Available online at www.sciencedirect.com
SCIENCE DIRECT®
PERGAMON
Marine Pollution Bulletin 47 (2003) 43–51
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Water pollution and habitat degradation in the Gulf of Thailand

Voravit Cheevaporn [a,*], Piamsak Menasveta [b]

[a] *Department of Aquatic Science, Burapha University, Bangsaen, Chonburi 20131, Thailand*
[b] *Department of Marine Science, Chulalongkorn University, Phyathai, Bangkok 10330, Thailand*

Abstract

The Gulf of Thailand has been a major marine resource for Thai people for a long time. However, recent industrialization and community development have exerted considerable stress on the marine environments and provoked habitat degradation. The following pollution problems in the Gulf have been prioritized and are discussed in details: (1) Untreated municipal and industrial waste water are considered to be the most serious problems of the country due to limited waste water treatment facilities in the area. (2) Eutrophication is an emerging problem in the gulf of Thailand. Fortunately, the major species of phytoplankton that have been reported as the cause of red tide phenomena were non-toxic species such as *Noctiluca* sp. and *Trichodesmium* sp. (3) Few problems have been documented from trace metals contamination in the Gulf of Thailand and public health threat from seafood contamination does not appear to be significant yet. (4) Petroleum hydrocarbon residue contamination is not a problem, although a few spills from small oil tankers have been recorded. A rapid decrease in mangrove forest, coral reefs, and fisheries resources due to mismanagement is also discussed.

Keywords: Gulf of Thailand; Waste water; Oil; Eutrophication; Red tides

1. Introduction

Thailand lies in the tropical zone of Southeast Asia, between latitudes 6° and 21° N and longitudes 98° and 106° E (Fig. 1). The country is bounded in the north, west, and east by mountain ranges, and in the south by the South China Sea and the Andaman Sea, with a total coastline of approximately 2600 km. The climate is mild, with typical Southwest and Northeast monsoons.

The Gulf of Thailand is situated between latitudes 5° 00′ and 13° 30′ N and longitudes 99° 00′ and 106° 00′ E, and constitutes a portion of the shallow Sunda Shelf, opening to the South China Sea. The Gulf is approximately 720 km in length, with a maximum depth of 84 m. The Gulf of Thailand is a major marine resource in terms of (1) fisheries, aquaculture, (2) coral and mangrove resources, and (3) oil and mineral resources. However, recently rapid industrialization and community development have exerted considerable stress on the marine environment. The pollution problems in the Gulf can be prioritized according to the following categories:

(1) untreated municipal and industrial waste water,
(2) eutrophication,
(3) trace metals contamination,
(4) petroleum hydrocarbon.

2. Untreated municipal and industrial waste water

In Thailand, most of the natural waterways serve as sewerage for domestic and industrial waste water. A study in Bangkok Metropolitan Area estimated that 60–70% of domestic waste was discharged to the Chao Phraya River and eventually to the Gulf of Thailand without prior treatment. Table 1 and Fig. 1 show the BOD load from the major coastal zones of Thailand namely: central basin, eastern seaboard, eastern south and western south. The central basin contributes the highest BOD load with 34 376 t/year, of which 29 033 t/year are from domestic sources and 5343 t/year are industrial. These untreated wastes are discharged directly or indirectly to canals, rivers and sea, causing high BOD values and bacterial contamination close to populated and industrialized areas. This is because there are not enough waste water treatment facilities in the area.

* Corresponding author.

0025-326X/03/$ - see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0025-326X(03)00101-2

