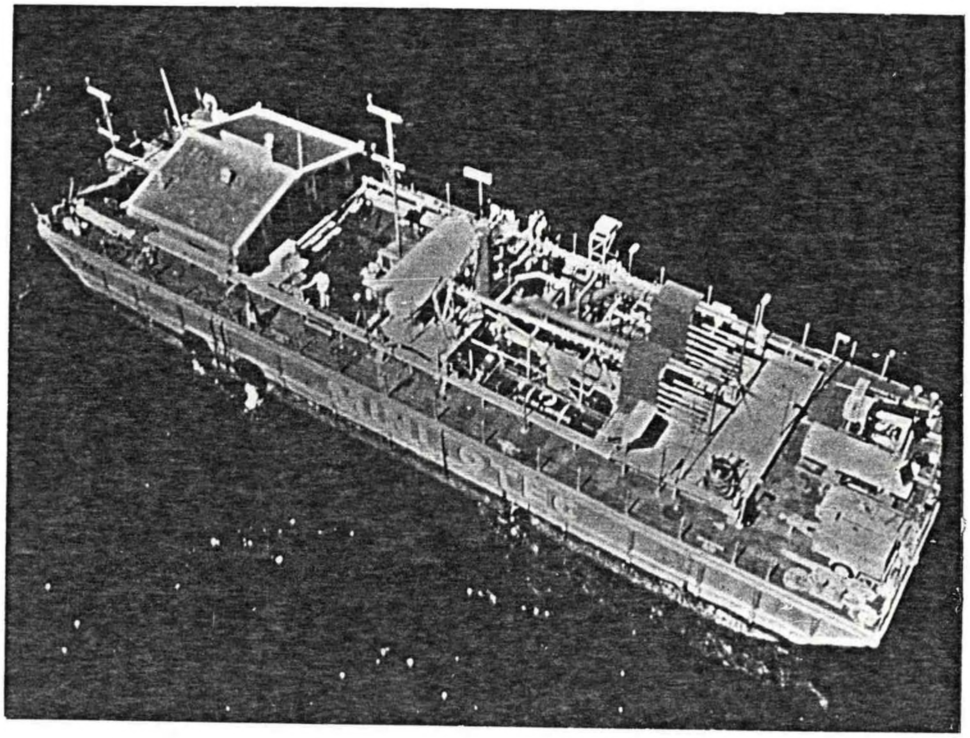
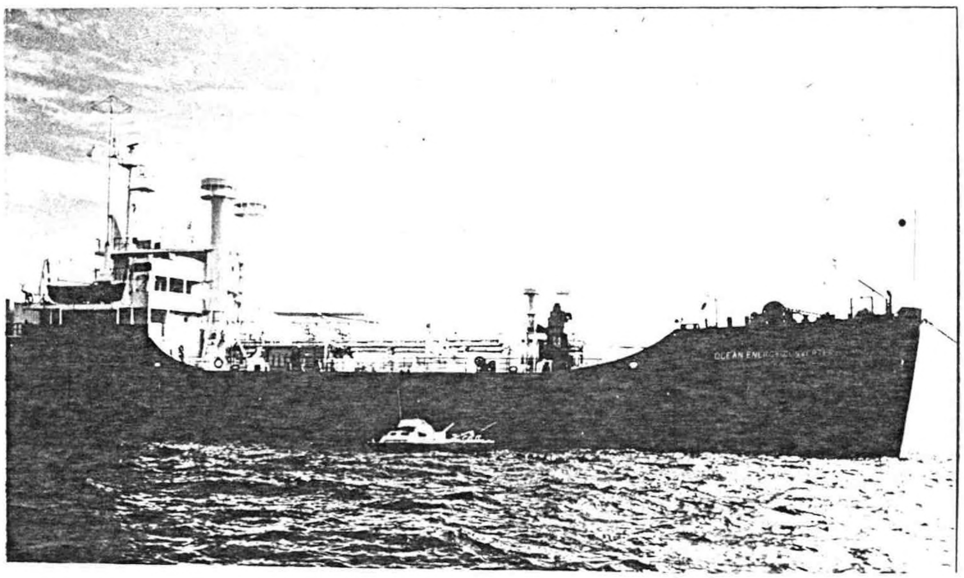
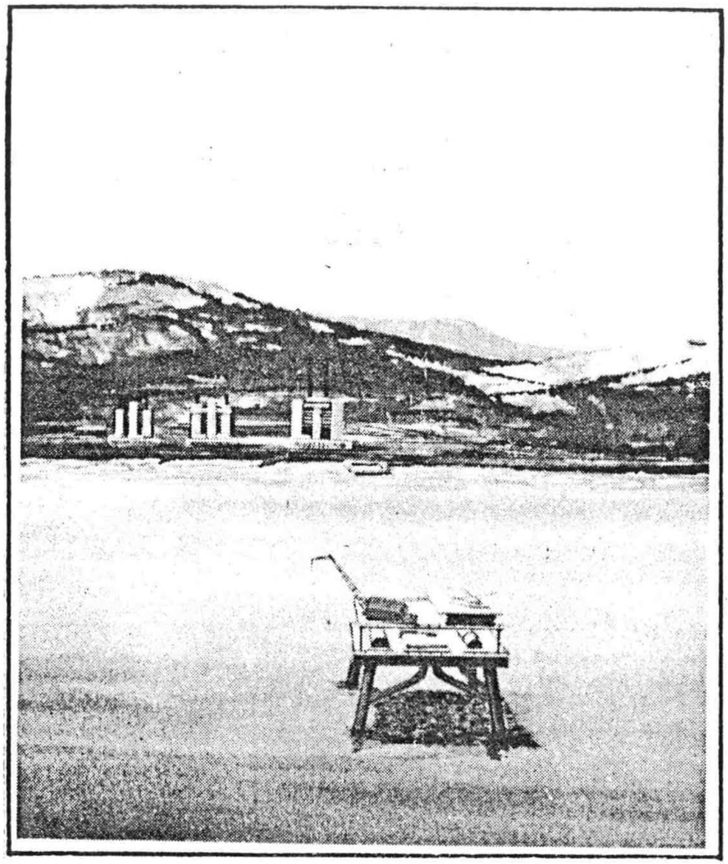


(a) Mini-OTEC
(Photo courtesy of the State of Hawaii, Department of Planning and Economic Development, Honolulu, Hawaii.)

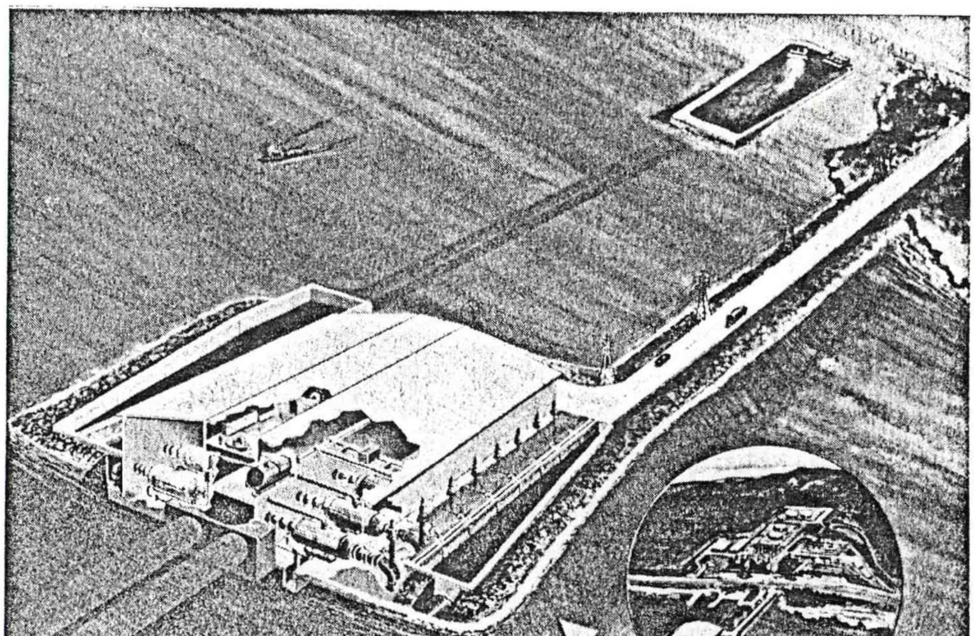


(b) OTEC-1
(Photo courtesy of J. J. Naughton, Western Pacific Program Office, National Marine Fisheries Service, NOAA, Honolulu, Hawaii.)

Figure 1.--Experimental open ocean plantships deployed off Keahole Point, Hawaii.



(a)



(b)

Figure 2.--The OTEC land based designs for Kahe Point, Hawaii.
(a) The General Electric tower concept pilot plant design.
(b) The Ocean Thermal Corporation man-made island pilot plant design.

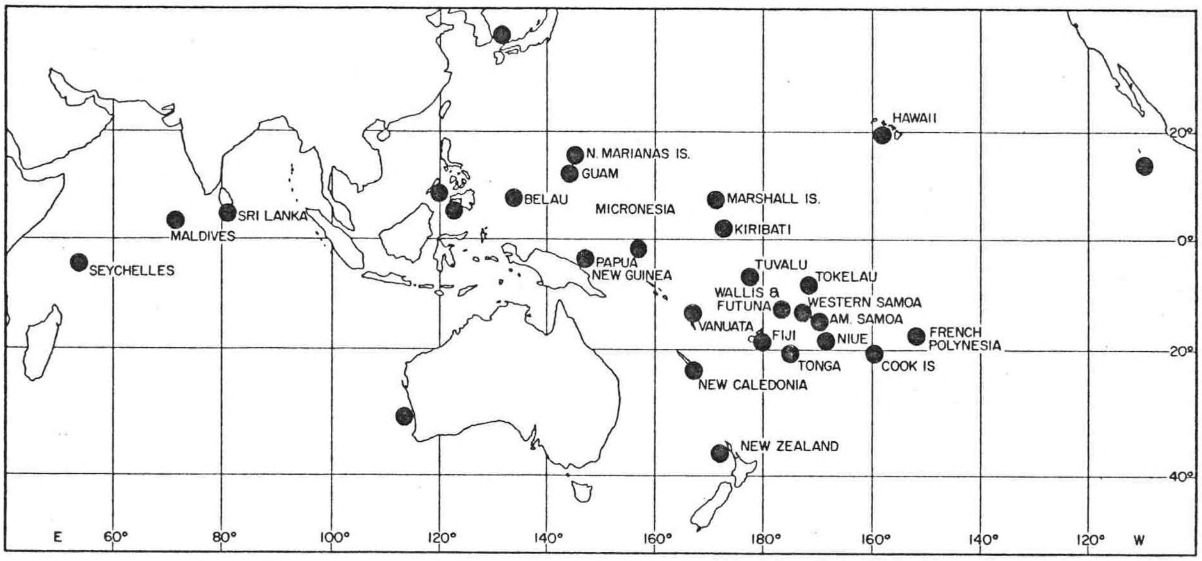


Figure 3.--Locations where fish aggregating devices have been deployed 1979-81, or where deployment is planned in the Pacific and Indian Oceans (Shomura and Matsumoto 1982).

