CHAPTER 1

INTRODUCTION

A. General Background

Rapid coastal development, due to the expansion in industry and production in order to compete with the socio-economic growth, is the major force in environmental deterioration. Thailand, is no exception, has faced the environmental problems due to the coastal reclamation for shrimp farming. High incentive returns from shrimp farming had pushed Thailand as one of the top country in the world in exporting shrimps in the world market. Since 1973-1998 from Table 1.1, the shrimp farm area and production had greatly increased 6.63 and 154.57 folds respectively. The monetary returns from these shrimp production had increased tremendously to 1670.27 folds. Eastern coast of Thailand was one of the suitable area for shrimp culture. Because of its shoreline lined by mangrove forest approx. 122,464.25 rai, the shrimp farms had expanded in this area in 5 provinces about 343,908 rai (Leeruksakiat, 2000). Chanthaburi Province has showed the highest development of shrimp farming comparing others province in the same area is calculated about 139,365.40 rai with the mangrove forest area 34,581.75 rai (Leeruksakiat, 2000). This study will concentrate on the Kung Krabaen Bay area which locates on upper part of Chanthaburi Province shoreline and surrounds by shrimp farms.

The consequences of the rapid development of shrimp farms in Chanthaburi Province led to the massive mangrove clearance, had pronounced impacts on the physical and chemical properties of water and sediment and the biodiversity of plant and animal communities. Many shrimp farms have been abandoned due to low production threatened by diseases and mass mortality and environmental deterioration. These were the signs for the need of better shrimp farm management and overall coastal zone management issues.

Shrimp farming contributed to tremendous loading of artificial nutrients to the environment in both organic and inorganic forms, especially from the intensive shrimp farming. The important sources were from artificial feeds, fertilizers, tea seeds and organic wastes from shrimp farms. Shrimp farms effluents, then circulated, transported and accumulated in forms of dissolved and particulated forms. These excess effluents loading would further accumulated as organic materials in bottom sediment. The effluents also contributed high quantity of saline water, and dissolved organic and inorganic compounds. These in turn degraded the water quality and coastal environment. As the shrimp farm area expanded, the more effluents would be loaded to the environment. The environmental impacts can not be avoided. The degree of impacts varied due to the responses of organisms and ecosystems concerned. The impacts on benthic communities would be pronounced. The species diversity, abundance and biomass of benthic organisms would be affected. In severe polluted condition by organic enrichment, the opportunistic species or opportunists for example the cosmopolitan polychaete species, *Capitella capitata* would dominated the area (Pearson and Rosenberg, 1978; Sanguansin, 1995). The use of indicator organism to monitor environmental change has been widely manipulated to assess the change in water quality and environmental impacts on ecosystem. The organisms, particular benthic organisms, play an important component in trophic level in coastal ecosystem. Some benthic fauna, for example, polychaetes, amphipods and mollusks, are widely used as indicators of prolific environment or enriched organic pollution in the coastal environment.

Tookwinas, *et al.* (1996) and Boonsong (1997) had concluded that Kung Krabaen Bay water quality was somewhat polluted. However, the present situation was not critical for shrimp farms in this area. It was found that a large amount of remaining nitrogen and phosphorus substance that circulated within the bay as well as the enriched organic material would dissolved and accumulated with silt and clay and settled at the bottom of the bay (Sangrungruang and Dumrak, 1997). Boonsong (1997) concluded from her study in the Kung Krabaen Bay area that mangrove forests played the important role as nutrient absorbents. She calculated that 29.4% and 23.2% of the total nitrogen and total phosphorus loadings from shrimp farming respectively were utilized by the mangrove forests prior to entering the Kung Krabaen Bay.

This study aims at the impacts of organic enrichment due to shrimp farming in the Kung Krabaen Bay in particular on the benthic communities. Polychaetes assemblage will be focused.

Polychaetes were highly abundance and diversity in coastal environment, both in marine and estuarine ecosystem. They contributed more than 50% of benthic macrofauna community in tropic zone as well as Thailand, both Andaman Sea and the Gulf of Thailand (Piyakarnchana, *et al.*, 1978; Chatananthawej and Bussarawich, 1987; Piumthipmanus, 1997). Polychaetes also played the role of secondary producers in the marine food chains. Their potential activities leaded to biogenic rework of bottom sediment. They also had commercial values as living food for aquaculture and fishing. Toxicologist and ecologist used polychaetes for toxicity tests (Reish, 1972) and for indicators of organic pollution, for example, the capitellid, *Capitella capitata* (Pearson and Rosenberg, 1978; Tsutsumi and Kikuchi, 1983). In Thailand many works has been conducted in both the Andaman Sea and the Gulf of Thailand involving biology, taxonomy and benthic community. Contributions relating to the benthic communities the Andaman coastline of Thailand particularly were from Seidenfaden, *et al.* (1968), Prasertwong (1984), Hylleberg, *et al.* (1985b), Nateewathana and Hylleberg (1986), Chatananthawej and Bussarawich (1987), Hylleberg and Nateewathana (1991). For the Gulf of Thailand, relating contributions were from Charoenruay (1979), Khatsamut, *et al.* (1980a, 1980b), Charoenruay and Piamthipmanus (1981), Charoenruay, *et al.* (1982), Angsupanich and Kuwabara (1995, 1999). Some works focused on polluted environment, such as Sanguansin (1995) and Tunsakul (1995). This study will focus on the changes in polychaete assemblages due to organic enrichment from shrimp farm effluents. Indicator species of high organic enrichment will be identified.

B. Establishment of the Kung Krabaen Bay Royal Development Study Center in Relation to Shrimp Farming

The Kung Krabaen Bay Royal Development Study Center (KKBRDSC) was on of the His Majesty the King initiation, was established on 28 December 1981 as the research and study center on appropriate development methods for coastal communities of Chanthaburi Province. The area of KKBRDSC project covered the area around the shoreline of Kung Krabaen Bay and the outer area of approx. 36,000 rai (5,760 ha). The major problems in the coastal communities were mangrove destruction, decline of coastal fish stocks, and saline water intrusion into agriculture lands. These not only cause environmental deterioration but also adversely affected the way of life of the local fishermen and farmers. This project operated in cooperation of several government agencies mainly the Ministry of Agriculture and Co-operatives. In order to gain high benefits, the activities implemented would be of interdisciplinary manner involving of various government agencies. One of the main focus for the KKBRDSC project was on aquaculture, especially shrimp farming, with the responsibility on environmental conservation. Kung Krabaen Bay itself lies along the eastern shoreline in Chanthaburi Province, which covers the area of 4,000 rai (640 ha) from the total area of the project 36,000 rai. When the project was initiated this area was once the deteriorated mangrove forest area of approx. 728 rai (116.5 ha). This land was on loan from the Royal Forestry Department for 30 years in order to develop the shrimp farming system by providing land for a total 104 families who were selected by Kung Krabaen Committee to participate in shrimp farming project.

The objectives of the King's Project on KKBRDSC as follows

1. To promote the effective of coastal fisheries, as well as agriculture and occupational development in the eastern coastline.

2. To provide the effective and integrated approaches of environmental conservation and solutions to environmental problems in relation to mangrove destruction in the coastal environment.

