คุณสมบัติของน้ำทะเลบริเวณท่าเรือประมงพื้นบ้านในจังหวัดพังงา หลังภัยพิบัติสึนามิ

นายพรอุมา ไกรนรา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต

สาขาวิชาชีววิทยาสิ่งแวดล้อม

มหาวิทยาลัยเทคโนโลยีสุรนารี

ปีการศึกษา 2556

PROPERTIES OF SEA WATER AROUND LOCAL FISHERY PIERS IN PHANG-NGA PROVINCE AFTER A DEVASTATING TSUNAMI

Porn-uma Krainara

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology

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PROPERTIES OF SEA WATER AROUND LOCAL FISHERY PIERS IN PHANG-NGA PROVINCE AFTER A DEVASTATING TSUNAMI

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Thesis Examining Committee

(Asst. Prof. Dr. Nooduan Muangsan)

Chairperson

(Asst. Prof. Dr. Nathawut Thanee)

Member (Thesis Advisor)

(Prof. Dr. Murray Potter)

Member

(Assoc. Prof. Dr. Napat Noinumsai)

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พรอุมา ไกรนรา : คุณสมบัติของน้ำทะเลบริเวณท่าเรือประมงพื้นบ้านในจังหวัดพังงาหลังภัยพิบัติสึนามิ (PROPERTIES OF SEA WATER AROUND LOCAL FISHERY PIERS IN PHANG-NGA PROVINCE AFTER A DEVASTATING TSUNAMI) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.ณัฐวุฒิ ธานี, 141 หน้า.

ภัยพิบัติสึนามิที่เกิดในมหาสมุทรอินเดียเมื่อวันที่ 26 ธันวาคม พ.ศ. 2547 ทำให้เกิดความเสียหายร้ายแรงต่อทรัพย์สิน ทรัพยากรทางทะเล และชีวิตมนุษย์ วัตถุประสงค์หลักของการวิจัยนี้เพื่อศึกษาคุณสมบัติทางกายภาพ เคมี และชีวภาพ และปริมาณโลหะหนัก ของน้ำทะเลบริเวณท่าเรือประมงพื้นบ้านในจังหวัดพังงา 3-4 ปี หลังประสบภัยพิบัติสึนามิ โดยตรวจสอบคุณภาพน้ำระหว่างเดือนมกราคมถึงเดือนธันวาคม พ.ศ. 2551 จาก 9 สถานี ในพื้นที่ 3 อำเภอ ของจังหวัดพังงา คือ อำเภอคุระบุรี อำเภอตะกั่วป่า และอำเภอท้ายเหมือง โดยทำการตรวจวัดคุณสมบัติทางกายภาพ คือ อุณหภูมิ ความโปร่งใส ปริมาณของแข็งที่ละลายน้ำทั้งหมด และค่าการนำไฟฟ้า คุณสมบัติทางเคมี คือ ความเป็นกรด-เบส ความเค็ม ปริมาณออกซิเจนที่ละลายน้ำ ปริมาณออกซิเจนที่จุลชีพใช้ในการย่อยสลายสารอินทรีย์ และปริมาณออกซิเจนที่สารเคมีใช้ในการย่อยสลายสารอินทรีย์ในน้ำ คุณสมบัติทางชีวภาพ คือ กลุ่มชนิดและความหนาแน่นของแพลงก์ตอนพืชและแพลงก์ตอนสัตว์ และปริมาณโลหะหนัก คือ ตะกั่ว แมงกานีส เหล็ก และ โครเมียม ผลการศึกษาพบว่าทั้งคุณสมบัติทางกายภาพและเคมีมีการเปลี่ยนแปลงน้อยมาก ซึ่งอยู่ในสภาวะปกติทุกพื้นที่ โดยอุณหภูมิของน้ำอยู่ในช่วง 29.84-31.29 องศาเซลเซียส ความโปร่งใสอยู่ในช่วง 49-108 เซนติเมตร ปริมาณของแข็งที่ละลายน้ำทั้งหมดมีค่าอยู่ระหว่าง 17,060-62,240 มิลลิกรัมต่อลิตร ค่าการนำไฟฟ้าอยู่ระหว่าง 34.12-52.48 มิลลิซีเมนต่อเซนติเมตร ความเป็นกรด-เบสมีค่าขึ้นลงอยู่ในช่วง 6.69-7.94 ค่าความเค็มเปลี่ยนแปลงอยู่ในช่วง 19.48-30.28 ส่วนในพันส่วน ปริมาณออกซิเจนที่ละลายน้ำมีค่าอยู่ในช่วง 6.36-7.49 มิลลิกรัมต่อลิตร ปริมาณออกซิเจนที่จุลชีพใช้ในการย่อยสลายสารอินทรีย์มีค่าอยู่ระหว่าง 2.04-3.80 มิลลิกรัมต่อลิตร และปริมาณออกซิเจนที่สารเคมีใช้ในการย่อยสลายสารอินทรีย์ในน้ำมีค่าอยู่ในช่วง 34.0-63.3 มิลลิกรัมต่อลิตร ผลของการตรวจนับกลุ่มชนิดและความหนาแน่นของแพลงก์ตอนพืชและแพลงก์ตอนสัตว์ทุกพื้นที่พบว่าอยู่ในภาวะปกติ ซึ่งพบแพลงก์ตอนพืชทั้งหมด 18 เจอเนรา ในกลุ่ม Euglenophyta Chlorophyta Chrysophyta Cyanophyta และ Pyrrhophyta โดยกลุ่ม Cyanophyta คือ *Oscillatoria* spp. *Spirulina* spp. *Trichodesmium* spp. และ *Urothrix* spp. ปริมาณสูงสุด $1,875 \times 10^3$ เซลล์ต่อลิตร ที่สถานีที่ 9 และตรวจสอบแพลงก์ตอนสัตว์ทั้งหมด 6 ไฟลัม ได้แก่ Chordata Annelida Arthropoda Rotifera Mollusca และ Protozoa ซึ่งพบว่าในทุกพื้นที่ Arthropoda มีปริมาณสูงที่สุด และยังพบว่า สถานีที่ 4 และ 8 พบ Arthropoda ทั้งหมด 7

กลุ่ม คือ cycloploid copepod calanoid copepod cladocera hapecticoid copepod balanus nauplii nauplius crustacean และ zoea larva ของ Brachyura ในปริมาณมาก ซึ่งจากการตรวจนับพบว่า ไฟลัม Arthropoda พบมากทุกพื้นที่ โดยบริเวณสถานีที่ 9 พบมากที่สุดมีจำนวน 470 ตัวต่อลิตร และพบน้อยที่สุดที่สถานีที่ 6 มีจำนวน 30 ตัวต่อลิตร และจากการตรวจวัดปริมาณโลหะหนักในแต่ละสถานีมีค่าแตกต่างกัน โดยพบว่า ปริมาณตะกั่วสูงสุด 0.3649 ไมโครกรัมต่อลิตร ที่สถานีที่ 8 ปริมาณแมงกานีสสูงสุด 0.2143 ไมโครกรัมต่อลิตร ที่สถานีที่ 1 และพบปริมาณเหล็กและโครเมียมสูงสุด คือ 0.1849 ไมโครกรัมต่อลิตร และ 0.0417 ไมโครกรัมต่อลิตร บริเวณสถานีที่ 5 ซึ่งปริมาณของโลหะหนักเหล่านี้ที่พบในบริเวณพื้นที่ต่างๆ โดยเฉพาะปริมาณเหล็กเมื่อเปรียบเทียบกับค่ามาตรฐานคุณภาพน้ำทะเลปกติยังมีค่าอยู่ในระดับที่ต่ำมาก

สาขาวิชาชีววิทยา
ปีการศึกษา 2556

ลายมือชื่อนักศึกษา_______________
ลายมือชื่ออาจารย์ที่ปรึกษา_______________
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม_______________

PORN-UMA KRAINARA : PROPERTIES OF SEA WATER AROUND LOCAL FISHERY PIERS IN PHANG-NGA PROVINCE AFTER A DEVASTATING TSUNAMI. THESIS ADVISOR : ASST. PROF. NATHAWUT THANEE, Ph.D. 141 PP.

PHYSICAL PROPERTIES, CHEMICAL PROPERTIES, PHYTOPLANKTON, ZOOPLANKTON, HEAVY METALS, SEA WATER, TSUNAMI 2004

The Indian Ocean tsunami on 26 December 2004 caused extensive destruction to property and marine resources and considerable suffering and loss of human life. The main objectives of this research were to study the physical, chemical, biological, and heavy metal properties of sea water around local fishery piers in Phang-Nga province, Thailand, 3-4 years after this destructive tsunami. Water quality was assessed between January and December 2008 at nine stations in three districts: Khura Buri; Takua Pa; and Tai Meung. The following specific parameters were studied: 1. Physical: temperature, transparency, total dissolved solids, and electrical conductivity; 2. Chemical: pH, salinity, dissolved oxygen, biochemical oxygen demand, and chemical oxygen demand; 3. Biological: phytoplankton and zooplankton diversity and densities; and 4. Heavy metals: Pb, Mn, Fe and Cr. All physical and chemical values fell within the ranges that are considered normal for unpolluted water: temperature ranged from 29.84-31.29°C; transparency ranged from 49-108 cm; total dissolved solids ranged from 17,060-26,240 mg/l; electrical conductivity ranged from 34.12-52.48 mS/cm; pH ranged from 6.67-7.94; salinity ranged from 19.48-30.28 ppt; dissolved oxygen ranged from 6.36-7.47; biochemical oxygen demand ranged from

2.04-3.80 mg/l; and chemical oxygen demand ranged from 34.0-63.3 mg/l. The numbers and diversity of phytoplankton and zooplankton at all sites fell within the normal range for unpolluted seawater. Eighteen genera of the following phytoplankton phyla were recorded: Euglenophyta; Chlorophyta; Chrysophyta; Cyanophyta; and Pyrrhophyta. The Cyanophyta (*Oscillatoria* spp., *Spirulina* spp., *Trichodesmium* spp., and *Urothrix* spp.) were most abundant, with a maximum of 1,875x10^3 cells/l at Site 9. Six phyla of zooplankton were identified: Chordata; Annelida; Arthropoda; Rotifera; Mollusca; and Protozoa. Arthropoda were the most numeral at all sites, with the largest numbers of individual arthropods being found at Site 4 and Site 8. The arthropods belonged to the following seven groups: cycloploid copepod; calanoid copepod; cladocera; hapecticoid copepod; balanus nauplii; nauplius crustacean; and zoea larvae of Brachyura. The highest density of arthropods (470 individuals/l) was found at Site 9 and the lowest (30 individuals/l) at Site 6. Concentrations of heavy metals differed between stations, with maximum levels as follows: Pb 0.3649 μg/l recorded at Site 8; Mn 0.2143 μg/l at Site 1; and Fe 0.1849 μg/l and Cr 0.0417 μg/l at Site 5. These levels, especially for Fe, are very low when compared with normal marine water quality standards.

School of Biology | Student's Signature P. Krainara

Academic Year 2013 | Advisor's Signature

Co-advisor's Signature

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Porn-uma Krainara

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LIST OF ABBREVIATIONS

B.E.	=	Buddhist era
St.	=	Station
Tran.	=	Transparency
Temp.	=	Temperature
°C	=	Celsius
Sal.	=	Salinity
ppt.	=	Part per thousand
DO	=	Dissolved oxygen
mg/l	=	Milligram per litter
pH	=	Potential hydrogen ion
EC	=	Electrical conductivity
mS/cm	=	Milli siemens per centimeter
TDS	=	Total dissolved solid
BOD	=	Biochemical oxygen demand
COD	=	Chemical oxygen demand
Pb	=	Lead
Mn	=	Manganese
Fe	=	Iron
Cr	=	Chromium
µg/l	=	Microgram per litter

LIST OF ABBREVIATIONS (Continued)

ng/l	=	Nanogram per litter
g/m^2	=	Gram per square meter
mg/m^3	=	Milligram per cubic meter
$gC/m^2/year$	=	Gram carbon per square meter per year
$inds/m^2$	=	Individuals per square meter
inds/l	=	Individuals per litter
$inds/m^3$	=	Individuals per cubic meter
$animals/m^2$	=	Animals per square meter
cm/sec	=	Centimeter/second
cm	=	Centimeter
m	=	Meter
ha	=	Hectare
UTC	=	Coordinated universal time
CFU	=	Colony forming unit
MPN	=	Most probable number
PCB	=	Polychlorinated biphenyl
DDT	=	Dichlorodiphenyltrichloroethane

CHAPTER I

INTRODUCTION

1.1 General introduction to tsunami 2004

Many times on the Earth, when natural disasters were occurred such as floods, cyclones, volcanic eruptions, sinkholes, landslides, earth quakes, tsunamis, extreme weather or infectious disease etc.. The most of natural phenomenon, tsunami are largely ruined severity lives, livelihoods, healthy and economic. Many countries, which are encountered damage by tsunami, have to use the long-term and lose enormous the budget in rehabilitation of these destructions. Moreover, Tsunami still leave to grieve for losing family member and properties, including immensely quantity of hazard wastes, numerous corpses, concrete construction ruins, trees and all agriculture mainland damage areas which were disaster from them.