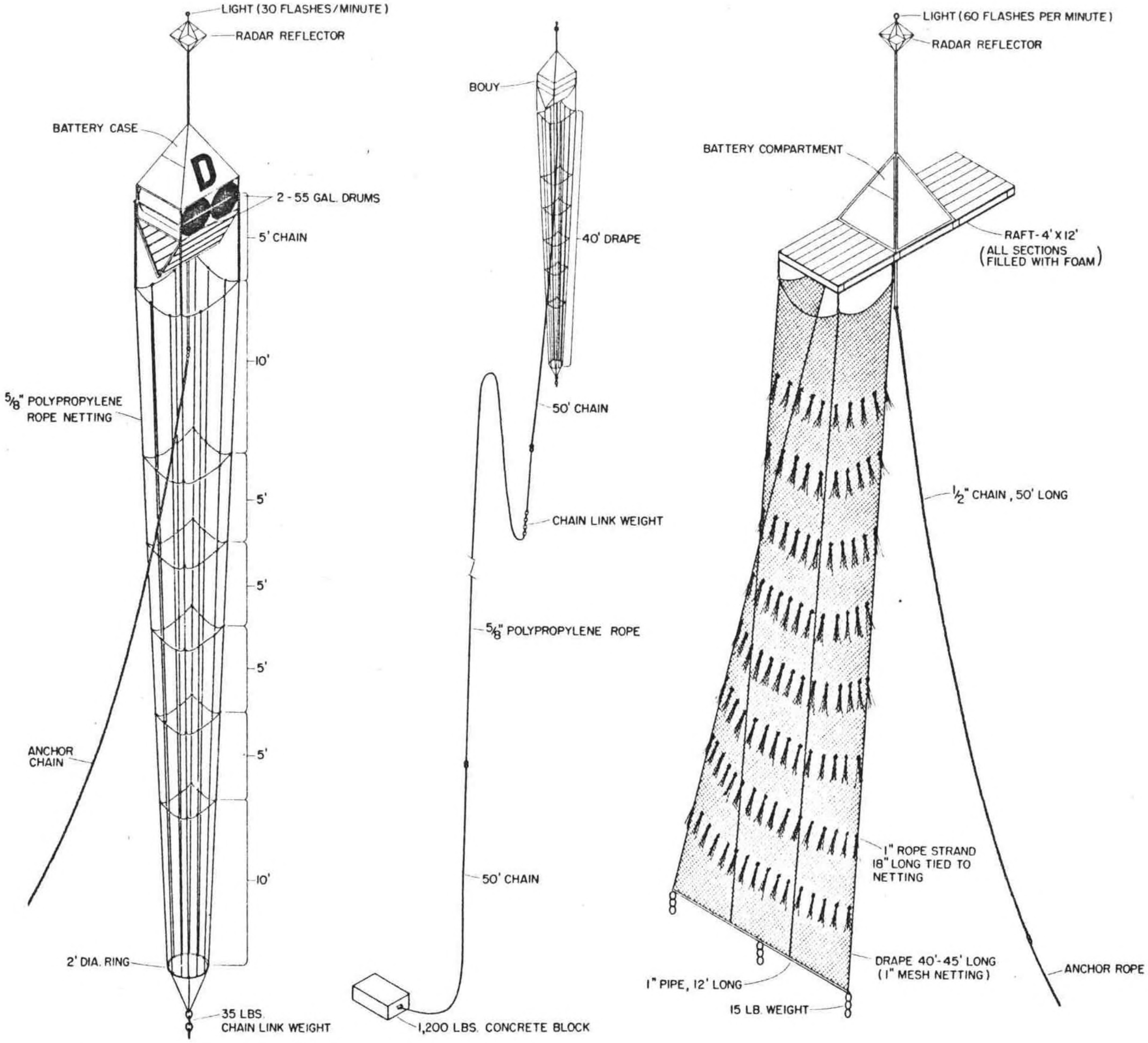


Figure 4.--Experimental designs for Honolulu Laboratory's fish aggregating devices.

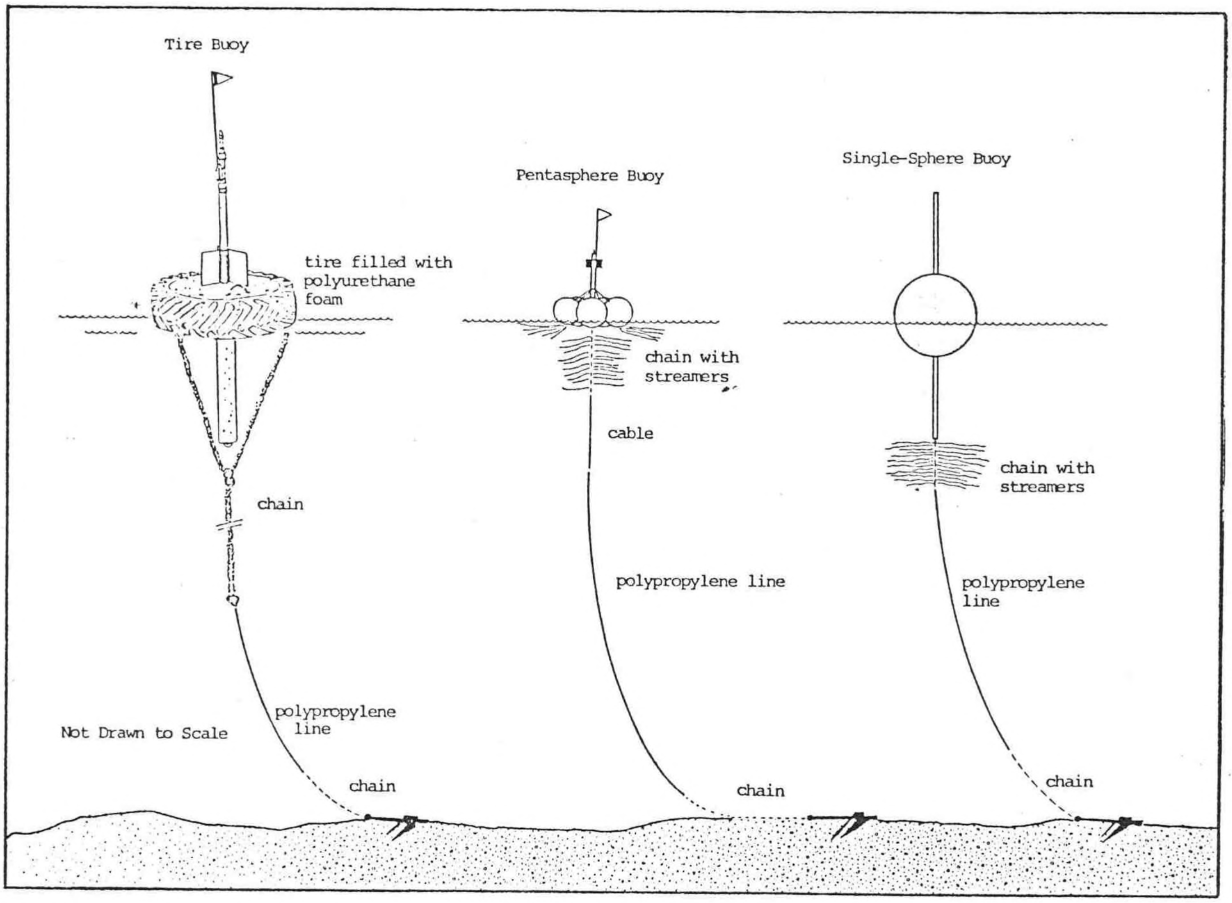
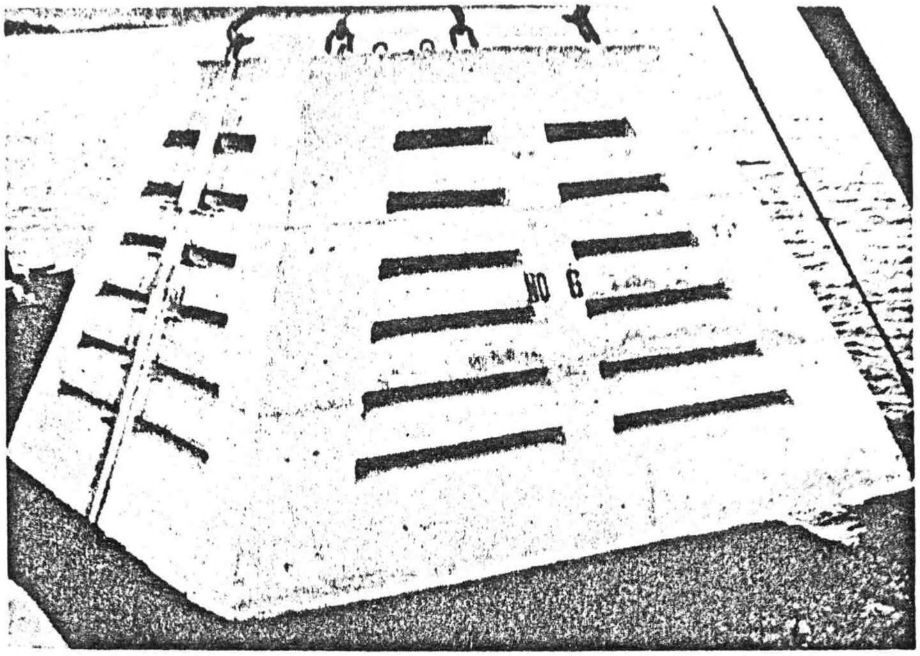
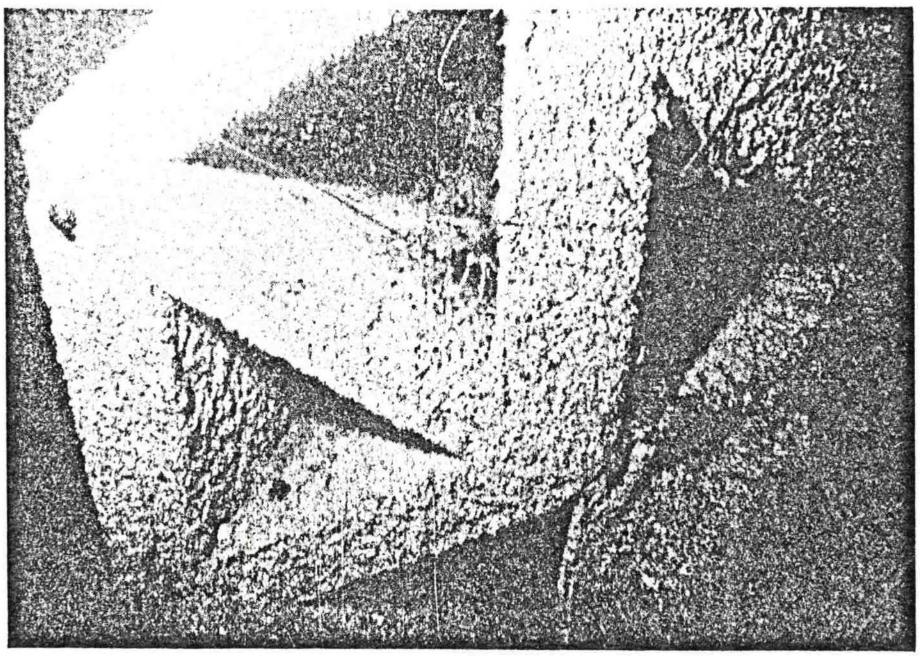


Figure 5.--Department of Land and Natural Resources' fish aggregating device designs ([Hawaii.] Department of Land and Natural Resources 1983).

