ARTIFICIAL REEF PROJECT
THAILAND

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EXECUTIVE SUMMARY

A review of the fishery in the Gulf of Thailand is presented which notes that the current level of trawling effort is excessive and suggests that a substantially lower trawling effort would probably improve the total economic value of the catch by reducing the proportion of trash fish in the catch and increasing the proportion and size at landing of fishes with high commercial value.

A review of the marine environment concludes that the Gulf with its modest waves and currents together with the large amount of relatively level shallow areas with reasonably firm bottom sediments provides an ideal physical environment for artifical reefs.

The results of the artificial reef work conducted by the Department of Fisheries, Government of Thailand at Rayong, Phuket, and Sonkhla indicate that reefs constructed from tires and open concrete blocks have shown minimal subsidence over the 6 years that the first unit have been in place, that commercially valuable snappers and groupers can be caught at the reef sites, and that artisanal fishermen frequently fish the artificial reef sites.

It is concluded that two approaches to fishery enhancement should be evaluated in a Pilot Program. One approach, termed trawler exclusion, would involve the random placements of concrete modules, which will damage trawl nets should trawlers attempt to trawl the area, over a large nearshore areas. At a very modest cost, it is possible to effectively exclude trawling from a relatively large area and it is hypothesized that once the heavy trawling pressure is eliminated, there will be an increase in the size and commercial value of the catch in the trawler exclusion area caught by artisanal fishermen using traps, handlines and nets. Further, it is speculated that the exclusion area will protect commercially-valuable fishes as juveniles and permit them to grow to a larger size when they may migrate out of the exclusion area and be caught by trawlers.

The second type of fishery enhancement approach which should be evaluated by the Pilot Program is the use of artifical reefs together with the trawl exclusion concept. It is hypothesized that artificial reefs may provide suitable habitat to improve recruitment, growth, survival, food availability, and ultimately the yield of commercially valuable fishes which can be harvested by artisanal fishermen.

In order to evaluate the costs and benefits of these two fishery enhancement approaches, a Pilot Program is proposed which would be conducted at Rayong and Songkhla. The program at Rayong would be the larger of the two in terms of structure and monitoring activity. The Rayong program would use 3 areas each covering about 50 km^2 (5 km by 10 km) with an average depth of about 15 m. One of the 50 km^2 areas would not receive any artificial reefs or trawler exclusion modules and serve as the control area. A second 50 km^2 area would receive 1,000 trawler exclusion module and the third 50 km^2 area would receive 1,000 trawl exclusion modules plus ten artificial reef groups composed of open concrete cubes of 1 and 2 m on a side with a combined enclosed artificial reef volume of about 50,000 m^3.

By monitoring the total fishing effort at each of the three sites together with catch rates from systematic and standardized fishing surveys and a time series of length-frequency data for the major species it will be possible to estimate the relative and total fishing yields from the three sites. This information together with social and economic surveys of artisanal fishing villages in the Rayong area will permit a cost and benefit analysis of the two fishing enhancement approaches.

The program at Songkhla will also receive trawler exclusion modules and artificial reef modules but on a smaller scale with the objective of providing sufficient information to enable the results of the Rayong program to be extended to the Southwest Gulf of Thailand.

It is estimated that one year will be required for module construction and pre-deployment data collection followed by 2 years of post-deployment data collection. While some preliminary results of the effectiveness of the fishing enhancement approaches will be available after the second year of the program (after 1 years of post-deployment sampling) it is envisioned that two years of post-deployment monitoring will be required for a total project duration including start-up and final analysis of 4 years.

The project budget is estimated at US$2 million with about US$1 million for module construction and deployment and US$1 million for the field program, data collection and analysis.

1. INTRODUCTION

The total fisheries landings of Thailand place it among the world's largest fishing nations and about 87% of the Thai fish harvest is taken by its marine fisheries sector, with the balance accounted for by aquaculture and inland fisheries.

However, there is general agreement that the marine fishery resources are either over-fished or are close to producing their greatest possible yields and that any future gains in production will be as a result of fisheries management, marine aquaculture or environmental enhancement. It is also generally agreed that decreases in production are likely to occur if the marine fisheries are not regulated and if steps are not taken to reduce or prevent pollution of the rivers and seas of Thailand. Lack of action in these sectors will result in diminishing catches and incomes, primarily in the artisanal sector, with concomitant social and political problems.

The largest part of Thai fishing production is by otter trawling in the Gulf of Thailand. The trawling technique was introduced in the 1960's and was rapidly adopted as the mainstay of an industry in which fishing for pelagic species had previously been predominant. The rapid development of the trawl fishery to its present highly intensive levels resulted in declining catch rates, as the available fish stocks were shared between increasing numbers of boats, and a decline in the proportion of the larger, higher valued components of the fish catches. This decline has, to some extent, been temporarily offset by increased catches of squid and shrimp, probably as a result of the elimination of most of their major fish predators, but these resources are also overfished.

The trawl fisheries of the Gulf of Thailand have exhibited an apparent resilience in the face of intensive fishing but this can, to some extent, be attributed to catches taken outside of the exlusive economic zone (EEZ) of Thailand. Access to extra-territorial resources is diminishing rapidly on a world-wide basis and, consequently, fishing pressure on Thailand's own resources is likely to increase. As all sectors are either fully-exploited or overfished the prospects for the industry are not encouraging and immediately action is necessary if a gross decline in the availability of fish and fish products is to be avoided.

1.1. Background to report

Early in 1984 the Asian Development Bank commissioned a Fisheries Sector Study for Thailand. This study produced a substantial and all-encompassing report based on the observations of the Bank's consultants and upon the priorities recognized and established by the Department of Fisheries of the Government of Thailand.

The priorities of the Department of Fisheries included the establishment of an Artificial Reef Program based upon the recognition of the possibility that artificial reefs might have the potential to increase fish and shellfish production per unit area.

It was further recognized that, based upon experience in Korea and Japan, artificial reefs and associated structures might inhibit the operations of capital-intensive trawling fleets and afford greater opportunities to the generally impoverished artisanal fishery sector which relies upon inexpensive fishing gears operated from small vessels with limited operational ranges.

Arising from the foregoing observations of the state of the marine fishing industry of Thailand, the Fisheries Sector Study Report suggested (p. 146) that

> "... an agressive program to enhance the production potential within Thailand's territorial waters offers the best potential for meeting Government's production, resources management and socio-economic objectives. This strategy would involve a major program to develop artificial reefs to increase production through

environmental enhancement and as a means of preventing destructive fishing activities within the nearshore waters of the Gulf. This program, in conjunction with much more effective fisheries management efforts to limit the number of vessels and to regulate fishing effort and gear types could result in a substantial increase in the productive capacity of marine fish stocks within Thailand's territorial waters."

The present report is a follow-up on the Fisheries Sector Study and aims at examining and summarizing available information on the suitability of the marine environment of the Gulf of Thailand for emplacement of artificial reefs and reviewing the status of the fishery resources of the Gulf of Thailand. Additionally, the current Artificial Reef Program being executed by the Department of Fisheries is reviewed and recommendations put forward concerning the siting, design, baseline studies, monitoring system and likely results of the proposed ADB-sponsored Artificial Reef Pilot Project in the Gulf of Thailand. The practicalities of institutional and administrative arrangements are addressed and estimates made of the costs of construction and monitoring of the Pilot Project.

The present report has been prepared as a collaborative and equal effort between Dr. J.L. Munro, Director of the Resources

Development and Management Program at the International Center for Living Aquatic Resources Management (ICLARM) which has headquarters in Manila, Philippines, and Dr. J.J. Polovina, Leader, Artificial Reef Program at the Honolulu Laboratory of the Southwest Fisheries Center, National Marine Fisheries Service of the U.S.A.

1.2 Artificial Reefs - present status and utilization

Fishermen have known for centuries that structures which add vertical relief to the sea bottom often create improved fishing sites. In many cases, artifical reefs were created simply as a means of disposing of scrap materials with little consideration given to the stability and biological appropriateness of the reef building materials and sites. In recent years, however, the Japanese and to a lesser extent the Taiwanese have developed extensive national artificial reef programs to improve fishing production from their coastal waters as the proliferation of the 200-mile exclusive economic zone declarations in foreign waters restricts the fishing grounds accessible to their fleets (Stone, 1982).

The Japanese commitment to artificial reefs began in 1976 with a 6-year program which allocated about US$45 million annually for artificial reef construction (Grove and Sonu, 1983). A second 6-year program beginning in 1981 continued this program with funding for reef construction and placement budgeted at US$40-60 million annually (Grove and Sonu, 1983).

The Japanese have developed numerous module designs specifically to be used as artificial reefs which are constructed from a range of materials including concrete, steel, and fiberglass. These modules enclose volumes from several cubic meters to over several hundred cubic meters, all designed to be stable on the ocean bottom, and remain functional for at least 20 years (Mottet, 1982).

However, even with the wide range of designs available in Japan, the most widely used module is some variation of the open or framework concrete cube (Mottet, 1982). While some modules are designed specifically to be seeded with organisms such as abalone and serve in an extensive mariculture operation, most are designed to provide habitat, orientation, and foraging grounds for a range of demersal and pelagic fishes. (Mottet, 1982)

The Japanese construct artificial reef complexes by deploying numerous reef modules, often of different designs, into large assemblages covering 1 to 50 km^2. A reef complex may be composed of one or more reef groups where each reef group is further composed of sets of reef modules. The Japanese felt that a reef set should contain a sufficient number of modules to have a cubic volume of at least 1,000 m^3 and a reef group will typically consist of 10-20 reef sets where the sets are separated from each other by 300-500 m (Grove and Sonu, 1983). The reef group should have a volume of 50,000 - 160,000 m^3, and each group represents an independent unit, separated from other reef groups by at least 3 km. (Grove and Sonu, 1983).

The theory behind this reef complex arrangement is that it provides varied habitat for a range of fish species including those which take up residence on the reef, those which forage on and around the reef and move between reef sets, and those which use the reef sets for orientation or are attracted to the oceanographic condition created by the reef (Grove and Sonu, 1983). It appears that pelagic fishes prefer reefs which have a height which is about one-tenth of the water depth while total reef horizontal area rather than height is more important for demersal resources (Grove and Sonu, 1983).

In spite of the large scale of the Japanese reef program, a rigorous economic analysis of the costs and benefits of artificial reefs has yet to be achieved. On a more basic level, the extent to which reefs can actually increase total fishery production rather than just aggregate fish from areas near the artificial reef, has yet to be well-documented (Brock and Buckley, 1984). However, the Japanese justify their artificial reef program on broad economic, social, and political grounds. For example, even if artificial reefs only aggregate stocks in harvestable quantities a number of strategically placed sites can reduce fishing time and fuel costs. Further, through the use of concrete, steel, and fiberglass in reef construction and the labor involved in their construction and placement, the artificial reef program contributes to local industries. Finally artificial reefs are popular with fishing villages and fishery cooperatives which often contribute to a portion of their cost and represent an important political group (Grove and Sonu, 1983).

2. MARINE ENVIRONMENT OF THE GULF OF THAILAND

The Gulf of Thailand is bounded principally by Thailand, Cambodia and Vietnam and covers an area of about 300,000 km^2. About 55% of the Gulf has a depth less than 50 m and the remaining 45% is less than 80 m. The benthic sediments are various clay and sand mixtures with fine silt occuring near river mouths. The geographic variation in surface temperature in the Gulf at any time is only about 1^o with the seasonal variation ranging from an average of about 29.0^o in April to to 26.0^{o} in January. The salinity typically ranges from 33.0% to 32.4% but lower values may be found near river outlets. Dissolved oxygen levels range from 4.4 to 4.8 or 5 ml/l, with most of the Gulf at a level of about 4.4-4.6 ml/l. (Royal Thai Navy, 1983)

There is a major clockwise current throughout the year in the southern portion of the Gulf, which covers about one-third to one-half of the Gulf depending on the season (Fig. 2.1-2.4). This clockwise current, together with prevailing winds, generates two or more current eddies in the northern portion of the Gulf. The prevailing winds are dominated by the southwest monsoons during May to September and the northeast monsoons from November to February. The likelihood of a typhoon in the Gulf is less than 1% (Morgan and Valencia, 1983).

Given the large amount of relatively level shallow bottom with moderate wave and current conditions, the Gulf of Thailand is environmentally well-suited for artificial reefs. The firmness of the bottom should be checked at a potential reef site and sites should be well removed from river outlets to avoid siltation of the reef structure.

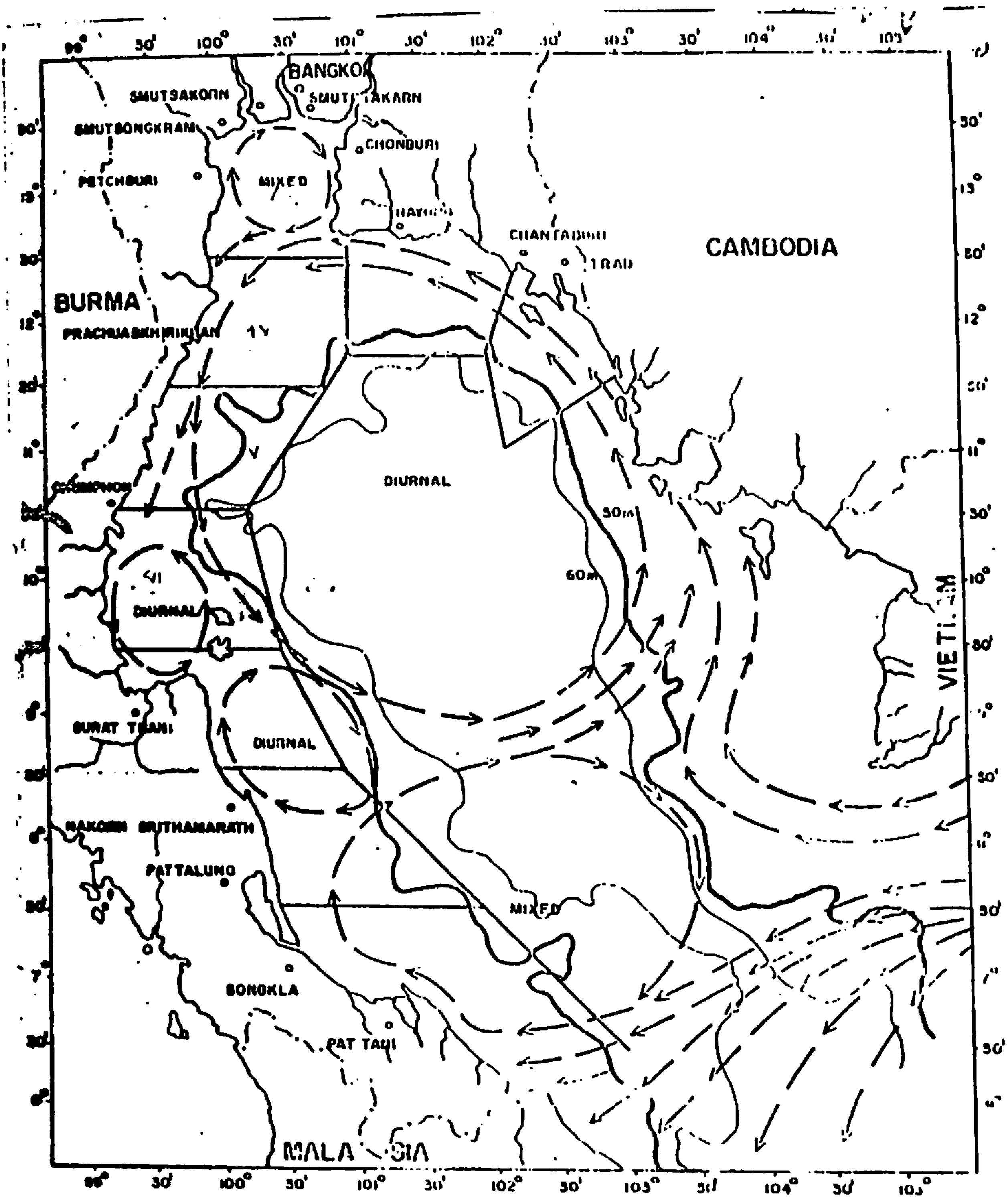


Figure 2.1 Current circulation in the Gulf of Thailand during January-March (from Royal Thai Navy, 1983).