December 26, 2004, at 7:58:53 am, local time (00:58:53 UTC), magnitude 9.0 earthquake were occurred off the west coast of northern Sumatra, Indonesia. The epicenter was located under seafloor at 3.32 N 95.85 E. This was followed by a series of aftershocks that triggered tsunami and moved at over 600 km/hr causing extensive coastal shore heavily damage to at least 17 countries namely Indonesia, Malaysia, Myanmar, Bangladesh, India, Sri Lanka, Maldives, Somalia, Seychelles, Madagascar, Kenya, Tanzania, South Africa, Mozambique, Mauritius, Australia, including Thailand. Moreover it murdered nearly 300,000 people in South Asia, Southeast Asia and East Africa. In this study, this tsunami is called tsunami 2004.

Tsunami 2004 was occurred from the Indian Ocean earthquake that happened seabed depth about 30 km, which was between the Australian and Eurasian plates. This earthquake was caused by stress release on the subduction zone known as the Sunda Arc, which was occurred by the steady movement of the Indo-Australian plate underneath the Burma/Sunda plate. This event, it conducted to create the huge wave. The deaths on country was confirmed and presumed as Indonesia 242,347, Sri Lanka 30,957, India 16,389, Somalia 298, Maldives 82, Malaysia 68, Myanmar 61, Tanzania10, Bangladesh 2, Kenya 1 and Thailand 5,393, which still excluded a great number of missing persons.

The destruction of Tsunami 2004 affected six provinces of Thailand, which were bombarded the large severely disaster along the Andaman coastal southern provinces namely Ranong (159 deaths), Phang-Nga (4,225 deaths), Phuket (279 deaths), Krabi (721 deaths), Trang (5 deaths) and Satun (6 deaths). The catastrophe damaged a numerous lives, which was reported from Department of Disaster Prevention and Mitigation Ministry of Interior in September 5, 2005 that as 5,395 deaths; 2,059 Thais, 2,436 foreigners and 900 unclarified. There were 2,817 people missing including 1,921 Thais and 896 foreigners. Total of 8,457 people were injured; 6,065 Thais and 2,392 foreigners. Phang-Nga province was the most affected area of the six provinces as 4,225 deaths, 4,344 injured and 1,352 missing. Therefore, this province might need to monitor on the environment impact, especially the areas which were used for coastal fisheries, coastal aquaculture, livelihoods, community and ecotourism. Because of many hazard rubbishes, solid and liquid wastes, electricity equipments, human corpses, numerous ruins of households, resorts and other buildings including concrete and metals were swept into the sea from the huge wave. This may be directly or indirectly impact to healthy, livelihood of coastal communities and environmental. Especially, the seawater quality in severely affected areas, which was directly impacted to growth and abundance of aquatic animals, including the heavy metals were very worried for residual in seawater, sediment and aquatic animal’s tissue in the local fishery areas and coastal aquaculture. Their effects were mainly concerned on the livelihood, occupation and safety health of fishers and mariculturists, including the tourists and consumers.

This study had been focused on the seawater quality in four different properties such as physical, chemical and biological properties, and some heavy metal concentrations at the areas around coastal fisheries, coastal aquacultures and coastal communities in 3 districts of Phang-Nga province. These areas were severely affected, which needed to monitor closely for management and prevention of danger.

1.2 Research objective

1.2.1 To investigate the seawater quality on physical, chemical and biological properties at around local fishery piers in Phang-Nga province after rehabilitation from disaster tsunami.

1.2.2 To compare seawater quality between each severely affected area from tsunami in Phang-Nga province.

1.3 Scopes and limitation of the study

1.3.1 Study areas

The seawater qualities in three districts of Phang-Nga province, where were severely affected from the tsunami 2004 namely Takua Pa district, Khura Buri district and Tai Meung district (Figure 1.1), during January to December 2008 were studied. The water samples were collected from nine stations (local fishery piers). The general parameters were detected in fields by using specific instruments of water testing and some collection of water samples were preserved in freezer before they were analyzed by different methods of each parameter. Finally, all data were recorded and analyzed to statistic with Analysis of Variance.

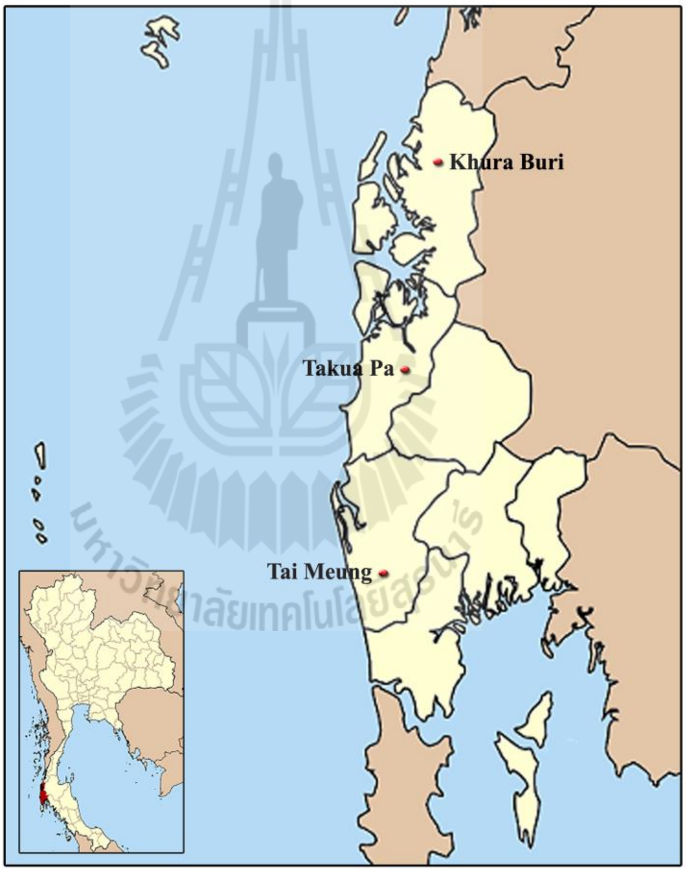

Figure 1.1 Map of study sites at three districts in Phang-Nga province.

1.3.2 Physico-chemical parameters

Analyzed physical and chemical parameters were transparency, temperature, potential hydrogen ion (pH), electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total dissolved solids (TDS) and salinity.

1.3.3 Biological parameters

Biological parameters were phytoplanktons and zooplanktons.

1.3.4 Heavy metals

Detected heavy metals were lead (Pb), manganese (Mn), iron (Fe) and chromium (Cr).

1.4 Expected results

1.4.1 Sea water quality after a devastating tsunami 3-4 years will be proved to be normal unpolluted concentration or not along coastal fisheries in Phang-Nga province.

1.4.2 The data of all parameters were used for solving of the problems that may happen to the livelihood and the health of population in the studied locations.

CHAPTER II

LITERATURE REVIEW

2.1 Worst natural disasters

Several events in the world have seen many disasters over the years. Many circumstances were caused by people such as wars, mass murder, genocide, terrorists attack and accidents. There are different ways of worst, that some would just count the dead, others would include the injured, still others would measure in terms of the amount of dollars required to repair the damages, or somehow calculate the damage to the environment. The worst of them are different upon the kind of disaster. Many natural disasters were mainly caused of a numerous deaths. Some of the world's worst natural disasters such as extreme weathers, infectious diseases, avalanches, tornadoes, hurricanes, cyclones, lightning, volcanoes, earthquakes, tsunamis, droughts, fires, famines, etc. However, the various natural disasters are largely caused to devastate lives of people everywhere occurrences on the earth. Over years, the most of them are registered and often argument. Since 1138 to 2005, all of these disasters took more than 25,000 lives and these disasters took over 100,000 lives (David, www, 2008) as follows:

In 1138, Syria, Aleppo: Earthquake killed 230,000 people.

In 1181, Japan: A famine wiped out at least 100,000 people.

In 1201, Egypt and Syria: The deadliest earthquake in history hit the eastern Mediterranean in July 1201. Approximately 1.1 million people were killed, mostly in Egypt and Syria.

In 1228, Netherlands: Estimate about 100,000 lives lost from the flooding after some dykes broke.

In 1287, Netherlands: The Zuider Zee flooded after a seawall collapsed. At least 50,000 people were killed in Holland and more than 500 in England as a result.

In 1290, China: Earthquake took at least 100,000 people.

In 1347-1350, Most of Europe and beyond: Approximately 25 million lost their lives through the "Black Death" - the bubonic plague. Between 25% and 33% of the entire population of Europe at that time, plus millions in Asia and North Africa lost their lives.

In 1556, China: Earthquake killed about 830,000 people in Shansi.

In 1642, China: Flooding took about 300,000 lives.

In 1649, Spain: Plague took about 80,000 lives in Seville.

In 1665, England: More than 100,000 lives were taken by the plague, London was worst hit.

In 1730, Japan: Earthquake took the lives of some 137,000 people.

In 1737, India: First it was thought to be an earthquake, but more recent scientific studies have re-classified it as a typhoon - this tragedy killed some 300,000 in Calcutta.

In 1755, Portugal: Over 100,000 lost their lives through the Lisbon earthquake and resulting tsunami.

In 1769, India: About ten million people lost their lives from a famine in Bengal.

In 1775-1782, North America: Smallpox took around 130,000 lives.

In 1780, Iran: As many as 200,000 were killed in an earthquake near Tabriz.

In 1783, Iceland: A volcanic eruption (that included the largest basalt flow in recorded history) poisoned the island's pastures and caused the starvation of about 25% of the population more than 30,000.

In 1815, Indonesia: The volcanic of Mount Tambora on Sumbawa Island released about 50 cubic kilometers of magma over at least 500,000 square kilometers of Indonesia and the Java Sea. That eruption and the resulting tsunami took at least 10,000 lives. But the famine and disease that followed took another 82,000 lives - total over 90,000 lives.

In 1826, Japan: Tsunami killed about 27,000.

In 1845-1848, Ireland: Potato famine took at least a million lives.

In 1870, France, Germany, America, etc.: Approximately 500,000 lives lost as a result of smallpox.

In 1876-1879, China: The deadliest drought in recorded history was in China between 1876 and 1879. Rivers were dry, so most crops and livestock died. There was no food production in a one million km^2 area of 9 provinces. The drought caused the death of an estimated 9 million people.

In 1883, Java and Sumatra: Krakatoa, a small volcano on an uninhabited island between Sumatra and Java (Indonesia), erupted with such fury it could be heard in Australia nearly 5,000 kilometers away. The Tsunami that followed took about 50,000 lives.

In 1896, Japan: About 28,000 people lost their lives from a Tsunami.

In 1887, China: The worst flood in "modern history" happened in China in 1887. The Yellow River overflowed, causing the death of about 900,000 people.

In 1902, Caribbean: Martinique, a small French colony in the Caribbean, has a volcano "Mont Pelee" which unleashed its fury and wiped out the town of St. Pierre. Around 30,000 people were killed.

In 1908, Italy: An earthquake of 7.2 magnitudes and the harbor wave that result destroyed several southernmost Italian cities and towns and approximately 123,000 people.

In 1911, China: Yangtze River flooded approximately 100,000 deaths.

In 1915, Avezzano, Italy: Earthquake 7.5 magnitudes took nearly 30,000 lives.

In 1918-1919, World-wide: Influenza pandemic took somewhere between 35 million and 75 million lives - at least 16 million people died in India alone.

In 1920, China: In the north China there was a drought that caused 20 million victims and took at least 500,000 lives.

In 1920, Gansu, China: Gansu, China was hit with an earthquake measuring 8.6 and killed around 200,000 people.

In 1923, Japan: A third of Tokyo was destroyed and much of Yokohama in an 8.3 earthquake which killed between 140,000 and 200,000 people.

In 1927, China: An earthquake 7.9 - hit Nanshan City and took about 200,000 people.

In 1931, China: A flood on the Changjiang River took at least 145,000 people.

In 1932, China: Another earthquake, this one northwest Gansu Province, killed about 70,000 people.

In 1933, China: Another Changjiang River flood took the lives of at least 140,000 people.

In 1935, China: Another Yellow River flood caused 27 counties inundated and 3.4 million victims.

In 1935, Pakistan: About 30,000 lost their lives in a 7.5 earthquake.

In 1939, Chile: Some 28,000 people were killed from an 8.3 earthquake in Chile.

In 1939, China: A flood took about 200,000 lives.

In 1939, Turkey: More than 32,000 lives were lost from a 7.9 quake in Erzican Province.

In 1942-1943, China: A drought in the Henan province took the lives of more than a million people.

In 1948, Turkmenistan (USSR): A 7.3 earthquake took over 110,000 lives.

In 1950, India: Around 30,000 people lost their lives in a quake of 8.6 magnitudes in Assam, India.

In 1957, World-wide: At least a hundred thousand people died from the Asian flu - about 70,000 in the USA alone.

In 1970, Peru: A 7.9 earthquake and resulting landslides killed about 66,000 in Northern Peru.