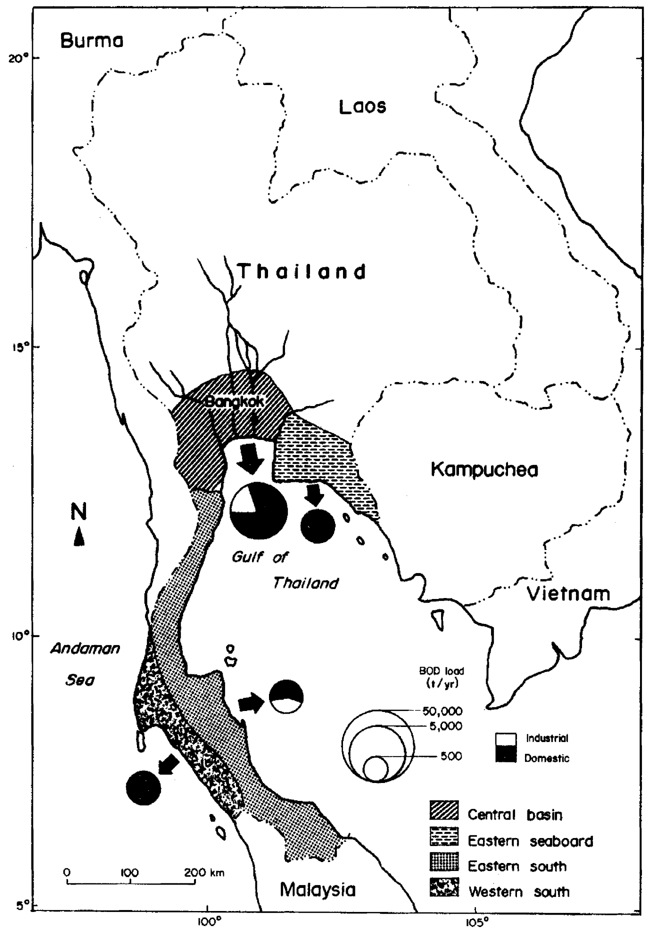

Fig. 1. The major coastal zones of Thailand and their BOD loads in 1986. Source: Taranatham (1992).

Table 1
The BOD load from the major coastal zones of Thailand in 1986

Zone	BOD load (t/year)		
	Industrial	Domestic	Total
Central Basin	5343	29 033	34 376
Eastern seaboard	–	1207	1207
Eastern south	208	451	659
Western south	–	1384	1384

Source: Taranatham (1992).

3. Eutrophication

Eutrophication of coastal waters has only recently become apparent as a problem in Thailand. In the Gulf of Thailand, the species found to bloom most frequently are the blue-green algae *Trichodesmium erythraem*, and *Noctilluca* sp. The relationship between these blooms and the nutrient enrichment of coastal waters (due mainly to the disposal of untreated sewage) is probably inescapable, but firm evidence is elusive. A widespread bloom in the Eastern coast of Thailand was recorded in 1983, and caused losses to local fish farming facilities (Suvapeepun et al., 1984). A red tide also occurred on the west coast of the Upper Gulf at about this time, and paralytic shellfish poisoning (PSP) was recorded for the first time in Thailand as a consequence. The responsible organism was identified as the dinoflagellate *Gonyaulax sp.* According to Suvapepan (1995), 43 major red tides were recorded in the Gulf during 1988–1995. 21 red tides were caused by *Trichodesmium sp.*, 17 were caused by *Noctiluca sp.* and the rest by diatoms.

The areas effected by phytoplankton blooms were nauseabond and discolouration of the water was usually observed. Red tides could cause mass mortalities in nearby shrimp and shellfish farms. For example, major shrimp farming areas in Samut Songkarm and Samut Sakorn provinces were severely affected in 1977 resulting in a sharp decline in output per hectare (Rientrairut, 1983). Green mussel larvae were also severely affected by red tides as they were unable to settle on the wooden poles during the outbreaks. This caused heavy losses to the shellfish industry during the outbreaks.

4. Trace metals contamination

4.1. Water sample

There have been several reports on the levels of trace metals in the Gulf of Thailand. However, there is little evidence of significant metal contamination of seawater, as the levels found are comparable to estuaries elsewhere in the world (Table 2) (Hungspreug, 1982).

In contrast to Hungspreugs's report in 1982, Environmental Health Division (1984) examined for the period 1981–1983 the six rivers flowing into the Gulf of Thailand which were arranged in order of deteriorating condition as follows: Chao Phraya, Bang Pakong, Mae Klong, Tha Chin, Petchaburi, and Pran Buri (Tables 3 and 4, Fig. 2) The first four major rivers contained high levels of organic wastes, suspended solids, heavy metals and bacteria. Elevated levels (much higher than world average values) in estuarine waters were found for chromium, copper, iron, mercury, manganese, lead and zinc. In addition, the Tha Chin, Petchaburi, and Pran Buri rivers were somewhat affected by pesticide contamination as a result of the high usage of pesticides in these areas for agriculture purposes.

4.2. Sediments

Sediment cores taken from the inner Gulf of Thailand showed enriched concentrations of Cd and Pb at the surface of the cores near the Chao Phraya River Mouth area (Hungspreugs and Yuangthong, 1983). It is estimated that the Chao Phraya River estuary has been affected anthropogenically by Cd and Pb for the past 30

Table 2
Comparison of the concentrations (μg/l) of dissolved Cd, Cu, Pb, and Zn in the Upper and the Lower Gulf of Thailand (1981–1982)

Element		Upper Gulf (19 stations)		Lower Gulf (8 stations)
		Wet season	Dry season	
Cd	mean	0.06	0.04	0.04
	range	0.01–0.26	0.02–0.08	0.02–0.06
Cu	mean	1.06	0.75	1.40
	range	0.50–2.00	0.52–1.35	0.70–2.10
Pb	mean	0.44	0.66	0.04
	range	0.20–1.13	0.16–1.16	0.01–0.06
Zn	mean	12.90	13.00	7.10
	range	10.80–17.00	11.00–21.00	4.00–12.00

Source: Hungspreug (1982).