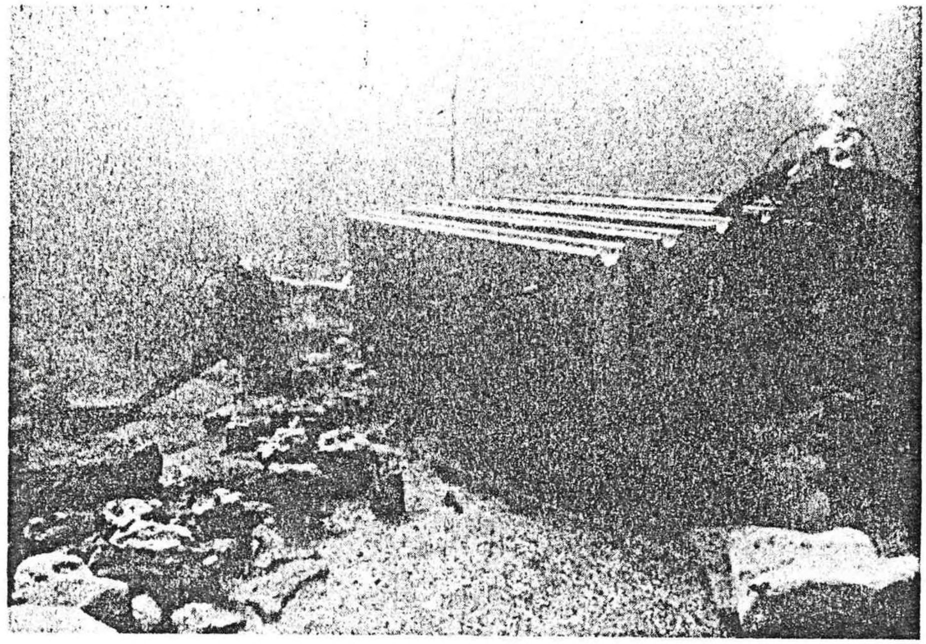


Shelter unit for spiny lobster used in Nagasaki.
Photo credit: Mr. Inui.

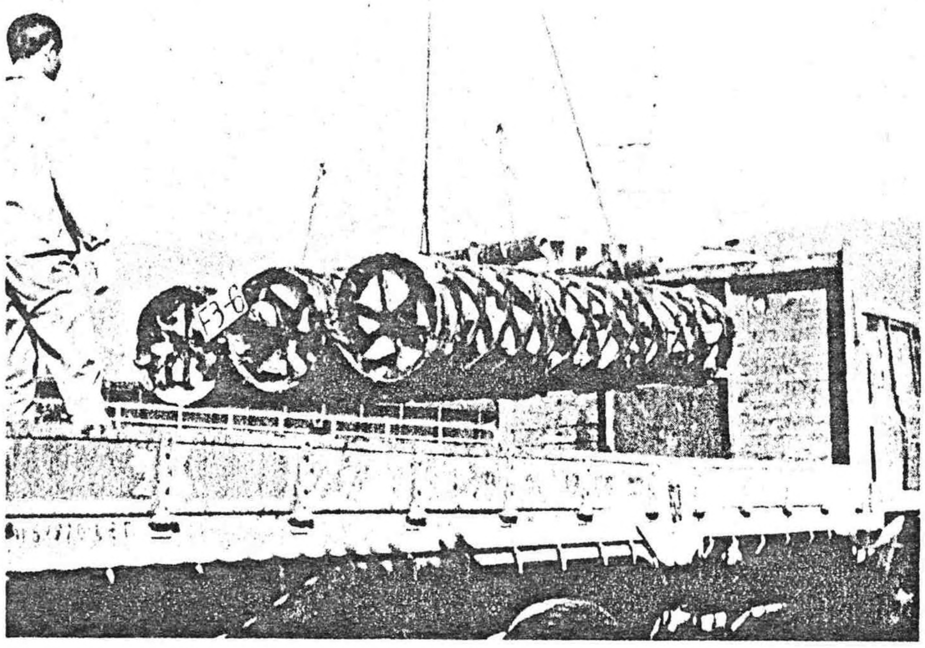


Shelter unit for lobster in Miyazaki.
Photo credit: Mr. Uchida.

Figure 6.--Variations of the Japanese tsukiiso or constructed beach (Sheehy 1981).

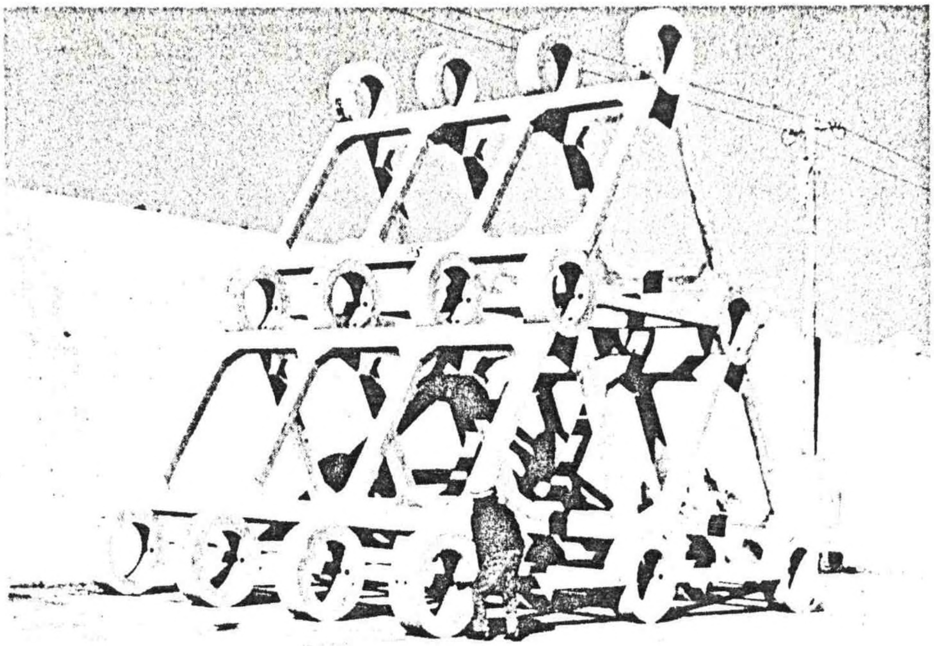


Abalone shelter unit being placed in Hokkaido.
Photo credit: Dr. Sato.

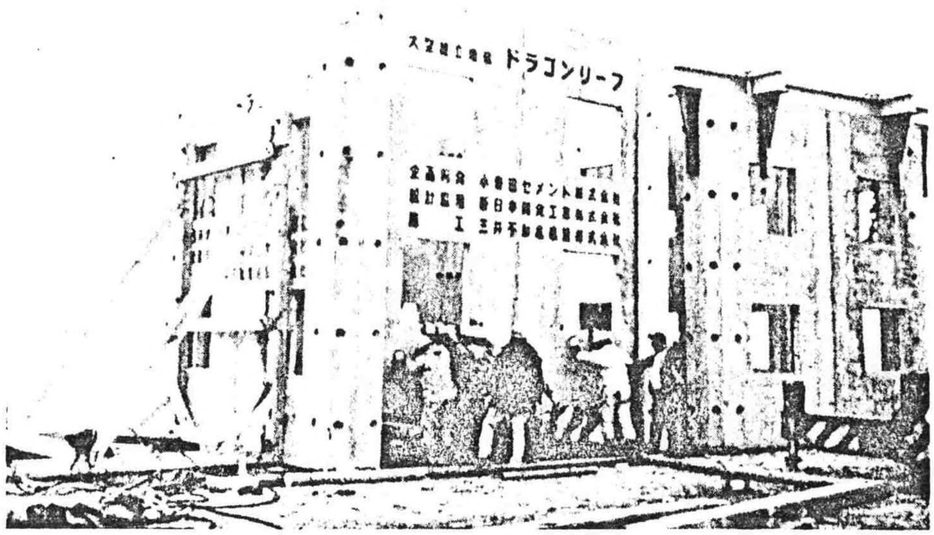


Abalone shelter unit composed of FRP frame with rocks. Asahi Chemical International, Ltd. Photo credit: Dr. Ogawa.

Figure 6.--Continued.

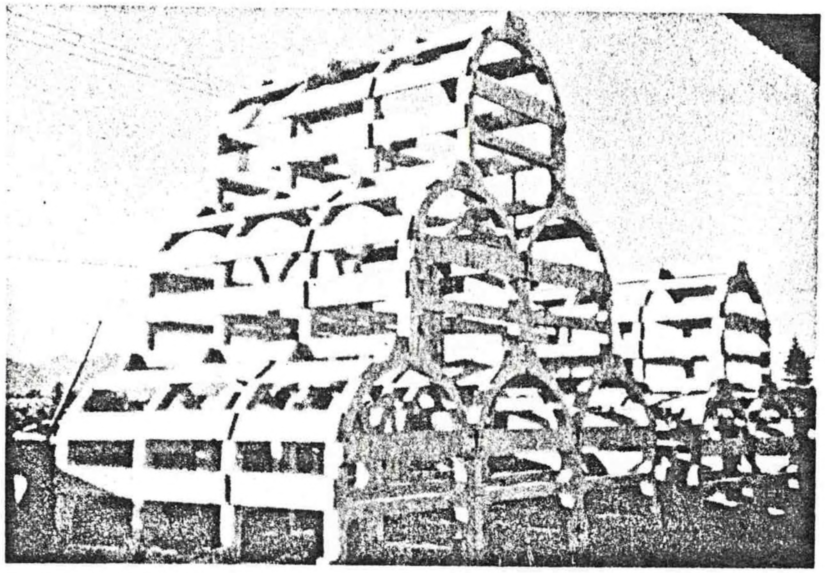


Large scale prefabricated fish reef of reinforced concrete by Ishikawajima Kensai Kogyo Co., Ltd. Photo credit: IKK Co., Ltd.

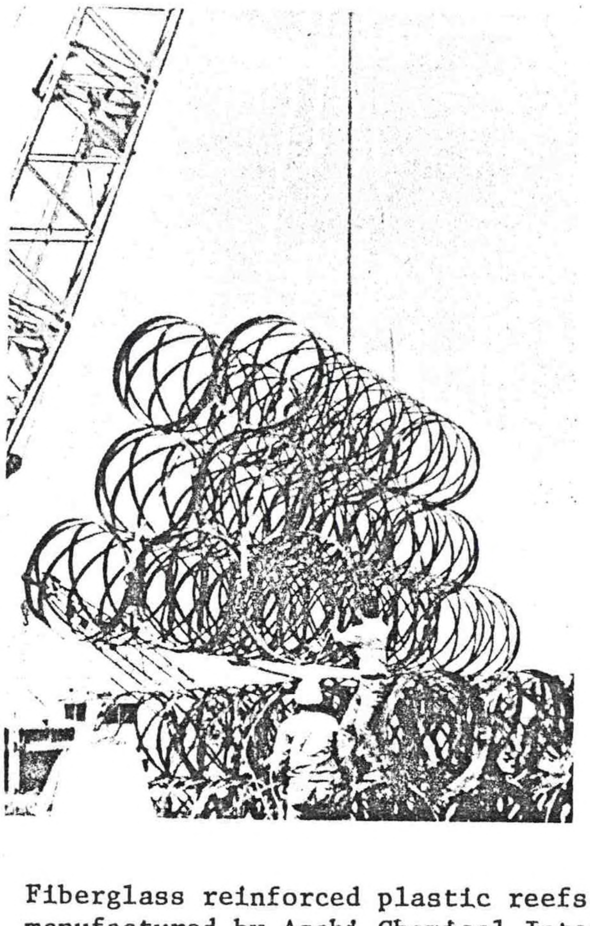


"Dragon Reef" under construction at shore staging area. Photo credit: Onoda Cememt Co., Ltd.