3. To increase the income of the surrounding villages and farmers and the improvement of their standard of living

4. To promote the dissemination of knowledge, skills and appropriate technology

on aquaculture, agriculture and animal husbandry, through the use of "demonstration project". Trainings on coastal environmental protection and conservation would also be offered. Provisions of training based upon research works conducted at the Center.

Table 1.1 Variations on number of shrimp farms, shrimp farm area and production in Chanthaburi Province from 1973 to 1998 (Department of Fisheries).

Year	No. of Farms	Area (Rai)	Production (ton)	Value (million baht)
1973	1,462	71,678	1,635,000	35.30
1974	1,518	75,576	1,775,000	43.20
1975	1,568	80,422	2,538,290	81.80
1976	1,544	76,850	2,533,330	79.45
1977	1,437	77,567	1,589,540	56.09
1978	3,045	151,055	6,394,830	349.16
1979	3,378	154,222	7,064,070	460.59
1980	3,572	162,727	8,063,050	458.91
1981	3,657	171,619	10,727,870	657.26
1982	3,943	192,453	10,090,770	765.68
1983	4,327	222,107	11,549,850	950.37
1984	4,519	229,949	13,006,750	1,024.01
1985	4,939	254,805	15,840,560	1,348.41
1986	5,534	283,548	17,885,830	1,737.58
1987	5,899	279,812	23,566,470	3,449.32
1988	10,246	342,364	55,632,840	7,900.55
1989	12,545	444,785	93,494,500	11,072.19
1990	15,072	403,787	118,227,050	14,365.36
1991	18,998	470,826	162,069,690	19,834.11
1992	19,403	454,975	184,884,321	25,500.14
1993	20,027	449,292	225,514,303	32,425.34
1994	22,198	457,793	263,445,965	39,745.25
1995	26,145	468,386	259,540,536	39,544.65
1996	23,413	454,148	239,499,530	40,312.13
1997	23,723	457,000	227,560,240	49,104.51
1998	25,977	475,117	252,731,005	58,960.42

Seawater irrigation system for shrimp farming

The promotion and development shrimp farms around KKB is one of the focus of the Kung Krabaen Bay Royal Development Study Center. This center managed the deteriorated forest area of 1,650 rai around KKB by dividing this land for 104 families participating in the project.

Shrimp culture in this area before the establishment KKBRDSC were operating as traditional shrimp farms without destroying the mangrove forests. The traditional shrimp farms trapped the wild shrimp seeds at high tide. The circulation of water in ponds was related to the duration of tidal changes. In 1984, the intensive shrimp culture was introduced to this area as well as the shrimp culture system introduced by KKBRDSC. Water from the Kung Krabaen Bay was the main source where the shrimp farmers used for the culture. At high tide the seawater flowed through the canals so that the shrimp farmers could bring the water into their ponds. The effluents would be drained off into the drainage canals when at shrimp harvest period. These drainage canals would circulated effluents separately from the clean water canals, back into the bay at low tide. The bay is accumulating the effluents from shrimp farms. The degraded water would then be used in shrimp farms again. This caused the low production of shrimps in the area. The problems for shrimp farming in the area can be concluded as follows:

1. Lack of good quality seawater for shrimp culture: Because the Kung Krabaen Bay was a semi-enclosed bay, it was considered that the circulation of water was not good enough. The accumulation of excess nutrients from shrimp farms created the degradation of water quality and the spread of unexpected disease outbreaks.

2. Untreated water in the bay: Eventhough the farm effluents had been passed through settling ponds before releasing to the drainage canals, the water with enrich nutrients was not treated. These effluents could accumulated in the environment and in turn had impacts on the environment and water quality. These impacts not only in Kung Krabaen Bay but on the coastal environment as well.

3. Disease outbreaks: Degraded water quality initiated the disease outbreak, which lowered the shrimp production in this area.

The Department of Fisheries was assigned to be responsible for solving the problems due to shrimp farming. The seawater irrigation system was designed and implemented as the solutions. The main objectives of the seawater irrigation system were:

1. To provide the good quality seawater for shrimp farms and this in turn would diminish disease outbreaks.

2. To lessen the environmental conditions due to shrimp farming.

3. To increase the potential shrimp farms in the area and to develop the culture in sustainable terms.

4. The seawater irrigation system introduced would provide the management practices to shrimp farms in other areas.

C. Conceptual Framework of Research

There were several factors determining the water quality in Kung Krabaen Bay as in Figure 1.1. The first major factor was the expansion of shrimp farm area. This would determine the organic loading in the area. But with strict enforcement of shrimp farm management such as the establishment of settling ponds prior the release of effluents, strict control of sedimentation and enforcement on the seawater irrigation system would lessen the problems. Hydrological characteristics of the bay itself in term of water circulation and the exchange of water between the bay and coastal area would determine the loading and accumulation of organic materials inside the bay. Mangroves and seagrass beds inside the Kung Krabaen Bay acted as the nutrient absorbents. These would help lessen the organic enrichment problems. Changes in any of these factors would have pronounced impacts on the environmental conditions in this area.

At present, the environmental condition at Kung Krabaen Bay was reported normal by the Kung Krabaen Bay Royal Development Study Center (KKBRDSC). This semi-enclosed estuarine bay was one of the unique area of specific physical environment among on the coastlines in Thailand. The bay consisted of various natural habitats for example, the flourish mangrove forest fringed along shoreline and sea-grass beds on the intertidal and subtidal flats. These habitats played the important roles of absorbents which help to lessen the nutrient inputs in this bay. Since 1999 the seawater irrigation system has already been installed and operated by the government. The system transported the fresh seawater from offshore outside the bay directly to shrimp farming areas directly. This system was mainly used for solving the problem of water quality in order to raise the shrimp production. This system was expected to decrease the environmental impacts by effluents loading from shrimp farms. The strict regulations in shrimp farm management were provided by the KKBRDSC. Nearly half of total shrimp ponds are controlled and regulated by the KKBRDSC. Large amount of waste water must be treated in settleing ponds before releasing into the environment. During this system can regulate the high organic waste by trapping these waste in the system.

Those mentioned factors were necessary in keeping the Kung Krabaen Bay system in normal condition. Eventhough several shrimp farmers did not follow the regulations and illegally drained the effluents. High exchange of water in the bay was about 83-86% during the tidal range help lessen the organic accumulation inside the bay. KKBRDSC only monitored the water quality routinely. However the organic nutrients may accumulated in the bottom sediment. It was necessary to monitor the sediment quality and the benthic communities to actually reflected the environmental condition of the bay.