In 1970, Bangladesh: A cyclone and related floods killed about 500,000 people. With winds of up to 230 km/h, the cyclone crashed into the heavily populated coastal area of the Bay of Bengal, where several river deltas normally provide fertile land. The terrible winds produced massive waves, which wiped out many entire villages. Millions of people were left homeless in this country that is one of the most densely populated and one of the poorest in the world.

In 1971, Vietnam: Red River flood killed about 100,000 lives.

In 1976, Tangshan, China: The worst earthquake damage in modern times was in northeast China in 1976. It was July 28 when a massive quake, measuring 8.3 on the Richter scale, shook the industrial mining city of Tangshan. Officially 255,000 people died, and another 164,000 were severely injured. But others estimate that about 655,000 perished. Some ninety per cent of the buildings were destroyed. It took at least ten years and massive investment to rebuild the city.

In 1978, Iran: An earthquake measuring 7.7 took about 25,000 lives.

In 1981-1984, Africa: Rivers and lakes dried up from the drought that had incredible impact on twenty African nations. During one season about 20,000 were starving to death each month. One hundred and fifty million were facing starvation if help didn't come right away. People from around the world began to respond to this crisis - but for hundreds of thousands of people, it was too late. When combined with other relatively recent African famines, the figure was well over 1,000,000.

In 1985, Colombia: Volcano Nevado Del Ruiz claimed the lives of at least 25,000 - mostly from the mudflow which resulted from the volcanic eruption.

In 1988, Armenia: An earthquake measuring 6.9 on the Richter scale devastated Armenia. At that time Armenia was a republic of the Soviet Union. The town of Spitak was destroyed and it took the lives of all of its residents. In Leninakan, Armenia's second largest city, eighty per cent of the buildings collapsed, and over 100,000 people perished there.

In 1990, Iran: A 7.7 earthquake in northwest Iran killed at least 50,000 people.

In 1991, Bangladesh: Flooding again took its toll on this nation. About 139,000 lost their lives.

In 1995-1998, North Korea: Over 3 million people were said to have died from famine and floods in North Korea.

In 1996, West Africa: About 25,000 lost their lives from a meningitis outbreak.

In 1996, West Africa: About 25,000 lost their lives from a meningitis outbreak.

In 2003, Iran: Earthquake in Bam, Iran, officially killed 26,271 people.

In 2004-2005, 12 South Asian Nations: Earthquake of 9.0 and the resulting Tsunami creates one of the world's worst disasters. It does major damage to: Indonesia, India, Sri Lanka, Thailand, Malaysia, Myanmar, the Maldives, Somalia, Tanzania, Seychelles, Bangladesh, and Andaman. Deaths were between 235,000 and 285,000.

In 2005, South Asia: Earthquake, primarily affected Pakistan, but also India and Afghanistan over 50,000 dead.

2.2 Earthquake

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. Earthquakes are recorded with a seismometer, also known as a seismograph. The moment magnitude of an earthquake is conventionally reported, or the related and mostly obsolete Richter magnitude, with magnitude 3 or lower earthquakes being mostly imperceptible and magnitude 7 causing serious damage over large areas.

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacing the ground. When a large earthquake epicenter is located offshore, the seabed sometimes suffers sufficient displacement to cause a tsunami. The shaking in earthquakes can also trigger landslides and occasionally volcanic activity.

In its most generic sense, the word earthquake is used to describe any seismic event; whether a natural phenomenon or an event caused by humans, that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by volcanic activity, landslides, mine blasts, and nuclear experiments. An earthquake's point of initial rupture is called its focus or hypocenter. The term epicenter refers to the point at ground level directly above the hypocenter (Wikipedia, www, 2005a) and which occurred many times in many areas in the world that were recorded on the top ten deathliest since 1900 to 2004 as shown in Table 2.1 and a large earthquake happened in this range as 11 times as revealing in Table 2.2 (Ross, 2005; Braile, 2007).

Earthquakes are not mainly caused in stimulation all cases of tsunami; types of movement of the earth's layers are majority caused to severe of seismic wave. In addition the earth's rock layers can move in five different directions that were shown in Figure 2.1 (Paiboon, 2005).

a) Lateral fault or strike–slip fault: the layers move to the side, either to the left or the right.

b) Normal fault or dip–slip fault: the layers move in vertical direction. The upper layer dips down more steeply in relation with the lower plate according to natural gravity of the globe.

c) Reverse fault or thrust fault: the layers move in vertical direction as b), but the dip down of the lower plate pushes the upper layer higher above.

d) Lateral normal fault or oblique fault: the combination of normal and side sliding are caused the upper rock layer to slide down from its original level.

e) Lateral reverse fault or oblique reverse fault: the combination of the side and reverse slides are caused the upper rock layer to slide up from its original level.

In normal earthquakes with less destructive force, most of the movements are of a) or b) type. The larger quakes were mostly caused by subduction of the lower rock layer that lifts up the upper plate as in type c). This type of quake occurred in 1995 in Chile, measuring 7.8 in the Richter scale, and on 26 December 2004 when a disastrous tsunami with a magnitude of 9.15 on the Richter scale occurred (Paiboon, 2005).

Once of natural disasters, tsunami was mainly ruined severity lives, livelihoods households, infrastructures, communities, socials, healthy and economic. All countries, which were encountered damage by disaster tsunami, have to use long term and lose enormous the budget on recovery of these destructions. In additions the event violence of tsunami previously was illustrated by death toll from the highest to the lowest on top ten of deadliest tsunamis following Table 2.3.

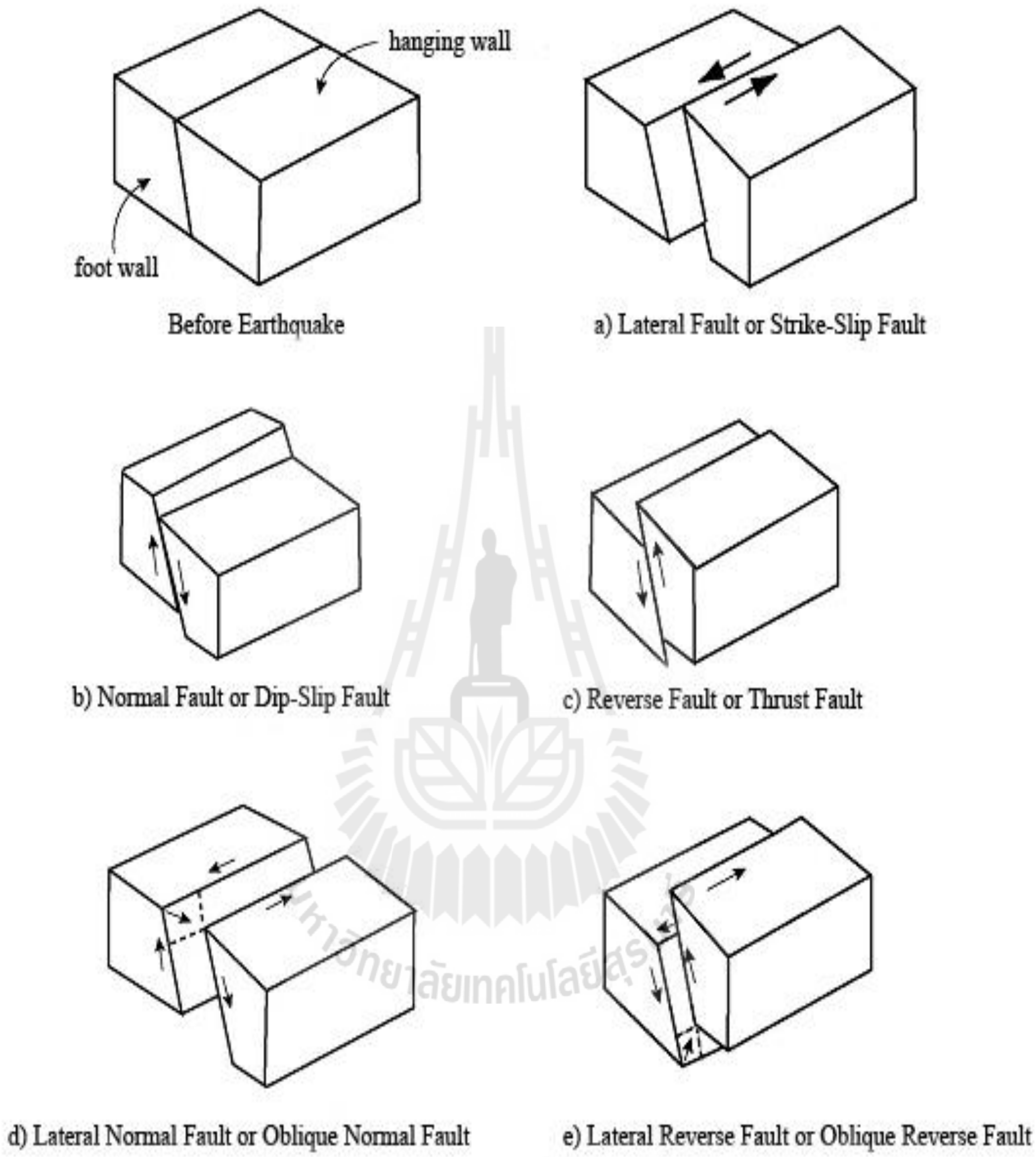

Figure 2.1 The earth’s rock layers can move in five different directions (Paiboon, 2005).

Table 2.1 The top 10 deadliest earthquakes since 1900.

Location	Date	Latitude	Longitude	Deaths	Magnitude	Plate margin	Comments
West cost of Sumatra, Indonesia	26/12/2004	3.32 N	95.85 E	300,000	9.0	Destructive	Massive tsunamis along Indian Ocean coastal countries
Tangshan, China	27/07/1976	39.6 N	118.0 E	255,000	8.0	Destructive	-
Gansu, China	16/12/1920	35.8 N	105.7 E	200,000	8.6	Destructive	Landslides
Xining, China	22/05/1927	36.8 N	102.8 E	200,000	8.3	Destructive	-
Kwanto, Japan	01/09/1923	35.9 N	139.5 E	143,000	8.3	Destructive	Great Tokyo fire
Ashgabat, Turkmenistan	05/10/1948	38.0 N	58.3 E	110,000	7.3	Destructive	-
Messina, Italy	28/12/1908	38.0 N	15.5 E	70-100,000	7.5	Destructive	Earthquake and tsunami
Gansu, China	25/12/1932	39.7 N	97.0 E	70,000	7.6	Destructive	-
Peru	31/05/1970	9.2 S	78.8 W	66,000	7.8	Destructive	Rock slides and floods
Quetta, Pakistan	30/05/1935	29.6 N	66.5 E	30-60,000	7.5	Transform	-

Source: Ross (2005).

Table 2.2 Largest earthquakes since 1900 to 2004.

Location	Date	UTC	Magnitude	Coordinates	
Chile	1960	05:22	9.5	38.24 S	073.05W
Prince William Sound, Alaska	1964	03:28	9.2	61.02N	147.65 W
Andreanof Islands, Alaska	1957	03:09	9.1	51.56 N	175.39 W
Kamchatka	1952	11:04	9.0	52.76 N	160.06 E
Off the West Coast of Northern Sumatra	2004	12:26	9.0	03.30 N	095.78 E
Off the Coast of Ecuador	1906	01:31	8.8	01.00 N	081.5 W
Rat Islands, Alaska	1965	02:04	8.7	51.21N	178.50 E
Assam - Tibet	1950	08:15	8.6	28.50 N	096.5 E
Kamchatka	1923	02:03	8.5	54.00 N	161.0 E
Banda Sea, Indonesia	1938	02:01	8.5	05.05 S	131.62 E
Kuril Islands	1963	10:13	8.5	44.90 N	149.6 E

Source: Braile (2007).

Table 2.3 The top 10 deadliest tsunami previously illustrated on death toll from the highest to the lowest.

Death toll	Event	Location	Date
> 229,866 (sources vary)	Indian Ocean Earthquake/Tsunami	Indian Ocean	2004
100,000	1755 Lisbon Earthquake/Tsunami/ Fire	Portugal, Morocco, Ireland, and the United Kingdom (Cornwall)	1755
100,000	1908 Messina Earthquake/Tsunami	Messina, Italy	1908
36,000	1883 Krakatoa Eruption	Indonesia	1883
30,000	-	Tokaido/Nankaido, Japan	1707
27,000	-	Japan	1826
25,674	1868 Africa Earthquake/Tsunami	Africa, Chile	1868
22,070	-	Sanriku, Japan	1896
15,030	1792 Mount Unzen Eruption in Southwest Kyushu	Kyushu, Japan	1792
13,486	-	Ryukyu Trench	1771

Source: Wikipedia, www (2005b).