Figure 7.--Variations of the Japanese gyosho or fish reef (Sheehy 1981).



"Kamaboko Reefs," in two different configurations.
Photo credit: Ryowa Concrete Industries, Inc.



Fiberglass reinforced plastic reefs manufactured by Asahi Chemical International, Ltd. Photo credit: Dr. Ogawa.

Figure 7.--Continued.

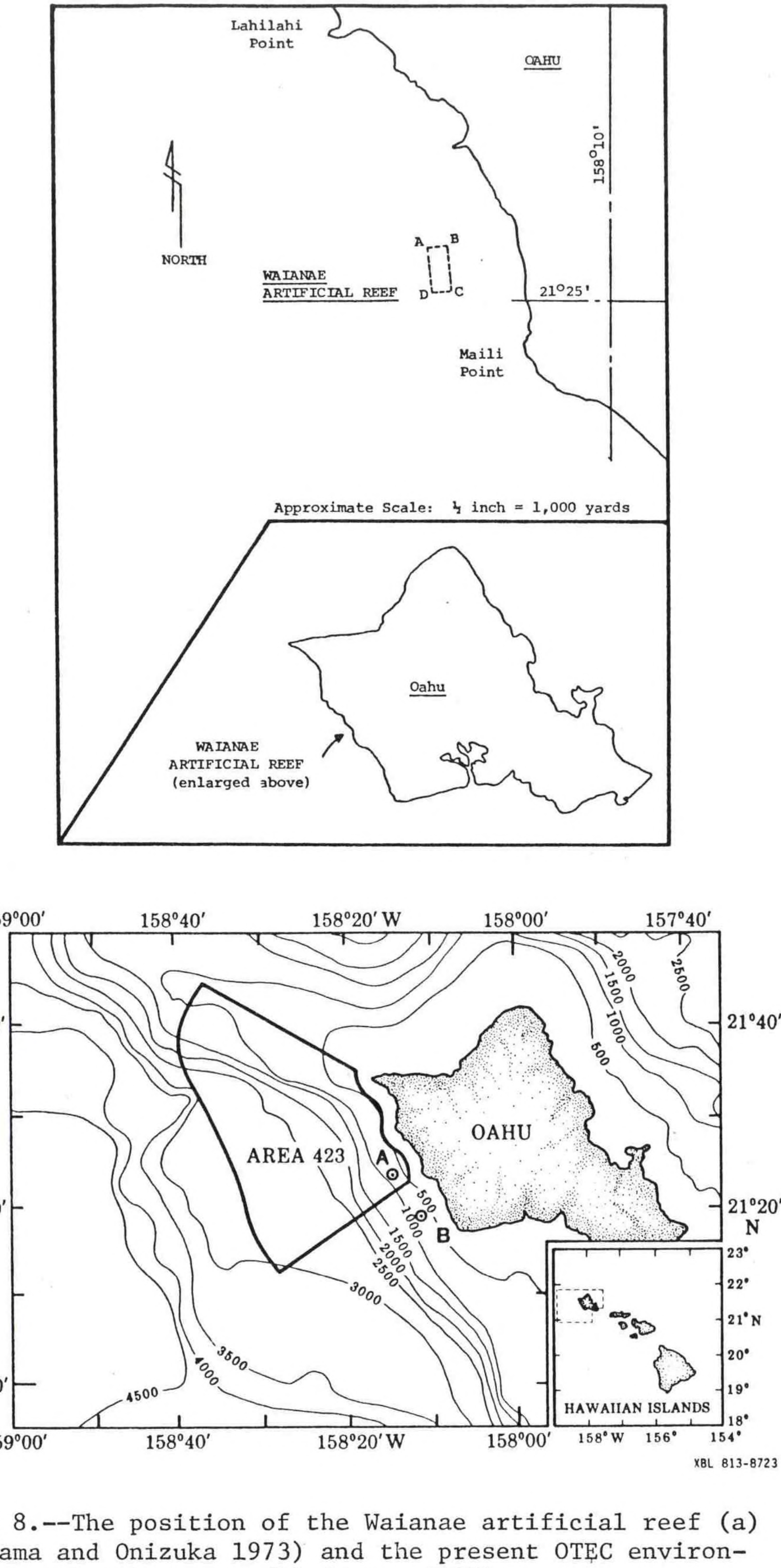


Figure 8.--The position of the Waianae artificial reef (a) (Kanayama and Onizuka 1973) and the present OTEC environmental benchmark survey (b) (Jones 1981).

TABLE 1. Potential adverse environmental impacts and mitigating measures related to biota attraction and avoidance at an ocean thermal energy conversion site (from Yuen 1981).

Issue	Community Affected					Mitigating Measures (Ranked by Effectiveness)	Research Needs
	Plankton	Nekton	Benthos	Threatened and Endangered Species	Man's Activities		
Biota Attraction and Avoidance	Increased number of organisms due to attraction to lights.	Increased number organisms due to attraction to structure and lights.	Colonization of exposed structures.	Possible avoidance of area due to human presence and noise.	-Increased fishing. -Loss of desired faunal diversity.	-Site away from breeding and nursery grounds. -Reduce lights and noise to minimum needed for safe operation. -Reduce attraction surfaces.	-Site evaluation studies to determine ecological sensitivity of areas. -Determine biota attraction and avoidance to different platform configurations and lighting systems.

TABLE 2. Deployment and longevity of fish aggregating devices in the Pacific and Indian Oceans,[1] 1979-81 (from Shomura and Matsumoto 1982).

					Fish aggregating device (days)			
Country or locality	Type of fish aggregating device	No. set	(planned)	No. lost	Range	Mean	Max.	Continuing[2]
American Samoa	3-drum	11		11	7-510	266.0	510	No
	Doughnut	5	(8)	3	14-60	35.0	250	Yes
Australia	3-drum	4		4	335-427	365.5	427	No
	Foam block	2	(6)	--	--	--	120	Yes
Cook Islands	3-drum	1		1	150	--	150	No
	Aluminum catamaran	4	(2)	--	227-592	--	592	Yes
Eastern Pacific	Plyboard raft	5		5	62-137	107.3	137	No
Fiji	Bamboo raft	120		96	1 year	--	--	--
	Wooden raft	2		1	--	--	120	--
	Aluminum catamaran	1		--	--	--	--	--
French Polynesia	3-drum	8		4	--	--	--	--
Guam	3-drum	3		3	6-123	70.3	123	No
	Tractor tire	5		3	28-258	142.6	338	Yes
Hawaii	Tractor tire	26		11	60-540	237.3	540	No[3]
	Pentasphere	34	(45)	25	30-450	164.4	450	No
Kiribati	Fiberglass-pole raft	3	(6)	3	7-40	25.0	40	No
Maldive Islands	Various types	9		--	--	--	--	--
Marshall Islands	Bamboo raft		(20)	--	--	--	--	--
Micronesia	--	20+		--	--	--	--	--
New Caledonia	--		(6)	--	--	--	--	--
New Zealand	--	3		--	--	--	--	--
Niue	Aluminum single hull		(2)	--	--	--	--	--
Northern Marianas	3-drum	5		5	150-310	162.0	210	No
Belau	Tractor tire	6		6	30-270	150.0	270	No
Papua New Guinea	Bamboo raft	76		25	--	--	--	--
Seychelles	Pipe-frame raft	5	(10)	1	60	--	123	Yes
Sri Lanka	--		(12)	--	--	--	--	--
Tokelau	--		(1)	--	--	--	--	--
Tonga	Aluminum catamaran	2	(2)	2	30-210	120.0	210	No
Tuvalu	--		(NA)	--	--	--	--	--
Vanuatu	Plyboard raft		(5)	--	--	--	--	--
Wallis and Futuna	--		(5)	--	--	--	--	--
Western Samoa	3-drum	5		5	236-270	257.4	270	No
	Aluminum catamaran	23	(3)	10	287-424	368.2	566	Yes
	Total/range	379+	(147)	224			40-592	

[1]Exclusive of countries that used FAD's prior to 1979.
[2]Maximum FAD life continuing as of April 1982.
[3]Maximum FAD life continuing as of June 1982. All existing tire type FAD's removed and replaced by pentasphere type.

TABLE 3. Animals seen from the observation chamber of a drifting raft* (from Gooding and Magnuson 1967).

SPECIES, GENUS, OR FAMILY (Common Name in Parentheses)	DRIFT LOCATION	BEHAVIOR CATEGORY	FORK LENGTH (cm)	MAXIMUM NUMBER SEEN AT ONE TIME
Abudefduf abdominalis (damselfish)	H	R	0.7–1.0†	24
Acanthocybium solandri (wahoo)	H03	R	45–90	3
Alutera scripta (scrawled filefish)	H	RV	10–35	2
Canthidermis maculatus (rough triggerfish)	H	R	25–35†	33
Caranx kalla (golden jack)	H	V	30	1
Caranx sp. (jack)	H	R	2.9–5.3†	3
Carcharhinus longimanus (whitetip shark)	H03	RV	125–175	2
Chelonia mydas (green turtle)	0	V	60	1
Coryphaena equiselis (pompano dolphin)	03	V	30	100+
Coryphaena hippurus (dolphin)	H03	R	60–100†	70+
Coryphaena sp.	H03	R	10–15	80
Decapterus pinnulatus adult (mackerel scad)	H03	RT	20–25	1,000+
juvenile	3	R	13.1†	1
Diodontidae (spiny puffer)	0	V	12	1
Echeneidae (free-swimming) (remora)	3	R	8	1
Elagatis bipinnulatus (rainbow runner)	3	R	75	1
Exocoetidae (flyingfish)	H03	T	10–15	10+
Fistularia petimba (cornetfish)	H	V	20–40	2
Globicephala scammoni (pilot whale)	H0	V	375	2
Holocentridae (squirrelfish)	H	R	2	1
Istiophoridae (marlin)	H	T	125	1
Katsuwonus pelamis adult (skipjack tuna)	H3	T	45	1,000+
juvenile	3	RV	10–15	50
Kyphosus cinerascens (sea chub)	H	R	2.5†	13
Manta alfredi (manta ray)	H	V	100–125†	1
Manta sp.	0	V		1

TABLE 3. Continued.

SPECIES, GENUS, OR FAMILY (Common Name in Parentheses)	DRIFT LOCATION	BEHAVIOR CATEGORY	FORK LENGTH (cm)	MAXIMUM NUMBER SEEN AT ONE TIME
Mulloidichthys samoensis (goatfish)	H	RV	10–12	1,000+
Naucrates ductor adult (pilotfish)	H03	RV	15–30	7
juvenile	H03	R	2.6–6.7†	7
Nomeus gronowi (man-of-war fish)	0	V	2	1
Prionace glauca (great blue shark)	0	V	150	1
Psenes cyanophrys (freckled driftfish)	H03	R	1.5–12.4†	1,000+
Remora remora (attached) (remora)	H03	RV	15–30	—
Rhincodon typus (whale shark)	3	V	300	1
Seriola rivoliana§ (amberjack)	H	R	20†	1
Seriola dumerili (greater amberjack)	H	R	3.7	1
Sphyraena barracuda (great barracuda)	H	V	50	1
Thunnus albacares (yellowfin tuna)	H3	RV	25–40	37
Tursiops sp. (bottlenose dolphin)	H0	V	150–200	20+

* Drift Location: H = Hawaii; 0 = 0° Latitude; 3 = 3° S.
Behavior Category: R = Resident; V = Visitor; T = Transient.
† Measured length; all other lengths are estimated.
‡ Breadth.
§ The first record for Hawaiian waters, identified by Dr. Frank J. Mather, Woods Hole Oceanographic Institution, from a specimen preserved after capture at the raft.