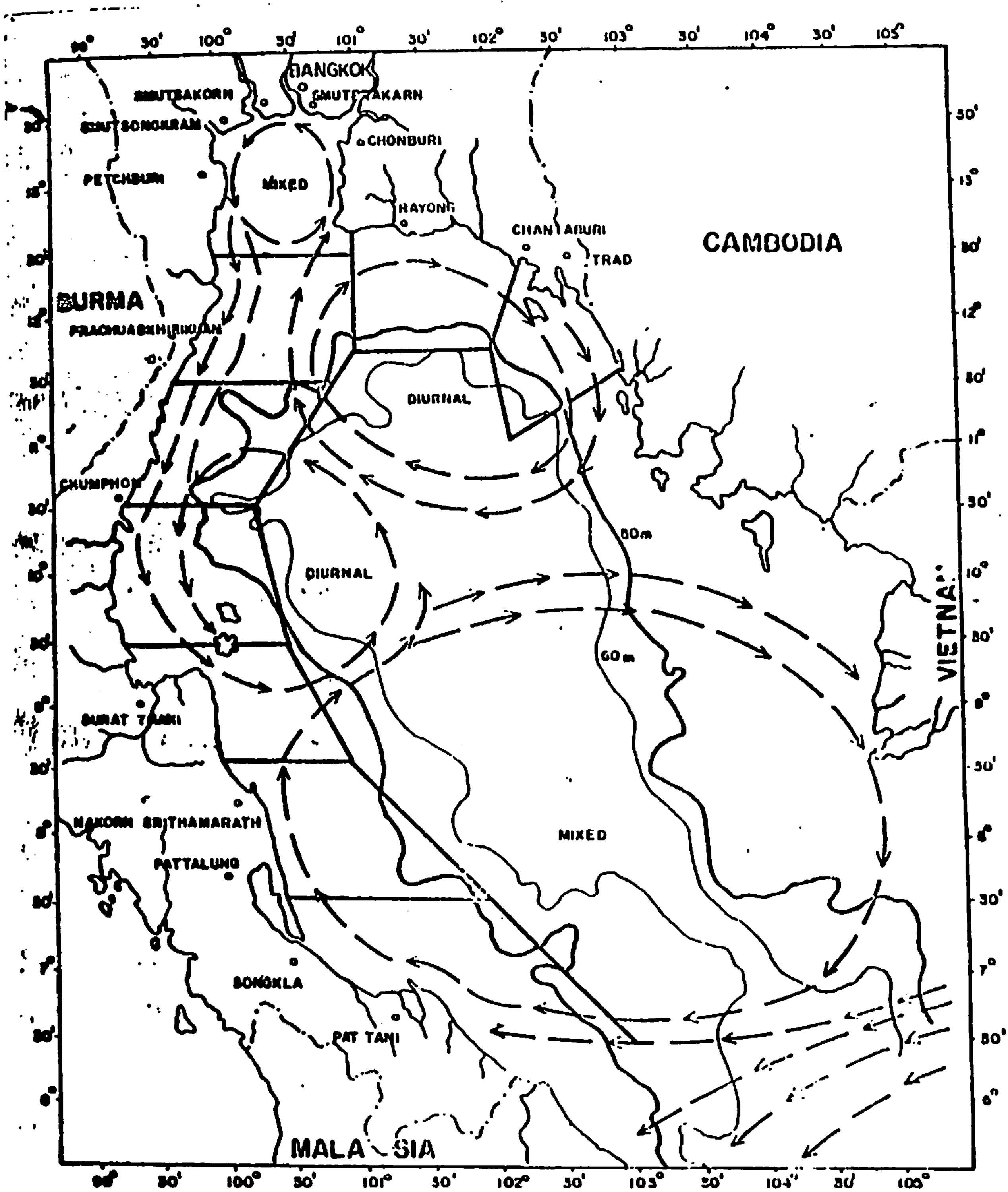


Figure 2.2 Current circulation in the Gulf of Thailand during April-June (from Royal Thai Navy, 1983).

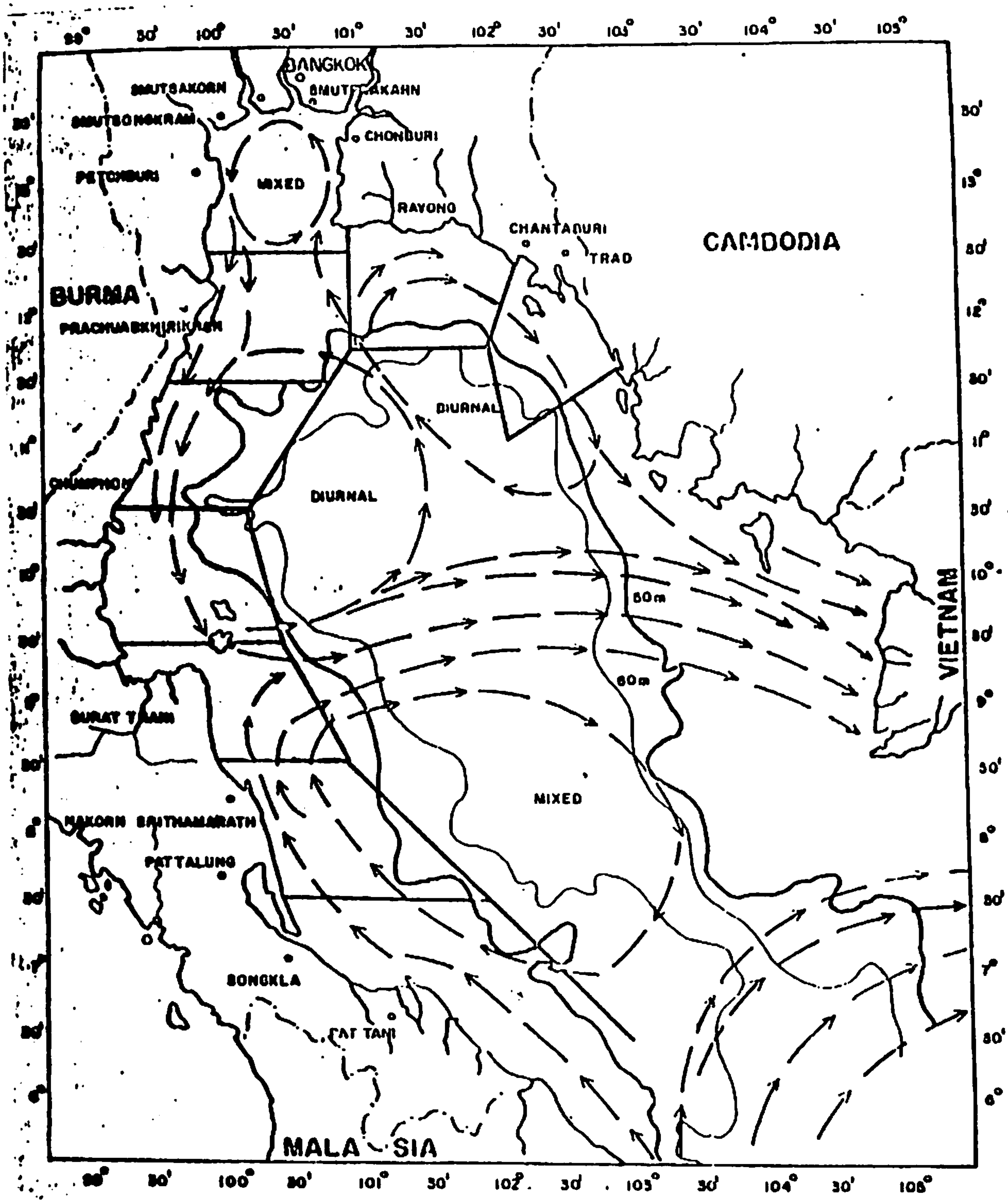


Figure 2.3 Current circulation in the Gulf of Thailand during July-September (from Royal Thai Navy, 1983).

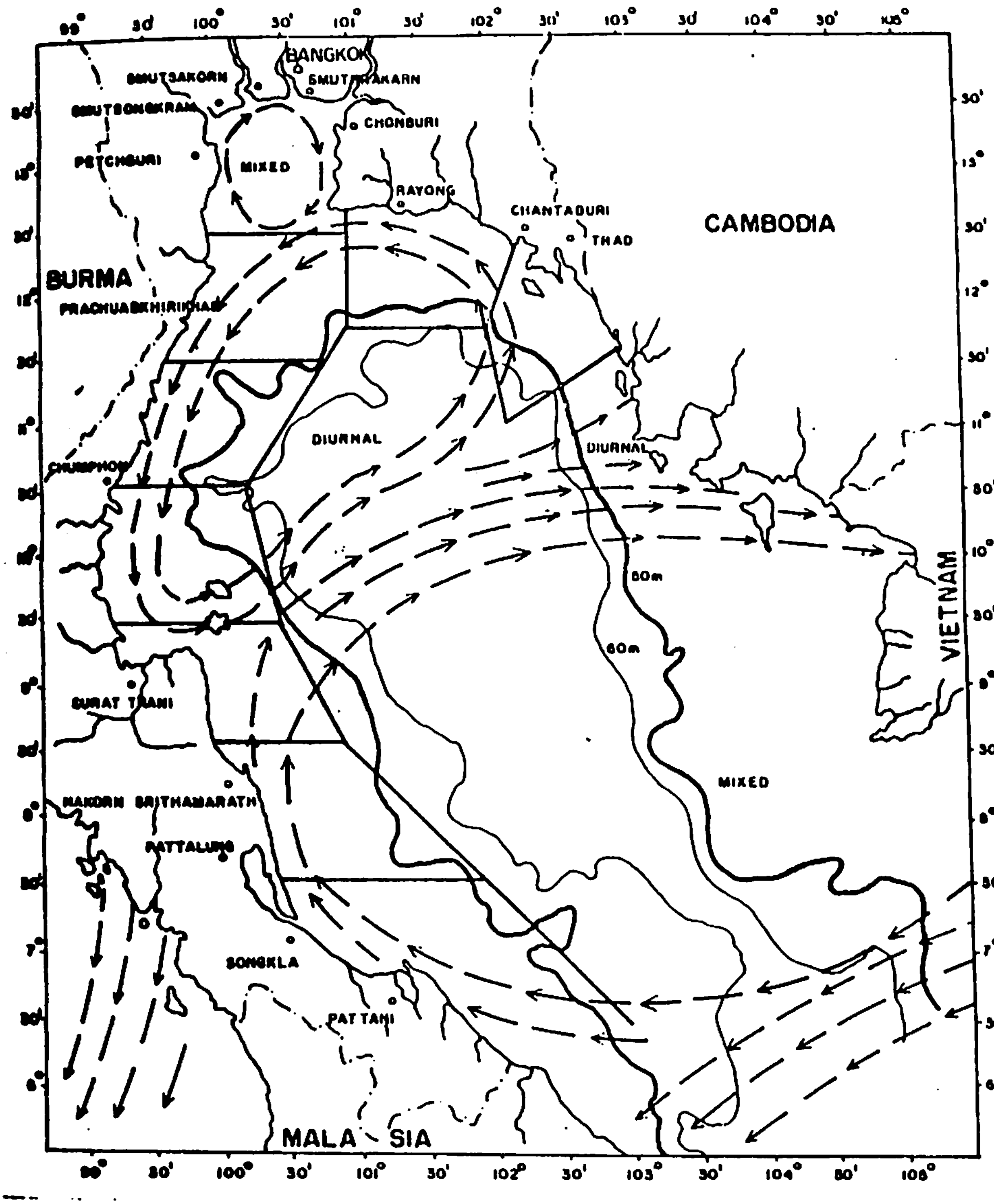


Figure 2.4 Current circulation in the Gulf of Thailand during October-December (from Royal Thai Navy, 1983).

3. MARINE FISHERIES

The marine trawl fisheries of the Gulf of Thailand have most recently been reviewed by Mattana Boonyubol and Somsak Pramokechutina (1982) and the pelagic fisheries reviewed by Somsak Chullasorn and Shindo (1983). Additionally, important reports are available on the cephalopod fisheries (Mala Supongpan, 1983), on the results of the trawling surveys of the Gulf in 1979 and 1980 (Monton Eimsaard and Direk Dhamniyan. 1981; Taweesak Charnprasertporn, 1982) and on the invertebrate catches taken by research vessel surveys during 1981 (Atchara Vibhasiri and Karuna Kongmaug, 1981a and b).

The above-mentioned reports all deal exclusively with the commercial fisheries and do not refer in any degree to the activities of the small-scale or artisanal fisheries which occur in all of the coastal waters. There are no detailed reports on this sector at present although a report (Navin Kuantanom, in prep.) is planned which will describe the small-scale fisheries of the inner and eastern Gulf of Thailand. This will include information on the species caught, the fishing gears and the general level of catch by different gears. However, the actual quantities landed each year by the artisanal sectors are entirely unknown.