Table 3
Water Quality parameters at the river mouths of the inner Gulf of Thailand in 1983 (see Fig. 3. for stations)

Quality parameters	Stations					
	1	2	3	4	5	6
Temperature (°C)	28	29	30	30	29	31
pH	7.3	7.3	7.6	7.2	7.3	6.8
Conductivity (μmhos/cm)	428	229	335	444	490	355
Turbidity (units)	5	17	28	14	42	77
Suspended solids (mg/l)	10	12	50	30	116	130
Dissolved solids (mg/l)	299	121	265	315	343	1,105
Dissolved oxygen (mg/l)	4.6	6.0	6.0	6.0	2.2	5.1
BODs (mg/l)	2.4	1.3	1.4	1.8	2.3	3.2
Total nitrogen (mg/l)	0.44	0.44	0.41	0.82	1.40	3.11
Nitrate (mg/l)	0.08	0.06	0.08	0.10	0.36	0.64
Phosphate (mg/l)	0.09	0.13	0.15	0.21	0.36	0.18
Heavy metals (mg/l)						
Arsenic	0.01	ND	ND	ND	ND	ND
Cadmium	0.001	0.001	0.001	0.001	0.004	0.002
Chromium	0.017	0.009	0.007	0.010	0.12	0.012
Copper	0.010	0.006	0.006	0.010	0.010	0.010
Iron	0.48	1.08	1.02	1.43	1.73	2.61
Mercury	0.0004	0.0002	0.0002	0.0008	0.0003	0.0002
Manganese	0.09	0.12	0.18	0.20	0.28	0.27
Lead	0.02	0.15	0.08	0.04	0.10	0.04
Zinc	0.17	0.19	0.14	0.15	0.15	0.14
Pesticides (μg/l)						
Aldrin	ND	ND	ND	0.010	ND	ND
α-BHC	0.030	0.056	ND	0.130	0.010	ND
β-BHC	0.018	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND
Endosulfan I	ND	ND	ND	0.044	ND	ND
DDD	ND	ND	ND	ND	ND	ND
DDE	ND	ND	ND	0.036	ND	ND
DDT	ND	ND	ND	0.346	ND	ND
Heptachlor	0.011	0.029	ND	0.056	ND	ND
Heptachlor Epoxide	0.009	0.028	ND	0.572	ND	ND
Lindane	0.017	0.040	ND	0.114	0.008	ND
Mirex	ND	0.037	ND	0.603	ND	ND
TDE	ND	ND	ND	ND	ND	ND

Source: Environmental Health Division (1984).
Note: ND = not detectable.

years. Similar results of Cu, Pb and Zn enrichment were observed at the top portions of the sediment cores from the Bang Pakong River estuary (Cheevaporn et al., 1994). In addition, the authors estimated the present-day anthropogenic fluxes of heavy metals to Bang Pakong River estuarine sediments to be about 1.32–1.84 μg/cm^2/yr for Cu, 1.99–6.57 μg/cm^2/yr for Pb, 2.36–7.71 μg/cm^{2}yr for Zn, 0.02–0.04 μg/cm^2/yr for Cd, 0.28–1.11 μg/cm^2/yr for Cr and 0.75–1.39 μg/cm^2/yr for Ni. The results of flux calculations showed that a site of

Table 4
Discharges into the inner Gulf of Thailand in 1983 (see Fig. 3 for stations)

Discharges	Total	Stations					
		1	2	3	4	5	6
Heavy metals* (kg/day)	51 018	258	500	6660	1800	23 400	18 400
BOD (kg/day)	207 690	1580	1620	28 900	6290	115 000	54 300
BOD (% loading)	100	0.8	0.8	13.9	2.9	55.5	26.1

Source: Environmental Health Division (1984).
*Note: Heavy metals = As + Cd + Cr + Cu + Fe + Hg + Mn + Pb + Zn.