TABLE 4. Fish species caught (in pounds) by pole-and-line boats around fish aggregating buoys during 1978 (from Matsumoto et al. 1981).

		Species								Total	
		Skipjack tuna		Yellowfin tuna		Kawakawa		Dolphin			
Buoy	Visits	Catch	Catch per visit	Catch	Catch per visit	Catch	Catch per visit	Catch	Catch per visit	Catch	Catch per visit
A	92	357,044	3,880.4	22,682	246.5	1,479	16.0	854	9.3	382,031	4,152.5
B	1	5,110	5,110.0	0	0.0	0	0.0	0	0.0	5,110	5,110.0
C	14	103,037	7,359.8	1,475	105.4	4,218	301.3	0	0.0	108,730	7,766.4
D	139	573,106	4,123.1	80,183	576.9	1,706	12.3	3,034	22.6	658,029	4,734.0
Total	246	1,038,297	4,220.7	104,340	424.1	7,403	30.0	3,888	15.8	1,153,900	4,690.6
Percent of total catch		89.73		9.28		0.64		0.34		99.99	

TABLE 5. Species and number of fish caught by trolling boats around fish aggregating buoys, May 1977-July 1979 (from Matsumoto et al. 1981).

	Buoy									Total			
	A			B			C						
Species	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Percent of total
Skipjack tuna	309	423	1.37	160	3	0.02	137	55	0.40	606	481	0.79	23.0
Yellowfin tuna		484	1.57		12	0.08		44	0.32		540	0.89	25.9
Bigeye tuna		11	0.04		0	0.00		10	0.07		21	0.04	1.0
Kawakawa		77	0.25		68	0.42		43	0.31		188	0.31	9.0
Dolphin		217	0.70		275	1.72		280	2.04		772	1.27	37.0
Wahoo		30	0.10		8	0.05		2	0.02		40	0.07	1.9
Blue marlin		15	0.05		3	0.02		1	0.01		19	0.03	0.9
Striped marlin		2	0.01		0	0.00		0	0.00		2	<0.01	0.1
Spearfish		3	0.01		0	0.00		0	0.00		3	<0.01	0.1
Rainbow runner		16	0.05		0	0.00		0	0.00		16	0.03	0.8
Greater amberjack		3	0.01		0	0.00		0	0.00		3	<0.01	0.1
Barracuda		2	0.01		0	0.00		0	0.00		2	<0.01	0.1
Total	309	1,283	4.15	160	369	2.31	137	435	3.18	606	2,087	3.44	

TABLE 6. Weight and value of products of night handline fishery for tuna (from Yuen 1979).

	Weight (t)			Weight (1,000 lb)			Value ($1,000)		
Species	1973	1974	1975	1973	1974	1975	1973	1974	1975
Bigeye tuna	65.4	120.2	63.0	144.2	265.0	139.0	102.6	249.8	149.5
Yellowfin tuna	23.3	22.9	75.5	51.3	50.5	166.4	38.0	38.4	157.0
Albacore	0.4	0.2	16.1	0.8	0.4	35.5	0.5	0.2	21.0
All tunas	89.0	143.3	154.6	196.3	315.9	340.9	131.1	288.4	327.5
Squid	5.0	1.7	1.3	11.1	3.7	2.8	6.2	3.5	3.5

TABLE 7. Invertebrates and ascidians collected from within a 0.06 m^2 area on the concrete shelter portions of the three replication reefs in Santa Monica Bay, 1963 (from Turner et al. 1969).

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Porifera												
Haliclona sp.	--	--	--	--	--	--	--	--	Col.	*15.50	--	--
Leucosolenia botryoides	--	--	--	--	--	--	Col.	<0.05	--	--	--	--
Cnidaria												
Hydroida												
Obelia sp.	Col.	<0.05	--	--	Col.	<0.05	Col.	<0.05	Col.	<0.05	Col.	0.08
Anthozoa												
Corynactis californica	--	--	--	--	--	--	--	--	133	29.30	--	--
Platyhelminthes												
Polyclad (unid.)	1	<0.05	--	--	--	--	--	--	--	--	2	<0.05
Sipunculoidea												
Phascolosoma agassizii	--	--	1	<0.05	--	--	--	--	2	0.08	--	--
Annelida												
Polychaeta	--	0.60	--	0.50	--	<0.05	--	0.85	--	3.70	--	1.00
Chaetopteridae												
Chaetopterus variopedatus	1	--	--	--	--	--	--	--	6	--	--	--
Chrysopetalidae												
Chrysopetalum occidentale	2	--	--	--	--	--	--	--	--	--	--	--
Cirratulidae												
Cirriformia sp.	11	--	--	--	--	--	--	--	--	--	--	--
unid. cirratulid	--	--	9	--	--	--	8	--	--	--	4	--
Flabelligeridae												
Stylarioides inflata	1	--	--	--	--	--	--	--	--	--	--	--
unid. flabelligerid	--	--	5	--	--	--	7	--	--	--	12	--
Lumbrineridae												
Lumbrineris sp.	5	--	--	--	--	--	--	--	1	--	--	--
unid. lumbrinereid	--	--	2	--	--	--	7	--	--	--	1	--
Nereidae												
Nereis sp.	12	--	--	--	--	--	--	--	--	--	--	--
unid. nereid	--	--	7	--	--	--	--	--	--	--	1	--
Opheliidae	--	--	--	--	--	--	--	--	3	--	1	--
Orbiniidae	12	--	10	--	--	--	--	--	--	--	--	--
Phyllodocidae	2	--	3	--	--	--	6	--	3	--	3	--

TABLE 7.--Continued.

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Annelida—continued												
Polychaeta—continued												
Polynoidae												
Eunoe sp.	5	--	--	--	--	--	--	--	--	--	--	--
Halosydna sp.	--	--	--	--	--	--	--	--	1	--	--	--
unid. polynoid	--	--	2	--	--	--	28	--	--	--	61	--
Sabellariidae												
Sabellaria cementarium	7	--	--	--	--	--	--	--	--	--	--	--
unid. sabellarid	--	--	8	--	--	--	3	--	--	--	--	--
Sabellidae												
Sabella sp.	2	--	--	--	--	--	--	--	--	--	--	--
unid. sabellid	--	--	4	--	--	--	--	--	--	--	1	--
Serpulidae												
Spirobranchus spinosus	--	--	--	--	--	--	--	--	3	--	--	--
Spionidae												
Polydora sp.	3	--	--	--	--	--	--	--	--	--	--	--
unid. spionid	--	--	2	--	--	--	--	--	2	--	1	--
Syllidae	--	--	--	--	1	--	--	--	1	--	--	--
Arthropoda												
Crustacea												
Cirripedia												
Balanus aquila	--	--	--	--	28	137.50	1	10.69	8	13.00	--	--
Balanus concavus pacificus	51	57.65	45	1.80	64	62.50	15	8.70	35	5.10	4	0.80
Balanus flos	--	--	--	--	1	0.08	--	--	--	--	--	--
Balanus tintinnabulum californicus	--	--	--	--	1	0.60	--	--	--	--	--	--
Balanus trigonus	--	--	15	0.85	--	--	--	--	20	1.60	2	0.30
Tanaidacea												
Leptochelia sp.	67	0.05	185	0.15	--	--	--	--	--	--	5	<0.05
Isopoda												
valviferan	1	<0.05	--	--	--	--	--	--	--	--	--	--
Amphipoda	--	0.05	--	<0.05	--	0.08	--	--	--	--	--	--
Gammaridea	48	--	11	--	45	--	21	<0.05	3	<0.05	28	0.05
Caprellidea	12	--	2	--	4	--	--	--	--	--	10	0.05

TABLE 7.--Continued.

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Decapoda												
Alpheus dentipes	--	--	--	--	--	--	1	0.50	--	--	--	--
Cancer anthonyi	--	--	--	--	--	--	--	--	--	--	8	0.20
Cancer jordani	--	--	--	--	--	--	2	0.10	--	--	--	--
Cancer sp.	--	--	6	<0.05	--	--	--	--	1	0.10	--	--
Lozorhynchus crispatus	--	--	2	0.08	--	--	--	--	2	0.70	1	<0.05
Pycnogonida	--	--	1	<0.05	--	--	--	--	--	--	3	<0.05
Mollusca												
Pelecypoda												
Chama pellucida	--	--	--	--	--	--	--	--	4	0.90	1	<0.05
Chione sp.	1	<0.05	--	--	--	--	--	--	--	--	--	--
Hiatella arctica	34	0.08	15	0.15	3	<0.05	1	<0.05	13	0.70	12	0.20
Kellia laperousii	5	<0.05	--	--	3	<0.05	3	<0.05	3	<0.05	10	0.10
Leptopecten latiauratus	--	--	--	--	--	--	--	--	1	<0.05	--	--
Lima hemphilli	--	--	1	<0.05	--	--	--	--	--	--	--	--
Modiolus capax	1	<0.05	3	<0.05	--	--	--	--	--	--	1	<0.05
Petricola sp.	--	--	1	<0.05	--	--	--	--	--	--	--	--
Parvilucina tenuisculpta	2	<0.05	23	0.05	--	--	--	--	--	--	--	--
Pododesmus cepio	1	0.18	--	--	--	--	--	--	2	4.20	--	--
Saxidomus nuttalli	--	--	--	--	--	--	--	--	--	--	1	0.05
Gastropoda												
Acanthodoris lutea	2	<0.05	--	--	--	--	--	--	--	--	--	--
Amphissa versicolor	--	--	35	0.05	--	--	--	--	--	--	--	--
Conus californicus	--	--	4	0.08	--	--	--	--	--	--	--	--
Crepipatella lingulata	19	0.55	65	1.10	4	0.05	2	0.08	--	--	3	<0.05
Dendronotus frondosus	1	<0.05	--	--	--	--	--	--	--	--	--	--
Epitonium bellastriatum	--	--	1	<0.05	--	--	--	--	--	--	--	--
Epitonium sawinae	--	--	3	<0.05	--	--	--	--	--	--	--	--
Fusinus traski	--	--	2	0.20	--	--	--	--	--	--	3	0.20
Hermissenda crassicornis	--	--	--	--	--	--	--	--	1	0.15	--	--
Micranellum crebricinctum	--	--	1	<0.05	--	--	--	--	--	--	--	--
Mitrella tuberosa	2	<0.05	--	--	--	--	1	<0.05	--	--	--	--
Nassarius perpinguis	--	--	17	0.10	--	--	1	<0.05	2	<0.05	9	<0.05
Olivella baetica	--	--	4	0.10	--	--	--	--	--	--	--	--
Retusa sp.	1	<0.05	5	<0.05	1	<0.05	--	--	--	--	1	<0.05
Serpulorbis squamigerus	--	--	--	--	--	--	--	--	1	0.30	--	--
Turbonilla kelseyi	--	--	10	0.05	--	--	--	--	--	--	--	--
Ectoprocta												
Crisia sp.	--	--	--	--	--	--	--	--	Col.	0.80	Col.	0.30
Diaperoecia floridana	--	--	Col.	0.30	--	--	--	--	--	--	--	--
Scrupocellaria diegensis	--	--	--	--	--	--	--	--	--	--	Col.	0.40
Victorella argilla	Col.	70.75	Col.	16.60	Col.	48.45	Col.	41.60	Col.	7.10	Col.	5.10
Phoronidea												
Phoronis sp.	20	0.40	125	2.70	6	<0.05	18	0.15	--	--	225	4.50

TABLE 7.--Continued.