The status of the marine fisheries is also reviewed in Part 3, p. 52 - 78 of the Thailand Fisheries Sector Study. The following sections recapitulate the most important features of the fisheries.

3.1. Demersal commercial fisheries

In 1980, the most recent year for which complete data have been published, the demersal commercial catch in the Gulf of Thailand amounted to 798,035 metric tons, comprised of 524,000 mt of fish, 61,000 mt of cephalopods, 96,000 mt of shrimp, 26,000 mt of crabs and 90,000 mt of miscellaneous invertebrates.

Otter trawlers comprised about 79% of the registered fishing vessels in 1981, with lesser numbers of pair-trawlers (14%) and beam trawlers (7%). The otter trawlers cover a wide size range, with some vessels exceeding 25 m length but the majority being less than 14 m long. In contrast, most pair trawlers are in the 18-25 m class. Beam trawlers are almost exclusively less than 14 m long. The numbers of registered trawlers is reported to have declined sharply between 1980 and 1981 with the greatest decreases in the smaller classes of vessels. The reason for this decline has been ascribed to the return of large trawlers to Thai fishing grounds as a result of enforcement of EEZ claims by other nations, with resultant intensification of competition for the resources. Additionally, numerous small trawlers have been converted to squid light fishing vessels as a result of an apparent increase in the abundance of squid. This in turn has been ascribed to the reduction of squid predators as a result of intensive trawling and purse seining.

Table 3.1 gives details of the changes in the demersal trawl fisheries since 1960.

3.2. Pelagic commercial fisheries

The pelagic catch in the Gulf of Thailand in 1980 amounted about 286,000 mt with the catch comprised mostly of sardines (96,000 mt) Indo-Pacific and Indian mackerels (59,000 mt), various scads and other carangids (69,000 mt) and the remainder comprised of a wide variety of species (Table 3.2). The total catch in 1980 represents a drastic decline from a peak of 476,000 mt attained in 1977.

Most of the catch is currently taken by the "luring purse seine" in which fish which have aggregated around drifting palm fronds are enclosed by a purse seine. There has recently been a trend towards the use of lights for aggregating the fish. The traditional Thai purse seine catches a greater proportion of sardines while the "encircling gill net" produces the largest proportions of Rastrelliger spp. There is a small specialized fishery for anchovies and large-meshed gill nets take a

Table 3.1. Historical records on catch, catch composition standardized research vessel catch rates and estimated total fishing effort in the Gulf of Thailand: 1960-1981 (data from Mattana Boonyubol and Somsak Pramokechutima 1982).

Year	Total demersal catch (m.t.)	% Good fish	% Trash fish	% shrimp and mantis shrimp	% Cephalopods	Estimated total demersal fishing effort (trawl hrs x 1,000)	Standardized catch rates in kg/hr in 2-5 cm mesh	Number of registered trawlers Otter	Pair	Beam
1960	58,852									
1961	106,552					358	298			
1962	129,700					515				
1963	198,190					672	295			
1964	320,614					1,114	288			
1965	343,141					1,471	233			
1966	363,842					2,051	177			
1967	437,424	26	55	12	4	2,773	158			
1968	513,380					3,493	147			
1969	518,650					3,621	143			
1970	530,174					3,875	137			
1971	608,580					6,065	100	2,203	522	613
1972	737,949					7,362	97	2,813	702	599
1973	830,873	15	66	10	6	9,810	85	3,927	824	533
1974	604,863	15	62	11	8	6,439	93	3,595	854	343
1975	752,107	16	64	10	7	9,683	77	3,397	850	283
1976	787,914	15	66	10	7	8,185	93	3,735	814	284
1977	848,103	15	50	16	9	11,216	75	4,536	878	420
1978	814,054	15	51	12	9	9,978	81	4,610	804	489
1979	832,392	15	50			9,932	80	6,273	1,120	537
1980	798,035	14	52	12	8	12,610	62	7,192	1,092	1,060
1981	780,000					15,672	50	5,227	910	496

Table 3.2. Commercial pelagic catch in the Gulf of Thailand in 1980 (from Somsak Chullasorn and Shindo 1980).

Gear	Catch in metric tons						
	Rastrelliger sp.	Tunas	Scads and other carangids	Sardines	Anchovies	Other pelagics	Total
Thai purse seine	9,259	2,151	2,172	11,344	0	1,334	26,260
Luring purse seine	24,779	4,082	64,038	64,223	1,908	46,091	205,121
Anchovy purse seine	0	0	9	550	4,490	55	5,104
Encircling gill-net	25,496	567	2,033	19,461	0	2,652	50,209
Spanish mackerel gill-net	0	5,721	261	166	0	5,357	11,505
Total	59,534	12,521	68,513	95,744	6,398	55,489	298,199

relatively small tonnage of spanish mackerel and the coastal tunas.

The numbers of "luring purse seiners" in the Gulf of Thailand increased from only one in 1971 to around 500 in 1980 while the numbers of Thai purse seiners declined by 70% to about 100 vessels over the same period. The anchovy purse seine fleet appears to be declining while gill netters have almost doubled in numbers over the past decade.

Overall, there has been a great intensification of the pelagic fisheries in the past decade, with all species coming under greater pressure; but particularly the scads and sardines which appear to be most vulnerable to the luring purse seine.

3.3 Current and potential harvests

Recent analyses of tropical multispecies fisheries have suggested that because of complex ecological interactions, the total harvests of those fisheries do not rise to a clear maxima and then decline in response to increases in fishing effort. Instead, they appear to rise to a plateau but ultimately abruptly collapse at extreme levels of fishing effort. For such fisheries, an arbitrary optimum has been suggested (and adopted for several North Atlantic fisheries) as being that level of effort at which an increase of one unit of effort will increase the catch by only 0.1 of the amount caught by the very first unit of effort (Gulland, 1984). This amount of effort and the corresponding yield are termed $F_{0.1}$ and $Y_{0.1}$, respectively.

Table 3.1 gives a summary of the available data on the demersal fishery of the Gulf of Thailand. Fig. 3.1 shows that a theoretical maximum catch of demersal species in the Gulf of Thailand using present fishing gears would not exceed 845,000 metric tons/ year, even at extreme levels of fishing effort and that a $Y_{0.1}$ of 760,000 mt would be generated by a fishing effort ($F_{0.1}$) of only 8.5 million trawler hours. In other words, 90% of the maximum possible catch could be produced by approximately one-half of the current fishing effort. Relatively greater harvests are conceivable if the mesh size used in the fishery were increased.

In economic terms, the situation is even more serious because the value of the catch would probably be greatest when the total harvest was substantially less than 760,000 mt, because the proportion of high quality fishes and invertebrates would be greatest at a relatively low level of fishing effort. Unfortunately, the data necessary to compute a bio-economic model are simply not available. This should not obscure the fact that by any criteria the demersal trawling industry is grossly over-capitalized and in serious need of management.

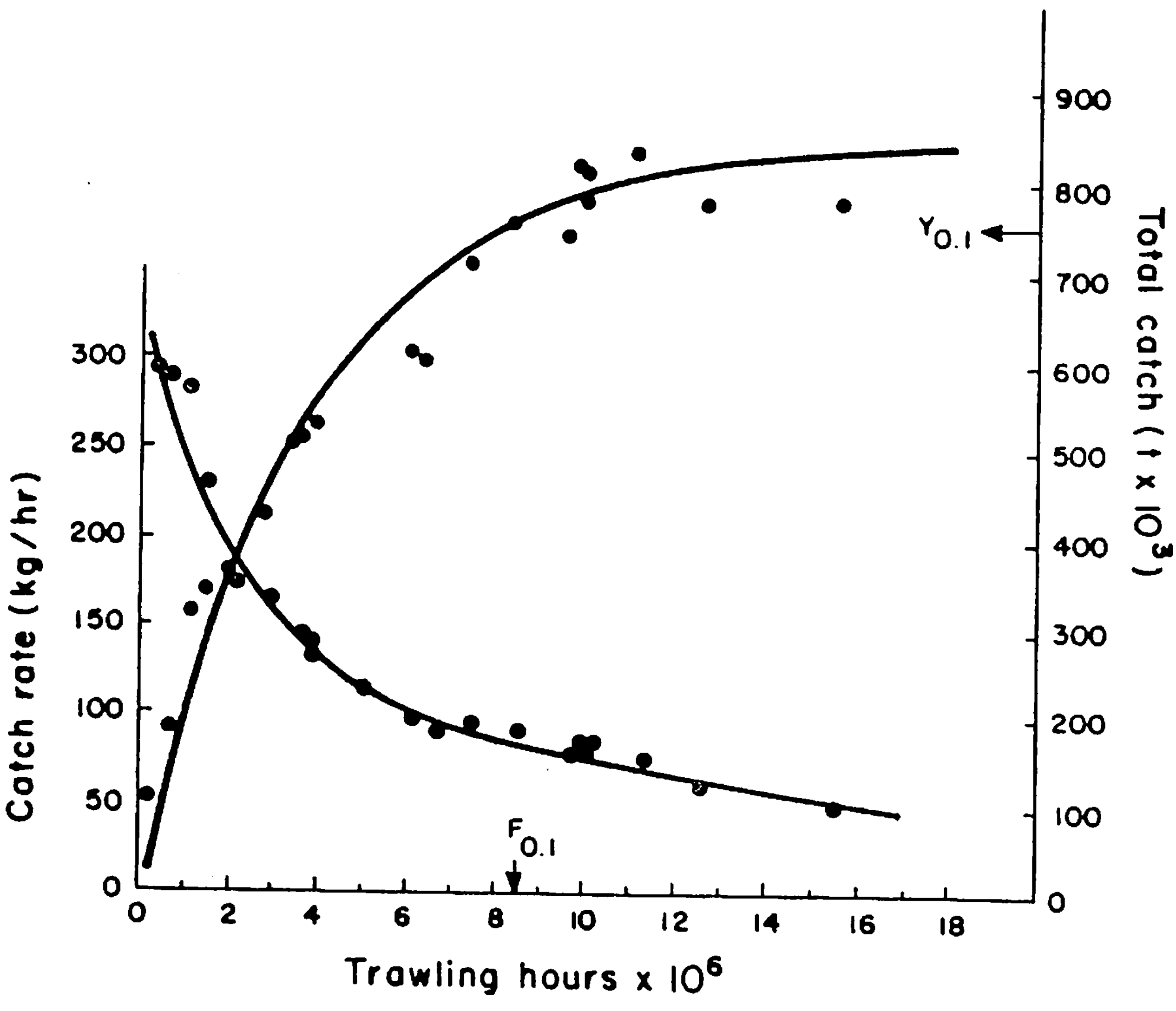


Figure 3.1 Changes in standardized research vessel catch rates (descending line) and total demersal catch (ascending line) in the Gulf of Thailand in response to increasing trawling effort. $F_{0.1}$ is the fishing effort at which an increase of one unit of effort which will produce an increase in catch equal to 0.1 of the catch taken by the first unit of effort. The corresponding catch, $Y_{0.1}$, represents an arbitrary defined optimum harvest (Gulland, 1984).

Menasveta (1973) estimated the "potential yield" of small pelagic fishes of the Gulf of Thailand to amount to 365,000 mt/yr. This value was exceeded in 1977 and 1978 and catches have subsequently declined, giving some credence to this estimate. Somsak Chullasorn and Shindo (1983) give details of the catches by the major components of the pelagic fishery over the period 1971-80 and concluded that the drop in the catches of the luring purse seines after 1977 "may be indicative of overfishing" and suggested that "the amounts of effort expended should not exceed that of 1977".

3.4 Constraints on management and the overfishing problem.

Although it has been recognized for a number of years (e.g. Pauly 1979) that the fisheries of the Gulf of Thailand are seriously over-capitalized and over-exploited, Thailand differs in no respect from any other country in finding it difficult to control an open access system in a free enterprise economy. The fact that new boat construction continues unabated suggests that profits are still generated by the Gulf fishing industry - at least for the best equipped and most able fishing entrepreneurs.

However, the diversion of capital into an industry which is highly energy intensive and which on aggregate is probably running at a loss is a situation which simply applies a brake to overall economic development. The profits which are made in the industry accrue to relatively prosperous individuals but the burden of declining catch rates caused by competition with sophisticated vessels falls most heavily on the artisanal fishermen. Social and political problems are a likely consequence of this situation.

The solution to these problems is simply to reduce overall fishing effort in the Gulf by about 50%. This poses an extremely difficult problem in licensing and/or enforcement of fishery regulations and still does not cope with the main problem which is that the nearshore areas (defined as being within 3 km of the shore) are the most seriously overfished. Although no detailed analyses are available or possible, it seems likely that a 70-80% reduction in fishing effort might optimize nearshore yields. In effect this means that the entire trawling fleet needs to be excluded from the nearshore zone. There are regulations which state precisely this, but they are ignored by the fishermen and it is not possible to enforce the regulation.

4. REVIEW OF THAI ARTIFICIAL REEF PROGRAM

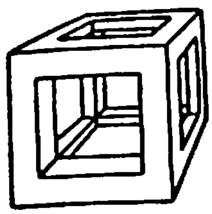
An artificial reef program was initiated in 1978 as a result of recognition by the Department of Fisheries in Thailand that artificial reefs could be a tool for enhancing production in the marine fisheries sector.

Artificial reefs have been constructed at sites at Rayong and Songkhla in the Gulf and at Phuket on the west coast of Thailand. Progress reports are available for Rayong (Samporn Boongird, et al., 1983) and for Phuket (Niyom Wakaharn, et al., 1984) but not for the Songkhla experiment.

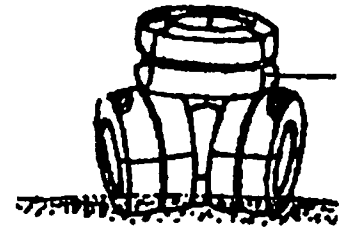
4.1 Reef type and locations

Artificial reef work is conducted by the Department of Fisheries from bases at the Rayong Marine Fisheries Station, at the Phuket Marine Fisheries Station, and at the National Institute of Coastal Aquaculture at Songkhla. A major objective of the artificial reef program is to develop fishing grounds for artisanal fishermen.