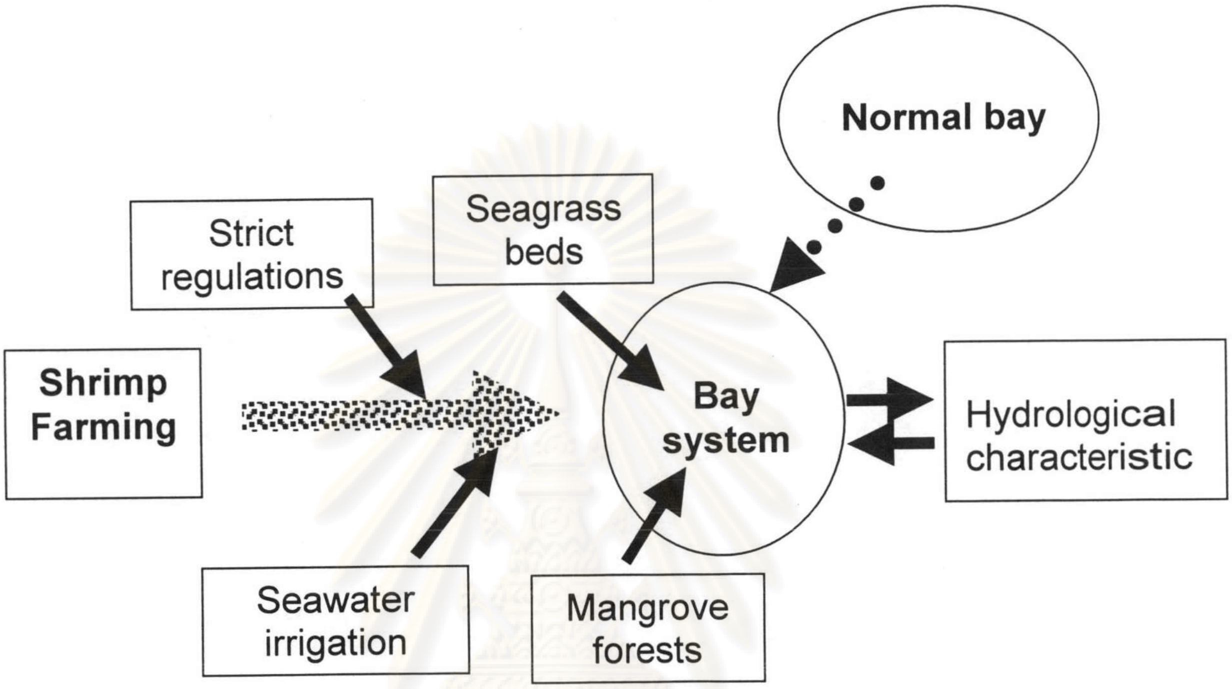


Figure 1.1 Factors determining the environmental condition in Kung Krabaen Bay

The concept of this study was the holistic idea that the landuse for development would affected the chemical, physical and biological environment. Shrimp farming was one of the land use development dominated in this area. Shrimp farming as well as urbanization and agricultures may cause the environmental impacts. However the impacts from shrimp farming in the area were pronounced in particular in forms of organic enrichment. It was evidenced that the area for shrimp farms was increasing, replacing paddy fields and mangroves because of the high price of shrimps. Effluents from shrimp farms contributed loadings of high nutrients and sediment into the canals and affecting the coastal environment. The accumulation and the settling of sediments caused the changes in benthic communities. The increases shrimp farm effluents will affect the chemical components. The nutrient concentration in the system varied according to the intensity of shrimp farming. This in turn would affect the existing benthic communities in term of species composition, abundance and biomass. In the severe case, the area would be enriched and there would be shifts in benthic communities. Opportunistic polychaetes that can tolerate the high organic enrichment may thrived and dominated the area. It is expected that several polychaetes would served as the pollution indicators. The conceptual framework on the ecological studies on the benthic polychaetes with respect to organic environment condition in Kung Krabaen Bay, Thailand is presented in Figure 1.2.

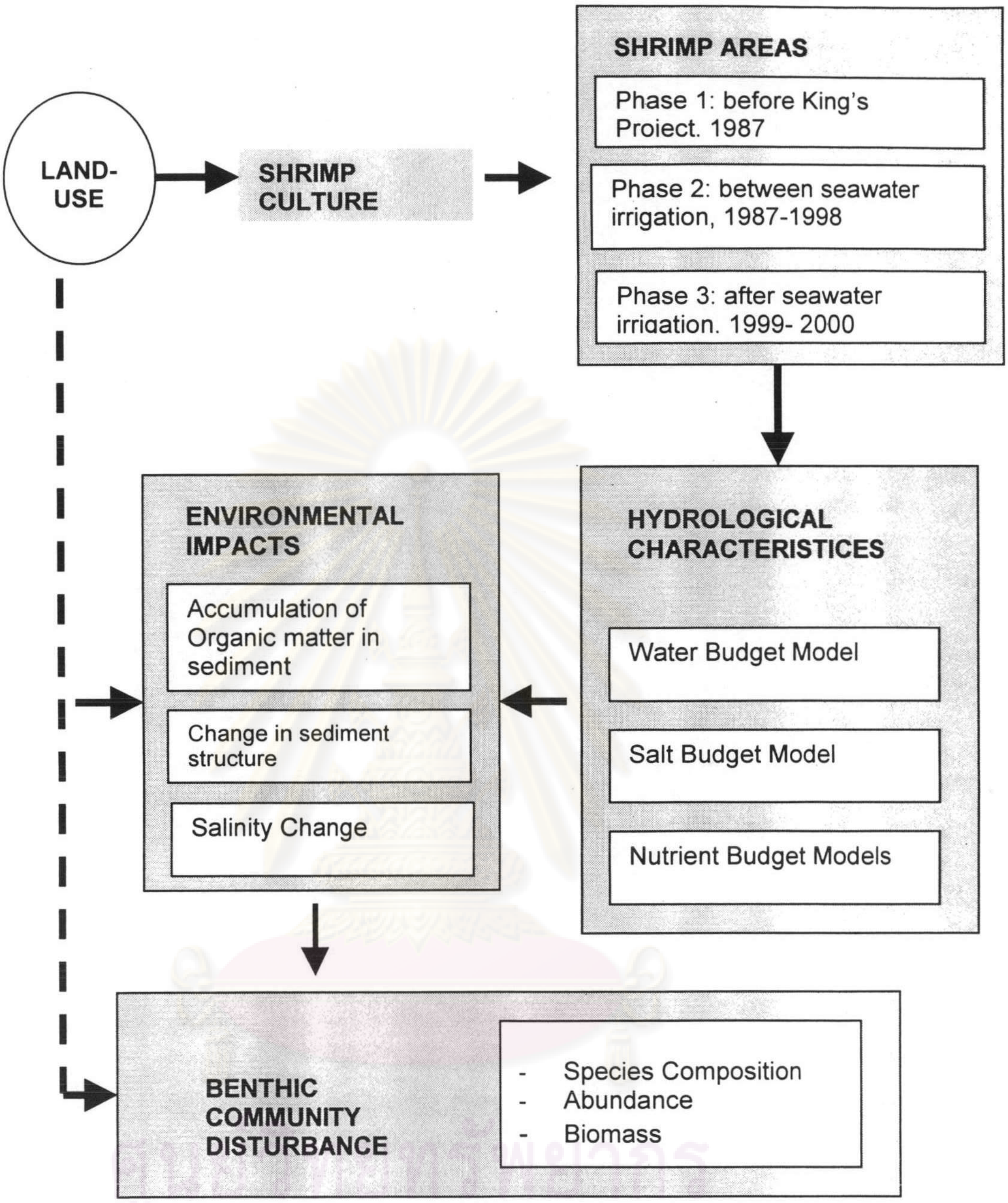


Figure 1.2 Diagram of holistic concept idea of the ecological studies on benthic polychaetes with respect to organic enrichment condition in Kung Krabaen Bay, Thailand.