Species	Number of individuals and their volume, by reef and collection											
	HERMOSA BEACH				SANTA MONICA				MALIBU			
	June		August		April		August		April		August	
	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)	No.	Vol. (ml)
Echinodermata												
Ophiuroidea												
Ophiothrix spiculata	--	--	--	--	--	--	--	--	1	<0.05	2	0.60
Holothuroidea												
Eupentacta quinquesemita	--	--	7	0.10	--	--	--	--	--	--	1	<0.05
Chordata												
Tunicata												
Pyura haustor	--	--	1	0.30	--	--	--	--	1	0.30	--	--
Total species	32	--	40	--	14	--	20	--	30	--	34	--
Total volume	--	129.77+	--	25.26+	--	249.26+	--	62.67+	--	83.53	--	13.93

• Col. = colony.

TABLE 8. Fishes recorded during underwater fish transects at the four artificial reefs between 1960 and 1973 (from Kanayama and Onizuka 1973).

		Artificial Reef			
Common Name, Local Name	Scientific Name	Maunalua Bay, Oahu	Keawakapu, Maui	Waianae, Oahu	Kualoa, Oahu
Shark, Mano	CARCHARHINIDAE (unident.)			X	
Eagle ray, Hihimanu	Aetobatus narinari	X		X	
Lizardfish, 'Ulae	SYNODONTIDAE (unident.)	X		X	
Lizardfish, 'Ulae	Synodus variegatus	X		X	
Lizardfish, 'Ulae	S. dermatogenys	X			
Moray eel, Puhi-paka	Gymnothorax flavimarginatus	X	X	X	
Moray eel, Puhi-oni'o	G. meleagris	X			X
Moray eel, Puhi	G. steindachneri	X		X	
Moray eel, Puhi-kapa	Echidna nebulosa	X			
Moray eel, Puhi	Echidna sp.			X	
White eel, Puhi-uha	Conger marginatus			X	
Cornetfish, Nunu peke	Fistularia petimba	X		X	
Trumpetfish, Nunu	Aulostomus chinensis	X	X	X	
Squirrelfish, 'Ala'ihi	Holocentrus ensifer		X		
Squirrelfish, 'Ala'ihi maoli	H. xantherythrus	X		X	X
Squirrelfish, 'Ala'ihi kalaloa	H. diadema	X			
Squirrelfish, 'Ala'ihi	Holocentrus sp.			X	
Squirrelfish, 'U'u	Myripristis berndti	X	X	X	X
Squirrelfish, 'U'u	M. argyromus	X			
Barracuda, Kaku	Sphyraena barracuda		X		
Barracuda, Kawalea	S. helleri		X	X	
Flatfish, Paku	BOTHIDAE (unident.)	X	X		
Flatfish, Paku	PLEURONECTIDAE (unident.)		X		
Flatfish, Paku	(unidentified)			X	
Grouper	Caesioperca thompsoni	X		X	X
Introduced grouper, Roi	Cephalopholis argus	X		X	
Introduced grouper, Rero	C. urodelus	X			
Introduced grouper, Tarao/Tarao-au	Epinephelus merra/hexagonatus	X			
Big eye, 'Aweoweo	Priacanthus cruentatus	X	X	X	
Big eye, 'Aweoweo	P. meeki	X			
Cardinalfish, 'Upapalu	Apogon snyderi	X	X		
Quakerfish, Maka-a	Malacanthus hoedtii	X		X	
Amberjack, Kahala	Seriola dumerilii	X		X	
Mackerel scad, 'Opelu	Decapterus pinnulatus	X	X	X	
Jack crevally, White ulua	Carangoides ajax		X	X	
Jack crevally, Ulua	C. ferdau		X	X	
Jack crevally, 'Omilu	Caranx melampygus	X	X	X	
Jack crevally, Ulua	C. lugubris		X		
Jack crevally, Pa'opa'o	Gnathonodon speciosus		X		
Snapper, Uku	Aprion virescens	X	X	X	
Snapper, Gurutsu	Aphareus furcatus	X		X	
Introduced snapper, Toau	Lutjanus vaigiensis	X	X		
Introduced snapper, Tuhara	L. gibbus	X	X		

TABLE 8.--Continued.

Common Name, Local Name	Scientific Name	Artificial Reef			
		Maunalua Bay, Oahu	Keawakapu, Maui	Waianae, Oahu	Kualoa, Oahu
Goatfish, Weke-'a'a	Mulloidichthys samoensis	X	X	X	X
Goatfish, Weke-'ula	M. auriflamma	X	X	X	
Goatfish, Moelua	M. pflugeri	X			
Goatfish, Malu	Parupeneus pleurostigma	X	X	X	
Goatfish, Kumu	P. porphyreus	X	X	X	
Goatfish, Munu	P. bifasciatus	X		X	
Goatfish, Moano	P. multifasciatus	X	X	X	X
Goatfish, Moano kea	P. chryserydros	X		X	
Porgy, Mu	Monotaxis grandoculis	X	X	X	
Convictfish, stripey	Microcanthus strigatus		X	X	
Black banded angelfish	Holacanthus arcuatus			X	X
Russet angelfish	Centropyge potteri	X	X	X	X
Butterflyfish, Lau-wiliwili-nukunuku-'oi'oi	Forcipiger longirostris	X	X	X	
Butterflyfish, False kihikihi	Heniochus acuminatus	X	X	X	
Butterflyfish	Hemitaurichthys zoster			X	
Orange striped butterflyfish	Chaetodon ornatissimus	X		X	
Blue striped butterflyfish	C. fremblii	X	X	X	X
Cross striped butterflyfish	C. auriga	X	X		
Butterflyfish	C. trifasciatus	X			
Butterflyfish	C. multicinctus	X		X	
Butterflyfish	C. lunula	X		X	
Butterflyfish	C. corallicola	X	X	X	X
Butterflyfish	C. miliaris	X	X	X	X
Hawkfish, Pili-ko'a	Paracirrhites cinctus	X		X	X
Hawkfish, Pili-ko'a	P. fosteri	X		X	X
Hawkfish, Pili-ko'a	P. arcatus	X		X	X
Damselfish, Maomao	Abudefduf abdominalis	X		X	
Damselfish	A. imparipennis	X			
Damselfish	Pomacentrus jenkinsi	X		X	
Damselfish, 'Alo'ilo'i	Dascyllus albisella	X	X	X	X
Damselfish	Plectroglyphidodon johnstonianus			X	
White tailed damselfish	Chromis leucurus	X	X	X	
Black damselfish	C. verater	X	X	X	X
Blue damselfish	C. ovalis	X	X	X	X
Damselfish	C. vanderbilti	X	X	X	
Wrasse, Kupoupou	Cheilio inermis	X		X	
Wrasse, 'A'awa	Bodianus bilunulatus	X	X	X	
Birdfish, Hinalea i'iwi	Gomphosus varius			X	
Wrasse	Pseudocheilinus evanidus	X			
Wrasse	P. octotaenia	X			
Wrasse, Hinalea lolo	Coris gaimardi	X		X	
Wrasse, Hilu	C. flavovittata	X		X	
Wrasse	C. venusta	X		X	
Wrasse, 'Opule	Anampses cuvieri	X	X	X	

TABLE 8.--Continued.

Common Name, Local Name	Scientific Name	Artificial Reef			
		Maunalua Bay, Oahu	Keawakapu, Maui	Waianae, Oahu	Kualoa, Oahu
Wrasse	Anampses rubrocaudatus	X	X	X	
Wrasse, 'Opule	A. godeffroyi	X	X		
Wrasse, Lae-nihi	Iniistius pavoninus	X	X		
Cleaner wrasse	Labroides phthirophagus	X	X	X	
Wrasse	Novaculichthys taeniourus	X		X	
Wrasse, Hinalea lau-wili	Thalassoma duperreyi	X	X	X	X
Wrasse, Hinalea luahine	T. ballieui	X		X	
Wrasse	T. umbrostigma	X			
Wrasse, 'Omaka	Stethojulis albovittata	X		X	
Wrasse, 'Omaka	S. axillaris	X			
Wrasse, Po-ou	Cheilinus rhodochrous	X	X		
Wrasse, Po-ou	C. bimaculatus	X	X		
Wrasse, La-o	Haliochoeres ornatissimus			X	
Wrasse, Lae-nihi	Hemipteronotus baldwini	X		X	
Wrasse, Hinalea 'aki-lolo	Macropharyngodon geoffroyi			X	
Parrotfish, Uhu	SCARIDAE (unident.)	X			
Parrotfish, Uhu	Scarus dubius	X	X	X	
Parrotfish, Uhu uliuli	S. perspicillatus	X	X	X	
Parrotfish, Uhu	S. sordidus	X		X	
Parrotfish, Uhu	S. ahula	X			
Parrotfish, Uhu	Calotomus sandvicensis	X	X		
Moorish idol, Kihikihi	Zanclus canescens	X	X	X	
Surgeonfish	ACANTHURIDAE (unident.)	X			
Surgeonfish, Surf maiko	Acanthurus guttatus	X			
Surgeonfish, Paku'iku'i	A. achilles	X		X	
Surgeonfish, Maikoiko	A. leucopareius	X	X	X	
Surgeonfish, Maiko	A. nigrofuscus	X		X	X
Surgeonfish, Maiko	A. nigroris	X	X	X	
Surgeonfish, Na'en'e	A. olivaceus	X	X	X	X
Surgeonfish, Palani	A. dussumieri	X	X	X	X
Convict tang, Manini	A. sandvicensis	X		X	X
Surgeonfish, Pualu	A. xanthopterus	X		X	
Surgeonfish, Pualu	A. mata	X	X	X	
Surgeonfish, Kala	Naso hexacanthus	X	X	X	
Surgeonfish, Kala	N. brevirostris	X	X	X	
Surgeonfish, Kala	N. unicornis		X	X	
Surgeonfish, Kala	N. lituratus	X		X	
Yellow tang, Lau'i-pala	Zebrasoma flavescens	X		X	
Surgeonfish, Kole	Ctenochaetus strigosus	X	X	X	
Triggerfish, Humuhumu-umauma-lei	Balistes bursa	X	X	X	X
Triggerfish, Humuhumu-uli	B. nycteris			X	
Triggerfish, Humuhumu-mimi	B. capistratus	X	X	X	
Triggerfish, Humuhumu	B. fuscus		X	X	
Triggerfish, Humuhumu	Balistes sp.			X	

TABLE 8.--Continued.