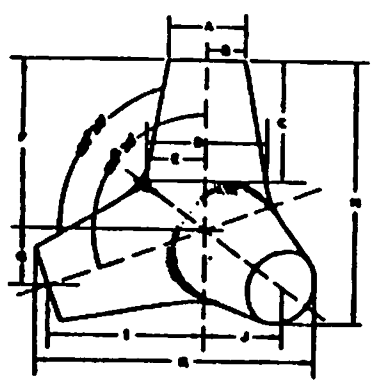
The artificial reef program began in 1978 at Rayong with the construction of a reef composed of 70 open or framework concrete cube modules each 0.5 m (Fig. 4.1a) on a side and 400 tires tied into a quadropod modules of 8 tires each (Fig. 4.1b). These modules were dropped over an area of 1200 m^2 in 18 m of water. Each subsequent year, another reef was constructed from modules including tires, concrete cubes, concrete pipes tied



A. Open concrete cube



B. Tire module



C. Tetrapod module

Figure 4.1 Three artificial reef modules. A. Open or framework concrete cube module proposed for the pilot reefs, B. Tire reef module used at Rayong, C. Tetrapod module proposed as a trawling obstruction unit.

together in pairs, each 1.5 m in diameter and .3 m in height, and in one occasion 18 large stones.

There are now 6 artificial reefs in place at Rayong and a seventh under construction. The reefs are in depths from 4-18 m and are composed of from 410 to 4,500 tires, concrete cubes and concrete pipes, covering areas from 900 m^2 to 40,000 m^2. The most recent artificial reef, constructed in 1983, with 4,500 tires in 15 m of water also employs a floating bamboo raft to aggregate pelagic fishes.

The reefs were placed on sandy bottoms near fishing villages. Department of Fisheries personnel built the reef modules and used their research vessel to place the modules. The cost for materials for the 6,678 tires, 526 concrete pipes, 143 concrete open cubes and 18 stones used to construct the 6 reefs was 184,103 Bht, or an average of 22 Bht per item.

The other artificial reef program in the Gulf of Thailand is near the National Institute of Coastal Aquaculture at Songkhla. This program began in 1982 with the placement of 20 units each composed of 40 tires tied together in two strips of 20 tires each placed in 6-7 m of water. In 1983, 120 open concrete cubes each 0.8 m on a side were added to this site. The concrete cubes had juvenile green sea mussels attached in order to initiate a population of mussels at the reef site. In

1984, 900 open concrete pyramids, each 0.8 m on a side were added to the site, which now currently covers 2,500 m^2 of sandy bottom.

The cost of material for each concrete cube was about 200 bht and for each concrete pyramid module about 80 Bht.

The third site of artificial reef work is in the Andaman Sea at the Phuket Marine Fisheries Station. Since 1982, ten artificial reefs have been constructed in Phangnga Bay at depths of 7-14 m using modules of tires, 1 m^3 open concrete cubes and concrete pipes, 1.0 m in diameter and 0.5 m in height. The construction of the ten reefs used 550 tires, 200 open concrete cubes, and 2,380 concrete pipes. The ten reefs were arranged in two parallel rows of 5 reefs each placed perpendicular to the trawling path in an attempt to obstruct trawling. The concrete pipes were fabricated with prison labor and cost about 250 Bht each for materials and labor.

4.2 Sampling program

Owing to budgetary constraints, the sites chosen for the artificial reefs at Rayong, Phuket and Songkhla were not given more that a cursory faunal survey before the reefs were emplaced and only at Rayong has there been a limited, but systematic, post-construction investigation of the fish and reef communities. For Songkhla only verbal reports were available concerning visual observations on the reef.

The sampling programs at Phuket and Rayong have relied upon the use of hand lines with small hooks and traps with 4-5 cm maximum aperture mesh size. Traps used at Phuket were of two types; semi-cylindrical (90 x 180 x 90 cm in size) and rectangular, 30 x 75 x 30 cm in size. At Rayong only the semi-cylindrical type was used for sampling.

Two of the Rayong reefs (#s 4 and 5) have been systematically sampled since their emplacement in 1981 and reef #6 continues to be fished on a monthly basis.

4.3 Results of sampling

4.3.1 Communities of organisms

In all cases the artificial reefs rapidly developed a cover of marine algae and encrusting organisms, thus forming the basis of a reef food web. The photosynthetic activities of the algae are important but of far more significance is the presence of filter feeding organisms which serve to entrap plankton brought to the reef by ocean currents and concentrate this energy source at the reef.

Filter feeding organisms which were reported from all sites were barnacles, oysters, mussels, sponges and soft corals. Additionally, typical small reef fishes such as Abudefduf sp. and other demoiselles, apogonids, Pterois sp. and small chromids were reported from the reefs. Pearl oysters

(*Pinctada*) and scallops were also reported at Phuket but no detailed inventory of the successional stages of colonization of the reef substratum is available for any of the sites.

In the case of Songkhla, mussels and oysters were introduced to the reefs and the reefs are reported to have been colonized rapidly by young oysters and mussels, either recruited from the local adult stocks or from the plankton.

Constraints of time in Rayong and Phuket and a severe storm in Songkhla frustrated attempts to dive on reef sites to make first hand observations on the established reef communities.

4.3.2 Harvestable components

The artificial reefs at Rayong and Phuket have been fished intermittently by Department of Fisheries staff since they were constructed and there is thus a record, albeit sparse, of the composition of catches taken in traps and on lines.

The Rayong reefs are best documented and give a record of the catch/line/hour and catch/trap/day covering the first year after construction and the species composition of the catches. The reefs were colonized quite rapidly by an assemblage of adult and juvenile reef fish and at the Rayong reef #5 the composition of the catch did not change markedly as the reef matured. Table 4.1 gives the percentage composition by species groups of catches taken in traps and on lines at the Rayong reefs.

Table 4.1 Composition of trap and line catches at Rayong artificial reefs

Family or species group	Percentage of catch	
	Traps	Lines
Serranidae (groupers)	37	9
Lutjanidae	23	38
Siganidae (rabbit fish)	15	0
Other quality reef fish	10	10
Other trash reef fish	9	+
Non-reef demersal fish	5	9
Scombridae (pelagic)	-	13
Carangidae (pelagic)	-	15
Other pelagics	-	1
Squid	+	4
Crabs	1	-

The trap catches are more representative of the fishes specifically associated with the reefs as they include only a small component of non-reef fishes derived from the muddy sea floor adjacent to the reefs. The line catches include a substantial percentage (28%) of mackerel (mostly Rastrelliger brachysoma) and small carangids (mostly Caranx (Atule) mate) which are not necessarily reef-associated but which might have been aggregated to some degree by the reef structures. The most significant features of the catches are the high proportion of valuable groupers (principally Epinephelus tauvina and E. areolatus) and snappers (Lutjanus lineatus, L. fulviflamma and L. malabaricus) which would not normally be captured frequently on the muddy level bottom habitat which existed before the emplacement of the reefs.

For the reefs at Phuket, a pre-deployment survey using a trammel net (a very unselective gear) showed a typical soft bottom community dominated by croakers (Sciaenidae), catfish (Tachysauridae) and thyrissid anchovies and with only small numbers of snappers and groupers. The limited amount of post-deployment fishing at these reefs showed snappers, groupers and rabbit fish to be the dominant species, as was the case at Rayong.

4.4 Utilization of reefs by artisanal fishermen

At all three sites, the artificial reefs are reported to be fished on a regular basis by artisanal fishermen from nearby villages. Hand lines and traps are the principal gears used, with gill-nets or trammel-net set adjacent to or over the reefs on an occasional basis. At Rayong, anchovies have been noted to aggregate over the reefs periodically and are captured by anchovy purse seiners.

The Rayong reef #6 is adjacent to a village of 69 families with over 200 fishermen. It is claimed that most of these fishermen fish the reef at least occasionally and that 4-5 boats might visit the reef each day. However, there are no details of the artisanal catch from this or any of the other reef.

Both at Rayong and Phuket, the reefs were reported to have been fished with explosives on occasions. There is general disapproval of this practice and the culprits were always said to be from elsewhere and never from the adjacent villages.

Fishermen at Rayong have claimed that they have benefited from the reef and that there is popular support for expansion of the artificial reef program.

4.5 Conclusions

The current artifical reef program has demonstrated that artificial reefs, whether constructed of concrete or of old tyres, will at least aggregate certain desirable species of fishes which can readily be captured by artisanal fishermen using inexpensive fishing gears. However, it is not possible to derive any cost-benefit estimates from the current program nor is it possible to conclude that total fish catches from any given area have actually increased.

The stability of the reefs over the six-year period under review suggests that environmental conditions are suitable for artificial reef construction.

5. PILOT PROJECT DESIGN

5.1 Rationale and objectives of pilot project

In theory, an array of artificial reef structures might generate the following beneficial effects when placed on an otherwise featureless, level, soft-bottom sea floor.

a) The reef will provide a refuge for post-larval and juvenile reef fishes which would normally succumb if they settled out of the plankton onto a non-reef habitat.

b) It will provide a habitat for plankton feeding fishes and for sessile filter feeding invertebrates which will extract their food from the passing water column and thus concentrate this energy source at the reef and thereby provide a resource which can be directly fished or which will provide a basis for an expanded food web for other desirable species. Fishes which use the reef as a refuge but forage for their food over the surrounding soft bottom habitat also concentrate energy in the reef system.

c) If the reef is in shallow sunlit water, the complex surface of a reef will provide increased habitat for filamentous algae and thus increase the primary productivity in the area covered by the reef.

Several separate beneficial effects can be expected to occur if as is the case in the Gulf of Thailand, the shallow waters are grossly overfished by trawlers using small-meshed nets,

a) the area in the immediate vicinity of the reef becomes untrawlable for fear of damage to the trawls and the reef can only be effectively fished by artisanal fishermen using relatively simple gears such as gill nets, traps or hook-and-line. A redistribution of wealth is thus achieved.

b) juvenile soft-bottom fishes will also find a refuge from trawlers in the area adjacent to the reef and thus be recruited to the trawl fishery at a larger size. This will benefit the trawling industry.

The exclusion of trawlers from selected areas can also be achieved by scattering single reef modules quite sparsely over the trawling grounds and this does not necessarily have to be combined with a program aimed at constructing proper artificial reefs. However, it seems highly likely that the greatest benefits will be achieved when the concepts of artificial reef construction and trawler exclusion are combined.

Although the benefits which will arise from an artificial reef and trawler exclusion program can be forseen and have been realized in many parts of the world, there exists no quantification of the costs and benefits and consequently, there is no basis upon which it can be judged whether or not an investment in artificial reef construction would be financially profitable or if the benefits would only manifest themselves in the form of politicially desirable redistributions of wealth, creation of jobs and alleviation of poverty.

In the context of this report, a Pilot Project is necessary to determine whether or not the large capital investments needed for an extensive artificial reef program in Thailand can be justified in social and economic terms.

The ADB Fisheries Sector Study tentatively suggested that a pilot study be conducted at five different sites (identified as Rayong, Chon Buri, Phetchaburi or Prachuap Khiri Khan, Surat

Thani and Songkhla (Fig. 5.1). However, it was the opinion of this Mission that dispersal of the resources available for the Pilot Project over five sites would not permit the development of an experimental design which would provide the answers which are needed for further development of the artificial reef and trawler exclusion concepts. The relative homogeneity of the marine environment of the Gulf of Thailand also suggests that dispersal of the resources of the Pilot Project will be counter productive and merely add to construction costs and create serious logistical problems in monitoring the impact of the reefs on the fisheries.

Additional criteria for site selection were:

a) proximity of a Department of Fisheries facility for logistical support and back-up;

b) the absence of major rivers which would cause siltation and unpredictable changes in salinity;

c) the presence of relatively deep water (20 m) fairly close to shore to provide an adequate depth range for the test reefs;

d) the presence of substantial concentrations of artisanal fishermen in adjacent villages competing for the same resources as the nearshore trawling industry.

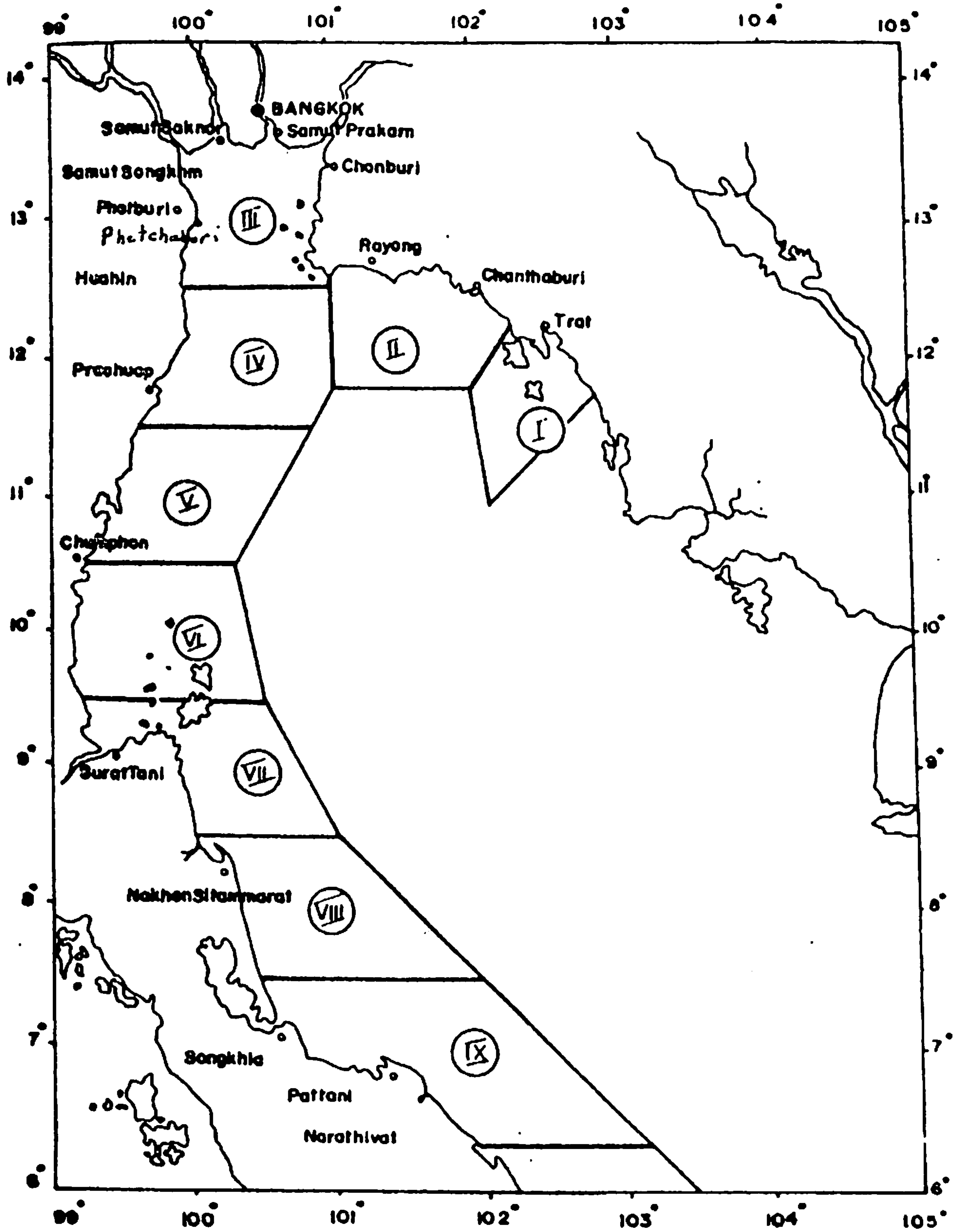


Figure 5.1 The Gulf of Thailand with coastal waters divided into 9 Statistical areas.