D. Objectives

The scope of this research will provide the impacts assessment of organic enrichments due to shrimp farm effluents in the Kung Krabaen Bay, Chanthaburi Province. The focus is on the changes in benthic communities in relation to certain chemical parameters. It is also provide the scenarios of the Kung Krabaen Bay in term of shrimp farm development and hydrological characteristics in particular the water, salt and nutrients models prior to the operation of seawater irrigation system and the first operational phase of the system in 1999.

1. To study the changes in the benthic communities, particularly species composition, abundance and biomass of the polychaetes assemblage, due to enriched organic materials in Kung Krabaen Bay.

2. To assess the land-use situation for shrimp farms and the hydrologic characteristics in Kung Krabaen Bay at before and after the installation of seawater irrigation system.

3. To determine polychaetes as indicator species of organic enrichment area.

E. Expected Results

1. The results can be used for forecasting the environmental impacts due to shrimp farming. This would be valuable for the guidelines for environmental management.

2. The results would also provide the guidelines assessment of the seawater irrigation system as one of the alternative to the aqua-culture management.

3. Indicator species of polychaetes would be focus in relation to the organic enrichment environment.

4. Taxonomic keys of the polychaete of Kung Krabaen Bay will be developed. This basic information will be beneficial for the further researches on ecology and other researches on polychaetes.

F. Literature Reviews

1. Description of Study Site: Kung Krabaen Bay

Kung Krabaen Bay (KKB), a small estuarine bay, located at Latitude 12° 36' – 12° 33' N and Longitude 101° 53' – 101° 56' E in Amphoe Thamai , Chanthaburi Province. The bay occupied the area approximately 10 km. The mangrove forest of 1000 rai fringed the bay on the north-east and southern part. Water exchange in this bay was controlled by diurnal tides and runoffs from small canals, both nature and man-made canals. In the western part of the bay, there is a 650 m width strait connecting the bay and open sea, the Gulf of Thailand. The bay was predominantly shallow tidal flats of sand and muddy bottom.

Kung Krabaen Bay represented as a catchment area where stream flow runoffs by 8 small canals, namely, Klong Hin, Klong Ta-U, Klong Ta-kauy, Klong Meaw-suk, Klong Bang, Klong Salud, Klong Plachorn and Klong Nam-kaow. Average stream-flow was approx. 0.123 m^3/s/day and 0.023-0.14 m^3/s/monthly (Boonsong, 1997). The volume of water inflows into the bay was calculated 13.50 x 10^6 m^3/12 hrs in December 1983 versus out flows of 12.259x10^6 m^3/12 hrs. Water exchange volume between high tide and low tide was estimated 86% (Sasaki and Inoue, 1985). Flushing time calculated by Tookwinas , *et al.*, (1996) was approximated 1.03 day.

The average water depth was approximately 2.5 m. The deepest part was at the mouth of the bay while the inner parts were mostly shallow sand and sandy mud flats. The area was under the tidal influences with the mean tidal range of 1.22 m. The offshore currents were affected by the tidal currents. At high tides, the seawater intrusion into the bay at the speed of 0.262 knot and 0.353 knot during low tide (Department of Land Development, 1981). The current speed at the mouth of the bay was 0.24 m/s during the rainy season while the average current speed recorded during the dry season was 0.17 m/s (Boonsong, 1997).

Changes in coastal sedimentation in the bay was rather small. Sedimentation rate was on the average of 3-10 cm/year. Sediment type at shoreline outside the bay was mainly sand while the muddy bottom appeared offshore. There was significant shift in sedimentation between the Southwest monsoon or wet season and the Northeast monsoon or dry season. During the Southwest monsoon, high sedimentation occurred in the central part of the bay but low sedimentation along the coastline and in drainage canals. However the high sedimentation occurred along the coast rather than in the central part of the bay and in the drainage canals during the Northeast monsoon season. Sedimentation rates also fluctuated accordingly to the shrimp farm activities in the nearby area. During the intensive shrimp farm period, suspended clay and silt were high in both the drainage canals and the coastal area. High mud appeared in the drainage canals throughout the year (Tookwinas, et al., 1998).

The rainy season in Chanthaburi usually start from May to October under the influences of the South-west monsoon. The average precipitation recorded during 1961-1980 was approximately 2345 mm with the highest precipitation in June, 512.6 mm.

2. Environmental Conditions of Kung Krabaen Bay

2.1 <u>Biological Characteristic of Kung Krabaen Bay</u>

<u>Mangrove forest</u>

Mangrove forest in Kung Krabaen Bay fringed the northern, southern and eastern shoreline of 30-200 m width and 5 km length. The total mangrove forest was approximated 610 rais (Provincial Forestry Office, 1995). The degraded forest behind the fringes mangrove were allocated for shrimp farming under the King's Project, Kung Krabaen Bay Royal Development Study Center (KKBRDSC) in 1981. The total area allocated was 1,040 rais. The classification of mangrove forests consists of 4 zones according to dominant trees. Zone 1 dominates by the *Avicennia alba, A. marina, Rhizophora apiculata* and *Sonneratia cascolaris* at the fringe of shoreline mostly muddy sand flat area; zone 2 dominates by the *Exoccaria agallocha* and *Clerodendrum inerme* next from zone 1; zone 3 dominates by the *Lumnitzer littorea* and *L. racemosa* at sand dune after group 2; zone 4 dominates by the *Melaleuca leucadendra, Pandanus odoratissima, Hibiscus tiliaccus, Heritiera littoralis,* etc. at the fringe of terrestial area. At present this latter area was developed into the shrimp farm area in Kung Krabaen Bay on the sand ridge area.

Sea-grass beds

Sea-grass beds was evidenced as nursery and feeding ground for marine and estuarine larvae, in particular groupers, shrimps, and blue swimming crabs . Two dominant species of sea-grass were recorded in this bay, *Halodule pinifolia* and *Enhalus acoroides* (Sudara, *et al.*,1991; Aryuthaka, *et al.*, 1992) as shown in Figure 1.3). The former species has thin needle-shaped leaves covering the tidal and sub-tidal zone and densely bed at the northern to eastern part of the bay. The latter species was big in size appeared as patch beds in the sub-tidal zone of northern and southern part of the bay. In addition, the seaweed, *Acetabularia major*, was the common green seaweed growing on sand and substrates as woods, rocks and shells (Lewmanomont and Ogawa, 1995). The total seagrass bed as estimated by KKBRDSC was approximately 1,559.75 rai.