2.3 Tsunami

Tsunami is the Japanese term; it is translated into the great 'harbor ('tsu') wave ('nami')' (Patterson, Makoto and Masashi, 2006; Ross, 2005; Kew, 2009). The most common tsunamigenic events are underwater earthquakes that could produce a co-seismic deformation that causes displacement of a huge body of water. This seabed deformation is normally caused by a subduction when two oceanic plates slip through each other at the contact region known as the plate boundary. The energy of that fault is transferred to the water and elevates the water upward exceeding the normal sea level (Koh et al., 2007). The length scale of this sea floor deformation is much larger than the water depth, which forms the initialization of the tsunami wave generation called the initial-conditions. It is presumed that the initial sea surface deformation is equal to the co-seismic vertical displacement of the sea floor. This is the birth of the seismic waves. Tsunamis may also be triggered by a violent horizontal displacement of water such as submarine landslide in the ocean (ISDR, 2008). For tsunami generated by submarine landslides, the initial waveforms at the source are more difficult to derive. The wavelengths are shorter, implying the increased significance of wave dispersion in subsequent propagation. Subsequent to the vertical uplift, the displaced water column then splits into two opposing directions. The transoceanic tsunamis waves can travel at high speeds exceeding 100 m/s, with long period and long wave-length in a deep ocean. This stage is known as tsunami propagation. The travelling speed depends on its wavelength, water depth, friction and slope. As the wave's propagation reaches the shallow coastal areas, the wavelengths are reduced thus slowing down the wave but are amplified in heights and velocities to reach the maximum vertical heights onshore, creating a destructive situation that can pose great danger to humans and properties. This final stage of a tsunami's evolution creates a dissemination of the waves with different frequencies or spectra and with different propagation speeds. This is known as tsunami runup and inundation. Tsunamis generated by the sudden vertical elevation of water column such as those caused by earthquakes are far better understood than those caused by submarine landslides. Submarine landslides are oftentimes the aftermath events that accompany major earthquakes, which are very likely to add up the overall power of a tsunami or creating additional tsunami waves. The most dangerous and devastating tsunami is a tsunami generated by submarine landslides located nearby to the coastal areas with distance less than several hundreds km and is known as near field tsunami. These types of tsunamis are considered more dangerous than those created in deep ocean uplift of similar volume because the potential energy of these tsunamis could be much higher and more focused. Reason for this to happen is because the slide depth could be in the order of thousands of meters, as compared with uplift, which is capped by the vertical displacement of the seafloor, which rarely exceeds 10 m. Hence, near field tsunami triggered by submarine landslides can be devastating. Especially the enormous volumes of water and energy concerned (Wikipedia, www, 2005c), the effects of tsunamis can be disastrous that illustrated in Figure 2.2 (Atwater et al., 2005).

Movement of rock layer that causes tsunami; the movement of the rock layer under the ocean causes a shallow quake with its epicenter located at a depth of less than 60 kilometers beneath the earth's surface. It the movement is the reverse fault (thrust fault) or normal fault (dip-slip fault), massive amounts of water will rise or dip rapidly. The water mass will then disperse to maintain hydrological energy, which cause seismic sea waves, or the so-called, tsunami. The reverse fault (thrust fault) that causes tsunami is shown in Figure 2.3, while the normal fault (dip-slip fault) is shown in Figure 2.4 (Paiboon, 2005).

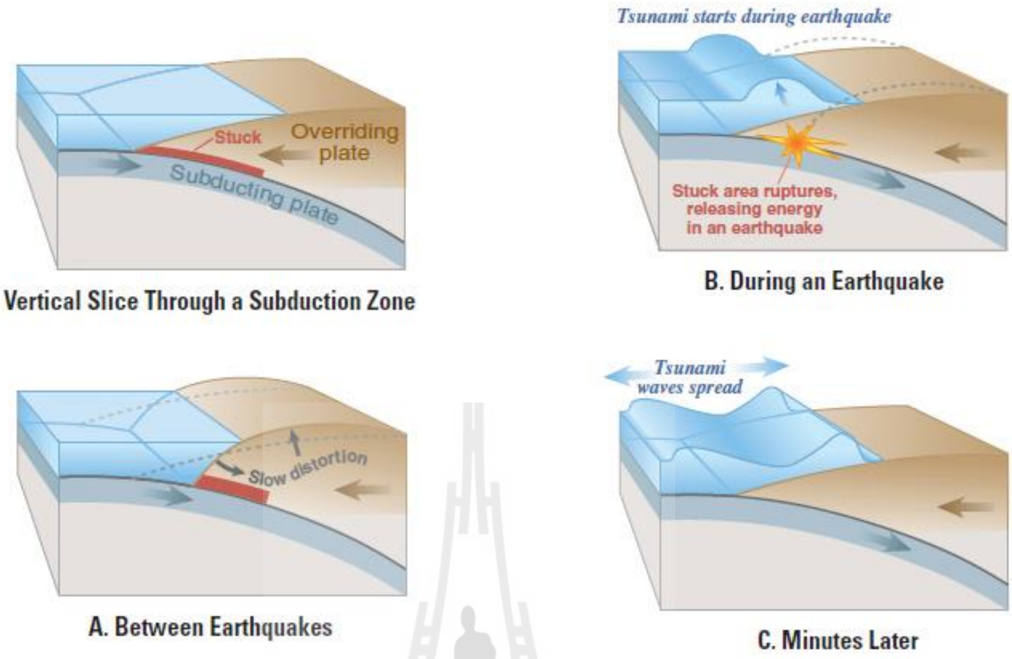

Figure 2.2 Tsunami – a series of waves, or “wave trains,” usually caused by a seismic shift of the sea floor (Atwater et al., 2005).

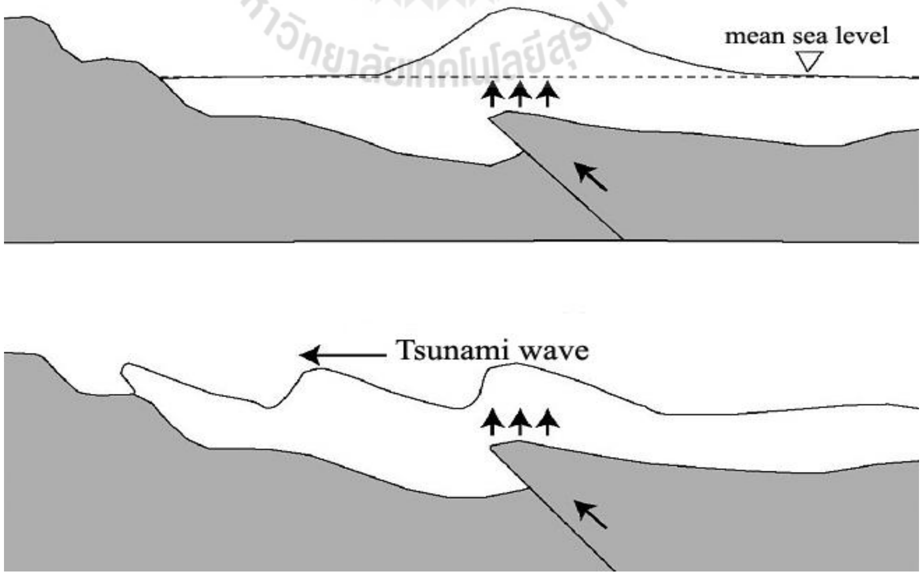

Figure 2.3 Reverse fault or thrust fault (Paiboon, 2005).

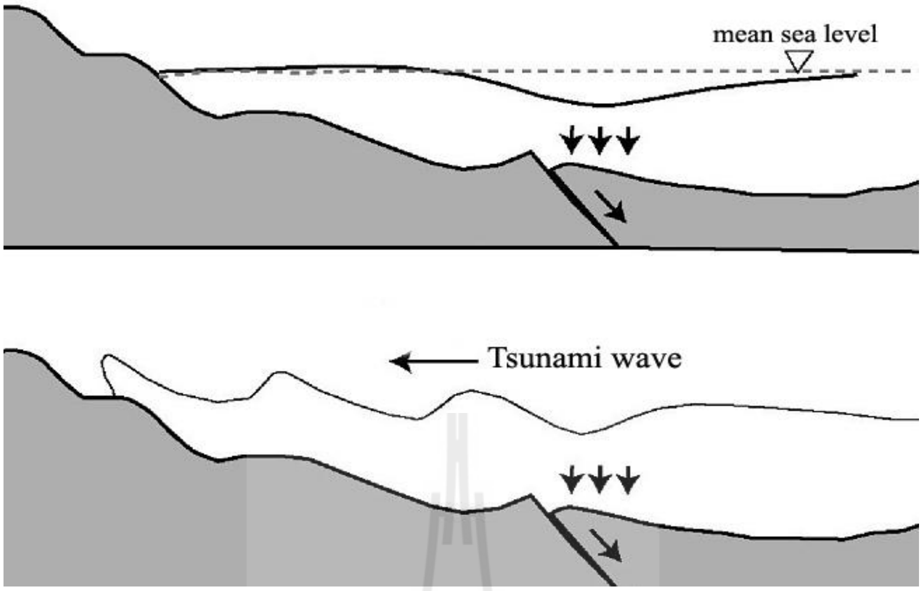

Figure 2.4 Normal fault or dip–slip fault (Paiboon, 2005).

2.4 Indian ocean tsunami

On 26 December 2004, 00:58:53 UTC (7:58:53 am local time), a magnitude 9.0 earthquake occurred off the west coast of northern Sumatra, Indonesia. The epicenter was located under sea water at 3.32 N 95.85 E. (NOAA's National Geophysical Data Center, 2004; National University of Singapore, 2004). This was followed by a series of aftershocks that triggered tsunami and moved at over 600 km/h causing extensive coastal damage to Indonesia, Malaysia, Myanmar and Thailand (Bernard et al., 2006) (Figure 2.5). After that the tsunami reached Bangladesh, India, Maldives and Sri Lanka. Finally, it reached the Seychelles, and, in Africa, Kenya, Somalia, Yemen and Tanzania. It was the largest earthquake since the 9.2 magnitude earthquake off Alaska in 1964 and was the fourth largest since 1900. Moreover it destroyed nearly 300,000 people in South and Southeast Asia and East Africa (Wikipedia, www, 2005c).

The 2004 Indian Ocean earthquake that happened under deep of the oceanic basin, which was between the Australian and Eurasian plates (Patterson, Makoto and Masashi, 2006). This earthquake was caused by stress release on the subduction zone known as the Sunda Arc, which was occurred by the steady movement of the Indo-Australian plate underneath the Burma/Sunda plate. So the subducting Indo-Australian plate gradually displaced down and it pulled the overlying Burma/Sunda plate along, increasing the stress until the strength was exceeded and the overlying plate bounced fault and down on the east side. After that the sudden back and the vertical component of fault movements, vertical displacement of the sea bottom caused extended all the way to the sea bottom, causing an immediate corresponding displacement of the seabed to move up on the west side of the sea that initiated the tsunami (Figure 2.6) (Ministry of Natural Resources and Environment, 2006).

2.5 The effect of Indian Ocean earthquake and tsunami in 2004

The Indian Ocean earthquake was an undersea earthquake that happened on December 26, 2004. Registering rated at 9.0 on the Richter scale and had a hypocenter off the west coast of Sumatra, Indonesia (Figures 2.7, 2.8 and 2.9). The thick slab of crust lying below South-East Asia finally created way to centuries of bumping against another slab of crust below the Indian Ocean. The sudden movement pushed one side up over an area about 1,200 km long and a few hundred kilometers wide. This was caused of more than people 214,344 deaths, 142,075 missing and 34,410 injured in eight countries and as the tsunami waves ruined the shallows, they reared up to hilly heights, 30 meters at the highest, forming awesome walls of water. It was one of the deadliness natural disasters in recorded history. The millions more

were homeless in 11 countries (WHO, 2005). Indonesia, Sri Lanka, India, and Thailand were hardest hit (Karen, 2006).