5.2 Sites examined

The characteristics of the possible sites (see Fig. 5.1) were examined in relation to the established criteria.

Chon Buri is located at the northeast end of the Gulf near the mouth of a major river and was eliminated from further consideration as a possible artificial reef site owing to the large silt and freshwater discharge from the river. Surat Thani is located on the west side of the Gulf at an area where the Gulf is very shallow and to place reefs at the target depth of 15-20 m at this site would require that they be placed far offshore. Prachuap Khiri Khan meets the basic criteria, as does Phetchaburi. However, Rayong and Songkhla appeared the most promising as sites for the pilot project because they have Department of Fisheries establishments which would facilitate project implementation and data collection and also have on-going artificial reef projects, so that data on reef stability and use by artisanal fishermen are already available. Site visits to Rayong and Songkhla were made to further evaluate the two sites.

Rayong is located in the northeastern end of the Gulf. The Department of Fisheries operates the Rayong Marine Fisheries Station which is about 2 1/2 hours by car from Bangkok. The total staff of the facility is about 100 with 12 professionals, including six biologists. The station has two research vessels, 15 m and 20 m in length, equipped for fish sampling.

The ocean bottom around Rayong is a sand and clay mixture. The artificial reefs in place show little evidence of siltation and subsidence after 6 years. The currents are along-shore, southeast to northwest during January to March and October to December and run along-shore northwest to southeast in April to June and July to September. Wave height rarely exceeds 2 m and the maximum current is about 2 knots. There are several small islands and coral reefs in the area. The sea bottom is gently sloping with the 10 m contour typically 3-5 km offshore.

Songkhla is located on the Southwest side of the Gulf. The Department of Fisheries facility at Songkhla is the National Institute of Coastal Aquaculture which has a total staff of 200 with about 30 professionals and one research vessel.

The ocean bottom is a sand clay mixture and the reefs which have been in place for 2 years in 6-7 m of water apparently show minimal subsidence or siltation. The currents are along shore from the southeast to the northwest throughout the year averaging about 1 knot with wave heights reported to not exceed 3 m. There are no coral reefs in the area. About 1,000 artisanal boats fish the area and a large trawl fleet operate out of Songkhla harbor.

5.3 Current fisheries at the sites

Although there are details of the estimated commercial landings by different categories of vessels at the major fishing ports, (including Songkhla and Rayong) details of the origins of the catches are not available because many vessels fish far afield from their home ports, even in extraterritorial waters, and their landings will not be indicative of the status of the fish stocks in the vicinity of proposed sites.

Data have therefore been extracted for the smallest categories of commercial vessels operating from these ports on the assumption that they fish nearby. These data can be supplemented by some of the more detailed information available on the results of the routine trawl survey work of the "Pramong" series of research vessels operated by the Department of Fisheries.

The "Pramong" vessels use nets with 4 cm mesh cod ends and therefore catch considerably less trash fish than the commercial boats which use a 2.5 cm mesh cod end. The Pramong catches are therefore mostly useful for comparisons between areas and are less useful for predicting commercial catch rates.

The most useful publications relating to the Pramong surveys of 1979 and 1980 are those of Monton Eimsaard and Direk

Dhamniyan (1981) and Taweesak Charnprasertporn (1982). Mala Supongpon (1983) and Atchara Vibhasiri & Karuna Kongmaug (1981a, b) provide recent data on invertebrate catches.

Unfortunately, there are simply no data on the artisanal catches and the only information is that gained by direct observations and by talking to fisheries officials in the area.

5.3.1 Rayong

5.3.1.1 Commercial fisheries

The commercial fisheries of Rayong are based mostly upon trawling and fishing for squid with light attraction. The squid fishery is a fairly recent development, believed to have arisen because of a major change in the composition of the marine communities caused by intensive otter trawling (Pauly, 1979). Many of the smaller trawlers have been converted to squid fishing boats.

In 1980, a total of 31,000 mt of fish were landed at Rayong, or 1.9% of the national total. This small percentage nevertheless places Rayong as the eight largest fishing port in the Gulf of Thailand and the largest port on the north-eastern shores of the Gulf.

The nearshore Rayong area is represented by station 19 in Area II of the standardized grid operated by the Pramong research vessels. Additionally, station 21 covers an ecologically similar area near Chanthaburi. Within these sectors, the 10-20 m depth zone is of most relevance to this report. These areas were covered by seven cruises in each quarter of 1980 but the 1979 cruises were mostly in January, March and May and are therefore less representative. In 1980, the average catch rate (kg/hr) in the 10-20 m zone was 12.4 kg/hr, increasing in 26.6 kg/hr in the 21-30 m zone. The 10-20 m was not fished in 1979 but the 21-30 m zone yielded 23.1 kg/hr. There is no evidence of seasonality in the catch rate data.

The average catch rate in 1980 in 10-20 m at Rayong was slightly less than half of the average reported for similar depths elsewhere in the Gulf and was in fact the lowest catch rate for any area. The catch rates in the 21-30 m zone were the second lowest in the Gulf in 1980 and the lowest in 1979. These figures are largely brought about by the particularly low catches of trash fish in Area II combined with relatively low catches of "good" fish in the 10-20 m zones. Additionally, station 19 is characterized by negligible shrimp catches and relatively poor squid and cuttlefish catches.

In summary, the Pramong data suggest that the shallow zones of Area II include some of the least productive trawling areas of the Gulf. In part, this might be ascribed to the relatively small outflow of rivers on the area (which accounts for the presence of coral reefs) which would limit the production of groups such as shrimp which require an estuarine environment for part of their life history.

5.3.1.2 Artisanal fisheries

In the immediate vicinity of the Marine Fisheries Research Station at Ban Dae village near Rayong, there are reported to be sixty-nine fishery families, with over 200 fishermen. These individuals fish in the immediate vicinity (within 5 km) of Ban Dae all year round but range further afield when weather conditions are good.

Hand lines and gill nets are the principal fishing gears and traps are set in midwater for squid or on the bottom for demersal species. Dynamite is frequently used and most of the coral reefs in the area are reported to have been reduced to rubble. No information is currently available on the size of the catch taken by the artisanal sector, on its composition (which will vary seasonally), or on the relative contributions of the various fishing gears to the annual income. However, at least one study is in progress (by a Canadian volunteer) and it can be expected that a baseline understanding of the local artisanal fishery will be available in the near future.

It should be noted that the Ban Dae fishermen are currently fishing, at least part-time, on the small artificial reefs constructed by the Department of Fisheries and their catches from these areas will be basically similar to those reported in section 4.3.2.

5.3.2 Songkhla

5.3.2.1 Commercial fisheries

Songkhla is the second largest fishing part in Thailand, with 10.5% of the national total in 1980. Most of the fleet are otter trawlers, together with larger otter trawlers and purse seiners.

The area is bracketed by stations 395 and 420 in Area IX of the Pramong trawl survey grid. The area had good coverage at all seasons during 1980, but coverage in 1979 was concentrated in January-May. The catch rate of the Pramong 9 in the 10-20 m zone was 26.2 kg/ha in 1979 and 29.4 kg/ha in 1980, while catches in the 21-30 m zone were 45.0 and 58.3 kg/ha in 1979 and 1980, respectively. These figures indicate that the Songkhla area can be considered one of the best trawling areas in the Gulf although as elsewhere, the best catch rates are taken in the 30-50 m depth zone and not in the 10-20 zone in which artificial reef construction is contemplated. No seasonality was apparent in 1980 catch rates.

The ratio of good fish to trash fish in the 10-20 m zone was more than 2:1 in both years which is a relatively favorable ratio in comparison with the same depth zone in other areas.

Catch rates of shrimp were relatively high in 1980, particularly at station 420, but in the 1970 surveys only negligible quantities were caught. The catch of cephalopods particularly squid, was moderately high, but the best catches were taken in deep waters.

5.3.2.2 Artisanal fisheries

There are reported to be at least 1,000 artisanal fishing boats operating in the marine waters of Songkhla Province. Traps, gill nets and hand lines are the principal gears.

Vessels observed were mostly open double ended boats, about 9 m overall length, either manually powered or fitted with longshaft diesel engines. All were stationed on beaches and launched through the surf. Sails are not used.

There is no information on the composition or size of their catches but as the only habitat available to be fished (other than the margins of a few islands) is the nearshore level soft-bottom habitat where the catches are unlikely to differ markedly from those of trawlers, except that a greater proportion of relatively high-valued species will be taken as a result of the use of hand lines.

5.3.3 Other fishing activities, including aquaculture

There are no significant aquacultural activities at either of the sites which would be adversely affected by the construction of artificial reefs.

5.3.4 Impact of Pilot Project on existing fisheries

Following from the foregoing sections, it is concluded that the impact of the proposed pilot artificial reefs upon the existing trawl fisheries would be negligible, that the reefs would have immediate and obvious benefits to the artisanal fishermen and that the fisheries for pelagic species would not be negatively affected in any way. Both the trawl fisheries and the pelagic fisheries can be ultimately expected to also benefit from artificial reef construction and/or exclusion zones but this expectation needs to be conclusively demonstrated by the Pilot Project before any assertion can be made on this topic.

The area covered by trawl survey areas I - IX in the Gulf of Thailand amounts to about 115,000 km^2. As the demersal catch in 1980 totalled 7980,035 mt, the annual average demersal harvest is 6.9 mt/km^2. Table 5.1 gives details of the average catch composition (1981) trawl survey data in the Gulf and approximate current values to the producer of various components of the catch. From these data the estimated average annual harvest/km^2 can be deduced together with an estimate of the average value of the harvest taken from each km^2 of the Gulf of Thailand trawling grounds. This amount to about 200,000 Baht (US$7,000)/km^2/yr.

It is emphasized that these figures are approximations, as the compositions of research vessel catches are not identical to those of the commercial fishery (more good fish and fewer shrimp and trash fish) and the figures are based upon the average catch rate in the Gulf and not upon the shallowest waters (10-20 m) where artificial reefs are likely to be placed. These waters are likely to produce larger quantities of shrimp but lesser quantities of good quality fish.

Bearing in mind these limitations, it can be stated that the emplacement of artificial reefs and exclusion zones will be economically advantageous only if the increase in the value of the artisanal catch exceeds about 200,000 Baht/km^2/year. However, the "loss" to trawlers might be largely offset by improved harvests near to the exclusion zones as a result of fish and shrimp which have grown to a large size in the protected areas migrating sea wards in search of deeper waters.

Table 5.1 Estimated annual average harvest and value of catches taken from each square kilometer of trawling grounds in the Gulf of Thailand

	Average hourly catch (kg)	Estimated catch/ Km^2/yr	Value B/kg	Estimated value of catch/km^2/yr (Bht)
Large table fish	23.0	2,720	28.20	76,704
Small table fish	9.0	1,080	14.00	15,120
Trash fish	15.8	1,870	0.43	804
Cephalopods	5.9		87.90	61,530
Shrimp	2.4	280	131.60	36,848
Crabs	1.2	140	50.00	7,000
Others	1.0	120	10.00	1,200
	58.4	6,900		199,206

5.4. Design of Pilot Artificial Reefs

Pilot Project will have two components - one at Rayong and one at Songkhla. The Rayong design will be the largest and most intensively monitored.

The objective of the Rayong portion of the pilot project is to answer the following questions:

1) What is the change in the fish yield and its value to both the trawlers and artisanal fishermen fishing in and around a 50 km^2 area which is closed to trawling using only trawl exclusion units such as tetrapods?

2) What is the change in the fish yield and its value to both trawlers and artisanal fishermen fishing in and around a 50 km^2 area which is closed to trawling and which also has about 50,000 m^3 of artificial reefs?

3) What are the effects of module size and the arrangement of module into reef groups on fishing yield and species composition?

Answers to these questions are basic to evaluating the benefits of a large scale program of trawler exclusions and artificial reefs, and further will facilitate the evaluation of different artificial reef designs. The economic importance of evaluating trawler exclusion versus trawler exclusion with artifical reefs for different sized reef modules can be seen with the following example. The cost of closing off a 50 km^2 area to trawlers can be effectively done with 1,000 tetrapod modules for a total cost of about US$30,000, while the cost of closing off 50 km^2 to trawling with 1,000 tetrapod modules and adding 48,000 m^3 of artificial reefs with 6,000 cubes 2 m on a side is about US$630,000 and if 1 m concrete cubes are used rather than 2 m cubes for the artificial reef the total cost of trawling closure plus 48,000 m^3 of artificial reefs is about US$1 million (Appendix 5 and 6). Thus, a clear understanding of the benefits of each of these fishery enhancement approaches is necessary to select the most cost effective design.

The objectives of the pilot program at Songkhla are to determine the extent that the Rayong reef results are applicable to the southwestern Gulf. Catch rates and species composition will be compared between the Rayong and Songkhla sites to determine if the site at Songkhla produces about the same species composition and relative abundances. The economic and social impact to the artisanal fishermen of the site at Songkhla will be assessed as will the response of the trawl fleet operating out of Songkhla.

5.4.1 Module Design

Although the Japanese have developed numerous reef module designs, no one emerges as the best for a multispecies fish community and the most commonly used module in Japan is still hollow concrete units, 1-2 m in their major dimensions (Mottet, 1981) (Fig. 4.1a). The popularity of the concrete module is due to a combination of factors including the relative ease which 1-2 m concrete modules can be constructed and deployed, their low cost, the relatively high mass to volume ratio of concrete, their long life in seawater, the rapid benthic growth which occurs on the concrete surface and the ability to construct artificial reefs from layers of modules which offer a variety of vertical and horizontal relief and refuge space.

For the construction of artificial reefs in the Gulf of Thailand, open or framework concrete cubes of 1 or 2 m on a side appear to be appropriate. They are relatively inexpensive, simple to construct, and permit the comparison of 1 m^3 vs. 8 m^3 module volumes. The present artificial reef work conducted by the Department of Fisheries has found that concrete framework cubes ranging in size from .5 to 1.0 m on a side are stable and provide habitat for commercially valuable snappers and groupers.