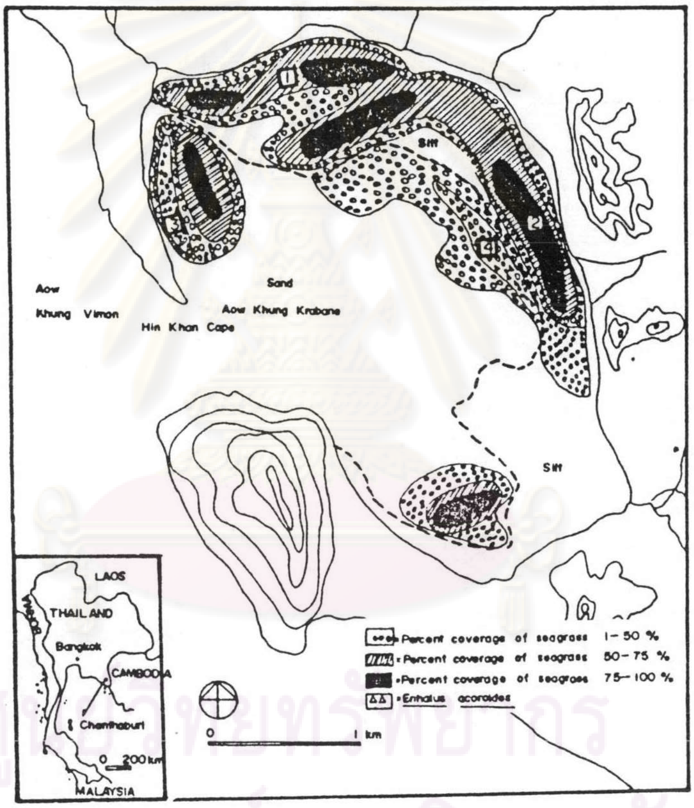


Figure 1.3 Seagrass beds at Kung Krabaen Bay, Chanthaburi Province, Thailand (After Sudara, *et al.,* 1991)

Phytoplankton and Zooplankton

In 1980, the phytoplankton and zooplankton in the Kung Krabaen Bay were investigated by the Institute of Science Research and Technology of Thailand (1981). The phytoplankton density was high of 19,429 cell/m^3 when compared to the vicinity of Wen River, Chanthaburi River and Kho-Nok Bay. The dominant phytoplankton species belonged to Chrysophyta group. For the zooplankton, the dominant groups were crustacea approx. 98 ind./m^2. Marumo, et al.(1985) reported that the phytoplankton abundance in the bay was lower than the coastal area. The diatoms, *Chaetoceros* sp., contributed dominantly 73% of the bay while the coastal area was dominant by phytoplankton, *Trichodesmium* sp. and *Ceratium* sp. But in the channel the diatom, *Chaetoceros compressus*, contributed more than 90%. Nozawa and Angsupanich (1985) found that the primary production in the southern part of the bay had the highest value in the range of 0.418-0.498 mg C/m^3 while the coastal area occupied 0.01- 0.023 mg C/m^3 and lower than the channels, 0.066-0.217 mg C/m^3.

Benthic Fauna

Department of Land Development (1981) reported on the benthic fauna survey in Kung Krabaen Bay that only gastropod was found at density 1.79 ind/ft^2. The result was rather similar to that of TESCO Report (1994). They found only small number of gastropods and bivalves. Polychaetes were not recorded at the time possibly due to sampling methodology. However Marumo, et al. (1985) found that Calanoidea, *Oithona brevicornis*, and Harpacticoida copepoda contributed 43% of epibenthic fauna. Polychaetes was found in the bay and cannals sharing 4% and 3% of epibenthic fauna, respectively, but major group was copepoda larvae 49% and 84%, respectively.

Chullasorn (1995) found that the common meiobenthic harpacticoid copepod, *Longipedia* sp. and *Ectinosoma* sp. were dominant species in the sea-grass bed, *Halodule pinifolia.* Other species recorded were *Canuella* sp., *Lacphonte* sp., *Stenhelia* sp., *Typhlamphiascus* sp., *Harpacticus* sp., *Cletodes* sp., *Enhydrosoma* sp. and *Tegastes* sp. Some benthic meiofauna was investigated by Ayuthaka (1990). Free-living nematodes was the highest abundance ranging of 75% to 95% and the harpacticoid copepods ranked second with a range of 1% to 23%. Besides these the kinorhynch, ostracod, amphipod, tardigrade, cumacean, turbellarian, polychaete, halacarid, bivalve, and crustacean nauplii were also found.

2.2 Water Quality in Kung Krabaen Bay

It was concluded by Department of Land Development (1981) that water quality in KKB was in good condition for coastal aquaculture. The number of shrimp ponds during that period were low. Water quality in the preceding years after the establishment of KKBRDSC in 1987 was still in good condition reported by Burapha University (1993). But the shrimp farming activities in the area contributed organic enrichment to the bay. The eutrophic conditions in the Kung Krabaen Bay, indicated by reports of plankton blooms and red tides in drainage canals and the coastal area, were pronouced in relation to the increases in the shrimp farm areas (Tookwinas, et al., 1995: Suthemeechaikul and Wongsangcharn, 1995; Tookwinas, et al., 1996; Boonsong, 1997).

It is obvious that the intensive shrimp culture play the important role in the environmental impact, especially water quality. During the intensive shrimp farming periods, water quality in general was enriched with nutrients, in particular in the drainage canals as compared to the coastal area (Suthemeechaikul and Wongsaencharn, 1995). The phytoplankton bloom in drainage canals indicated the high effluents mainly nutrients accumulating in the water near shrimp ponds as reported by Tookwinas, et al. (1996). However the quality of water in the bay was in better condition for aquaculture than in the drainage canals (Tookwinas, 1993; Burapha University, 1993; KKBRDSC, 1996, 1997 and 1998; Boonsong, 1997). This was probably affected by the action of tides. However, BOD measurement recorded during 1992 and 1993, were between 1.7 and 4.33 mg/l.

Sediment Properties and Organic Matters in Kung Krabaen Bay

Kung Krabaen Bay characterized the shallow coastal water that the bottom sediment was easily disturbed by wind and wave actions. Saengroongruang and Dumrak (1998) reported that the central of bay was mainly composed of sand of approximately 89.6%. The sand fraction decreasing facing inland while the high content of mud increasing, 30.4% and 21.4% in drainage and supporting canals respectively. The pH value in sediment varied from 7.5 to 8.48 and higher in rainy season than in summer. Organic matter was highest in drainage canals about 6.97 mg/g of soil and decreased seaward: at 500 m from shore, 0.77; at the central of bay, 0.25 mg/g of soil, coastal zone, 2.04. Total nitrogen and total phosphorus were high during the intensive shrimp farm period. The natural organic sources in the Kung Krabaen Bay were from the biological and chemical processes from the mangrove forests and seagrass beds. Boonsong (1997) estimated that the natural organic matter in the bay was 24.85 tons/ha/yr.

According to Pollution Control Department (1997), the average BOD loading from shrimp farms in the Tachin River was approximately 35.04 g/rai/day while the domestic loading estimated 0.5 g/person/day. The relative calculation of BOD loading was carried out for comparison between the shrimp farming and domestic waste in Kung Krabaen Bay area. In 1997, the total shrimp farm area was 1881.5 rais (personal communication of KKBRDSC's staff) while the local residents totaled 2,090 persons (modified from Provincial Royal Forestry Office, 1995). The BOD from shrimp farming contributed 65,927.76 g/day and from the domestic waste 1,045 g/day giving 63:1 ratio. It is evidence the shrimp farming activity was the major source of organic enrichment.