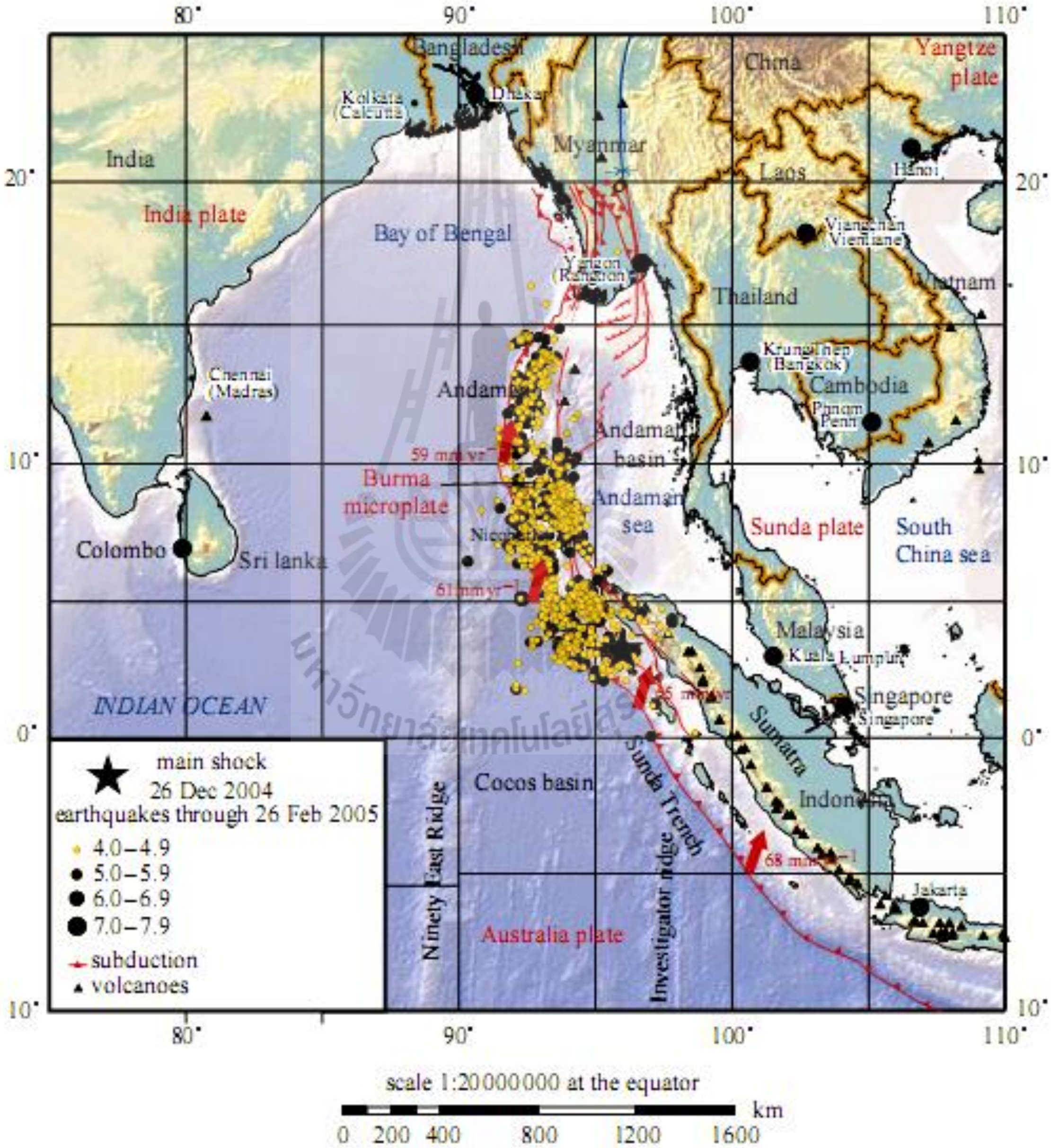

Figure 2.5 Sumatra source for the 26 December 2004 Sumatra tsunami. (Bernard et al., 2006).

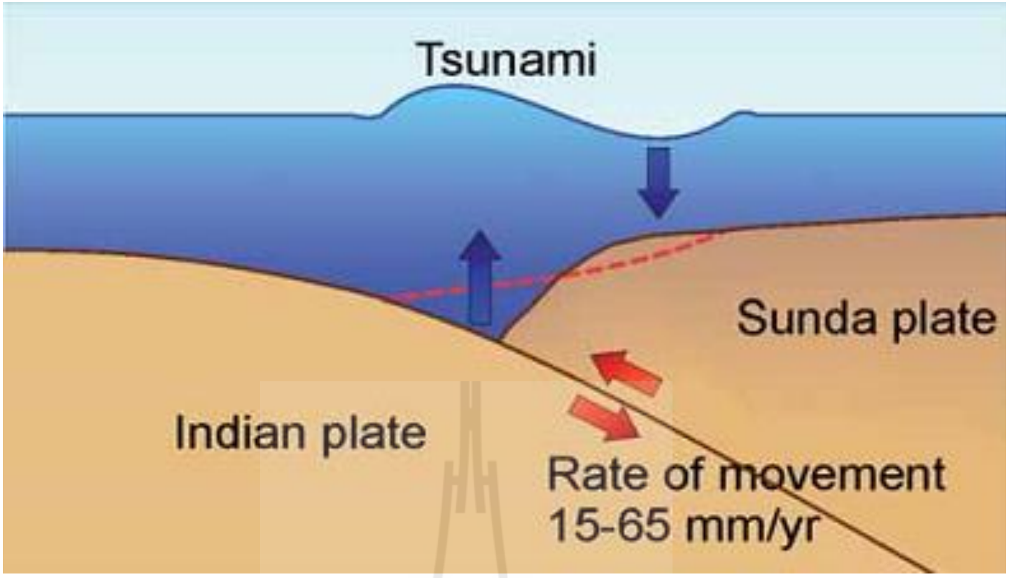

Figure 2.6 The Indo-Australian plate slowly moved down and pulled the Burma/Sunda plate (Ministry of Natural Resources and Environment, 2006).

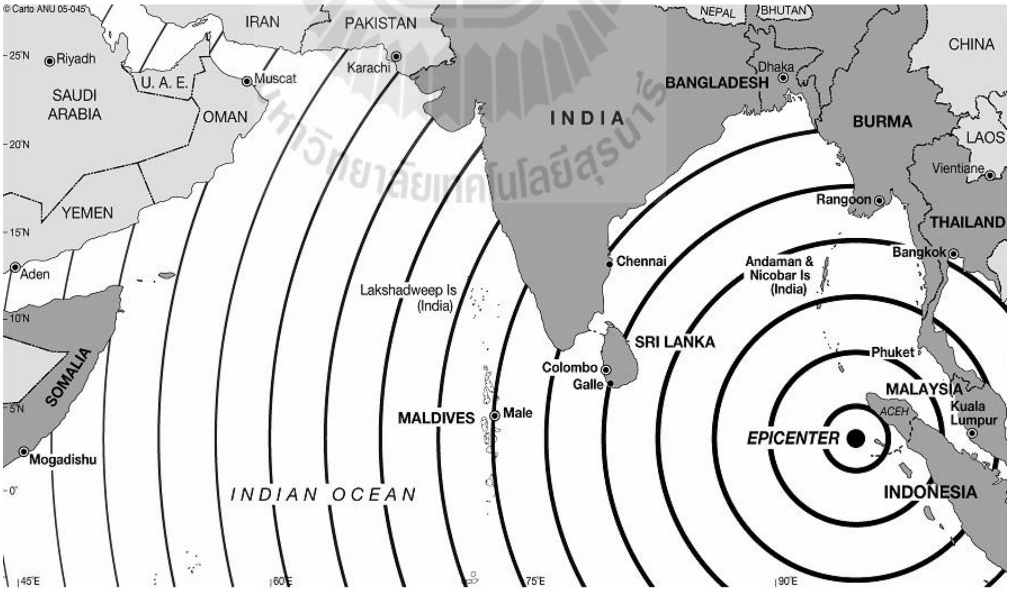

Figure 2.7 Indian Ocean earthquake, 26 December 2004: Tsunami disaster areas (Prema-chandra and Budy, 2006).

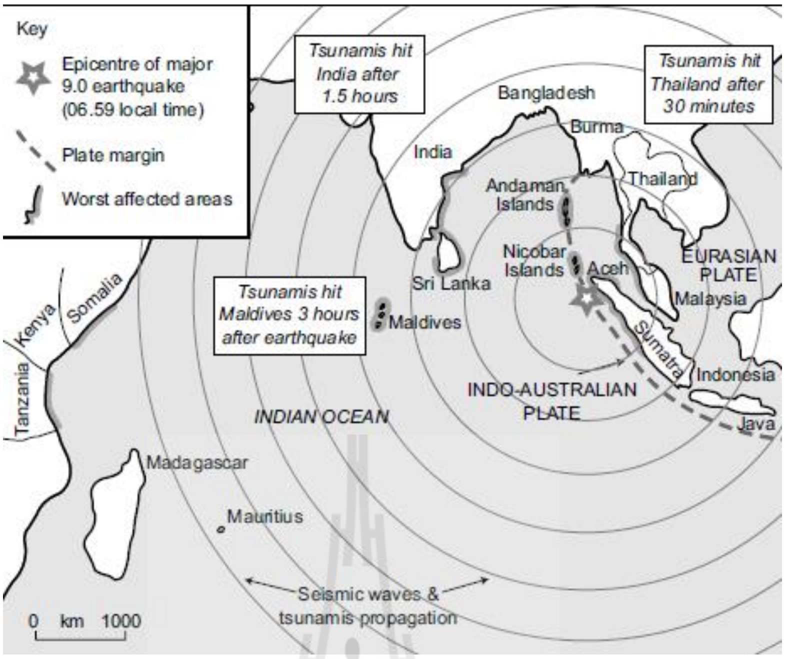

Figure 2.8 Indian Ocean: earthquake location and worst affected areas. (Ross, 2005).

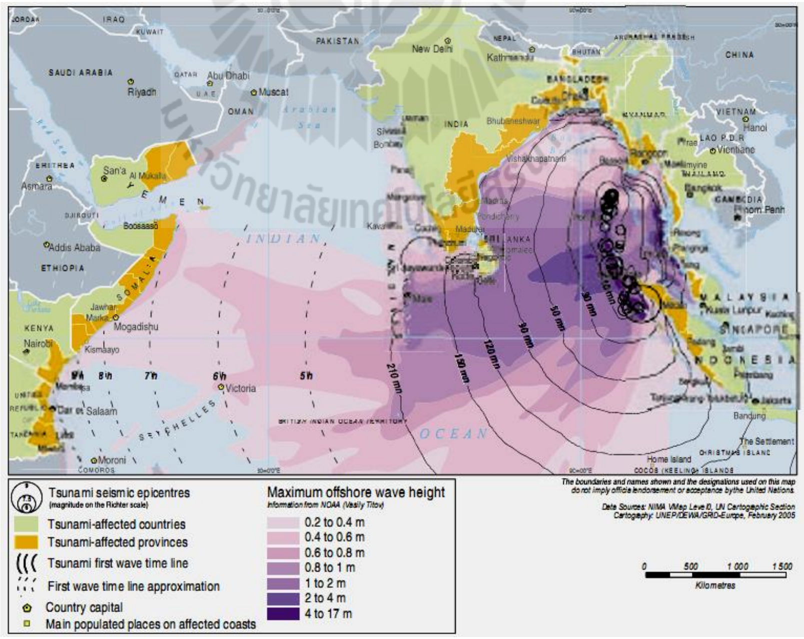

Figure 2.9 The communities were overwhelmed by the damage and loss from the earthquake and tsunami of 26 December 2004. (Bonafede, 2005).

2.5.1 Countries suffering major casualties and damage

India: According to reporting of casualties on the Home Ministry website 10,749 casualties had been confirmed on 18 January 2005, most of them in the state of Tamil Nadu. There were 5,640 people missing, nearly all of them on the Andaman and Nicobar Islands. In the meantime the death toll has been slashed down by 1,458, and the number of missing by 2,927 on the Andaman and Nicobar Islands (Wikipedia, www. 2005d; Bernard et al., 2006) (Figure 2.10).

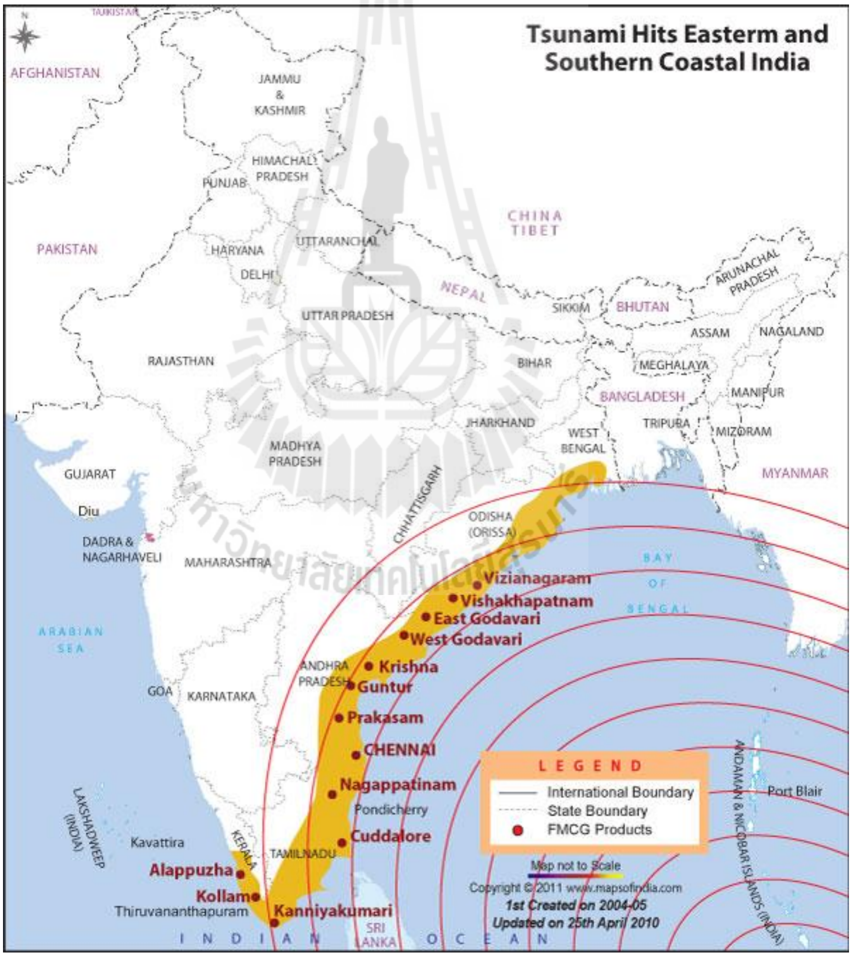

Figure 2.10 Tsunami affected areas in eastern and southern coastal India. (Bernard et al., 2006).