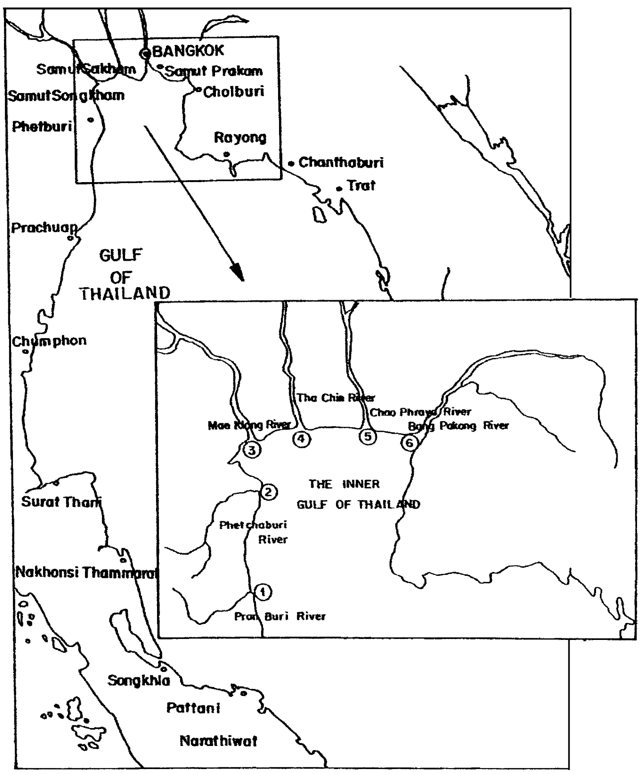

Fig. 2. Map of the Gulf of Thailand showing the six major rivers that flow into the inner Gulf of Thailand.

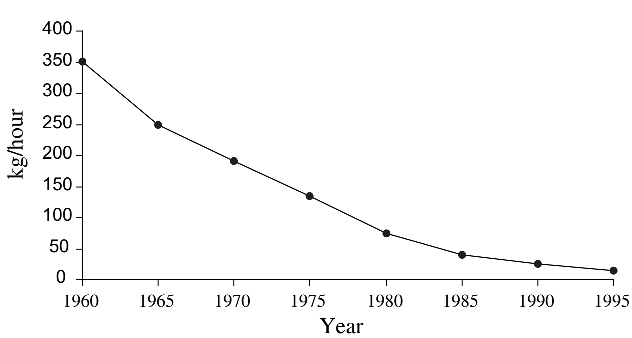

Fig. 3. Catch per hour of demersal fish in the Gulf of Thailand. Source: Department of Fisheries (1994).

intense industrial activities produced highest anthropogenic inputs of heavy metals to the area.

4.3. Organisms

Sample from the Upper Gulf and Lower Gulf in Southern Thailand exhibited low concentrations of metals in general (Huschenbeth and Harms, 1975). In 1981–1982, as part of Thailand's participation in international Mussel Watch programmes, investigations of selected metals in commercially popular bivalves were undertaken. The organisms studied were the green-lipped mussel (*Perna viridis*), the rock oyster (*Crassostrea commercialis*), the bloody cockle (*Andara granosa*), the short neck clam (*Paphia umdulata*) and the moon scallop (*Amusium pleuronectes*). The metal levels appear quite low by comparison to these same species from elsewhere in the world (Hungspreugs and Yuangthong, 1983; Philip and Muttarasin, 1985). However, Rojanavipart (1990) disclosed that in his study in the inner Gulf of Thailand in 1986 using the green mussel as a biological indicator (Table 5), high concentrations of most heavy metals were found at the mouths of Pran Buri, Phetchaburi, Mae Klong, Tha Chin, and Bang Pakong rivers. Highly elevated levels of cadmium in the mussel samples from Pran Buri and Tha Chin rivers found in his study were strikingly high. The author suggested that the contamination by heavy metals in the inner Gulf of Thailand would be more severe if preventive measures were not taken promptly.

4.4. Mercury contamination

Total mercury in seawater and sediment of the Gulf of Thailand is shown in Table 6. Considering the data obtained from several surveys, it can be found that the mercury concentration in seawater during the period 1974–1980 is comparable to natural level as suggested by Kothny (1973), i.e. in the range of 0.01–0.38 ppb. High mercury concentrations (44.7–847 ppb) nevertheless were reported during 1983–1987. The levels were even higher than those detected in Minamata Bay, Japan (1.6–3.6 ppb). Whether these reported data are valid or not, there is a need for clarification both on sample collection and analytical methods. Most mercury concentrations in the sediments were still within the acceptable limit of 0.3 ppm (Ministry of Transport, Japan, 1976), except certain locations such as the Chao Phraya

Table 5
Metal concentration (mg/kg dry weight) in green mussels (*Perna viridis*) at the river mouths of the inner Gulf of Thailand in 1986

Metals	Stations					
	1	2	3	4	5	6
Cadmium	26.1	9.5	1.5	23.3	–	6.8
Chromium	1.1	1.0	2.7	0.6	–	0.5
Copper	7.2	7.6	6.8	8.8	–	10.1
Iron	212	418	822	817	–	328
Manganese	10.8	15.8	12.0	9.2	–	6.9
Nickel	3.3	1.2	1.3	0.9	–	0.8
Lead	0.6	1.2	1.1	0.4	–	0.5
Zinc	45	39	42	55	–	76

Source: Rojanavipart (1990).