As has been previously described, the objective of the pilot project is to evaluate both closing an area of the Gulf to trawlers and placing large artificial reef groups in the Gulf. The concrete framework cubes will be used to construct the artificial reefs and while a number of concrete cubes scattered over an area of the Gulf at the appropriate density would discourage trawling it may be more effective to close an area to trawling with a unit specifically designed to obstruct trawl nets. An example of one possible unit is the tetrapod (Fig. 4.1c).

An estimate of the cost of construction and deployment at Rayong of the modules for reef construction and trawl obstruction based on the quantities needed for the Pilot Program are as follows (Appendix 5):

1)	Concrete cube 1.0 m x 1.0 m x 1.0 m	Baht 560/cube	(US$21.5)
2)	Concrete cube 2.0 m x 2.0 m x 2.0 m	Baht 2,730/cube	(US$105)
3)	Tetrapod unit (1 ton)	Baht 780/unit	(US$30)

5.4.2. Layout

The Rayong design will be the largest and will use 3 separate 50 km^2 areas, roughly rectangular 5 km by 10 km, each with an average depth of about 15 m. One of the 50 km^2 areas will be a control site and will not receive any modules. Another 50 km^2 site will receive only 1,000 tetrapod trawl obstruction modules, randomly scattered over the 50 km^2 area, to test the effects of just trawl exclusion. Based on the swept area of a Gulf trawler, it has been determined that with 1000 trawler exclusion modules randomly scattered over a 50 km^2 area the probability that a trawler will snag one or more module in 1 hour of trawling is 0.92 which is probably sufficiently frequent to deter trawling in the area (Appendix 6). The third 50 km^2 site will contain both 1,000 tetrapods to obstruct trawling and 48,000 m^3 of artificial reefs arranged into ten reef groups using both 1 and 2m cubes. This latter 50 km^2 site will permit the evaluation of the effect of both trawling exclusion and artificial reefs on fish production. The ten reef groups is this design will be arranged in 2 rows of 5 reef groups each with about 1 km spacing both between the rows and between the reefs in each row. Each reef group is composed of one or more reef sets where a reef set is an assemblage of reef modules separated from other reef sets in the reef group by 300-500 m. The design of the ten reef groups is given in Table 5.2. The objective of the design of the ten reef groups and the reef sets within the reef groups is to evaluate the effects of reef module size (1 m and 2 m cubes) and the effects of the number of reef sets within a reef group on fish yield and species composition. Data collected from reef groups numbered 1, 2, 3 and 4, 5, 6 (Table 5.2) will permit the comparison of the effects of block size (1 m vs. 2 m cubes) on fish yield and species composition for two levels of reef volume. Data collected from reef groups numbered 3, 7, 8 and 6, 9, 10 (see Table 5.2) will permit an evaluation of the effect of the number of reef sets within a reef group on the fish production and species composition at two level of reef group volume.

The pilot program at Songkhla will consist of a 50 km^2 control region which will not receive any modules, a 50 km^2 trawl exclusion area which will receive 1,000 trawl obstruction modules and a third site which will receive secure 6,400 m^3 of artificial reefs without any trawl modules. The arrangement of these artificial reef modules will consist of two reef groups, each identical to the reef group number 3 at Rayong (Table 5.2). The two reef groups will be separated by 1-2 km. Not only will the Songkhla reef design evaluate the extent that the results from Rayong are applicable to the southwest Gulf but due to the replicated reef design at Songkhla estimates of the variance between sets within a reef group and between identical reef groups will be obtained for variables such as catch rates and species composition which will further improve the quantification of the Rayong results.

TABLE 5.1 The number of units, volume of the reef, and number of reef sets per reef group for ten reef groups to be placed at Rayong.

Reef Group Number	Total Number of Units and size	Total Volume (m^3)	Number of sets*	Number of units per set	Volume per set (m^3)
1	400 - $8m^3$	3200	2	200	1600
2	3200 - $1m^3$	3200	2	1600	1600
3	200 - $8m^3$, 1600 - $1m^3$	3200	2	900 (100 - $8m^3$; 800 - $1m^3$)	1600
4	800 - $8m^3$	6400	4	200	1600
5	6400 - $1m^3$	6400	4	1600	1600
6	400 - $8m^3$, 3200 - $1m^3$	6400	4	900 (100 - $8m^3$; 800 - $1m^3$)	1600
7	200 - $8m^3$, 1600 - $1m^3$	3200	1	1800	3200
8	200 - $8m^3$, 1600 - $1m^3$	3200	4	450 (50 - $8m^3$; 400 - $1m^3$)	800
9	400 - $8m^3$, 3200 - $1m^3$	6400	2	1800 (200 - $8m^3$; 1600 - $1m^3$)	3200
10	400 - $8m^3$, 3200 - $1m^3$	6400	8	450 (400 - $1m^3$; 50 - $8m^2$)	800

* The sets within a reef group will be separated by 200 - 300 m.

5.5 Baseline studies and monitoring system

In order for the Pilot Project to provide clear and unequivocal answers on the cost and benefits of artifical reefs in the Gulf of Thailand, it is essential that carefully organized baseline studies should be conducted before reef or exclusion zone deployment is initiated. Without such data, the results of the Pilot Project will be virtually meaningless. Unfortunately, there are very few site-specific data available for either Rayong or Songkhla. The available publications and statistical reports only give generalized accounts of the status of the fisheries over wide areas and no information is available on the artisanal sector.

Secondly, the changes which occur in the reef areas, exclusions zones and control areas will have to be carefully monitored for several years before conclusive results are available, although some preliminary indications of the viability of the Pilot Project might be available within one year of completion of the construction and emplacement phase.

This monitoring program will form the core of the entire Pilot Project and it is essential that it should be meticulously executed. If it is not, no conclusive results will emerge from the program and the entire effort will prove futile. For this reason, it is recommended that an experienced reef fishery scientist be recruited to direct the scientific activities of the Pilot Project.

5.5.1 Baseline studies

5.5.1.1 Mapping, hydrography and sedementology

The areas selected for the sites will have to be surveyed and the distribution of sediments and of contours and any other topographical features mapped with some precision.

5.5.1.2 Benthic communities

Along with the sediment studies, the basic characteristics of the benthic communities, principally of invertebrate animals, will have to be described and quantified as these form the lower-most portions of the food web upon which the increased fish communities are expected to subsist in reef and exclusion zones. This could be accomplished with a basic pattern of sampling with grabs and dredges, probably at quarterly intervals during the first year.

5.5.1.3 Fish and epibenthic invertebrates

The fish and larger invertebrates living on the sediments (such as octopus, scallops and prawns) will have to be enumerated in detail during the first year of the Pilot Project, and estimates made of the standing stocks of these organisms.

From previous research work in the Gulf of Thailand, there is a good basic understanding of the identity and distribution of the major elements of the potential trawl catch and the major task will be to organize systematic surveys to quantify the abundance of these organisms. This will most easily be accomplished by means of a systematic trawling survey of the Pilot Project sites, using the swept area method, probably on a quarterly basis.

Additionally, systematic test fishing must be done using hand lines, bottom long lines, gill nets, traps and trammel nets in order to establish baseline catch rates at the sites, which can in due course be compared with those obtained in the reef and exclusion zones.

A preliminary evaluation is needed of the extent to which the commercial fishing vessels, particularly trawlers, utilize the Pilot Project sites. This can be done by interview and direct observation. It will be necessary to prohibit trawlers from the attempting to trawl in the exclusion and artificial reef areas and some degree of care will be necessary in approaching this matter.

5.5.1.4 Socio-economic status of the artisanal fishing communities.

Possibly, the most vital component of the baseline studies will be a program aimed at evaluating the socio-economic status of the artisanal fishing communities.

This should aim to provide a detailed account of the composition and magnitude of their catches, a description and inventory of fishing gears, estimates of income and of direct subsistence use of fish and an analysis of their social and economic problems.

This will be difficult to accomplish as fishermen are not particularly receptive of the attention of outside bodies. However, the artisanal fishermen both at Rayong and Songkhla fish on the present small artificial reefs and are said to recognize the potential benefits of the reefs. If the socio-economic studies were tied into a program directed towards keeping the fishermen fully aware of the intentions and progress of the Pilot Project at each site, it seems likely that good cooperation would be forthcoming, at least from the more able and better informed members of the community.

5.5.2 Monitoring system

The monitoring activities at Rayong will be continuous from the time the fish reef structures are emplaced and the following account of the monitoring system refers to activities at Rayong except where Songkhla is specifically mentioned.

Monitoring at Songkhla will be much less intensive as this part of the project will concentrate on before-and-after socio-economic appraisals and work to test specific differences of various reef emplacements and trawler exclusion zones.

5.5.2.1 Physical structures

An array of selected reef modules will be examined immediately after emplacement and their orientation, structural integrity, and degree of embedding in the sediments noted.

These structures will be regularly re-examined to detect any degree of settling into the sediments and to estimate their likely useful life as reef structures or trawler exclusion modules.

5.5.2.2 Development of reef biota and changes in the benthic communities.

The reef structures will be colonized by sessile organisms at a rate which is dependent upon the time of the year and upon the natural abundance of the larvae of colonizing organisms.

Colonization of the artificial reefs emplaced by the Department of Fisheries was relatively rapid.

As the communities of sessile organisms are the means whereby energy is concentrated in the reef system, these communities must be described as they develop and monitored until they stabilize. Organisms which prey directly upon the sessile animals or plants are important as they are the means whereby energy is passed along the food chains to man. Carefully considered introductions of appropriate species can be contemplated if monitoring reveals that these species are absent from the area. For example, mussels and oysters were introduced to the Songkhla artificial reef by DOF because it appeared that natural spatfall was limited. These animals are now established in the Songkhla and will undoubtedly colonize any reef structures.

Within the trawler exclusion zone and the reef complexes, some changes in the soft bottom invertebrate communities can be expected as a result of changes in the abundance of and composition of the fish fauna which preys on these organisms. These changes should be monitored.

The reef biota will be best monitored by biologists who are adequately trained in the use of scuba-diving techniques. Some supplementary training might be necessary for DOF staff to ensure that these efforts are productive.

Samples of the soft bottom sediments and the fauna should be taken at varying distances from reef structures of different sizes, in the exclusion zones and in the control areas. As the depths are modest, scuba divers should be used to ensure that grab samples of sediments are unformly collected. This will remove much variability in the data.

5.5.2.3 Demersal fish monitoring

The development of the harvestable components of the reef fish and invertebrate communities and the changes in the soft-bottom fish communities must be carefully monitored and compared with the soft-bottom communities in the control areas.

Anticipated changes include the colonization of the reef modules by adult reef fish which move in from the reef systems surrounding adjacent islands or by juvenile reef fish which settle out of the plankton and become resident on the modules. In the exclusion areas, larger standing stocks of soft bottom fishes and some changes in species composition can be expected.

Additionally, as there is a general tendency for larger individuals of most species to move towards deeper waters, it can be expected that trawl catch rates at the seaward sides of the reef and exclusion areas will be increased.

Monitoring should therefore take the form of a continuous rotation of fishing the reef, exclusion, and control areas, preferably on a lunar monthly basis, with identical sets of hook-and-line, gill nets, trammel nets and traps. These gears must include elements which are identical to those used by the artisanal fishery plus some elements which will capture fishes at a size smallerl than is normally taken by the fishery (i.e., the pre-recruits).

Trawling must be done in the seaward strips adjacent to the three zones, again in a standardized manner and on a lunar monthly basis. Gear should be identical to the commercial fishing gear.

All fish captured in the monitoring program must be identified, counted and measured. For those species which, on the basis of the baseline studies, it appears that there are sexually dimorphic growth rates, the sexes must be measured separately.

The gonads of an adequate sample of adult fishes should be examined each month and the stage of maturation noted. Stomach contents of all species should be noted and, if possible, detailed studies should be done on the feeding habits of the most important species.

Otoliths should be removed from a sample of all species, particularly of the smaller size groups, for ageing on the basis of daily or annular rings. It may be possible to send such samples for analysis at a fisheries laboratory with specialized equipment.

An adequate number of fishes covering the full length range of the species should be accurately weighed and measured to enable length-weight relationships to be defined.

It is most important for analysis of the data that the fishing effort expended in monitoring be accurately recorded as the catch rate data for specific gears will be needed to estimate the catches taken by the artisanal fishery.

5.5.2.4 Pelagic fish monitoring

Although marked changes in the fishery for pelagic species are not expected it will nevertheless be necessary to maintain some modest monitoring activity using fishing gears identifical to those used by the artisanal fishing community. This would probably include fishing with floating gill nets and setting mid-water traps for squid.

Data gathered would be identical to that for the demersal fishes.

5.5.2.5 Fishing effort monitoring

The fishing effort expended by the artisanal fishermen in the reef, exclusion and control areas must be monitored on a nearly continuous basis, as must any commercial fishing, including incursions by trawlers, into the zone. This aspect is of particular importance because changes in abundance of fishes in the different areas will tend to be masked by the tendency of fishermen to fish in what they perceive to be the "best" areas. This results in catch rates becoming fairly uniform in all areas and not by themselves providing a reliable measure of the relative abundances of various exploited species. It is suggested that the best measure of overall fishing effort will be obtained by establishing a small radar station on one of the small islands off Rayong or on the mainland. Provided the tower has sufficient elevation, a relatively modest marine radar sets will be able to monitor the activities of various fishing boats in the Pilot Project areas. A back-up radar will be necessary in case of equipment failure. These data combined with the planned inventory of fishing gears will provide a measure of trips, proportioned in terms of available gears, in the case of the artisanal fishery and of trawler-hours in the case of trawlers fishing in the control areas and intruding into the exclusion or reef zones or fishing in the seaward strips.

The data on fishing effort will provide some degree of corraboration of estimates of mortality rates which will be derived from length-converted catch curves, derived in turn from the length-frequency data (see section 5.7).

5.6 Socio-economic investigations

Following on from the basis provided by the baseline studies a selection of fishing families will be chosen for extended investigation on a voluntary basis. In addition to baseline sociological information, fishermen would be requested to maintain a simple log book recording catches by species groups made in various gears effort outside of and within the reef and exclusion areas income received and operating expenses on a weekly basis. Care would be taken to ensure confidentiality of the data.

5.7 Data analysis

The objective of the data-gathering operation described above is to require data sets which are amenable to analysis by several techniques and which will provide estimates of fish yields from different reef systems which are of sufficient accuracy to provide a basis for evaluation of the cost effectiveness of various artificial reef and trawler exclusion systems.