Indonesia: Indonesia's Ministry of Health confirmed 131,028 deaths on June 18, 2005, mainly in the northern province Aceh of the island Sumatra. Some 37,000 people are missing (Figure 2.11)

Figure 2.11 The main affected areas in the northern province Aceh of the island Sumatra, Indonesia (USGS, 2009).

Malaysia: Despite its proximity to the incident, Malaysia escaped the kind of damage that struck countries thousands of miles further away. The number of deaths currently stands at 69 with 5 people missing.

Maldives: In the Maldives, 82 were killed and 26 reported missing and presumed dead.

Myanmar: Independent media reports 90 people killed in Myanmar due to the tsunami. The official death toll was 61. Witnesses in Myanmar estimate up to 600 deaths.

Somalia: Villages and coastal communities in Somalia, as far as 4,500 km (2,800 mi) from the epicenter of the earthquake, were swept away and destroyed by the huge waves. 176 people were confirmed dead, 136 were missing and more than 50,000 have been displaced.

Sri Lanka: Sri Lankan authorities report 31,229 confirmed deaths, and 4,093 people missing. Other authorities are speaking from 38,940 combined dead and missing people. The south and east coasts were worst hit. Nearly 2,000 of the dead were suffered on the Queen of the Sea holiday train which was destroyed by the tsunami. One and a half million people have been displaced from their homes, and many have been orphaned or separated from their families.

Thailand: The Thai government reports 5,395 confirmed deaths, 8,457 injuries and 2,817 missing on 20 June 2005. Damage was confined to the six southern provinces facing the Andaman Sea. The Thai government is keen to point out that the rest of the country is operating normally, and that even some resorts in the south have now re-opened (Figure 2.12 and Figure 2.13).

2.5.2 Countries suffering some casualties and damage (Wikipedia, www. 2005e)

Bangladesh: Two children killed after a tourist boat capsized in surging waves.

Kenya: Waves struck Kenya causing some minor damage. One person reported drowned at Watamu, near Mombasa**.**

Seychelles: Three killed, seven people missing. Major bridge in Victoria destroyed**.**

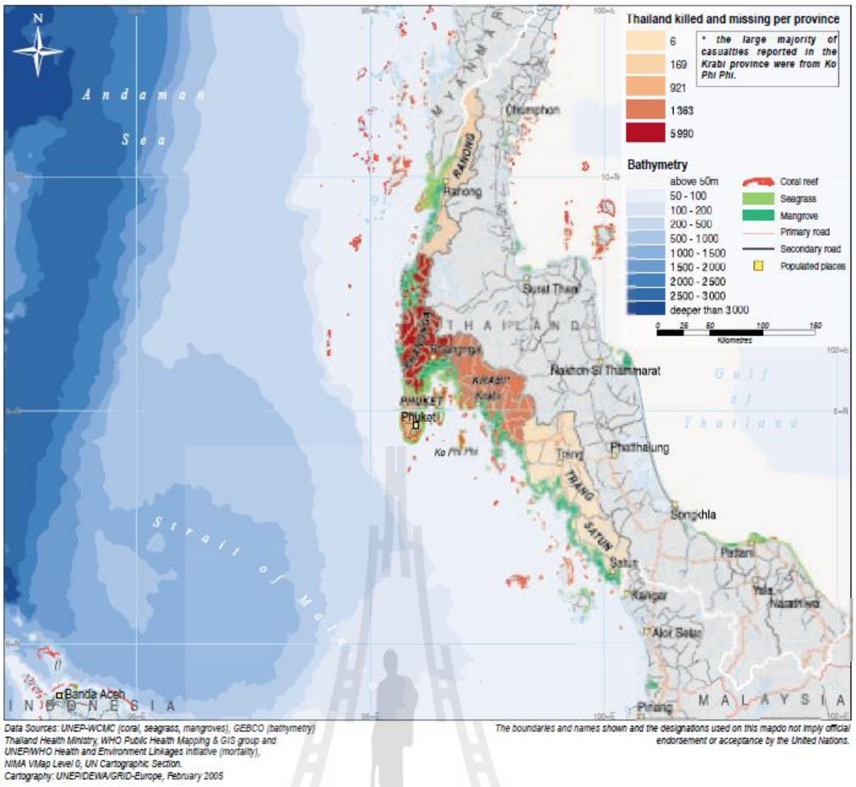

Figure 2.12 Map showing the provinces in Southern of Thailand tsunami affected (Minister of Natural Resources and Environment, 2005).

Figure 2.13 Satellite images of Thailand's western coast before and after the tsunami (Minister of Natural Resources and Environment, 2005).

South Africa *Casualties:* Two reported dead: Ten boys dead after swimming in the Quinera River at Gonubie, close to East London; an adult dead at Blue Horizon Bay near Port Elizabeth, the furthest point from the epicenter of the earthquake where a tsunami-related death was reported. *General observations:* Ocean level variance two to three meters outside normal reported in Kwa Zulu-Natal and Eastern Cape, and a surge of 1.5m was observed as far as Struisbaai in the Western Cape, 8500 km from the epicenter of the earthquake. Some steps were taken in South Africa to warn ports and disaster management centres, although full details are not public. *Damage:* Large concrete blocks were uprooted in East London harbour, where boats also broke from their moorings. Boats and cars were submerged at the Algoa Bay Yacht Club in Port Elizabeth harbour. Durban harbour, Africa's busiest general cargo port and home to the largest and busiest container terminal in the Southern Hemisphere, was closed for some time on 27 December because of unusually strong surges across the entrance channel.

Tanzania: Ten killed, an unknown number of people missing. Oil tanker temporarily ran aground in Dares Salaam harbour, damaging an oil pipeline.

Yemen: One child killed, 40 fishing boats wrecked on Socotra Island.

2.5.3 Countries suffering damage only (Wikipedia, www. 2005f)

Australia: Tremors felt along the north-western coast, some minor flooding. Seas off Western Australia reportedly surged between Geraldton, 425 km north of Perth, where several boats were ripped from their moorings, and Busselton, 230 km south of Perth, where a father and son in a boat were washed out to sea, but were later rescued. No direct casualties have been reported within Australia. Despite early worries about Cocos (Keeling) Islands, no casualties were reported. People swimming at Christmas Island were sucked 150 m out to sea, but were safely carried back to shore after a pause.

Madagascar: Flooding in low-lying coastal districts. No reported casualties. Waves reported variously as being between 1.6 and 10 metres in height swept through southeastern coastal areas near the towns of Manakara, Sambava and Vohemar; over 1,000 reported homeless. Problems were exacerbated by the approach of cyclone Chambo.

Mauritius: Struck by wave, no reports on casualties, a village in the north of the island completely submerged. Police had issued warnings to bathers to keep out of the water although this reportedly had the opposite effect with crowds thronging the beaches to watch the phenomenon. Speculation is that coral reefs surrounding much of the island protected the coastline.

Oman: Waves hit coastline but no casualties.

Réunion (French DOM): Over 200 boats sunk; damage to port infrastructure estimated at over €500,000, according to the Chamber of Commerce.

Singapore: Tremors felt by residents in high-rise apartment blocks in the south of the city-state.

2.5.4 Detection of the tsunami outside the Indian Ocean region

American Samoa: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 13 cm from crest to trough at Pago Pago.

Antarctica: Wave fluctuations of 73 cm due to the tsunami were detected at Showa Station (*Shōwa Kichi*), 8900 km (5500 miles) from the epicenter**.**

Brazil: Although it is on the coast of the Atlantic Ocean the city of Rio de Janeiro detected strange tides fluctuations that changed up and down 30 cm each half hour (normally it should vary up to 1.3 m in four hours). In the close city of Niterói, the sea level went up to 60 cm entering in 50 fisherman houses. No significant loss was detected.

Chile: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 19 cm from crest to trough at Iquique.

Fiji: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 11 cm at Suva.

Russia: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 29 cm at Pacific Ocean coast of Russia Far East.

Mexico: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 89 cm at Manzanillo, Colima, due to focusing of tsunami energy from the Pacific plate rise and local terrain.

New Zealand: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 65 cm at Jackson Bay and 50 cm at Waitangi on Chatham Island.

Peru: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 50 cm from crest to trough at Callao.

United States: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 22 cm at San Diego, California, and 6 cm at Hilo, Hawaii.

Vanuatu: Tsunami energy that passed into the Pacific Ocean caused wave fluctuations of 18 cm at Port Vila. (Wikipedia, www. 2005g).

2.6 Tsunami disaster in Thailand

2.6.1 Areas of the tsunami affected in Southern of Thailand

On December 26, 2004 at around 9.30 am local time, a quake-triggered tsunami lashed the Andaman coast of southern Thailand which far from Phuket Island about 580 kilometers. It was the first to strike the shorelines of southern Thailand in living memory. Coastal provinces along the Andaman coast suffered a total of 5,395 deaths that more than half of whom were foreign tourists (Thanawood et al., 2006).

Six Andaman provinces of Thailand namely Ranong, Phang-Nga, Phuket, Krabi, Trang and Satul were among those areas having received severally affect, particularly the violent damage; lives, healthiness, households, livelihoods, economics, public infrastructure, natural resources and environment pollutions (garbage, waste water and sea water). Those provinces were affected for 24 districts (87 subdistricts), wherein 408 out of the total 1,946 villages. Table 2.4 showed the district boundaries of the tsunami-affected areas (Figure 2.14) (Pratap et al., 2006).

Table 2.4 District boundaries of tsunami-affected areas in Thailand.

Six provinces of southern Thailand					
Ranong (3 Districts)	**Phang-Nga** (5 Districts)	**Phuket** (3 Districts)	**Krabi** (5 Districts)	**Trang** (4 Districts)	**Satul** (4 Districts)
Suk Samran	Ko Yao	Thalang	Muang Krabi	Hat Samran	Thung Wa
Kapoe	Takua Thung	Kathu	Ko Lanta	Sikao	Langu
Muang Ranong	Khura Buri	Muang Phuket	Khlong Thom	Palian	Tha Phae
	Takua Pa		Ao Luk	Kantrang	Muang Satun
	Thai Muang		Nua Khlong		

Source: Pratap et al. (2006).

2.6.2 Communities and livelihoods

2.6.2.1 Coastal communities

Estimated 490 fishing villages along the Andaman coast and islands were affected by the Tsunami that struck on 26 December 2004. The tsunami caused extensive damage to lives and properties in six southern coastal provinces of Thailand (Phuket, Phang-Nga, Krabi, Ranong, Trang and Satul). The losses figure stands at 5,395 dead, 8,457 injured and 3,100 missing (WHO, 2005). In these areas, 20,537 households with a total population of 91,638 were considered to have been directly affected through loss of, or injury to, a family member (FAO, 2005; Kateruttanaku et al., 2005) (Figure 2.15).

2.6.2.2 Coastal fishery

More than 6,100 fishing boats; 4,678 small and 1,475 large boats were damaged by the tsunami, 76% of which are less than 10 meters. About 22% of the large and 5% of the small fishing boats were salvaged after the disaster: 549 large and small fishing boats were salvaged at a cost of 112 million baht. The total value of damaged fishing boats was 687.4 million baht (331.9 million baht for the large, 355.5 million baht for the small boats). The part of fishing gears, loss of fishing gears normally accompanies the damage done to the affected fishing vessels. The damage in this assessment covers the loss of bamboo stake traps, nets, crab traps, squid traps, and fish traps. Damage to these gears was placed at 160 million baht. The total value of damage to fisheries excluding aquaculture was placed at 1.9 billion baht. In 2000 the total fish production of Thailand was almost 4 million metric tons. Nearly one-third of the total marine catch is taken in the Andaman Sea, valued in 2000 at 1.1 billion baht. After the tsunami, the fishing industry and coastal aquaculture suffered major losses in terms of vessels, gears and aquaculture facilities. In addition 8 harbors were severely damaged (Pedro, 2005) (Figure 2.16).

2.6.2.3 Coastal aquaculture

The most severe damage in the aquaculture sector was to fish cages for marine fish farming of which Phang-Nga, Ranong and Satun were mostly affected. The cultured species included grouper, sea bass, red snapper and lobster. Though fish cages were mainly located in sheltered areas, well protected by mangroves such as the mouth of rivers and canals, the rapidly rising tides and their reversal caused the fragile cage structures to break by crashing them in to other cages or rigid structures or mangrove trees. If the fish stocks did not escape from the damaged cages, the remaining stocks might be injured by the collision and subsequently die as a result of bacterial infection of their wounds. The total damage to shrimp ponds was reported to amount to only 233 rai because most shrimp farms along the Andaman coast were located on higher ground which the tsunami waves could not reach. Shrimp hatcheries were heavily damaged in Muang district, Phuket, Takua Pa District and Tai Muang District, Phang-Nga, where the structures were mainly destroyed. Because of good water quality, many of these hatcheries also operated brood stock development and sold the newly hatched larvae to other small-scale hatcheries. Fortunately, the main areas for shrimp hatcheries were in the Gulf of Thailand. The rest of the hatcheries were only slightly affected (Figure 2.17), such as by the loss of and damage to water pumps, other equipment and shrimp seed stocks. The impact on shellfish culture covered 819 rai of seabed concession for cockles and mussels as well as 165,013 m^2 of mussel and oyster rafts. The worst shellfish damage was in Phang-Nga, Phuket, Satun and Ranong (Figures 2.18 and 2.19) (FAO and MOAC, 2005).