Table 6
Total mercury in seawater and sediment of the Gulf of Thailand

Study period	Location	Total mercury in		Reference
		Seawater (μg/l)	Sediment (μg/g wet)	
1974	Bang Pra Coast	0.015–0.019	0.003–0.069	Menasveta (1976)
1975–1976	Inner Gulf	0.01–0.11		Sidhikasem (1978)
1977	Inner Gulf	0.02–2.00		Sidhikasem (1978)
1975–1976	Inner Gulf	0.467		Piyakarnchana et al. (1977)
1976	Chao Phraya Estuary	0.216 ± 0.280	0.012–0.264	Menasveta (1978)
1979–1980	Estuarine areas	0.24–0.38	0.007–0.017	Sidhichaikasem and Chernbamrung (1983)
1980	Estuarine areas			Menasveta and Cheevaparanapiwat (1981)
	Mae Klong		0.23 ± 0.1	
	Ta Chin		0.67 ± 0.1	
	Chao Phraya		2.80 ± 0.4	
	Bang Prakong		0.52 ± 0.2	
1983–1984	Bang Prakong Estuary	44.7	0.14	Bamrungrachirun et al. (1987a)
1983–1987	East coast of the Inner Gulf	847.0	2.26	Bamrungrachirun et al. (1987b)
1983–1987	Inner Gulf	0.2–203.0		Jarach (1987a)
1984–1986	West coast of the Inner Gulf	0.1–88.7		Jarach (1987b)

River estuary and the east coast of the Gulf. Higher mercury concentrations in such areas might be due to the contamination from urban and industrial areas.

Total mercury concentration in biota of the Gulf of Thailand are shown in Table 7. In the coastal area, almost all mercury concentration in fish were lower than 0.2 μg/g wet. These concentrations could be regarded as a natural background of mercury in fish in general. Nevertheless fishes in the off shore area, in the vicinity of natural gas platforms, exhibited higher mercury concentrations. These fishes were caught and analyzed recently (ARRI, 1998). Between 5% and 10% of fish at Erawan and Funan platforms had mercury concentrations higher than 0.5 μg/g. This concentration is the maximum permissible concentration in fish set by the FAO. The biological magnification of mercury was mentioned in several reports. Fish of higher trophic levels bore higher residue than those in the lower trophic levels. This suggests that mercury might be concentrated in the same manner as organic compounds such as organochlorine compounds, i.e. passed through and amplified along the food chain.

A positive linear relation between size and mercury content of fish is well documented. However, for low levels of mercury in fish (below 0.2 μg/g) no increase, or a very moderate increase in mercury content was found to occur as fish weight increased. As the level of mercury increased, the mercury level in relation to the weight increased noticeably. At extremely high levels of mercury, caused by manifest contamination, no relation to age or weight was found. This indicates that there is a threshold level of mercury in the environment, above which fish cannot eliminate mercury from their muscular tissues faster than it is incorporated and accumulation thus occurs. This relationship also indicates that fish are adapted to a mercury concentration of less than 0.2 μg/g. All past data indicated that the maximum natural concentration in fish is 0.2 μg/g or less. It should be noted that 23.3% of fishes caught in the vicinity of the natural gas platforms in the Gulf of Thailand had mercury above 0.2 μg/g.

In order to prove that mercury contamination in the middle of the outer gulf was due to natural gas production, an investigation was made by comparing mercury

Table 7
Total mercury in biota of the Gulf of Thailand

Study Period	Location	Kind of biota	Total mercury (μg/g wet)	Reference
1974	Bang Pra Coast	3rd trophiclevel fishes	0.003–0.010	Menasveta (1976)
		4th trophiclevel fishes	0.002–0.057	
1976	Chao Phraya Estuary	Fishes and shellfish	0.009–0.205	Menasveta (1978)
1977–1980	Inner Gulf	Fishes and shellfish	0.002–0.206	Sivarak et al. (1981)
1978–1979	River estuaries	Bivalves	0.013–0.120	Menasveta and Cheevaparanapiwat (1982)
1976–1977	Inner Gulf	3rd trophiclevel fishes	0.002–0.130	Cheevaparanapiwat and Menasveta (1979)
		4th trophiclevel fishes	0.010–0.650	
1980	Estuarine areas			Menasveta and Cheevaparanapiwat (1981)
	Mae Klong	Mullets	0.04 ± 0.03	
	Ta Chin	Mullets	0.07 ± 0.04	
	Chao Phraya	Mullets	0.15 ± 0.06	
	Bang Prakong	Mullets	0.08 ± 0.03	
1982–1983	Inner Gulf	Bivalves	0.001–0.041	Sivarak et al. (1984)
1982–1986	Inner Gulf	Bivalves	0.001–0.153	Boonyachotmongkol et al. (1987)
1990	Sichang Island	Fishes	0.012–0.032	Menasveta (1990)
	Mab Tapud	Fishes	0.013–0.049	
	Off-shore (Erawan)	Fishes	0.055–0.324	
1997	Outer Gulf of Thailand	Demersal Fishes	0.003–0.93	ARRI (1998)

in fish caught from the natural gas production area and the coastal area, including from the Andaman Sea. It was found that mercury in cobia (*Rachycentron canadus*) in the area of the natural gas production was significantly higher than the concentrations detected in cobia of the coastal areas and the Andaman Sea (Pongplutong, 1999).

