CHAPTER 16

ENVIRONMENTAL ISSUES IN THE GULF OF THAILAND

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1. INTRODUCTION

The Gulf of Thailand is a semi-enclosed tropical sea located in the South China Sea (Pacific Ocean), surrounded by the countries Malaysia, Thailand, Cambodia and Vietnam. The Gulf covers roughly 320,000 km². The boundary of the Gulf is defined by the line from Cape Camau in southern Vietnam (just south of the mouth of the Mekong River) to the coastal city of Kota Bharu on the east coast of Peninsular Malaysia. It is relatively shallow; the mean depth is 45 m, and the maximum depth only 80 m. The general shape of the Gulf's bottom topography can be considered elliptic parabolic. It is separated from the South China Sea by two ridges that limit water exchanges with the open South China Sea. The first extends southeast from Cape Camou for about 60 nautical miles with an average sill depth of less than 25 m. The second ridge, which extends off Kota Bharu for approximately 90 nautical miles, has an average sill depth of 50 m. There is a narrow, deeper channel between the two ridges with the observed depth of 67 m (Emery and Niino, 1963). The Gulf may be divided into two portions, Upper Gulf and Lower Gulf. The Upper Gulf at the innermost area has an inverted U-shape. The Upper Gulf is the catchment basin of four large rivers on the northern side and two on the western coast. Numerous rivers discharge freshwater and sediment into the Gulf. Among them, the Chao Phraya River has the biggest volume transport next to the Mekong River. The average runoff per year of the Chao Phraya is 13.22 x 10^3 km^3 and that of the Mekong is 326 x 10^3 km^3. It is estimated that a considerable amount of nutrients is also discharged from these rivers, promoting primary productivity in the Gulf (Piyakarnchana et al., 1990).

Seasonal circulation in the Gulf of Thailand, deduced from oceanographic data measured in 1993-1994, suggested that circulation the Gulf is generally weak and variable. The mean circulation in the Gulf is forced by the South China Sea and not by the local wind as previously suspected, a phenomenon particularly marked during the Northeast monsoon when Mekong River water enters the lower Gulf (Wattayakorn et al., 1998). During January to February, currents throughout the Gulf are at their weakest, with little mixing of Upper and Lower Gulf water masses.

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From March to August, anticyclonic (clockwise) circulation predominates in the Lower Gulf, and penetrates into the Upper Gulf. In September, the circulation direction reverses to cyclonic in the Lower Gulf, initially producing cyclonic current in the Upper Gulf; by November the flow in the Upper Gulf becomes anticyclonic (Figure 2). On the whole, the Gulf of Thailand is poorly flushed. In the Upper Gulf, little mixing occurs between coastal and offshore waters. As a consequence of these comparatively static conditions, contaminants discharged into the Upper Gulf may accumulate. Variability in current directions may also result in the return of contaminants that were initially flushed from an area.