Shrimp farms around the bay were the major sources of organic matter in this area. The bulks of organic matter were released during growing-out period, the exchange of water and draining processes from the intensive shrimp farms. Source of organic material as in Table 1.2 came from artificial feeds, tea-seeds, shrimp protein itself , shrimp's waste releasing and fertilizers (Suthemechaikul and Wongsaengcharn, 1995).

Table 1.2 Average content of nitrogen and phosphorus in terms of dry weight from various sources (Suthemechaikul and Wongsangcharn, 1995).

Source	% Dry weight (g) analysis	N (% dry weight)	P (% dry weight)
Feed	92.47 ± 0.80	7.86 ± 0.42	1.15 ± 0.07
Urea	-	46.00	-
Fertilizer, 15-15-15	-	15.00	15.00
Tea seed	91.80 ± 0.20	0.18 ± 0.01	0.16 ± .01
Shrimp seeds			
PL 15	19.18	11.04	1.10
PL 18	20.97	11.01	1.09
PL 21	20.99	11.05	1.11

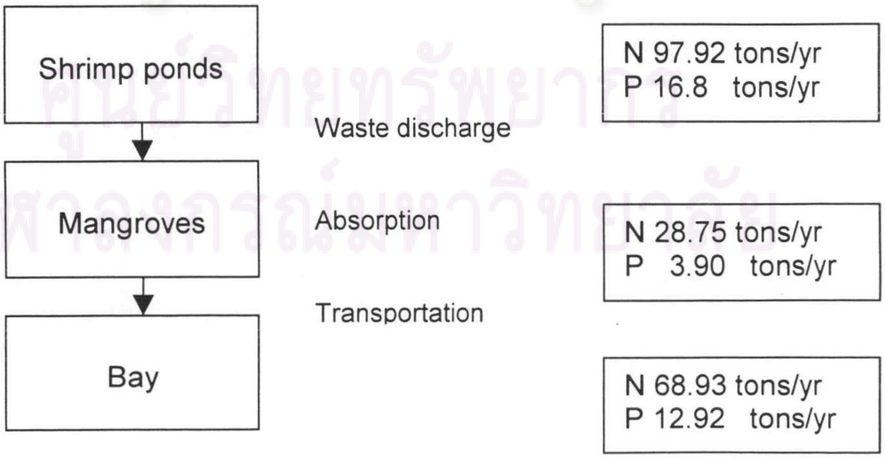


Figure 1.4 Estimated N and P content transported from shrimp ponds to Kung Krabaen Bay (Boonsong, 1997)

Boonsong (1997) reported that amount of suspended sediment released to the bay was approximately 77,569 tons/yr with the additions of nitrogen of 97.7 tons/yr and phosphorus of 16.8 tons/yr. Mangrove forests can absorbed nitrogen 28.7 tons/yr and phosphorus 12.9 tons/yr for their utilization. Excess N and P were transported into the bay calculated at 68.9 and 12.9 tons/yr respectively (Figure 1.4).

Kung Krabaen Bay Carrying Capacity

Nutrients, both organic and inorganic substances, were released into the bay through the drainage canals. Tookwinas and Suthemechaikul (1996) estimated the carrying capacity of the bay by using the mass balance model at ammonia-nitrogen 0.1 mg/l. They had calculated the maximum ammonia loading inside the bay of 739.53 kg/day and the output of 2,154.40 kg/day. They concluded that the carrying capacity of the bay was 552.93 ha while the total shrimp farm area at that time was 142.16 ha. Boonsong (1997) also estimated the carrying capacity of the Kung Krabaen Bay to 563.41 ha. The water exchange, affected by daily currents, according to the flushing time was approximate less than 2 days (Tookwinas and Suthemechaikul, 1996; Boonsong (1997). However Boonsong (1997) suggested that the mangrove area in Kung Krabaen Bay could help in improving water quality. She had estimated the suitable proportion of mangrove forest area to the shrimp farm area that would help to lessen the nitrogen and phosphorus loadings in the bay were 4.25:1 and 5.39:1 respectively. The actual ratio of mangroves to shrimp farm area measured at the time was 1.25:1. Thus she suggested that the mangrove restoration and plantations in the area should be launched to increase the mangrove area.

3. Impacts of Organic Enrichment on Benthic Communities

Impacts on Water Quality and Bottom Sediment

The organic effluents from shrimp farms, mainly remaining food and wastes, would settle to the bottom of the pond and accumulated in the sediment. Some would dissolved in water. These organic loading would be transported from shrimp ponds into drainage canals and entered the bay system. Suthemechaikul and Wongsangcharn (1995) concluded that the bottom sediment in most shrimp ponds were the place for organic material accumulation. They found that nitrogen and phosphorus concentrations at surface layers of pond sediment were higher than those at deeper layer sediment. The organic materials induced the decomposition process by benthic bacteria which lead to hypoxia or anoxia environment in the sediment in shrimp ponds. In anaerobic environment the production of gas hydrogen sulfide was poisonous to living organisms. This condition may affect the structure of benthic communities in terms of species composition, abundance and biomass. Only few species, opportunistic species, can survive and tolerate in the oxygen deficiency condition by increasing their biomass, such as the capitellid and spionid polychaetes (Pearson and Rosenberg, 1978).

Impact on Benthic Communities Structure

Deposit-feeding polychaetes which feed on surface and sub-surface sediment layer can created biogenic re-working to sediment. They induced the the physical, chemical and biological changes in bottom sediment. The deposit-feeders always dominate area of high content of organic material while the suspension-feeders are found small number and favor to live on stable substrate. Muddy bottom in estuaries can be resuspended and decreased the feeding efficiency of feeding in these animals. The dissolved oxygen, pH, and sulfide in enriched organic sediment were always relative high compared to other areas. These conditions favored the population growths of opportunistic species which are mostly small in size and rapid reproduction. They could colonize the sediment in short periods. Charoenpanich, *et al.*(1993) and Khomvilai (1997) found that the opportunists polychaete capitellids can tolerate enriched or polluted environment and play the active role biogenic re-working to improve the sediment by decreasing hydrogen sulfide concentration in sediment. The benthic communities structure in natural equilibrium ecosystem consisted of diversing organisms in different trophic levels, namely, herbivores, deposit-feeders, suspension-feeders and carnivores-scavengers. However in the enriched organic sediment, the detritus-feeders rapidly increase their populations. They can survive in the environmental conditions of low oxygen, high turbidity, and high concentration of nutrients and organic materials. This stress condition, the RPD layer shrift upward and diminished the area for suspension-feeders. Pearson and Rosenberg (1978) noted that the non-selective deposit-feeders polychaete, such as *Peloscolex benedeni* and *Capitella capitata* could live in organic enrichment area.

Another impacts of organic enrichment on benthic communities were the shifts in numerous of species diversity and abundance. The chemical and physical properties of water and bottom sediment would changed in the organic enrichment environment. Dissolved oxygen content would be severely decreased by aerobic bacteria due to biodecomposition processes in water column and sediment. The denitrifixation process in sediment may resulted in hypoxia or anoxia condition. The abundance, biomass and diversity of benthic organism would also decreased. Pearson and Rosenberg (1978) demonstrated the species-abundance-biomass (SAB) diagram of change along a gradient of organic enrichment (Figure 1.5).