5. Petroleum hydrocarbon

Thailand has taken part in the IGOSS Marine Pollution Monitoring (Petroleum) Programme (MAPMOPP) since 1976. In 1983, dissolved petroleum hydrocarbons in seawater, sediments, and certain species of bivalves and fish were measured, using the spectrofluorometric method with chrysene as a standard, following the methodology set out by the Intergovernmental Oceanographic Commission. The results are shown in Table 8.

Seawater is considered polluted when there is more than 100 μg/l. An index of 100 μg/g of hydrocarbons in dry sediment is also employed as an indicator of oil pollution (Merchand, 1982). By considering this standard value, it can be concluded that petroleum hydrocarbon contamination level in the marine environment of the Gulf of Thailand is still below those standard values.

Table 8
Petroleum hydrocarbons in seawater, sediments, and biota of the Gulf of Thailand in 1983

In sea water (Upper Gulf)	
April–May	0.380–5.646 $\mu g\,l^{-1}$
mean	1.305 ± 1.724 $\mu g\,l^{-1}$
September–November	0.059–6. 095 $\mu g\,l^{-1}$
mean	0.782 ± 1.148 $\mu g\,l^{-1}$
In sediments	
April–May	0.064–2.164 $\mu g\,g^{-1}$ (wet sediment extraction)
	0.047–1.820 $\mu g\,g^{-1}$ (dry sediment extraction)
September–November	0.059–6.095 $\mu g\,g^{-1}$ (wet sediment extraction)
Mean	0.096–0.55 $\mu g\,g^{-1}$
In tissue of marine organisms (analysis made on freeze-dried tissue)	
Fish	
Polynemus sp.	0.117 $\mu g\,g^{-1}$ (dry wt)
Cynoglossus sp.	0.598 $\mu g\,g^{-1}$
Parastramateus sp.	0.415 $\mu g\,g^{-1}$
Bivalves	
P. undulata	0.462 $\mu g\,g^{-1}$
P. viridis	0.059 $\mu g\,g^{-1}$
A. granosa	2.376 $\mu g\,g^{-1}$

Source: Sompongchaiyakul et al. (1986).

6. Habitat degradation

Mangrove forest is a productive ecosystem and constitutes a natural barrier against storm surges and strong winds. It serves as nursery and feeding grounds for many commercially important aquatic species. During the past 32 years (1961–1993), social and economic development have caused severe destruction of mangrove forests in Thailand. The existing mangrove forest area in Thailand has decreased more than 50% in the past 32 years (Kongsangchai, 1995). Changes of the areas are shown in Table 9. The deterioration of mangroves in the past and at present is approximately 6.2 thousand ha/year. The major causes are economic, political, and social pressures which can be separated into many activities as show in Table 10. It is clearly seen that the conversion of mangrove forests to shrimp farming is one of the most severe problems and has tremendous impacts on the coastal ecosystem. For example the removal of tree-cover, loss of nutrient-supply from the forest to the sea, obstruction of tidal flushing and fresh water runoff, coastal erosion and the discharge of waste from ponds lead to change in the natural equilibrium and ultimately to the ecosystem destruction. Human activities can directly cause catastrophic mortality on reefs through dredging, dynamite fishing, and/or pollution. ONEB (1992) reported on the status of the coral reefs in the Thai waters during the period of 1987–1992 that only 36% remained in good condition, 33% in fair condition, 30% in poor condition (Table 11). It is expected that the destruction of the coral reefs will be more severe if preventive measures are not promptly taken.

Table 9
Changes of the existing mangrove forests in Thailand

Periods	Decreased area (ha)	Rate of decreasing (ha/yr)
1964–75	55 500	3943
1975–79	25 392	6348
1979–86	90 871	12 982
1986–89	15 878	5293
1989–90	2528	2528
1990–92	2644	1322
1992–93	6704	6704

Source: Kongsangchai (1995).

Table 10
Conversion of mangrove areas by various human activities

Activities	Change of area (ha)	
	Before 1980	1980–1986
Shrimp farming	26 036	84 223
Mining	926	4525
Others	53 630	2132
Total	80 592	90 880

Source: Kongsangchai (1995).

Table 11
Status of the coral reefs in Thai waters during the period of 1987–1992

Status	Gulf of Thailand		Andaman sea	Total
	East coast	West coast		
Good	58%	24%	34%	36%
Fair	29%	37%	32%	33%
Poor	13%	39%	32%	30%

Source: ONEB (1972).