Common Name, Local Name	Scientific Name	Artificial Reef			
		Maunalua Bay, Oahu	Keawakapu, Maui	Waianae, Oahu	Kualoa, Oahu
Triggerfish, Humuhumu-uli	Melichthys vidua			X	
Triggerfish, Humuhumu-'ele'ele	M. buniva	X		X	
Triggerfish, Humuhumu-nukunuku-a-pua'a	Rhinecanthus aculeatus	X		X	
Triggerfish, Humuhumu-nukunuku-a-pua'a	R. rectangulus	X			
Triggerfish	Xanthichthys ringens			X	
Filefish	Amanses sandwichiensis	X			
Filefish	A. carolae	X			
Filefish, 'O'ili lepa	Alutera scripta	X	X	X	
Filefish, 'O'ili uwiwi	Pervagor spilosoma	X	X	X	
Boxfish, Moa	Ostracion lentiginosus	X		X	
Cowfish, Makukana	Lactoria fornasini	X			
Puffer, 'O'opu-hue	Arothron hispidus	X	X	X	
Sharpback puffer	Canthigaster cinctus	X	X	X	
Sharpback puffer	C. jactator	X	X	X	X
Sharpback puffer	C. rivulatus	X	X	X	
Sharpback puffer, Pu'u-u-ola'i	C. amboinensis			X	
Spiny puffer, 'O'opu-kawa	Diodon hystrix	X	X	X	
Blenny	BLENNIDAE (unident.)	X			
Blenny	Runula goslinei			X	
Frogfish	Antennarius moluccensis	X			
Spiny lobster, Ula	Panulirus japonicus	X		X	
Spiny lobster, Ula	P. penicillatus			X	
Octopus, Hee	Octopus cyanea	X			
Crown-of-thorns starfish	Acanthaster planci	X		X	
Total Species:		126	70	114	24
Total Species Recorded at all Artificial Reefs:		156			

TABLE 9. Summary of fish counts at the four artificial reefs (from Kanayama and Onizuka 1973).

		ARTIFICIAL REEFS									
		Maunalua Bay		Keawakapu		Waianae				Kualoa	
						Cars		Pipes			
Year	Date	No. of Species	Pounds per Acre	No. of Species	Pounds per Acre	No. of Species	Pounds per Acre	No. of Species	Pounds per Acre	No. of Species	Pounds per Acre
1960	8/24	20	37								
		(Pre-Reef Count)									
1961	3/16	45	1,585								
	5/12	46	829								
	9/14	47	936								
	12/20	38	627								
1962	3/01			6	3						
				(Pre-Reef Count)							
	4/17					32	103	32	103		
						(Pre-Reef Count)		(Pre-Reef Count)			
1963	3/06			12	11						
	9/19					24	1,423				
	9/27	36	774								
	10/22			20	356						
1964	2/17			24	131						
	2/18			19	102						
	3/13					19	2,631				
	4/03	31	583								
	9/16			29	446						
	9/30					33	491				
	10/09	43	528								
	10/13							50	711		
1965	3/17			29	555						
	3/29					29	1,084				
	4/19	36	1,390								
	6/10							24	48		
	6/30							37	662		
	8/31							35	176		
	10/07			24	98						
	10/08			22	77						
	10/29							42	412		

TABLE 9.--Continued.

ARTIFICIAL REEFS

Year	Date	Maunalua Bay No. of Species	Maunalua Bay Pounds per Acre	Keawakapu No. of Species	Keawakapu Pounds per Acre	Waianae Cars No. of Species	Waianae Cars Pounds per Acre	Waianae Pipes No. of Species	Waianae Pipes Pounds per Acre	Kualoa No. of Species	Kualoa Pounds per Acre
1966	1/11							44	261		
	1/24	47	1,333								
	3/17					45	724				
	3/18							40	1,288		
	4/07			31	70						
	5/18							46	466		
	7/28							44	267		
	9/22			37	376						
	9/30	44	921								
1967											
1968	5/1							37	977		
	11/18							59	470		
1969	3/12	56	984								
	10/24	42	196								
	11/11							60	749		
1970	12/07							47	180		
	12/10	52	114								
1971	2/19	47	1,062								
1972	3/16	36	1,820								
	4/21							61	339		
	5/10									24 (Pre-Reef Count)	93
	8/25									≠	≠
1973	1/16	34	544								
	4/23							50	435		
	4/24	58	491								
	5/09									≠	≠
	5/11									≠	≠
	6/25									≠	≠
	6/28	42	340								
Average of Post-Reef Counts		43	837	25	222	30	1,271	45	496	-	-

TABLE 10A. Fishes recorded at Stage I off Panama City, Florida, with estimates of usual abundance and habitat occupied (from Hastings et al. 1976).

Species	Abundance[1] Spring (Apr.)	Summer-fall (July-Nov.)	Winter Dec.	Jan.	Habitat[1]
Carcharhinidae:					
Carcharhinus milberti	—	few	—	—	O
Dasyatidae:					
Dasyatis sp.	—	few	—	—	B
Muraenidae:					
Gymnothorax nigromarginatus	—	few	few	—	B
Clupeidae:					
Sardinella anchovia	—	com-abun	abun	—	U
Ariidae:					
Arius felis	—	sev	—	—	B
Batrachoididae:					
Opsanus pardus	sev	sev	sev	com	B
Antennariidae:					
Antennarius ocellatus	few	few	few	few	B
Ogcocephalidae:					
Ogcocephalus radiatus	—	few	few	few	B
Serranidae:					
Centropristis ocyurus	com	com	com	com	B
Diplectrum formosum	sev	sev-com	sev-com	—	B
Epinephelus nigritus	—	—	—	few	L
Mycteroperca microlepis	—	few-com	few	sev	L
Serranus subligarius	sev	sev-com	sev-com	com	B-P
Grammistidae:					
Rypticus maculatus	—	sev-com	sev	com	B-P
Apogonidae:					
Apogon pseudomaculatus	few	sev-com	—	sev	B
Rachycentridae:					
Rachycentron canadum	—	few	few	—	O-U
Echeneidae:					
Echeneis neucratoides	—	few-sev	—	sev	([2])
Carangidae:					
Caranx crysos	—	com	—	—	U
Caranx hippos	—	sev-com	—	—	O-U
Caranx ruber	—	few-com	few	—	U
Decapterus punctatus	—	com-abun	abun	few	U
Elagatis bipinnulata	—	sev	sev	few	O-U
Seriola dumerili	sev	few-com	com	com-abun	L-O-U
Seriola rivoliana	—	—	few	—	U
Trachurus lathami	—	com	—	—	L
Lutjanidae:					
Lutjanus campechanus	—	few	few	—	L
Lutjanus griseus	few	sev-abun	few	sev	L-U
Rhomboplites aurorubens	sev	com-abun	—	com	L
Pomadasyidae:					
Haemulon aurolineatum	com	com-abun	com-abun	sev	L
Haemulon plumieri	—	—	few-sev	—	L
Sparidae:					
Archosargus probatocephalus	—	few	—	—	U
Lagodon rhomboides	—	sev	—	—	L-U
Sciaenidae:					
Equetus lanceolatus	—	sev-com	—	com	B
Equetus umbrosus	com	sev-com	com	com	B
Equetus sp.[3]	—	few	—	—	B
Kyphosidae:					
Kyphosus sectatrix	—	sev	—	—	U
Ephippidae:					
Chaetodipterus faber	com	sev-com	sev	com	L-U
Chaetodontidae:					
Chaetodon ocellatus	few	few	few	few	B-P
Chaetodon sedentarius	—	few	few	—	B
Holacanthus bermudensis	sev	sev-com	sev	sev	L-U
Pomacentridae:					
Abudefduf saxatilis	—	few-sev	—	sev	P
Chromis enchrysurus	—	few	—	few	B
Chromis scotti	—	sev-com	—	sev	B-P
Pomacentrus partitus	—	few-sev	—	—	P
Pomacentrus variabilis	com	sev-com	sev	com	B-P
Labridae:					
Halichoeres caudalis	com	sev-com	—	few	B
Thalassoma bifasciatum	—	few-sev	—	sev	P
Sphyraenidae:					
Sphyraena barracuda	—	sev-abun	sev	few	O-U
Blenniidae:					
Blennius marmoreus	—	sev	—	—	B-P
Hypleurochilus geminatus	few	few-com	—	—	P

TABLE 10A.--Continued.

Species	Abundance[1] Spring (Apr.)	Summer-fall (July-Nov.)	Winter Dec.	Winter Jan.	Habitat[1]
Gobiidae:					
Coryphopterus punctipectophorus	few	few	—	—	B
Ioglossus calliurus	—	sev	—	—	B
Acanthuridae:					
Acanthurus coeruleus	—	—	—	few	P
Scombridae:					
Euthynnus alletteratus	—	sev-com	sev	sev	O-U
Bothidae:					
Paralichthys albigutta	—	few	—	—	B
Balistidae:					
Balistes capriscus	few	few-sev	few	few	L-U
Monacanthus hispidus	—	few-sev	—	—	P
Ostraciidae:					
Lactophrys quadricornis	few	few	few	—	B
Tetraodontidae:					
Canthigaster rostrata	—	few	—	—	B
Sphoeroides spengleri	—	few	—	—	B
Diodontidae:					
Chilomycterus schoepfi	few	few	few	few	B
61 species 100%	21 species 34%	57 species 93%	31 species 51%	32 species 52%	
Number of observations	1	6	2	1	
Temperature range	17°-20°C	23°-29°C	18°-19°C	18°C	

[1]Abbreviations are as follows: sev-several, com-common, abun-abundant, B-on bottom, L-lower water column, P-on pilings, O-open water around platform, U-middle to upper water column under platform.

[2]*Echeneis neucratoides* on *Epinephelus, Sphyaena, Seriola, Balistes,* and *Caretta.*

[3]*Equetus* sp. - an undescribed species listed by Bullis and Thompson (1965) as "*Equetus* sp. nov." and by Struhsaker (1969) as "Blackbar drum *Pareques* sp. (undescribed)."

TABLE 10B. Fishes recorded at Stage II off Panama City, Florida, with estimates of usual abundance and habitat occupied (from Hastings et al. 1976).