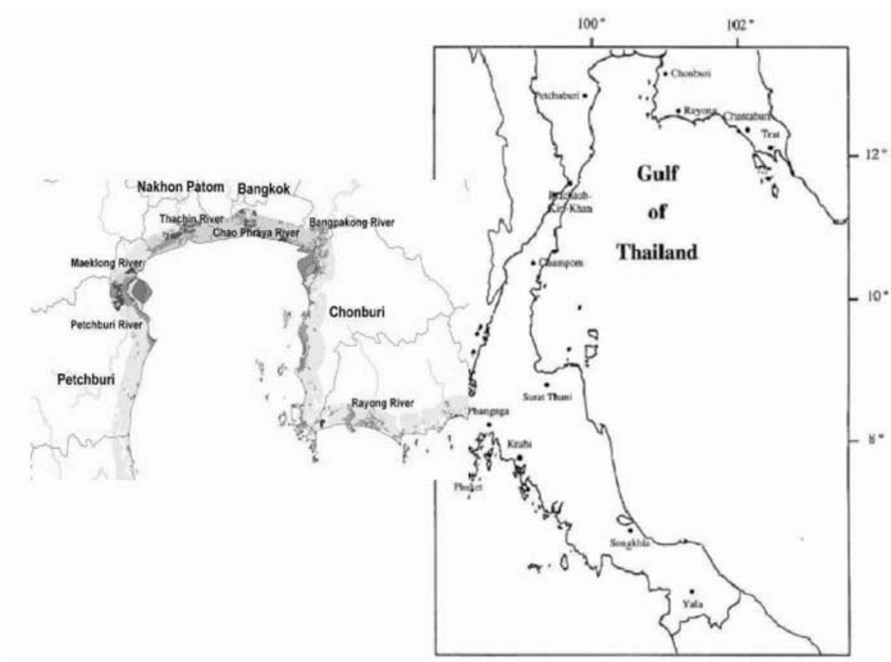

Figure 1. *Map of the Gulf of Thailand, showing major rivers discharging into the Inner Gulf.*

The innermost part of the Gulf, in the vicinity of Bangkok, extends from Ban Pak Thale, Phetchburi Province, in the west, north and east past the mouths of the Maeklong, Thachin, Chao Phraya, and Bangpakong Rivers, to the town of Chonburi in the southeast (Figure 1), is a large area of intertidal mudflats around the shores of a huge, shallow sea bay forming the estuary of the four major rivers. The area formerly supported extensive mangroves. While the largest areas have now been cleared for aquaculture and salt pans, much secondary mangrove still remains and is usually found as a narrow (10-l00 m) fringe along the seaward margins. Extensive areas of low scrub are found in the brackish marshes along the landward edge. In places, the open shrimp ponds and salt pans extend two to three km inland and, together with the offshore mudflats, provide an important feeding and roosting area for many thousands of shorebirds (Erftemeijer and Jugmongkol, 1999). They are also important fish breeding and nursery grounds, where many species reproduce. The barriers on most major rivers, such as dams, weirs, and hydropower structures, also have a major impact on migratory species that swim upriver to spawn.