The rapid expansion of the marine fishery industry since the early 1960s has put tremendous pressure on the available resources in the Gulf of Thailand. The exploitation of fish resources in the Gulf of Thailand has exceeded maximum sustainable level and caused adversely affects on the fish stocks in the Gulf, resulting in the drastic decrease from about 300 to 30 kg/h. However, another serious problem affecting fish resources is pollution, especially in the inner Gulf of Thailand. It is evident that the increasingly deteriorating conditions in the marine environment of the inner Gulf of Thailand have threatened the existence of several economically important organisms in the area. Thus, better management of marine resources is a prerequisite to any improvement to the existing situation.

7. Conclusion

It can be concluded that rapid population growth and industrialization have brought about resource degradation and a decline in environmental quality. Untreated waste water discharged directly and indirectly to the waterways are the most serious problems of the country. Eutrophication of coastal waters is an emerging problem. By contrast, few problems have been documented from trace metals discharged by industries, and public health threat from seafood contamination does not appear to be significant. Oil pollution has not been a problem, although occasional spills fromoil tankers have been recorded and fears of a major spill exist. Although many efforts have been undertaken to solve the degradation of marine habitats, problems of habitat degradation are still an important issue to be addressed. The problem is agreeing a sustainable management plan for natural coastal resources conservation and utilization. Thailand has implemented a program on marine pollution control during the past three decades. Such a program includes basically four components i.e., 1. Baseline and monitoring studies, 2. Water quality criteria establishment, 3. Identification of sources, pathways and quantity of pollutants and 4. Pollution control, abatement, rehabilitation. So far Thailand has implemented such a program, but certain components need to be emphasized.

References

Aquatic Resources Research Institute (ARRI), 1998. Mercury monitoring in the Gulf of Thailand, 1997. Final Report, Submitted to Mineral Resource Department, 77 pp.

Bamrungrachirun, R., Jarach, W., Jringjit, K., 1987a. Heavy metals in seawater and sediments of the eastern coast of the Inner Gulf of Thailand. In: Proceedings the 5th Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 7–9 July 1987, National Research Council of Thailand, pp. 130–135.

Bamrungrachirun, R., Jarach, W., Jringjit, K., 1987b. Heavy metals in seawater and sediments of the Inner Gulf of Thailand. In: Proceedings the 5th Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 7–9 July 1987, National Research Council of Thailand, pp. 114–121.

Boonyachotmongkol, T., Boriboon, P., Rojpanthip, L., 1987. Total mercury in bivalves of the coastal areas of the upper Gulf Thailand. In: Proceedings the 5th Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 7–9 July 1987, National Research Council Thailand, pp. 245–260.

Cheevaparanapiwat, V., Menasveta, P., 1979. Total and organic mercury in marine fish of the upper Gulf of Thailand. Bull. Environm. Contam. Toxicol. 23, 291–299.

Cheevaporn, V., Jacinto, G.S., San Diego-McGlone, M.L., 1994. History of heavy metals contamination in bang pakong river estuary, Thailand. J.Sci. Soc. Thailand. 20, 9–22.

Department of Fisheries, 1994. Fisheries record of Thailand 1982. Ministry of Agriculture and Cooperatives, Bangkok.

Environmental Health Division, 1984. Survey of the water quality in the estuary. Proceeding of the 3rd Seminar on the Quailty of Living Resources in Thai Waters, National Research Council of Thailand, Bangkok, pp. 62–78.

Hungspreug, M., 1982. Baseline levels of Cadmium, Chromium, Copper, Lead, and Zinc in seawater from the Gulf of Thailand. J. Sci. Soc. Thailand. 8, 193–204.

Hungspreugs, M., Yuangthong, C., 1983. A history of metal pollution in the Upper Gulf of Thailand. Mar. Pollut. Bull. 14, 465–469.

Huschenbeth, E., Harms, U., 1975. On the accumulation of organochlorine pesticides, PCB and certain heavy metals in fish and shellfish from Thai coastal and inland waters. Arch. Fisch. Wiss. 2, 109–122.

Jarach, W., 1987a. Heavy metals in seawater of the Upper Gulf of Thailand. In: Proceedings the 5th Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 7–9 July 1987, National Research Council Thailand, pp. 122–130.

Jarach, W., 1987b. Heavy metals in seawater of the Pranburi River Estuary and the Ban Leam coastal area. In: Proceedings the 5th Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 7–9 July 1987, National Research Council Thailand, pp. 67–74.

Kongsangchai, J., 1995. Problems of mangrove degradation in Thailand. In: Ecology and Management of Mangrove Restoration and Regeneration in East and Southeast Asia, 18–22 Jan. 1995, Surat Thani, Thailand.

Kothny, E.L., 1973. Advance in Chemistry Series 123. American Chemical Soc., Washington DC.

Menasveta, P., 1976. Total mercury in the food chain of Bang Pra coastal area, Chon Buri. J. Sci. Soc. Thailand 2, 117–126.