In addition to the baseline data, the monitoring will provide information on the catch rates of different fishing gears and the monthly size frequency distributions from those gears by species in the reef, exclusion and control areas. As an enormous amount of data will be accumulated, it is essential that the data are compiled and analyzed as they are received, so that a preliminary set of results are available within one year and a more definitive set of results within two years after module deployment.

A possible approach to the data analysis is the systems approach described by Munro (1984). A time series of length-frequency samples together with otolith data will produce estimate of growth and total mortality for the major species in the control, exclusion, and artificial reef areas. The estimate of the total fishing effort from trawlers and artisanal fishermen in and around the three areas coupled with a systematic fishing survey will produce estimates of the total catches in each area. Length-frequency based cohort analyses and/or Beverton-Holt yield assessments will be used to evaluate the absolute and relative yield potential from the control, exclusion, and artificial reef areas. This information together with social and economic data from a survey of artisanal fishermen will constitute the basis of the cost and benefit analysis.

6. PROJECT ORGANIZATION AND COSTS MANAGEMENT

The questions to be addressed by the Pilot Project are highly complex and the answers sought are not available elsewhere because of this complexity and of the expense involved in developing such a project with such rigorous requirements.

The Department of Fisheries lacks highly experienced reef fishery biologists and does not have the analytical skills necessary to evaluate the data base and it is therefore recommended that the Pilot Project be executed in collaboration with a recognized external fisheries research institute (referred to hereafter as EFRI).

If properly executed, in a rigorous scientific manner, the Pilot Project could be of enormous value, not only to Thailand but to other tropical countries of Asia and elsewhere with similar marine environments and identical fishery management problems.

6.1 Project organization

The suggested institutional arrangements are shown in fig. 6.1. The total operational staff of the Pilot Project is estimated to be 15 persons, comprising an expatriate Project Manager supplied by the EFRI and a Thai counterpart, plus 3 biologists, a socio-economist, vessel crew and technicians and a computer operations/data management officer.

It is recommended that the Pilot Project operates as a semi-autonomous unit, based at the Rayong Fisheries Research Station and receiving supporting services and facilities from that institution and reporting administratively either to the Director of the Marine Fisheries Division or to the Director of the Rayong Marine Fisheries Station (whichever is most appropriate).

The Artificial Reef Committee of the Department of Fisheries should serve as a general advisory and supervisory board and a link on policy matters to the office of the Director-General.

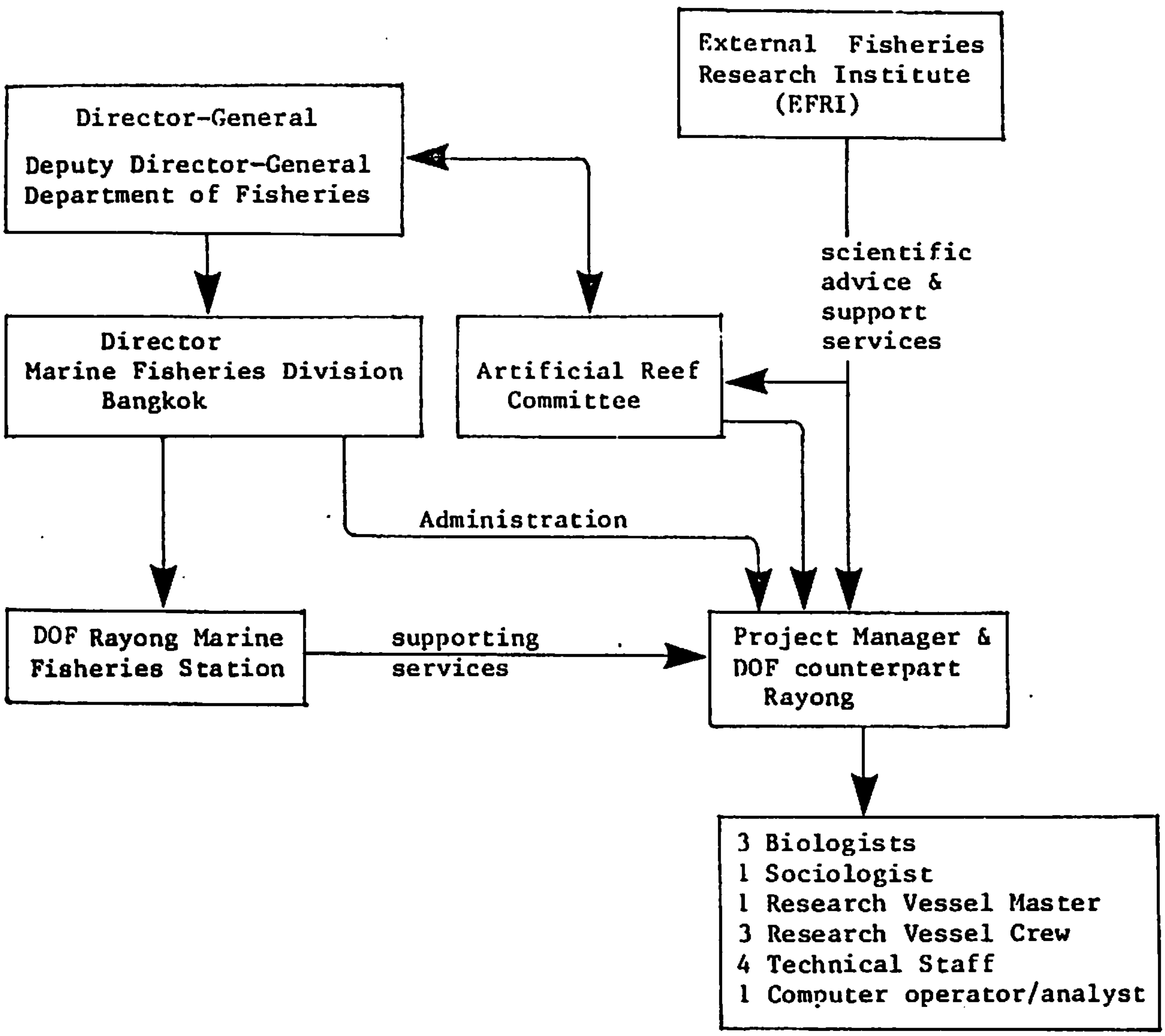


Figure 6.1 Pilot Program Organization

The EFRI which is invited to collaborate with the Department of Fisheries in this Pilot Project should provide scientific advice and guidance via the Project Manager, who should be a highly experienced fishery biologist. Additionally, the EFRI should be required to provide or procure the necessary analytical skills, computer programs and facilities, provide training in data analysis and be responsible for the preparation and publication of interim and final reports, both in English and Thai.

However, the first and most important task of the EFRI will be to draw up a detailed analytical format and sampling scheme. This will involve drawing on existing methodologies in population dynamics and adopting some of these methods to the needs of the artificial reef program. Based on the analytic approaches, a detailed field sampling program would be developed which specifies the type of data to be collected, the sampling gear to be used, the frequency of sampling, and the amount of data to be collected.

Subsequently, the EFRI should provide biological and analytical support to the Pilot Project and assist, if needed, in the final data analysis.

The Department of Fisheries should be requested to provide a Senior Marine Fisheries Biologist as a counterpart to the

Project Manager, plus three Fishery Biologists, a socio-economist, a research vessel master and three crew, three fishery technicians and a computer operator/analyst. One of the Fishery Technicians should be a highly qualified scuba diver and to be designated as the Diving Officer.

6.2 Project Implementation

This section outlines the likely timing of activities of the pilot project and highlights the logical steps which must be accomplished in order for the project to produce a clear cut and unequivocal result.

It is anticipated that an initial assessment of the benefit of the trawl exclusions and artificial reefs may be achieved after the modules have been in place for 1 year but that data based on two years of sampling after module deployment will be required to quantify the benefits of the Pilot Program. The scheduling of the major tasks to be performed are outlined in Table 6.1. Initially, 3-4 months are required to start the program. This initial work would consist of recruiting the Project Manager, developing the analytical approaches and the field sampling program and preparing module construction contracts. An estimate of the time for module construction is ten months with six months for deployment. One year of pre-deployment on baseline data would be collected while the modules are being constructed then after module deployment two years of post-deployment data would be collected. Data analysis would begin at the end of the pre-deployment data collection period and reports of the results would be prepared both one and two years after the module deployment. The total duration of the Project is anticipated to be 4 years with some results available after 3 years (Table 6.1).

6.3 Project Costs

The costs of the Pilot Program fall into four categories - construction costs, manpower costs, recurrent costs, and equipment costs. The total costs for the 4 year program is estimated at US$2,040,000. The costs breakdown into US$1,060,000 for module construction and deployment (Table 6.2) US$540,100 for manpower (Table 6.3), US$388,100 for recurrent costs (Table 6.4), US$87,000 (Table 6.5) for equipment costs. (For converting Bht to US$ a conversion of Bht 26 to 1 US$ is used.)

Table 6.1 Pilot Program Task Scheduling

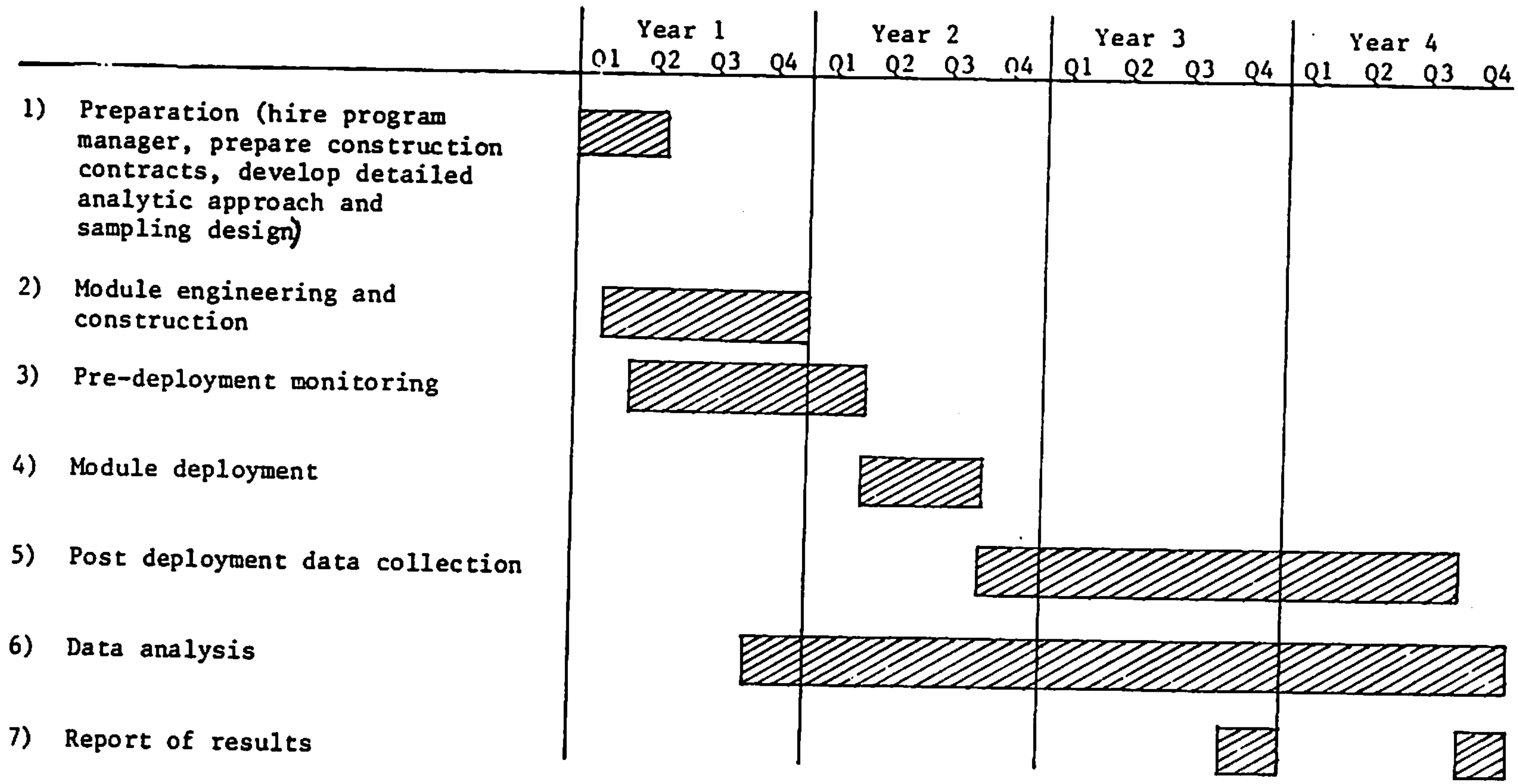


Table 6.2 Construction Costs

Cost of construction and deployment of modules (prices based on estimates in Appendix 5).

Rayong

1)	2,000 tetrapods at Bht 780/unit	=	Bht 1,560,000
2)	3,000 2 x 2 x 2 m concrete cubes at Bht 2,730/unit	=	Bht 8,190,000
3)	24,000 1 x 1 x 1 m concrete cubes at Bht 560/unit	=	Bht 13,440,000
	Total		Bht 23,190,000 (US$ 892,000)

Songkhla*

1)	1,000 tetrapods at Bht 780/unit	=	Bht 780,000
2)	3,200 1 x 1 x 1 m concrete cubes at Bht 560/unit	=	Bht 1,792,000
3)	400 2 x 2 x 2m concrete cubes at Bht 2,730/unit	=	Bht 1,092,000
	Total		Bht 3,664,000 (US$ 141,000)

Total module cost for Rayong and Songkhla: Bht 26,854,000
or (US$1.04 million)

*Cost for construction and deployment of modules at Songkhla are assumed to be the same as the costs estimated for Rayong.