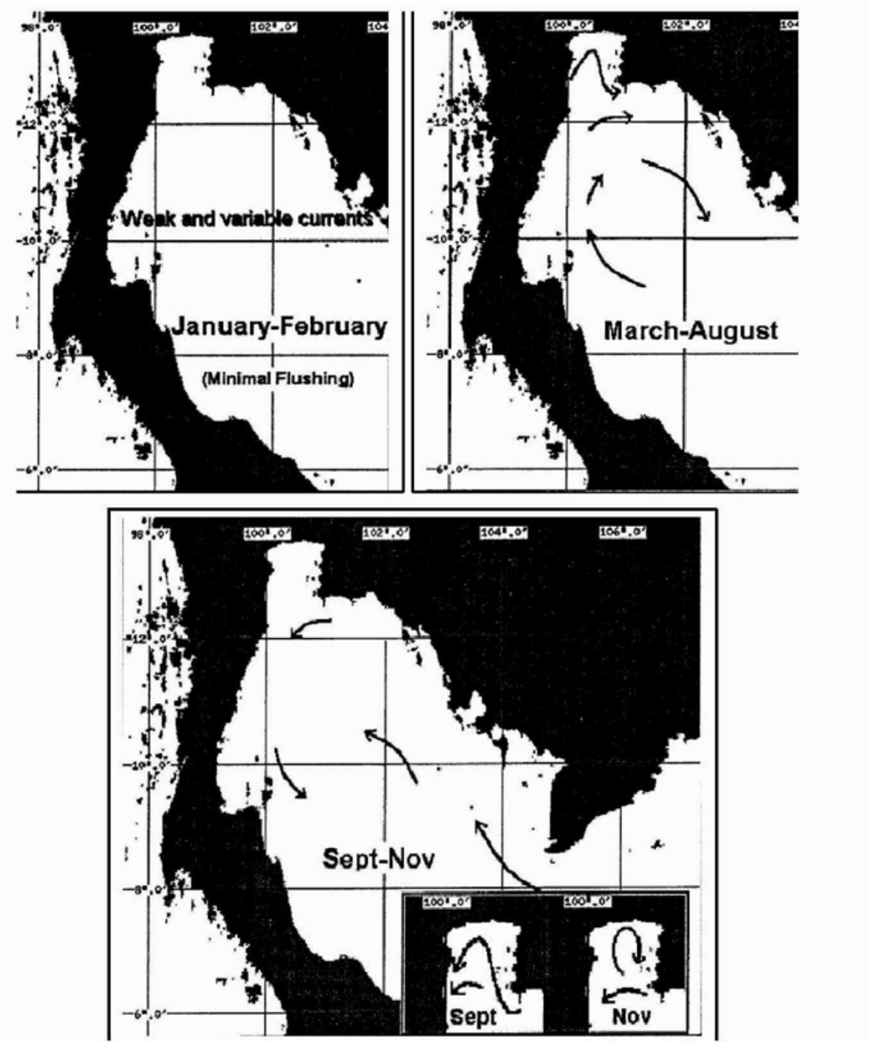

Figure 2. Sketch of the water circulation in the Gulf of Thailand, deduced from the oceanographic data during 1993–1994. (Adapted from Wattayakorn et al., 1998).

The Gulf of Thailand is an important resource to the national economy of Thailand that receives income from the Gulf fishing industry, tourism and port operations. Bangkok is the economic center of Thailand. The human population density is extremely high, and there is an increasing amount of heavy industry, especially extending eastwards from Bangkok along the lower reaches of the Chao Phraya River. The Port of Bangkok, at the mouth of the Chao Phraya River, is the transportation life-blood of the country. It serves as the main egress point for agricultural export products from the country's interior as well as access for raw materials such as fertilizer, grain, steel and oil products. In addition, several deep sea ports within the Gulf have been constructed to facilitate the huge increase in sea transport of import and export cargoes. The deep sea port at Laem Chabang provides relief to the congestion in Bangkok, while the ports at Songkhla and Map Ta Phut offer ocean shipping alternatives to industries and resources within the Gulf of Thailand.

Thailand's population increased from 23 million in 1961 to 65 million by 2004. The rapid increasing population with associated industrialization and economic development in the coastal areas in the past two decades has resulted in construction and planning of many coastal development projects. Many of these developments have altered local coastal and estuarine processes, which have caused changes in the shoreline and sediment processes. In addition, the Gulf of Thailand has been a receptacle for agriculture; lumbering; ports and shipping; fishing and aquaculture; human settlement; recreation and tourism for a long time. The marine waters and coastal areas of Thailand, therefore, have been threatened by both the forces of nature as well as by human activities. Foremost among these threats are siltation; pollution from domestic and industrial wastes; heavy metals; agrochemicals, particularly pesticides; pollution resulting from oil spills from tankers and from onshore and offshore drilling for oil and minerals. In addition, the vast ecosystems of mangrove forests, coral reefs, and intertidal flora and fauna of the country are threatened by the conversion and/or reclamation of land for multipurpose uses and by recreational activities. Therefore, the problems of the marine environment in the Gulf of Thailand may be broadly divided into those of overexploitation of fisheries, loss of habitats, and pollution. This paper will briefly deal with specific items under these three headings.

2. OVER-EXPLOITATION OF FISHERIES RESOURCES

The Gulf of Thailand is among the productive areas of the South China Sea in which Thai people are dependent on marine fisheries. The rising demand for fish from the increasing population, for food and export, has led to the rapid increase in marine fishery production in the country, especially in the seventies and eighties. In the Gulf of Thailand, most of the pelagic fishery except Indian mackerel is fully exploited. Almost all demersal stocks are also overfished including fish, shrimp, squid, cuttle fish, and others (FAO, 1995). Overfishing of the inshore and coastal waters has also been reported in many technical publications (Chullasorn and Chotiyaputta, 1997; Jirapanpitat, 1992).