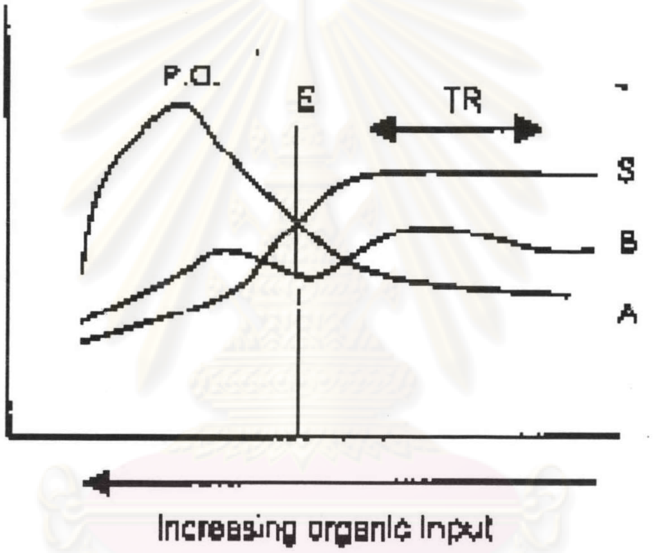


Figure 1.5 Generalized SAB diagram of change along a gradient of organic enrichment: S, species numbers; A, total abundance; B, total biomass; P.O., peak of opportunistics; E, ecotone point; TR, transition zone. (Pearson and Rosenberg, 1978)

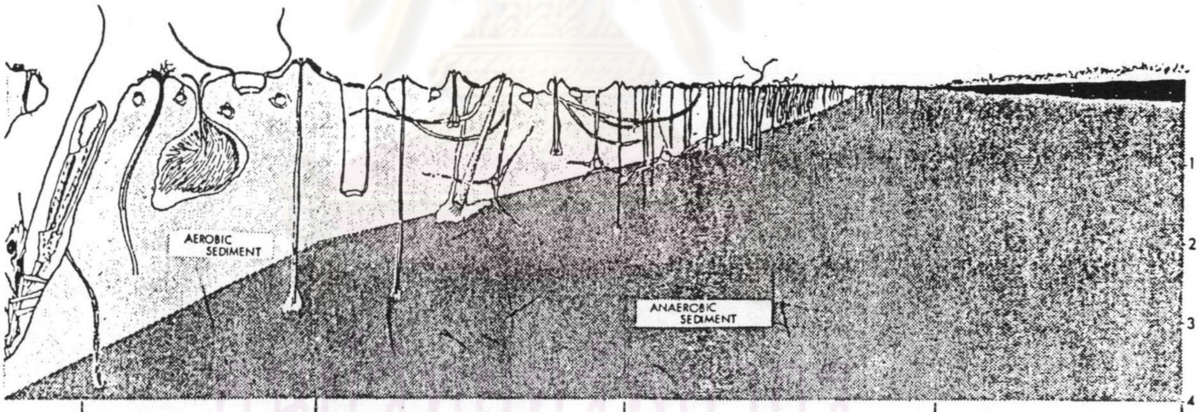
Pearson & Rosenberg (1978) suggested the composite of number of species, abundance , and biomass or SAB relationships along an environment gradient of organic enrichment that may be generally applicable to study a spatial change at all areas subject to organic enrichment. Explanation was given that the poor community abundance (A) at highly enriched organic content encountered rise dramatically. The increase at P.O. (peak of opportunistics) is caused by extremely abundant populations of one or two opportunistic species. This community, rich in individuals, has a narrow distribution and the numbers fall equally rapidly down to the ecotone point (E) as distance from the source of organic material is increased. Following the ecotone point abundance declines to the steady state level usually found under normal condition as pointed by TR zone (the transition zone). Meanwhile a maximum in the number of species (S) is reached after the ecotone point, before a decline to the lower species numbers usual in the unperturbed environment. Biomass (B) of the was lowest at high organic enriched point and slightly increased a low peak of biomass created by these opportunist population before slightly dropped at the ecotone point before distinctly shifted upward to the low organic enriched area in the transition zone.

The number of species is high and the abundance will be small in natural stabilize equilibrium (Odum and Odum, 1959). The increased organic input to the system will in turn increase the biomass and abundance of the opportunistic species. These opportunistic species can tolerate the stress of oxygen deficiency in the system. They can survive and increase their populations indicated by high peak of abundance curve.

Organic Enrichment and Indicator Species

Indicator species is characterized by its small size, common species and widely distribution. The environmental impact assessment consumed time and budgets. The use of living organism as indicators for monitoring of pollution could become more cost-effectiveness. Indicator species was not specified by one species but there were possibly several species. KiKuchi (1991) found the spionid, *Paraprionospio* sp.A, *Prionospio cirrifera* and *Capitella* sp. dominated in heavily polluted shallow mouth in Osaka Bay. Gee, *et al.* (1985) reported the nematodes population decreased in high organic matter but harpacticoid copepod population increased in high organic environment in Solberg Stand in Oslofjord. Changes in these species could use to indicate the impact of pollution on benthic community. In Thailand Tansakul (1995) conducted monitoring survey on impacts of shrimp farm effluents on coastal environment in Ranode District and Satingphra District, Songkhla Province. He found that low diversity of plankton and benthic fauna occurred in coastal water adjacent to shrimp farms. The biomass increased in the area far from shrimp activity. He also reported that capitellid polychaetes were common in high organic enrichment sediment.

Pearson and Rosenberg (1978) demonstrated the shifts in fauna and sediment structures along a gradient of organic enrichment (Figure 1.6). This showed that certain species can be used to indicate the change that occurred along the gradients. The occurrence of certain groups of benthic fauna seemed more realistic in the monitoring of changes in community structure than the use of single indicator species (Gray, 1981).



ZONE	NORMAL	TRANSITORY		POLLUTED	GROSSLY POLLUTED
TYPICAL MACRO-FAUNA DOMI-NANTS	Nucula Amphiura Terebellides Rhodine Echinocardium Nephrops	Labidoplax Corbula Goniada Thyasira Pholoe	Chaetozone Anaitides Pectinaria Myriochele Ophiodromus	Capitella Scolelepis	No MACROFAUNA Surface covered by Fibre 'blanket'

Figure 1.6 Diagram of changes in fauna and sediment structure along a gradient of organic enrichment. (After Pearson and Rosenberg, 1978)

Bailey-Brock, et al.(1991) reported the polydorid polychaetes dominated the ground of shrimp and oyster culture on Oahu Island of Hawaii, namely *Polydora nuchalis*, *Polydora websteri*, and *Polydora armata*. Shin and Koh (1999) found the dominant polychaete species *Heteromastus filiformis, Tharyx pacifica,* and *Lumbrineris longifolis* were common from the polluted area resulted from industrial pollution in the several estuaries of South Korea. The similar result as described by

Tunsakul (1995). Sanguansin (1995) also reported that around the fishing pier at Ban Phe District, Rayong Province, the capitellidae was the dominant group.