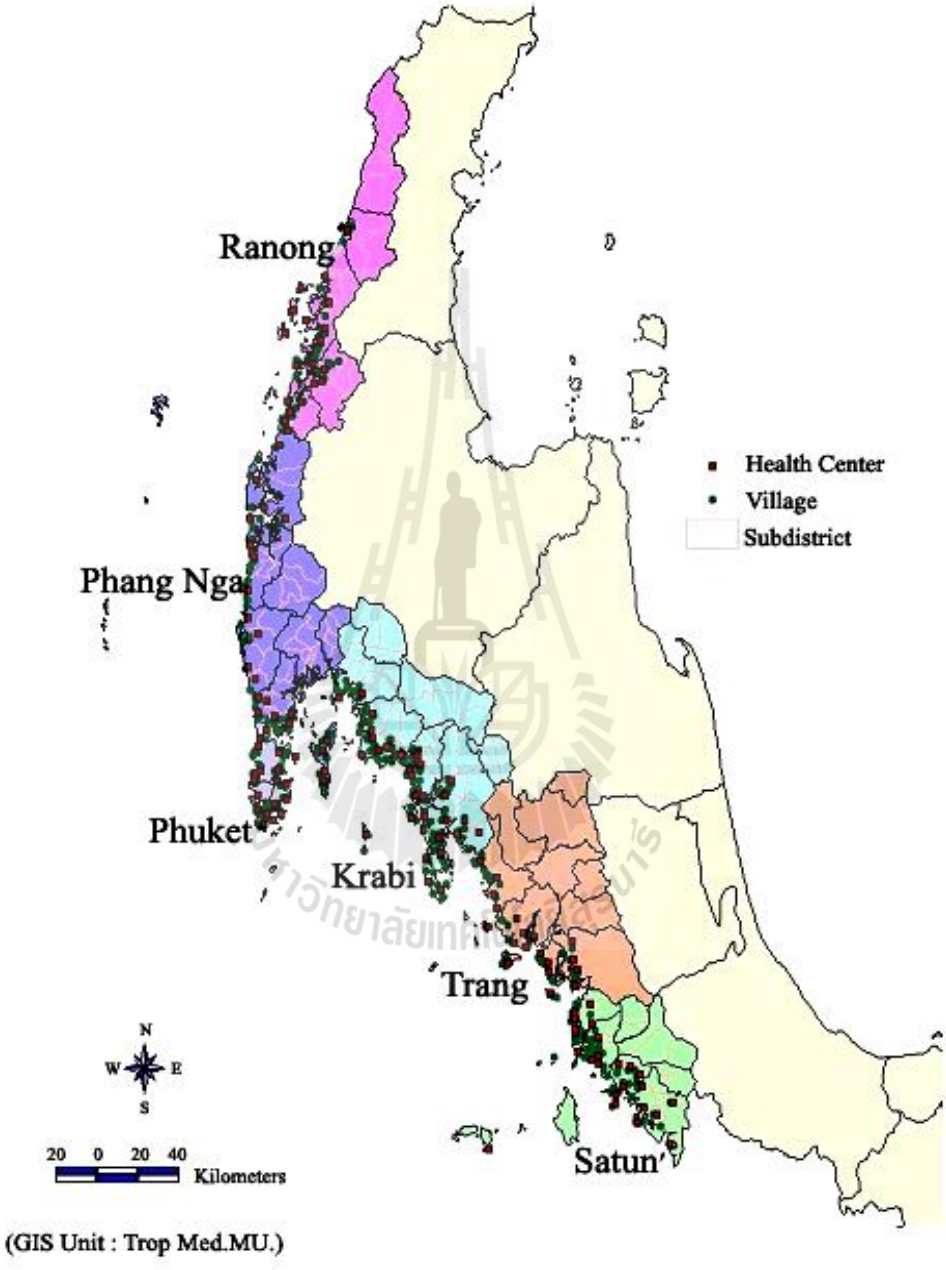

Figure 2.14 Tsunami-affected areas in Thailand (Pratap et al., 2006).

Figure 2.15 Damages of coastal communities and casualties; (a), (b) disaster in Phi Phi Island (The Nation & Phuket Gazette Special, 2005) and (c), (d) were households damaged and deceased in Phang-Nga (Tawatchai, Arturo and Watchara, 2005).

Figure 2.16 Small fishing boats were worst hit (a) and large trawlers were damaged by the tsunami (b) (FAO and MOAC, 2005).

Figure 2.17 Shrimp hatcheries were damaged (FAO and MOAC, 2005).

Figure 2.18 Smashed fish cages (FAO and MOAC, 2005).

Figure 2.19 Fish cages were washed onshore (FAO and MOAC, 2005).

2.6.2.4 Agriculture

The destruction in the agricultural sector, on 9,726 rai of agricultural lands owned by 1,157 farmers was affected. Significant cause to agricultural land resulted from the intrusion of sea water. Damage due to direct impacts of the tidal waves to crops at close proximity to the coast line was minor. However, the majority of crops suffered from the high level of salinity. Fruit and plantation trees showed toxicity symptoms such as yellowing and drying leaves. The agricultural land of in the six provinces were reported that about 8,000 rai to be affected by salinity (FAO and MOAC, 2005) (Figure 2.20).

Figure 2.20 Damage to agricultural lands due to sea water intrusion (a), sea water intrusion and uprooting of young oil palm trees (b) and crops affected by sea water intrusion (c) and severely damaged oil palm plants (d) (FAO and MOAC, 2005).

2.6.2.5 Livestock

The livestock sector was damaged by tsunami about 535,560 head including cattle, buffaloes, pigs, sheep, goats, ducks, chickens and geese belonging to 4,898 farmers were affected because of feed shortages and damage to infrastructure in addition to 10,730 animals which were dead or missing and estimated the sustained losses of the livestock sector at US$ 0.5 million with 90 percent of the animal, losses occurring in Phang-Nga and Ranong provinces, including cattle, buffaloes, pigs, sheep, and goats. Chickens, ducks, quails, and geese were directly ruined by the tsunami and died as a result. The surviving animals were in a critical condition because their barns were destroyed and there was a shortage of feed. They were, therefore, relocated one to two kilometers inland where the area had escaped damage and better conditions were available for raising livestock (FAO and MOAC, 2005) (Figure 2.21).

Figure 2.21 Damaged pasture lands and emergency supply of feed to surviving livestock (FAO and MOAC, 2005).

2.6.3 Natural resources and environments

2.6.3.1 Mangrove and other coastal forests

The mangrove forest destruction was caused by the tsunami that about 1,900 rai and 10 rai of mangrove forest in Phang Nga, and Satun respectively were affected. The damage was less than one percent of the total mangrove forest in the six provinces. In Phang Nga Province, the mangrove destruction was minor and partly caused by being hit with the tsunami affected fishing boats which ended up in the mangrove forests. The damage to the mangroves was concentrated in the sea front areas where the tsunami had the greatest physical impact. Mangrove trees were broken and knocked down in a landward direction. The tsunami's impact was confined to less than 10 meters inland in most cases. Mangroves further inland were unharmed. Another type of serious damage observed was caused by the boats that were swept up by the force of the tsunami. In many places, a mangrove forest was a buffer to protect communities, including houses and land from the force of the tsunami. Moreover the local people believed that the mangrove forest in front of their community protected them from tsunami damage. Thus, only about 0.17 percent of the mangroves were in fact damaged and the damage mostly occurred on sandy beaches where, sometimes, a layer as deep as one meter was lost as a result of sand erosion. Large trees which had deeper and more developed root systems to hold them against the impact of a tsunami and therefore uprooted large trees were seldom seen. Uprooted medium and small size trees were common. However mangrove and other coastal forests appeared to have played a significant role in protecting beaches, land, houses, animals, and fruit trees from the destruction of the tsunami (FAO and MOAC, 2005) (Figure 2.22).

2.6.3.2 Coral reefs

The coral reefs along the Andaman coast of Thailand were estimated that 13% of the total coral reef area was significantly impacted. The level of impact was site specific and varies from 0 to 80%. Reefs located in channels between islands were suffered more severe impacts; shallow water reefs were most affected; deep water reefs and those around Phuket remained largely intact. The types of impact were also site specific and included siltation and sand sedimentation as well as partial damage by debris from land swept by the receding waves. There was also some dislocation or removal of coral heads (FAO and MOAC, 2005).

Figure 2.22 Serious damage to the mangroves was caused by the boats swept there by the force of the tsunami (a) (b) and smaller tree was uprooted by the loss of the sandy layer (c) (FAO and MOAC, 2005).

2.6.3.3 Seagrass beds

The seagrass beds on the Andaman coast were of considerable importance as a basis for fishery production, as food source for certain threatened wildlife particularly the green sea turtle and the dugong, and for coast stabilization. Seagrass meadows covering the inter-tidal zone appeared to have prevented soil erosion during the tsunami event, as those in Kuraburi, Phang-Nga province and found that 3.5% of the inspected area was impacted by silt and sand sedimentation, 1.5% suffered total habitat loss; the most impacted seagrass meadows were those of Yao Yai Island in Phang-Nga Province which registered a total habitat loss of 10%. The seagrass meadows of Talibong Island in Trang Province, which are the biggest areas in the Andaman coast of Thailand providing foraging ground to a large population of dugongs, did not suffer any total habitat loss, although 10% of the area was silted or sand-sedimented (FAO and MOAC, 2005).

2.6.3.4 Marine wildlife (sea turtles and marine mammals)

The tsunami disaster affected significantly four sea turtle conservation projects. The Turtle Conservation Project (Phang-Nga Province) lost two project staff and the project camp was totally destroyed. The Tap Lamu Naval Base (Phang-Nga Province) where the breeding/conservation centre was in ruins and around 2,000 turtles were reported to have been lost. The Phuket Marine Biological Centre lost 18 breeding Olive Ridley turtles. Finally, the Sea Turtle Conservation and Wildlife Sanctuary Project (Ranong Province) with participating communities was also reporting heavy impacts and damage. In addition, two dugongs and three dolphins were carried inland by the waves. One of the dugongs and two of the dolphins died (United Nations Environment Programme, 2005; Pedro, 2005).

2.6.3.5 Surface and groundwater

The tsunami flooded coastal areas to 2-3 kilometers inland. Surface waters in the inundated areas were likely to have been significantly contaminated with saltwater. Short duration flooding caused negligible infiltration of saline water. However, seawater that remained in pools, lakes and depressions could lead to saline infiltration in areas with permeable soils, hence eventually impacting on groundwater. In addition, the washed away coastal sediments that resulted in a landward shift of the coastline in some areas. The intrusion of saltwater in the coastal aquifers was expected to shift landwards over a similar distance, which could affect nearby groundwater production wells. In the long term salinization of groundwater may also occur by deposited salts leaching from unsaturated zones into the groundwater. The problem of groundwater quality could be further compounded by the potential contamination from sewage and the huge amount of waste generated by the tsunami. The Department of Health analyzed the quality of well water in the 6 provinces for coliform bacteria, chlorine and particulates. Contamination of well water in Phang-Nga was significant. The majority water was found unsafe due to coliform bacteria contamination and seawater intrusion. In Phuket, it was contaminated by coliform that affected severely of post-tsunami (FAO and MOAC, 2005).

2.6.4 Tourism situation

Thailand is one of the eight Asia Pacific countries impacted by Tsunami disaster on December 26, 2004 at the peak of the tourist season. The major affected areas were at the Andaman Sea side provinces of Phuket, Phang-Nga and Krabi. Most casualties and injured were concentrated in the two areas of Khao Lak in Phang Nga and Koh Phi Phi in Krabi Province. Many of the hotels and resorts in the

Tsunami affected areas were not hit. All basic infrastructures were restored very quickly without any foreign help, and no wide spread diseases were found. Still many tourists decided to opt out due to psychological reasons which had a major impact on the Thai tourism industry.

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Tourism industry contributed about 12% of Thai GDP and employed 3.9 million workers or 8.3% of total work force in 2004. The Tsunami hit areas were estimated to represent at least 20% of the Thai tourism economy. In the aftermath, international arrivals to Thailand were fairly flat in the first half of the 2005 and several holiday makers and tour operators relocated their destinations inside the country away from the Tsunami hit areas. According to Visa International the inbound tourist spending in Phuket plunged from a 30% growth prior to Tsunami to a 75% decline by the end of January 2005. According to the Deloitte Hotel Benchmark Survey hotel occupancy rates in Phuket were still perching around 40% in June 2005 compared to 70% the year before, and the revenue per available room was down by more than 40% during the first six months of 2005 (Pongsak and Jukka, 2005).