The marine capture fisheries in the Gulf are characterized by the use of multi-gear by a large number of small-scale fishermen, to exploit a large number of fish and other aquatic organisms. The Gulf trawl fisheries suffer from overcapacity, due to their uncontrolled growth in the late 1960s - early 1970s. Statistics from the Department of Fisheries have shown that the coastal and inshore fishery resources have been fully exploited since the early seventies (Supongpan, 1996). The massive increase in trawling effort that occurred from the early 1960s on, and which resulted, in the early 1980s, in a strong decline in catch per effort (CPUE), from about 290 kg h^{-1} in 1963 to about 50 kg h^{-1} in the 1980s and 20-30 kg h^{-1} in the 1990s. Night-time CPUE has also declined drastically to less than half of its earlier value from 57 kg h^{-1} in 1976 to about 21 kg h^{-1}in 1995 (Eiamsa-Ard and Amornchairojkul, 1997). Captured fisheries statistics (1986-1995) of Suratthani indicate that fishery production of Bandon Bay area was greatly declined during this period. Most of fish production was mainly trash fish resulting from excessive fishing effort, capture of undersize fish as well as the destructive nature of the push net which was used as the main fishing gear in the area (Wattayakorn et al., 1999). Changes in the species and size composition of the catch are other clear evidence of the onset of overfishing. Chullasorn and Chotiyaputta (1997) reported that the catch from trawl surveys shows that 30% to 40% consists of trash fish. Of this trash fish, 30% comprised of juveniles of commercially important species. Due to overfishing and the resulting decreased availability of fish, subsistence and artisanal fishermen are often forced into destructive fishing techniques such as blast fishing and poisons. The use of such fishing techniques can result in lasting deleterious impact to the marine environment, especially to coral reefs.

3. DEGRADATION OF COASTAL ECOSYSTEMS

3.1. Mangroves

Approximately 60% of the current population in Thailand (roughly 39 million inhabitants) lives in coastal towns and villages. This leads to rapid coastal development for industries and housing, and extensive coastal habitat destruction and loss. Mangrove destruction is the most obvious and has probably had the greatest loss. With Thailand's developing economy, since the 1960s the mangrove forests along the Gulf of Thailand have been reduced by 50-80% (Table 1). Mainly shrimp farms, hotels, growing cities and other coastal developments, have replaced them. Estimates of the amount of mangrove conversion due to shrimp farming vary, but recent studies suggest that up to 50-65% of Thailand's mangroves have been lost to shrimp farm conversion since 1975 (Aksornkoae and Tokrisna, 2004; Charuppat and Charuppat, 1997; Dierberg and Kiattisimkul, 1996). Mangroves are still being cut down for agriculture, aquaculture, and coastal construction but at a much lower rate. For example, mangrove forest in the Bandon Bay area was depleted by 30% during the period of 1993-1998 as compared to 87% during 1961-1986, most of which has been converted to shrimp ponds (Wattayakorn et al., 1999).

The high profits of shrimp farming resulted in the increase in the number of shrimp farms and culture areas from about 6,000 farms in 1987, taking up an area of 45,000 hectares, to 28,000 farms covering 79,000 hectares in 1999 (DOF, 2001).

Rapid expansion of intensive shrimp farming along the coast, some of which involved clear-cutting of mangrove forests, has caused many environmental problems such as poor coastal water quality, deteriorating of marine resources, and saltwater intrusion into nearby agricultural areas. The catastrophic collapses of several shrimp farms in the Upper Gulf of Thailand in 1989 were attributed to poor water quality originated from industrialization within the watersheds and to pollution from the farms (Dierberg and Kiattisimkul, 1996). Many shrimp ponds are abandoned after they become unprofitable, leaving vast areas unsuitable for agriculture or other aquaculture activities.