Table 6.3

Manpower costs (in thousands $US):

	Position	Year 1	Year 2	Year 3	Year 4	Total
1)	Program manager (EFRI)	80.0	80.0	80.0	80.0	320.0
2)	DOF Senior Fishery Biologist	1.9	1.9	1.9	1.9	7.6
3)	3 DOF Fishery Biologists	4.0	4.9	4.9	4.0	17.8
4)	Research vessel master	2.6	3.2	3.2	2.6	11.6
5)	3 Research vessel crew	7.5	8.3	8.3	7.5	31.6
6)	4 Technical staff	5.0	5.5	5.5	5.0	21.0
7)	Computer programmer	0.5	1.0	1.5	1.5	4.5
8)	Socio-economist	1.5	1.5	1.5	1.5	6.0
9)	Consultants (EFRI)	30.0	30.0	30.0	30.0	120.0
	Total Manpower Costs:					540.1

Table 6.4

Recurrent costs (in thousands $US):

	Item	Year 1	Year 2	Year 3	Year 4	Total
1)	Fuel (boats & vehicle)	10.0	10.0	10.0	7.0	37.0
2)	Laboratory supplies & services	10.0	20.0	20.0	10.0	60.0
3)	Office supplies	5.0	5.0	5.0	10.0	25.0
4)	Equipment repairs	0.0	5.0	10.0	10.0	25.0
5)	Overhead (DOF)	7.9	7.9	7.9	7.9	31.6
6)	Overhead (EFRI)	33.0	33.0	33.0	33.0	132.00
7)	International travel	5.0	5.0	10.0	5.0	25.0
8)	Domestic travel	10.0	10.0	10.0	2.5	32.5
9)	Publication costs (EFRI)		5.0	5.0	10.0	20.0
	Total Recurrent Costs:					388.1

Table 6.5 Equipment costs (in thousands US$)

	Total
1) Nets, traps, bouys, line, etc.	20.0
2) Radar system to monitor total fishing effort	15.0
3) Microcomputer and supplies	10.0
4) Diving gear	10.0
5) Vehicle	15.0
6) Skiff, trailer and outboard motor	12.0
7) Lab and office equipment	5.0
Total equipment costs:	87.0

7. ANTICIPATED RESULTS OF THE PILOT PROJECT

The pilot program in the Rayong area will produce cost and benefit evaluations for both trawler exclusion and artificial reefs at Rayong and provide guidelines for reef module size and arrangement if a subsequent large scale artificial reef program is pursued. The pilot program at Songkhla will evaluate some of the social, economic, political, and biologic effects of trawler exclusion and artificial reef in the Songkhla area and serve to extend the results of the Rayong pilot program.

In total, the pilot program will provide an evaluation of the costs and benefits of trawler exclusions and artificial reefs as tools for fishery enhancement and management in the Gulf of Thailand.

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APPENDIX 1. TERMS OF REFERENCE

MARINE RESOURCES/FISHERIES SPECIALIST - (J. MUNRO)

1. The expert shall provide an assessment of marine fisheries resources including both demersal and pelagic resources in the Gulf of Thailand with a view to determining the most appropriate location for establishing five sites suitable for the construction of pilot (experimental) artificial reefs.

2. The expert shall examine the results of the ongoing artificial reef program undertaken by DOF and provide an assessment regarding the desirability of introducing a larger scale artificial reef program in the Gulf of Thailand.

3. The expert shall examine present fishing methods including both large commercial operators and artisanal fishermen near the proposed sites. An assessment will then be made of the effect of introducing artificial reefs in these areas in terms of increasing marine fisheries resources and the impact this will have on fishing methods.

4. Together with the Marine Fisheries/Artificial Reef Expert, the expert shall prepare a plan which outlines the steps to be undertaken for establishing a pilot program of artificial reefs in the Gulf of Thailand. This plan will include recommendations as to where the reefs should be located (five sites), the cost of construction and the necessary institutional and administrative arrangements required to implement the program.

MARINE FISHERIES/ARTIFICIAL REEF EXPERT - (J. POLOVINA)

1. The expert shall assess marine conditions in the Gulf of Thailand and together with the Marine Resources Expert determine the most appropriate sites for the construction of pilot test reefs.

2. The expert shall recommend various designs of reef which could be established at the recommended sites and provide a rational for these recommendations.

3. The expert shall estimate the cost of constructing the recommended designs and assess whether materials required are available locally and which materials (if any) would have to be imported.

4. Together with the Marine Resource Expert, the expert shall prepare a plan which outlines the steps to be undertaken for establishing a pilot program of artificial reefs in the Gulf of Thailand. This plan will include recommendations as to where the reefs should be located (five sites), the cost of construction and the necessary institutional and administrative arrangements required to implement the program.

APPENDIX 2

Itinerary

Sun, November 25, 1984	Consultants arrive in Manila for briefing at ADB
Mon, Nov. 26	Briefing at ADB, gather documentation
Tue, Nov. 27	Manila - Bangkok
Wed, Nov. 28	Preliminary meetings with DOF officials
Thu, Nov. 29	Visit Rayong for discussions with DOF scientists
Fri, Nov. 30	To Phuket for discussions with DOF scientists
Sat, Dec. 1	To Songkhla for discussions with DOF officials
Sun, Dec. 2	Songkhla-Bangkok. Preliminary report preparation
Mon, Dec. 3	a) Meeting with Dr. Kitjar Jaiyen, Director, Planning and Special Projects and Department of Fisheries staff at DOF Headquarters, Bangkok (see Appendix 4).

	b) Visit to Marine Fisheries Division for consultations with staff.
	c) Visit construction firms to obtain quotation on reef modules.
Tue, Dec. 4	Data analysis and report preparation
Wed, Dec. 5	Report preparation
Thu, Dec. 6	Report preparation and meetings with Director-General (Administration) of Department of Fisheries
Fri, Dec. 7	Bangkok-Manila
Sat, Dec. 8	Data analysis and report preparation
Sun, Dec. 9	Data analysis and report preparation
Mon, Dec. 10	Data analysis and report preparation
Tue, Dec. 11	Discussions at ADB and submission outline of report. Dr. J.L. Munro departs for Australia.
Wed, Dec. 12	Finalization of report
Thu, Dec. 13	Finalization of report
Fri, Dec. 14	Submission of report. Dr. J. Polovina departs for U.S.A.

APPENDIX 3

PERSONS MET

Delegation of the Commission of the European Communities for South-east Asia, Thai Military Bank Building, 34 Phyathai Road, Bangkok.

Mr. Seri Euvari, Development Projects Engineer

Department of Fisheries, Ministry of Agriculture and Cooperatives, Bangkok.

Mr. Vanich Varikul, Director-General

Mr. Urupan Boonrakob, Deputy Director-General (Administration)

Dr. Kitjar Jaiyen, Director, Planning and Special Projects

Mr. Kajornsak Wetchagarun, Planning and Special Projects

Mr. Kasemsart Chalayondeja, Senior Fisheries Biologist, Office of Planning and Special Projects

Mr. Surapon Vadhanakul, Senior Marine Fisheries Biologist, Marine Fisheries Division

Mr. Somsak Chullasorn, Senior Marine Fisheries Biologist

Mr. Navin Kuantanom, Senior Marine Fisheries Biologist

Rayong Marine Fisheries Station, Ban Dae, Muang District, Ray.

Province

Mr. Tongsueb Taweesith, Chief Scientist

Mr. Somporn Boongird, Senior Biologist (artifical reefs)

Mr. Chaiyos Boobphaves, Senior Biologist (aquaculture)

Mr. Prawin Wudthisin, Senior Biologist (aquaculture)

Phuket Marine Fisheries Station, Phuket

Mr. Niyon Lokakarn, Chief Scientist

Mr. Udon Bhatia, Senior Fisheries Biologist

National Institute of Coastal Aquculture, Songkhla

Mr. Wiset Chondej, Director

Mr. Poonsin Parnichsune, Senior Fisheries Biologist

APPENDIX 4

Minutes of Discussion Between the Asian Development Bank/EEC Fact Finding Mission and Officials of the Department of Fisheries, Government of Thailand Regarding the Proposed Artificial Reef Program

1. An Asian Development Bank/EEC fact-finding Mission comprising Mr. Richard Gold (ADB project economist),[1] ADB staff consultants Dr. John Munroe (fisheries biologist), Dr. Jeffrey Polovina (artificial reef/ fisheries expert) and Mr. Seri Euvari (EEC development project engineer) assembled in Bangkok 28 November 1984 to undertake investigations regarding the captioned program.

2. The Mission accompanied by Mr. Kasemsan Chalayondeja and Mr. Suraporn Vadhanakul of DOF undertook a field trip from 29 November to 02 December 1984 to potential sites for the artificial reef program including sites at Rayong, Phuket and Songkla. As well as investigating the suitability of the sites for establishing a pilot artificial reef program, the Mission also examined on-going artificial reef programs being implemented by DOF and held discussions with biologists from the Marine Fisheries Stations and the National Institute of Coastal Aquaculture .

3. A meeting was held in Bangkok on 03 December following their trip during which the Mission provided a debriefing to officials of the Department of Fisheries. (A list of participants is attached).

[1] Participated in meetings of 28 November and 03 December only.

4. The Mission outlined the desirable criteria for selecting a site. This included an area which is currently heavily fished, near DOF facilities(to facilitate monitoring) and an area which is easily accessible (to facilitate construction and installation). Following an examination of the on-going programs at Rayong, Phuket and Songkla, the Mission observed that it would be difficult to show adequate or precise data from small-scale programs which would be applicable or valid to justify a larger scale artificial reef program.

5. A tentative observation make by the Mission was that in order to adequately test the viability of establishing a larger scale program it would be desirable to construct a large scale site at Rayong, (as opposed to five smaller sites as suggested in the Fisheries Sector Study), with a subsidiary program being undertaken at Songkla which would test the viability of various reef arrangements, designs and materials.

6. The Mission outlined the steps required to implement the program which would consist of undertaking baseline resource and socio-economic surveys, detailed mapping, installation of reef system and monitoring.

7. The DOF indicated its support to the program and its willingness to facilate its early implementation by acquiring the necessary baseline data and undertaking the necessary surveys.

8. The Mission tentatively suggested that a concrete block design would be appropriate noting that little silting was observed in the relatively sandy areas proposed for the sites, and that present structures have being productive since 1978.

9. It was suggested by the Mission that at least two years of observation would be required to test the validity of the larger scale program. A major determinant of the programs viability would be whether the artisinal catch (from a 50 square kilometer area) would exceed the present catch in the same area currently being harvested by trawlers.

10. DOF noted tnat there would also be social benefits of this program including the provision of employment to artisinal fishermen which would be difficult to quantify. DOF outlined the objectives of their program which included the prevention of trawling within three kilometers of the coastline, the protection of larvae and the provision of habitat. DOF further noted that in support of the artificial reef program the Department was emphasizing the production of reef species in their research stations.

11. The Bank indicated its willingness to assist in the further development of the program noting that it would be necessary to obtain a cofinancing source in order to finance the requirements of the program which are currently estimated in excess of $ 2 million.

Signed in Bangkok 03 December, 1984.

Richard Gold

Richard Gold, ADB Mission Chief

MEETING PARTICIPANTS

DOF

Dr. Kitjar Jaiyen	Director, Planning and Special Projects
Mr. Kachornsak Wetchagarun	Planning and Special Projects
Mr. Somsak Chullasorn	Senior Marine Fisheries Biologist
Mr. Niyom Sohakam	Senior Marine Fisheries Biologist Phuket Statiion
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Mr. Udom Bhatia	Senior Marine Fisheries Biologist
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Mr. Kasemsant Chalayongdeja	Senior Marine Fisheries Biologist Planning and Special Projects
Mr. Poonsin Parnichsure	Senior Fisheries Biologist

EEC

Mr. Seri Euvari	Development Project Engineer

ADB

Mr. Richard Gold	ADB Mission Chief
Dr. John Munroe	ADB Staff Consultant
Dr. Jeffrey Polovina	ADB Staff Consultant

APPENDIX 5. Estimates of module construction and deployment at R...

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PD/MCH

4th December 1984

Letter No. 232

BY HAND

Mr. Jeffrey Polavina
c/o Dusit Thani Hotel

Dear Sir,

Re: Artificial Reef

As requested we submit herewith our indicative prices for manufacturing and placing of the artificial reef and trawling protection units as follows:

1. Artificial reef, small unit of 1.0x1.0x1.0 m.
   20,000 Nos. @ 560.- wall thickness 12 cm. = Baht 11,200,000.-
2. Artificial reef, large unit of 2.0x2.0x2.0 m.
   20,000 Nos. @ 2,730.- wall thickness 20 cm. = Baht 54,600,000.-
3. Trawling protection ½ ton
   10,000 Nos. @ 460.- = Baht 4,600,000.-
   (or 1.0 ton, 10,000 Nos. @ 780.-) = (Baht 7,800,000.-)

The above prices are based on the prices as at today's date i.e. December 3, 1984 and also on the following assumptions:

1. Time for mobilization and other temporary facilities including time for manufacturing as well as placing is 14 months.
2. Placing within the selected areas shall be random.
3. Levelling of the sea bed is not included.

Should this ADB and EEC financed project be feasible, we are looking forward to be given the opportunity to quote for this interesting project.

Yours faithfully,

CHRISTIANI & NIELSEN (THAI) LTD.

A. Steen Pedersen

(Managing Director)

APPENDIX 6

Determination of the number of trawl obstruction modules required for a 50 km^2 area.

1) Computation of area swept by a trawl in 1 hour:

$$Area = \alpha \cdot H \cdot S \cdot B$$

where H is the length of the trawl's head rope - taken as 36 m or .036 km.

α is a constant which adjust the head rope to the width of the net - taken as 0.67

S is the trawling speed in knots - taken as 2.80 knots

β is a constant which converts knots to km/h - taken as 1.85 (all parameter values taken from Pauly 1979)

Thus in 1 hour, a trawler sweeps an area of 0.125 km^2.

2) Let X be a random variable defined as the number of trawl obstruction modules a trawler encounters in 1 hour during which 0.125 km^2 is covered.

X has a Poisson Distribution where the probability that $X = K$, $P(X = K)$, is given by:

$$P(X = K) = \frac{e^{-\lambda} \lambda^{K}}{K!} \quad \text{for } K = 0, 1, 2, \ldots$$

where λ is the ratio of the number of trawl obstruction modules in the 50 km^2 area divided by the number of 0.125 km^2 blocks in 50 km^2.

Let γ be the probability that a trawler hits one or more trawling obstructions which is sufficient to effectively eliminate trawling from the 50 km^2 area. For the purposes of the study, we assume $\gamma = .90$, that is if in 9 out of 10 times when a trawler attempts to trawl in the 50 km^2 area, the trawler rips its net within one hour of trawling by catching it on a trawling obstruction module, then, this frequency will deter trawling in the 50 km^2 area.

4) When $\gamma = .90$ the number of trawling obstruction modules (N) is computed as follows:

$$\gamma = .90 = P(X = 1 \text{ or more}) = 1 - P(X = 0) = 1 - e^{-\lambda}$$

Therefore $\lambda = -\ln(1 - .90) = 2.3$, where λ is defined as the number of trawling obstruction modules (N) divided by the number of 0.125 km^2 blocks in 50 km^2 which is 400.

Thus, $2.3 = N/400$ and $N = 920$

Thus, if N = 1,000 trawling modules are used the probability that a trawler snags one or more in one hour of trawling exceeds 0.90 and should be a sufficient deterrent to close the 50 km^2 area from trawling.