Species	Abundance[1] Spring (Apr.-May)	Summer-fall (June-Nov.)	Winter Dec.	Feb.	Habitat[1]
Carcharhinidae	—	few	—	—	O
Sphyrnidae:					
Sphyrna sp.	—	few	—	—	O
Dasyatidae:					
Dasyatis sp.	—	few	—	—	B
Rajidae:					
Raja eglanteria	—	few	few	—	B
Muraenidae:					
Gymnothorax nigromarginatus	few	few	few	—	B
Congridae	—	—	few	—	B
Ophichthidae:					
Mystriophis intertinctus	few	few	few	—	B
Clupeidae:					
Etrumeus teres	—	sev-com	—	—	U
Harengula pensacolae	—	sev-abun	sev-com	—	L-U
Opisthonema oglinum	sev	com	—	—	U
Sardinella anchovia	com-abun	com-abun	sev-abun	—	U
Engraulidae	—	com-abun	—	—	L-U
Ariidae:					
Arius felis	—	few-abun	—	—	B
Batrachoididae:					
Opsanus pardus	few-sev	few	few-com	—	B
Antennariidae:					
Antennarius ocellatus	few	few	few-com	—	B
Ogcocephalidae:					
Ogcocephalus radiatus	few	few	few	—	B
Syngnathidae:					
Syngnathus sp.	—	few	—	—	O
Serranidae:					
Centropristis melana	few	sev	few-sev	sev	B
Centropristis ocyurus	com	com-abun	com	com	B
Centropristis philadelphica	—	—	few	—	B
Diplectrum formosum	sev-com	few-com	sev	sev	B
Epinephelus morio	few	few	few	—	B-L
Epinephelus sp.[2]	—	few	—	—	B
Mycteroperca microlepis	few	few-sev	few-sev	—	L
Serranus subligarius	sev	sev-com	sev-com	few	B-P
Grammistidae:					
Rypticus maculatus	—	few-com	few-com	—	B-P
Priacanthidae:					
Priacanthus arenatus	—	few	—	—	B
Apogonidae:					
Apogon pseudomaculatus	few	few-com	few-sev	—	B
Pomatomidae:					
Pomatomus saltatrix	few-sev	—	few	—	O-U
Rachycentridae:					
Rachycentron canadum	—	few-sev	—	—	O-U
Echeneidae:					
Echeneis neucratoides	—	few	—	—	([3])
Carangidae:					
Caranx bartholomaei	—	few-sev	few	—	L-U
Caranx crysos	—	sev-abun	few	—	U
Caranx hippos	—	com	sev	—	O-U
Caranx ruber	—	few-com	—	—	U
Decapterus punctatus	com-abun	abun	com-abun	com	L-U
Selar crumenophthalmus	—	sev-com	—	—	L-U
Seriola dumerili	few	few-sev	sev	—	L-O-U
Seriola zonata	few	—	—	—	U
Trachurus lathami	com	com	few-abun	—	L
Lutjanidae:					
Lutjanus campechanus	—	few-sev	sev	—	L
Lutjanus griseus	—	sev	few-sev	—	L-U
Lutjanus synagris	—	few	—	—	L
Rhomboplites aurorubens	sev	sev-com	few-sev	—	L-U
Lobotidae:					
Lobotes surinamensis	—	few	—	—	U
Pomadasyidae:					
Haemulon aurolineatum	com	com-abun	few-com	few	L
Haemulon plumieri	few-sev	few-sev	few	—	L
Orthopristis chrysoptera	com	abun	few-abun	—	L
Sparidae:					
Archosargus probatocephalus	few	sev	few	—	L-U
Calamus-Pagrus	—	few	few	—	L
Diplodus holbrooki	—	few-sev	few	—	U
Lagodon rhomboides	com	sev-com	sev-com	sev	L-U
Stenotomus caprinus	—	com	—	—	B-O

TABLE 10B.--Continued.

Species	Abundance[1] Spring (Apr.)	Summer-fall (July-Nov.)	Winter Dec.	Jan.	Habitat[1]
Sciaenidae:					
Equetus lanceolatus	few-sev	few-com	few-com	com	B
Equetus umbrosus	sev	sev-com	few-sev	—	B
Leiostomus xanthurus	—	com	sev	—	B
Sciaenops ocellata		few	few		B
Mullidae	—	few	—	—	O
Kyphosidae:					
Kyphosus sectatrix	—	few-sev	—	—	U
Ephippidae:					
Chaetodipterus faber	sev	few-com	sev	—	L-U
Chaetodontidae:					
Chaetodon ocellatus	—	few	few	—	B
Holacanthus bermudensis	sev-com	few-com	sev-com	sev	L-U
Pomacentridae:					
Pomacentrus variabilis	sev-com	sev-com	few-sev	—	B-P
Labridae:					
Halichoeres bivittatus	few	few-com	few	—	B
Halichoeres caudalis	sev	sev-com	few-sev	sev	B
Hemipteronotus novacula	—	few	few	—	B
Lachnolaimus maximus	—	few	—	—	L
Sphyraenidae:					
Sphyraena barracuda	—	few-sev	—	—	L-O-U
Sphyraena borealis	—	sev	—	—	U
Polynemidae:					
Polydactylus octonemus	—	—	sev	—	O
Blenniidae:					
Blennius marmoreus	few	few-sev	few	—	P
Hypleurochilus geminatus	sev-com	sev-com	—	—	P
Acanthuridae:					
Acanthurus chirurgus	—	few	—	—	B-P
Scombridae:					
Euthynnus alletteratus	sev-com	sev-com	few-com	—	O
Scomber japonicus	com	com	few	—	U
Scomberomorus cavalla	—	sev	—	—	O
Stromateidae:					
Peprilus burti	few-sev	sev	—	—	U
Scorpaenidae:					
Scorpaena brasiliensis	—	few	few	—	B
Triglidae:					
Prionotus sp.	—	few	—	—	B
Bothidae:					
Paralichthys albigutta	sev	few-sev	sev	few	B
Syacium papillosum	—	few	—	—	B
Balistidae:					
Balistes capriscus	few-sev	few-com	few-sev	few	L-U
Cantherhines pullus	—	few	few	—	P
Monacanthus hispidus	—	few	sev	—	L-P
Ostraciidae:					
Lactophrys quadricornis	few	few-sev	few	—	B
Diodontidae:					
Chilomycterus schoepfi	few	few-sev	few	few	B
86 taxa	41 species	81 taxa	57 taxa	13 species	
100%	48%	94%	66%	15%	
Number of observations	3	13	4	1	
Temperature range	17°-20°C	20°-30°C	15°-19°C	13°C	

[1]Abbreviations are as follows: sev - several, com - common, abun - abundant, B - on bottom, L - lower water column, P - on pilings, O - open water around platform, U - middle to upper water column under platform.

[2]*Epinephelus* sp. - A juvenile apparently either *E. flavolimbatus* or *E. niveatus* based upon color pattern (brownish with small white spots on lateral surface and a dark saddle on caudal peduncle, Smith 1971).

[3]*Echeneis neucratoides* on *Caranx* and *Sphyraena*.

TABLE 11. Summary of major game species caught at oil rig platforms by bottom, drift, and troll fishing in nearshore and blue water areas (from Dugas et al. 1979).

Species	Bottom		Drift		Trolling	
	Nearshore	Blue-water	Nearshore	Blue-water	Nearshore	Blue-water
Shark (several species)			X	X		
Arius felis (sea catfish)	X					
Bagre marinus (gafftopsail catfish)	X					
Epinephelus spp. (grouper)		X				
Mycteroperca phenax (scamp)		X				
Pomatomus saltatrix (bluefish)			X		X	
Rachycentron canadum (cobia)			X			
Caranx crysos (blue runner)			X		X	
Caranx hippos (crevalle jack)			X		X	
Seriola dumerili (greater amberjack)		X		X		X
Coryphaena hippurus (dolphin)						X
Lutjanus campechanus (red snapper)	X	X				
Lutjanus griseus (gray snapper)	X	X				
Lutjanus synagris (lane snapper)		X				
Archosargus probatocephalus (sheepshead)	X					
Cynoscion arenarius (sand seatrout)	X					
Cynoscion nebulosus (speckled seatrout)	X					
Cynoscion nothus (silver seatrout)	X					
Menticirrhus americanus (southern kingfish)	X					
Micropogon undulatus (Atlantic croaker)	X					
Pogonias cromis (black drum)	X					
Sciaenops ocellata (red drum)			X			
Sphyraena barracuda (great barracuda)				X		X
Acanthocybium solanderi (wahoo)						X
Euthynnus alleteratus (little tuna)					X	
Sarda sarda (Atlantic bonito)			X		X	
Scomberomorus cavalla (king mackerel)			X		X	
Scomberomorus maculatus (Spanish mackerel)					X	
Thunnus albacares (yellowfin tuna)				X		
Thunnus atlanticus (blackfin tuna)		X		X		
Istiophorus platypterus (sailfish)						X
Makaira nigricans (blue marlin)						X
Tetrapturus albidus (white marlin)						X

TABLE 12. Endangered and threatened species of candidate sites (from Sullivan et al. 1981).

Scientific Name	Common Name	Status*	Distribution
		MARINE MAMMALS	
Balaenoptera musculus	Blue whale	E	Oceanic, Pacific, Atlantic
Balaenoptera borealis	Sei whale	E	Oceanic, Pacific, Atlantic
Balaenoptera physalus	Finback whale	E	Oceanic, Southern Hemisphere
Eubalaena glacialis	Right whale	E	Oceanic, Pacific, Atlantic
Megaptera novaeangliae	Humpback whale	E	Oceanic, Caribbean, North Pacific, Atlantic
Physeter catadon	Sperm whale	E	Oceanic, Caribbean, Pacific, Atlantic
Trichechus manatus	Caribbean manatee	E	Off Florida, Caribbean
Monachus schauinslandi	Hawaiian monk seal	E	Northwest Hawaiian Islands (NWHI)
Monachus tropicalis	Caribbean monk seal	E	Caribbean (extinct ?)
		SEA TURTLES	
Chelonia mydas	Green sea turtle	T E	Hawaii Florida
Eretmochelys imbricata	Hawksbill	E	Tropical Pacific, Caribbean
Dermochelys coriacea	Leatherback	E	Tropical Pacific, Caribbean

* E = Endangered
T = Threatened

TABLE 12.--Continued.

Scientific Name	Common Name	Status	Distribution
SEA TURTLES			
Lepidochelys kempii	Kemp's ridley	E	Caribbean
Lepidochelys olivacea	Olive ridley	T	Tropical circumglobal
Caretta caretta	Loggerhead	T	Tropical circumglobal
OTHER REPTILES			
Cyclura pinquis	Anegada Island ground iguana	E	Virgin Islands
Cyclura stejnegeri	Mona Island ground iguana	T	Puerto Rico
Ameiva polops	St. Croix ground lizard	E	St. Croix, Virgin Islands
Eprcrates inornatus	Puerto Rican boa	E	Puerto Rico
AMPHIBIANS			
Eleutherodactylus jasperi	Golden coqui	T	Puerto Rico
BIRDS			
Pelecanus occidentalis	Brown pelican	E	Caribbean, U.S. west coast, Gulf coast
Puffinus puffinus newelli	Newel's Manx shearwater	T	Hawaiian Islands
Acrocephalus familiaris kingi	Nihoa miller-bird	E	Nihoa, Hawaiian Islands

* E = Endangered
  T = Threatened

TABLE 12.--Continued.

Scientific Name	Common Name	Status	Distribution
		BIRDS	
Psittirostra cantans cantans	Laysan finch	E	Laysan, Hawaiian Islands
Anas laysannensis	Laysan duck	E	Laysan, Hawaiian Islands
Anas wyvilliana	Hawaiian duck	E	Hawaiian Islands
Pterodroma phaeopygia sandwichensis	Hawaiian dark-rumpled petrel	E	Hawaiian Islands
Fulica americana alai	Hawaiian coot	E	Hawaiian Islands
Himantopus himantopus knudseni	Hawaiian stilt	E	Hawaiian Islands
Gallinula chloropus sandvicensis	Hawaiian gallinule	E	Hawaiian Islands
Branta sandvicensis	Hawaiian goose	E	Hawaiian Islands
Caprimulgus noctitherus	Puerto Rican Whip-poor-will	E	Puerto Rico
Amazona vittata	Puerto Rican Parrot	E*	Puerto Rico
Columba inornata wetmorei	Plain Pigeon	E	Puerto Rico
Agelaius xanthomus	Yellow-shouldered Blackbird	E	Puerto Rico
Falcon peregrinus anatum	American Peregrine Falcon	E	North American, Carribean

* E = Endangered
T = Threatened