Table 1. *Comparison of the mangrove areas in Thailand in 1975 and in 1996. (Adapted from Charuppat and Charuppat 1997).*

Mangrove area	1975 (rai)*	1996 (rai)*	Decrease (rai)*
Gulf of Thailand	756,250	216,741	539,509
Eastern Region: Trat, Chantaburi, Rayong, Chonburi, Chachoengsao	306,250	79,113	227,137
Central Region: Bangkok, Samut Prakarn, Samut Sakhon, Samut Songkhram, Petchburi, Prachuab Khirikhan	228,875	34,057	194,068
Southern Region: Chumphon, Suratthani, Nakhon Si Thammarat, Phattalung, Songkhla, Pattani	221,125	103,571	118,304

Note: 1 rai = 0.16 hectare

3.2. Coral reefs

Coral reefs are under stress in many areas in the Gulf, especially those near shallow shelves and dense populations. Storms and monsoon waves are the major natural causes of coral reef damage. Typhoon Gay hit southern Thailand in 1989 and caused major damage to some reefs. Extreme low tides and coral bleaching are other natural phenomena causing severe damage. The erosion that has resulted from logging has killed coral reefs by increasing the turbidity of coastal waters, such that the coral polyps no longer have enough light to photosynthesize metabolites and may even be buried by increased sedimentation. Over 60% of all major reef groups in the Gulf of Thailand have less than 50% live coral cover and there is increased algal growth because of nutrient pollution from the land, including near the major tourist resorts of Pattaya Bay and Samui Island (Chansang and Phongsuwan, 1993). Other anthropogenic disturbances on localized coral reefs in the Gulf are boat grounding and destructive fishing methods such as the use of dynamite and bottom-trawlers (Sudara and Patimanukasem, 1991). Loss of coral reefs has long-term implications because of the time that they take to recover.

3.3 Seagrass beds

Seagrass beds are the least studied marine habitats compared to coral reefs and mangroves. Seagrass beds in Thailand are more abundant in the Andaman Sea than in the Gulf of Thailand. However, no comprehensive evaluation on the seagrass cover in the country has been undertaken to date. Species of seagrass such as *Enhalus acoroides, Halodule pinifolia,* and *Halophila ovalis* were reported in the Gulf of Thailand. A survey of seagrass around Samui Island found degraded seagrass beds in those areas where there were considerable industrial construction, shrimp farming and land development (Poovachiranon et al., 1994). It is apparent from the site surveys that economic activities are the main factor affecting seagrass depletion (Nateekanjanalarp and Sudara, 1992).

4. COASTAL AND MARINE WATER POLLUTION

Pollution has considerably degraded the coastal and marine environment, including estuaries, of Thailand over the past three decades. Coastal and marine water pollution in Thailand is mainly due to direct discharges from rivers, surface runoff and drainage from port areas, domestic and industrial effluent discharges through outfalls and various contaminants from ships. Urban centers in Thailand are often located on coasts and estuaries and much of the domestic wastes and garbage is dumped directly into the shallow coastal environment. Hence, rivers are generally heavily contaminated with municipal sewage, industrial effluent and sediments.

The primary sources of marine-based pollution are offshore oil and gas operations, wastes from maritime transportation, shipping and oil spills. For land-based pollution, the primary sources are domestic sources, industrial development and tourism areas, especially beach resorts and agriculture and aquaculture activities (Piyakarnchana et al., 1990). Land-based sources contribute some 70% of the pollutants, mostly from domestic sources. An estimated volume of more than 200,000 tonnes of waste quantified as BOD is discharged into the Gulf each year (Chongprasit and Srinetre, 1998). A smaller quantity of industrial waste consisting of more toxic chemical substances is also released into the Gulf. About 50% of the land-based contaminants are delivered into the Gulf by the four large rivers at the head of the Upper Gulf. In general, water quality is lower than acceptable standards in the Inner Gulf region, especially at the mouths of the four major rivers, the popular tourist spots along the coast, and near certain islands. Water quality is deteriorating due to increasing inputs of nutrients from the increased use of fertilizers in agriculture, the mariculture industry and from household sewage. This chapter will address some current problems i.e. eutrophication (red tides) and oil pollution in the Gulf of Thailand.