Menasveta, P., 1978. Distribution of heavy metals in the Chao Phraya River Estuary. In: Proceeding the international Conference on Water Pollution Control in Developing Countries, Asian Institute of Technology, pp. 129–145.

Menasveta, P., Cheevaparanapiwat, V., 1981. Heavy metals, organochlorine pesticides, and PCBs in green mussels, mullets, and sediments of river mouths of Thailand. Mar. Pollut. Bull. 12, 19–25.

Menasveta, P., Cheevaparanapiwat, V., 1982. Heavy metals in bivalves collected from various river estuaries of Thailand. Report no. RR-52-82, Institute of Environmental Research, Chulalongkorn University, 16 pp. (Unpublished manuscript).

Menasveta, P., 1990. Total mercury in marine fishes collected from Sichang Island, Mab Tapud, and the Off-shore area of the Gulf of Thailand. A report to Petroleum Authority of Thailand (Unpublished manuscript).

Merchand, M., 1982. The AMOCO CADIZ Oil spill distribution and evolution of oil pollution in marine sediments. In: Ecological Study of the AMOCO CADIZ Oil spill Report of the NOAA-CNEXO Joint Scientific Commission, pp. 143–157.

Ministry of Transport, Japan, 1976. Report on marine pollution surveys: results of surveys in 1974. Hydrographic Department, Maritime Safety Agency, Ministry of Transport, Japan, 30 pp.

Office of the National Environmental Board (ONEB), 1992. A national coral reef strategy for Thailand. Thailand Coastal Resources Management Project, 43 pp.

Piyakarnchana, T., Watcharangkul, R., Ithikasem, A., 1977. Variation of lead, mercury and cadmium in seawater and sediment of the Inner Gulf of Thailand. In: Proceedings the Seminar on Pollution Problems of Heavy Metals in Thai Environment, 13–15 Oct. 1977, Institute of Environmental Research, Chulalongkorn University, pp. 146–154.

Pongplutong, R., 1999. Mercury concentration is tissue of cobia (Rachycentron Canadus) from the Gulf of Thailand and Andaman Sea. M.S. Thesis, Chulalongkorn University, Bangkok.

Rientrairut, S., 1983. Fisheries development planning system in Thailand. Department of Fisheries, Ministry of Agriculture and Cooperatives, Bangkok, 85 pp.

Rojanavipart, P., 1990. The effects of marine pollution on fisheries in the inner Gulf of Thailand. In: Oceanography and Marine Pollution: An ASEAN EC Perspective. Proceeding of the ASEAN-EC Seminar/Workshop on Marine Sciences, 12–16 April 1987, Manila, Philippines, pp. 215–224.

Sidhichaikasem, S., Chernbamrung, S., 1983. Contamination of heavy metals in the estuarine environment of the Inner Gulf of Thailand. A report of Marine Fisheries Laboratory, Department of Fisheries, Bangkok, 17 pp. (Unpublished manuscript).

Sidhikasem, A., 1978. The analyses of heavy metals in seawater and sediment. In: Proceedings the Symposium on Survey and Research of Pollution in Thai Waters, National Research Council of Thailand.

Sivarak, S., Boriboon, P., Jangsawang, J., Iswas, A., 1981. Mercury in marine fauna. In: Proceedings the Symposium on Survey and Research of Pollution in Thai Waters, National Research Council of Thailand.

Sivarak, S., Boriboon, P., Rojpanthip, L., 1984. Total mercury in bivalves of the east coast of the inner Gulf of Thailand. In: Proceedings the 3rd Seminar on Research in Water Quality and Quality of Living Resources in Thai Waters, 26–28 March 1984, National Research Council of Thailand, pp. 285–289.

Sompongchaiyakul, P., Hungspreugs, M., Lim, S., 1986. Baseline values of petroleum hydrocarbons in the Upper Gulf of Thailand and the Eastern Seaboard. Paper presented at the 3rd Symposium on Marine Science, 6–8 August 1986, National Research Council of Thailand, Bangkok.

Suvapepan, S., 1995. Red tides and red tides research in Thai waters. Department of Fisheries, Bangkok, 11 pp (in Thai).

Suvapeepun, S., Chernbamrung, S., Wangchareonporn, W., 1984. Effect of water discolouration on coastal fisheries. In: Report of the Marine Fisheries Division, Department of Fisheries, Bangkok.
Taranatham, P., 1992. Problems and trends of waste management in Thailand. In: Chua, T.E., Garces, L.R. (Eds.), Waste Management in the coastal areas of the ASEAN region. ICLARM Conference Proceedings 33, Philippines, 218 pp.

Further Reading

Phillips, D.J.H., Muttarasin, K., 1985. Trace metals in bivalve mollusc from Thailand. Mar. Environ. Res. 15, 215–234.