Odum in 1969 and O'connor in1972 (Pearson and Rosenberg, 1978) described that an equilibrium mature ecosystem, the benthic community consisted of deposit-feeder, suspension-feeders, carnivorous-scavengers, and herbivores. High organic sediment and low oxygen content environment were suitable for detritus feeders which tolerate such condition.

Pearson and Rosenberg, (1978) presented a diagram of changes in fauna and sediment structure along a gradient of organic enrichment as shown in Figure 1.6. They described that the changes in trophic structure and sediment stability along the gradient were accompanies by changes in the depth of sediment occupied by the macrofauan and in the physical size of the individual species. At the low input end of gradient (normal condition) a complicated faunal structure involving burrow complexes of large species such as *Nephrops norvegicus, Brissopis lyifera* and *Scalibregma inflatum* intermingled with smaller tube dwelling and burrowing species is maintained to depths far below 10 cm in larger surface area of oxygenated sediment over RPD layer in silty sediment. The increasing of organic materials, correlating with high sulfide and low oxygen, in sediment on transitory zone caused the larger species and deeper burrowing forms gradually eliminated and replaced by greater numbers of lamellibranch suspension and surface deposit-feeders, e.g. *Thyasira* and *Corbula*, and holothurian and annelids, which were either static or relatively inactive in the sediment. This must have the concomitant result of further restricting the passage of oxygen into the sediment and the free movement of reduced material upwards. The original complex structure tends towards laminar stratification with oxygenated area confined to a narrow zone immediately below the sediment-water interfaces. As organic inputs further increased, the width of this zone decreases progressively as the RPD layer approached the surface and son the potential area available to those faunal species requiring the oxygenated environment was progressively reduced (in polluted zone). Those species surviving at this stage were smaller than those of the earlier stages. Along any organic gradient the reduction in structural and ecological complexity was accompanied by a decrease in physical size of the macrofaunal species involved, e.g. *Capitella capitata* and *Scolelepis* spp. At the high inputs end of the gradient the sediment was almost completely stable and anoxic up to the water interface. These were confined to the immediate sub-surface layers, and were eliminated should the oxygen demand of the sediments become great enough to cause de-oxygenation of the overlying water column under the prevailing hydrographic conditions. In this stage of grossly polluted condition there were rare or no macrofaunal found.

Evaluation of Organic Enriched Benthic Communities

The study of benthic communities in most areas usually identified environmental factors that influence benthic community structure and evaluated the health of benthic communities as an indication of environmental perturbations of natural or anthropogenic origin. Evaluation of environmental disturbance usually based on the interval monitoring of water quality. This method is widely popular for detection water pollutions and consumes short period of determination in laboratory.

The benthic communities structure and assessment of changes within communities was the alternative method used in environmental impact assessment. Grall & Glemaree (1997) formulated an analytic method of evaluation based on the recognition of ecological groups of different sensitivity to organic loading. The use of relative abundance of these ecological groups allowed identification of stages of perturbation including eutrophication. Engle, *et al.* (1994) presented an index developed for estuarine macrobenthos in the Gulf of Mexico that discriminated between areas with degraded environmental conditions and areas with undegraded or reference conditions. They suggested a discriminant analysis used to identify a suite of measures of benthic community composition and diversity that would successfully distinguish degraded from undegraded sites. This resultant benthic index was composed of a linear combination of three factors: the Shanon-Wiener diversity index, the proportion of total benthic abundance as tubificid oligochaetes, and the proportion of total benthic abundance as bivalve molluscs, to evaluate the spatial patterns of degraded benthic resources in the Gulf of Mexico.

Pearson & Rosenberg (1978) created a SAB diagram used the synthetic parameters, species richness (S), abundance (A) and biomass (B), and identified a group of opportunistic species of universal character. These species-abundance (SAB) curves summarize the changes in the basic faunal parameters occurring along transects originating at the effluent discharge points and culminating in areas beyond the effects of the discharged material. The explanation of this situation reveals that the sediment in the vicinity of the discharge point were devoid of benthic macrofauna. On this side, the benthic community was composed of only few pollution-tolerant oppotunistic species with low biomass but high abundance. Further away from the high enriched area, the number of species increased. Beyoun the ecotone point the number increased more rapidly. On the less polluted side of the ecotone point, the different transitory assemblages gradually approached the composition of the community in the unpolluted environment with high biomass but less abundance. At this ecotone point, species from both side communities were found or as transition zone region where two organizations met along gradually enriched transects.

Methods to evaluate benthic communities health traditionally measured abundance, diversity, or the presence of pollution indicator species in area of disturbance (Pearson and Rosenberg, 1978). Warwick (1986) presented an abundance and biomass comparison (ABC) method of determining levels of disturbance (pollution-induced or otherwise) on benthic macrofauna communities. The basis is concerned K-selected or conservative species, with the attributes of large body size and long life-span. These are rarely dominant numerically but are dominant in terms of biomass. The presence of smaller r-selected or opportunistic species with a short life-span, which are usually numerically dominant but do not represent a large proportion of the community biomass. The ABC method involved the plotting of separate k-dominance curves for species abundances and species biomasses on the same graph. Comparisons were made of the forms of these curves. Three conditions in which these curves were formed: unpolluted, moderate polluted and grossly polluted, as shown in Figure 1.7. In unpolluted condition the biomass curve lies over abundance curve. Under moderate pollution the biomass and abundance curves are closely coincident and may cross each other one or more times. As pollution becomes more severe, benthic communities becomes increasingly dominated by one or a few very small species and the abundance curve lies above the biomass curve (Clarke & Warwick, 1994).

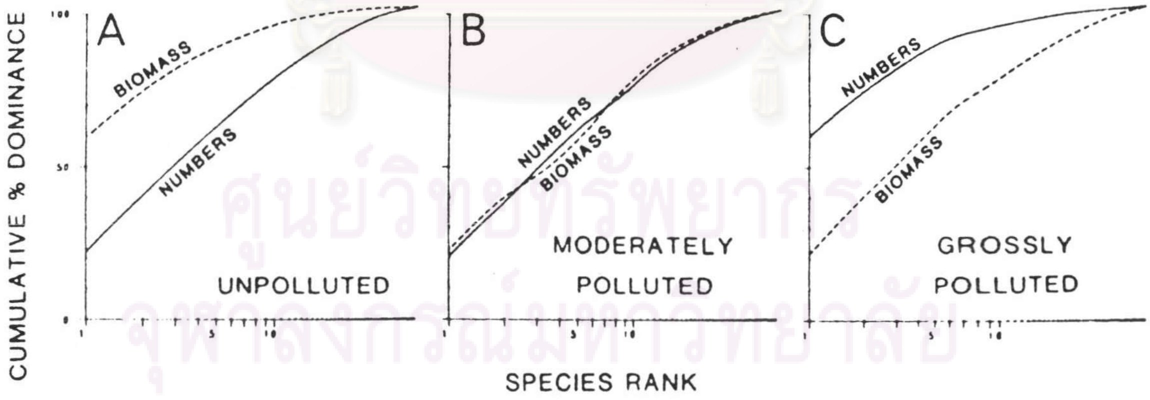


Figure 1.7 Hypothetical k-dominance curves for species biomass and abundance, showing unpolluted, moderately polluted and grossly polluted condition.