4.1. Red Tides

Primary production prevailing in the Gulf of Thailand is known to be relatively high, with a recent boost by increased nutrients from rivers and shrimp farms, which in turn leads to increasing occurrences of phytoplankton blooms (or “red tides”), oxygen depletion events, food poisonings and other pollution effects, particularly in the Inner Gulf (Eiamsa-Ard and Amornchairojkul, 1997; Longhurst, 1998; Piyakarnchana, 1999).

The occurrence of red tides in Thailand was first reported in 1957. In the past, red tides were regarded as natural phenomena and there was no serious impact of red tides on the marine environment or organisms. However, its frequency has been increasing in recent years. *Noctiluca scintillans* and *Trichodesmiun erythraeum* were the two species of plankton that frequently bloom in the Inner Gulf (Suvapeepan, 1995). Blooming of *Noctiluca* sp. usually changes the apparent color of water into dark green. The bloom of *Trichodesmium* sp. changes the apparent color of seawater into yellow green color and then to red brown. The algal blooms caused by both species of phytoplankton have no direct harmful effects on fish and shellfish. However the heavy blooms can result in sudden reduction of dissolved oxygen and a high amount of ammonia concentration in the water, which in turn sometimes lead to fish kills. A large bloom of *Noctiluca sp.* caused a mass mortality of fish at Sriracha Bay in August, 1991 and along the Pattaya Bay in August, 1992 (Sukasem, 1992). Blooming of diatoms i.e. *Rhizosolenia* sp. and *Chetoceros* sp. was also reported to occur as a result of eutrophication in the Inner Gulf (Suvapeepan, 1995).

According to the survey by the Aquatic Resources Research Institute, Chulalongkorn University (2003), 97 incidents of red tides were recorded in the Gulf of Thailand from 1957 to 2001. To date, there is only one incident of paralytic shellfish poisoning (PSP) recorded in Thailand, in May 1983 after consuming the contaminated green mussels (*Perna viridis)* in the red-tide area of the Pranburi River mouth. Sixty-three people were ill and one died because of this incident (Tamiyavanish, 1984). The causative organism of that incident could not be established. Since then, all the phytoplankton blooms recorded in Thailand are harmless to humans.

4.2. Oil pollution

Oil pollution in the Gulf of Thailand has risen with industrial development in coastal regions. The shipping of oil coupled with increasing emphasis on offshore oil exploration makes the Gulf of Thailand extremely vulnerable to oil pollution. Wattayakorn (1986, 1987 and 1991) has reported chronic petroleum hydrocarbon contamination in coastal waters. Pollution was believed to originate primarily from the discharge of oil from small coastal boats, via urban, industrial, refinery and sewage effluent. Additional oil contamination could also originate from maritime transportation of crude and refined oil through the region, as a result of the discharge of ballast water from tankers. Increased pollution in the form of tarballs and oil slicks has been observed in the past years (Wattayakorn et al., 1998). The deleterious effects on the marine environment and living resources as a result of the growing frequency of oil spills (due to both constant deballasting activities and accidents such as collision in shallow waters) have caused public concern and gained widespread attention in environmental protection in Thailand.

The accidental oil spills have been frequently reported along oil transport routes, at points of discharge and loading of oil carriers. There have been over 50 oil spill accidents reported to occur in the Gulf during 1973-2002. Frequent spills were found at the mouth of the main entrance to the Bangkok Port (Chao Phraya River mouth) and Laemchabang Port (Chonburi Province). These oil spills represent the greatest source of petroleum related pollution in the Gulf. These incidents are expected to continue because of insufficient understanding of navigational routes and inadequate contingency plans. A list of large oil spill accidents that have occurred recently in the Gulf can be found in the Table 2.

Table 2. *Recent major oil spill accidents in the Gulf of Thailand.*

Date	Oil type	Volume (tonnes)	Location	Cause
6 Mar 1994	Diesel	400	Chonburi Province	Collision of tanker and container vessel
30 Oct 1996	Crude Oil	160	Rayong Province	Leaking during loading
15 Jan 2002	Diesel oil	230	Chonburi Province	Grounding
17 Dec 2002	Bunker Oil	230	Chonburi Province	Collision of tanker and container vessel

Under normal operations, most cargo and oil/gas ports are not major sources of pollution. Only in fishing ports, where regulations on pollution control are difficult to implement on small boats, is oil pollution from fuel/lubrication oil dumping and bilge water discharge seen. Fishing ports exist in every coastal province and they are usually near to major urban areas, thus making it difficult to separate the contribution from the two sources. There are probably over 40,000 fishing boats of various sizes registered and operating in the Gulf of Thailand. The used lubricating oil from these fishing boats is believed to be illegally dumped into the sea. In addition, leaks and spills of fuel (diesel) oil during filling and transfer also occur.

There is insufficient institutional and administrative capacity to ensure environmentally responsible maritime practices. There is also a prevalence of inadequate skills to detect, control and enhance areas of spills.

5. MANAGEMENT APPROACHES

Despite the growing awareness and concern of the public, coastal and other aquatic ecosystems continue to be degraded by pollution and unsound forms of utilization. Scientists have been conducting research and monitoring activities on the Gulf for decades. These activities were typically geared for a specific need, limited in coverage, and failed to provide an overall picture of the Gulf's condition. There is still a poor understanding of the biological, physical, chemical and socio-economic In addition, politicians and the general public are not aware of the potential value of marine science to society.

However, several measures have been taken for protection and conservation of marine resources in the Gulf. Since 1972, trawlers are prohibited from an area within 3 km from the shoreline, and within a perimeter of 400 m of any stationary fishing gear. In 1984, an area of about 26,400 km^2 in the Gulf was declared as a conservation area, prohibiting fishing by all gear types during spawning season from

15 February to 15 May (Phasuk, 1994). To provide protection of endangered and threatened species, the Department of Fisheries issued regulations prohibiting the catching of sea turtles, the collection of their eggs and the export of sea turtle shells. Catching of dugongs and collection of corals are also prohibited. The Department of Fisheries also emphasizes the rehabilitation of fishing grounds, and promotes artificial reef projects to create protected habitats for marine life. However, enforcement of these regulations is far from effective (Phasuk, 1994). Royal Forestry Department (RFD) has also established and managed several marine national parks, and prohibited some fishing activities in certain areas.

Economic measures have been introduced to support the prevention of environmental problems. Incentives such as import tax reduction for environmentally friendly equipment and machines, recognition for companies that operate in an environmentally friendly manner, and use of the polluter pays principle (PPP) to encourage voluntary action on pollution prevention in private companies. An environmental fund was set up and managed effectively as a financial support for environmental liability and cleanup. The budget derived from the energy conservation fund was also used to conduct the energy saving campaign.

Other government activities undertaken include education and the dissemination of environmental knowledge through the media. The government also encourages more involvement from the private sector and non-government organization (NGOs). Many obsolete environmental laws and regulations were amended to suit the current situation. Moreover, the government attempted to issue several significant laws such as the Community Forest Act and Water Resource Act. The Thai government has shown its commitment to international environmental problems by finalizing its ratification of the Convention on Biodiversity while implementing the other ratified conventions. These activities will all help to alleviate environmental problems in the future.

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