2.6.5 Pollution (solid and liquid waste)

With the extensive damage to the built environment, including individual houses (6,791 damaged and 3,619 destroyed), shops tourist facilities and public infrastructure, large amounts of debris ranging from inert building material to hazardous wastes were generated. The total amount of debris was not precisely known, although preliminary estimates for Phi Phi Islands (Krabi Province) 30,000 to 35,000 tones of which 13,000 tones had already been collected. With the powerful action of the receding waves, debris was scattered across the coastal zone from the settlement areas to the beaches and into the marine ecosystems such as sea grass meadows and coral reefs (United National Environment Program, 2005).

2.7 Tsunami disaster in Phang-Nga Province

Phang Nga was the worst-hit province with some 4,224 lives lost and 7,003 ha of land area devastated. Takua Pa District, which was a prime tourist area with numerous beach resorts, was the most severely affected area in Phang-Nga Province.

Through the use of the aerial photographs and Ikonos images, it was found that 4,738 ha of Takua Pa District's coastal area were affected by the tsunami. The tsunami run-up heights of 7-8, 5-7 and 10-12 meters, were observed at, respectively, Ban Namkhem, Pakarang Cape and Ban Bangnieng in Takua Pa District. The tsunami caused heavy damage to houses, tourist resorts, fishing boats and gear, culture ponds and crops, and consequently affected the livelihood of large numbers of the coastal communities. The destructive wave impacted not only soil and water resources, but also damaged healthy coral reefs, sea grass beds and beach forests. The surviving victims faced psychosocial stresses resulting from the loss of their loved ones, being rendered homeless and fears of another tsunami. The tsunami effects on human settlements, livelihoods, coastal resources, natural environment together with the psychosocial well being of the coastal communities have contributed to the degradation of the coastal ecosystems (FAO and MOAC, 2005).

Indeed, the large severely disaster from Tsunami along coastal Southern of Thailand provinces; Phang-Nga was the mostly affected among these six provinces. Therefore, this province may need to monitor on environment impact, especially the areas which were used for coastal fisheries, coastal aquaculture, livelihoods and community settle. Because many hazard rubbishes, solid and liquid wastes were swept into the sea from the huge wave. This may be directly or indirectly impact to healthy and livelihood of coastal communities. Their affected were earned decreases income from selling fishery goods including productions by local fisheries and ecotourism. In this case study, the research was focused on the chemical and biological properties of sea water around coastal fisheries, coastal aquacultures and coastal communities which were mainly affected areas and the significance was necessarily examined on first priority for safety and protection all problems to health of fishers, aquaculturists, consumers and tourists that may be happened in the future.

2.8 Properties of sea water (Gordon, 2005)

2.8.1 Temperature

The temperature of the ocean ranges from about -2 ^{o}C to 30 ^{o}C. Ocean water that is nearly surrounded by land may have higher temperatures, but the open sea, where the water is free to move about, hardly ever heats above 30 ^{o}C. Here, the ocean currents distribute the heat and tend to equalize the temperature. Deep and bottom water temperatures are always low, varying between 4 ^{o}C and 1 ^{o}C. The diurnal variation of sea surface temperature in the open ocean is on the average only 0.2 ^{o}C to 0.3 ^{o}C. The greatest diurnal variation takes place in the Tropics, with lesser variation at higher latitudes. The range of diurnal variation depends on the amount of cloudiness and the direction and speed of the wind. The temperatures near the equator experience a semiannual variation. This corresponds to the twice yearly passage of the Sun's most direct rays across the equator.

2.8.2 Salinity

The salinity values of ocean water range between 33 ppt and 37 ppt with an average of 35 ppt. In the open ocean, surface salinity is decreased by precipitation, increased by evaporation, and changed by the vertical mixing and inflow of adjacent water. Near shore, salinity is generally reduced by river discharge and freshwater runoff from land. Salinity is at its minimum in the fall. This corresponds with tropical storm season. The vast amount of precipitation associated with these tropical storms as they moved across the ocean surface decreases salinity.

2.8.3 Dissolved Oxygen

The oxygen content of natural waters can vary widely depending on the physical, chemical and biological processes in the water body as already indicated. Running waters generally have higher oxygen content than stagnant waters. As explained the major source of oxygen in natural waters is the atmospheric air. Oxygen enters water by the process of diffusion and higher the mixing of air and water due to surface-water agitation such as by wave action and turbulence in running water or due to artificial process of aeration by compressed air diffusers and use of agitators, in aquaria and ponds, the higher and oxygen saturation. Apart from diffusion from the air, water bodies gain oxygen through photosynthesis of chlorophyll bearing aquatic organisms i.e. higher plants, phytoplankton and photosynthetic bacteria. Oxygen is not very soluble in sea water. More oxygen concentration is in the air than in seawater. Seawater contains about 4 to 6 milliliters of dissolved gas per 1 liter of seawater. However, the oxygen produced in seawater is by photosynthesis of certain capable marine organisms. This oxygen gets released into the atmosphere and cellular respiration removes dissolved oxygen from the seawater.

2.8.4 Transparency

Sunlight can penetrate into the ocean, because the ocean is relatively transparent. If the seawater was not transparent, then photosynthesis would hardly occur in the sea except on the surface. The blue light penetrates the deepest in the ocean water. The red light penetrates the least in the ocean water, because the red is the most absorbed. Transparency of water is greatly affected by the substances that are in the seawater and a lot of plankton were caused decrease the transparency of seawater.

2.8.5 Total dissolved solids and Electricity conductivity

Total dissolved solids found in sea water or brackish water (<3000 mg/l). The primary difference between the types of water mentioned above is in the amount of total dissolved solids they contain. Brackish water typically contains total dissolved solids in concentrations ranging from 1,000 mg/l to 10,000 mg/l, saline water or salt water has more than 10,000 mg/l and seawater typically is very salty (total dissolved solids >35,000 mg/l). In many cases, electricity conductivity is linked directly to the total dissolved solids. The typical sea water has a conductivity value about 50,000 µS/cm.

2.9 The Andaman Sea coast of Thailand

The provinces of Ranong, Phang-Nga, Phuket, Krabi, Trang and Satul face the Andaman Sea and have a total coastline of about 700 km. Approximately 100,000 m^2 constitutes the narrow sea shelf, which is about 108 km wide in the north (Ranong Province), narrows down to 27 km in the middle (Phuket Province) and widens again to about 130 km in the south (Satul Province). The sea off the Phang-Nga, Phuket, Krabi and Trang provinces is influenced by semi-diurnal tides of approximately 3 m in spring and 1 m in neap tide. The water circulation is tidally dominated by a major flow in a northeasterly direction. During the Northeast Monsoon, the surface and subsurface flow in the nearshore areas appears to move northwards at a speed of 2-4 cm/sec, while during the Southwest Monsoon, the surface flows southwards at a speed of 5-8 cm/sec, gliding over a counter subsurface flow northwards of 2-5 cm/sec.

The northern stretch, from Ranong to Phuket Province, is influenced by deepsea upwelling resulting in high salinity (32.9-33.4 ppt), while the southern stretch (Phuket to Satul Province) is influenced mainly by surface run-off resulting in a lower salinity (32.6-32.8 ppt). The dissolved oxygen, pH and temperature values are 5.5-6.4 mg/l, 8.06-8.15 and 27.6^{o}C- 29.3^{o}C respectively and are fairly uniform along the coast. The southern waters are relatively well-mixed, with total suspended solid values being 9.9-14.8 mg/l. Somewhat lower values are recorded in the northern waters. The nutrient concentrations of nitrate and phosphate ranged between 0.12-3.40 and 0.08-0.87 µg/l, respectively. The surface water in the south is fertilized mainly by mangrove run-off resulting in a primary production of 180-880 gC/m^2/year, while surface water in the north is fertilized by upwelling bottom water resulting in a high primary production of around 700 gC/m^2/year.

Along the western coast of Thailand, there are vast areas of turbid water. This is caused by silt from the rivers, especially after heavy rains. Part of it is of natural origin, but during the last decade the silt outflow has increased exponentially due to bad land management and mining. The decreased light penetration causes a loss of primary production, which has a considerable negative impact on fisheries.

The density of macrobenthic fauna on the coastal seabed of the Andaman Sea ranges from 200 to 1000 animals/m^2. The majority are molluscs, *Echinodermata* and *Chordata*.

Of the 49 fish families in the Andaman Sea, 25 set larvae along the Thai coasts. Of these, 64 per cent belong to economically important species. Zooplankton occur with an average density of 682 inds/m^3 corresponding to a biomass of approximately 20 mg/m^3. Clupeoids are the most abundant. The crustacean comprising are 30 per cent of the biomass, while *Brachyura* larvae, shrimps and bivalves comprise 1.2-10.7, 0.9-2.6, and 0.2-5.5 per cent of the biomass respectively (Boonruang, 1985). The sea around Phi Phi Island, south of Lanta Yai Island and east of Yao Yai Island are a spawning ground for Chub Mackerel. Fish larvae abound in March and April.

The benthic fauna has been studied along the coasts of Phuket. In Phang-nga, Krabi and Trang an average biomass of 26.5 g/m^2 was found. Polychaetes dominated in numbers and an average density of 256 inds/m^2 was noted. Crustaceans and molluscs also made up a considerable part of the bottom fauna, recording densities of 224 and 138 inds/m^2 respectively. Only a few echinoderms occurred. Fish and other animals were found at a density of 23.7 and 48 inds/m^2 each and with a biomass of around 1 g/m^2. The bottoms mainly consisted of the silt-clay fraction (40 per cent).

The annual maximum sustainable yield of commercial pelagic fish in the Andaman Sea is estimated to be 50,000 tonnes. For demersal fish it is estimated to be 200,000 tonnes. The catches of commercial fish are still under the sustainable yield. During some years, however, fisheries in the Andaman Sea are close to the annual production. The total catch of fish and other species, such as shrimp, crab, squid and bivalves, was 300,000 tonnes in 1985, about 85 per cent of it fish. This is about 15 per cent of the total catch in the country. Marine demersal fish catches in 1985 in the Andaman Sea amounted to roughly 100,000 tonnes, valued at 450 million baht. Bivalve production from natural beds was 630 tonnes valued at about 5 million baht. Shrimp catches were about 1,660 tonnes valued at about 80 million baht. And the pelagic fish catches of 38,500 tonnes were valued at about 238 million baht. The most important species found in the catch were Chub Mackerel, Spotted Tuna, Bonito, scad, Hairtail Scad, Bigeye Scad and trevallies.

There are three types of aquaculture practiced on the Andaman coast: culture of molluses, cage culture of finfish (mariculture) and land-based shrimp culture. The most intensely developed areas are found in Phang-Nga Province, where about 85 per cent of the coast is used for farming shrimp production here in 1986 touched about 15,800 tonnes valued at 1,340 million baht. Cockle production yielded 4,320 tonnes valued at 23 million baht. Farmed fish also contributed significantly; 176 tonnes worth 15 million baht. In addition, there was a small production of a few tonnes oysters and other bivalves in 1987, valued at about 37,000 baht. A coastal area of 350 ha has been developed for aquaculture in the region. Mollusc mariculture has also been intensively promoted in the coastal region. In 1984, the total mollusc mariculture beds in the Andaman Sea covered 1030 ha. The mollusc production was 1,100 tonnes**,** including both cultured and naturally harvested mussels. The species included bloody cockle (*Anadara granosa, A. nodifera*), green mussel (*Perna viridis*), oyster (*Crassostrea belchen, C.lugubris, Saccostrea cucullata*), horse mussel (*Odiolus senhaysenii*), pearl shell (*Pinctada maxima, P. margaritierae*) and shortnecked clam (*Paphia undulate*).

Fishery harbors are located along the Andaman Sea coastline, often close to mangrove forests and estuaries. They produce organic wastes, derived from fish cleaning, degutting and garbage, besides oily bilge water. The principal harbors are the Ranong, Phuket and Satun fishery harbors. Each of these harbors provides berthing and fish handling facilities for approximately 200-400 fishing vessels. There are also a number of smaller fishery harbors along the coast. About 10,000 people, connected in some way with fishing activities, are active in each main harbor. The amounts of organic waste generated by these people are difficult to estimate, but very high levels of bacterial content have been recorded in the harbor waters. Waters around fishery harbors are also utilized for many human activities. They are also often support rich marine life. Organic wastes provide an important nutrient input in estuaries, supporting primary production and improving fish growth. Phytoplankton blooms occur regularly in Patong Bay, which continuously receives treated and untreated organic wastes from hotels and other sources.

Fishing vessels also discharge bilge waters and other oily wastes into the surrounding waters. Each vessel is bound to renew about thirty litres of used lubricant every month. The minimum number of vessels, 200 will produce 6,000 litres, or about six tonnes of oily bilge wastes, every month at each fishery harbor. Fortunately, dumping does not occur at the same time. All harbor 5 should have facilities for collecting and cleaning this waste, since it has a commercial value and can be reused instead of being discarded. The concentrations of heavy metals in seawater are very low around Phuket and the average values of copper, zinc and iron are 1.3 µg/l, 1.5 µg/l and 2.6 µg/l respectively (Limpsaichol, 1994).

2.10 Coastal water state of Thailand

In 2002, according to seawater quality survey along the Gulf of Thailand and the Andaman Sea during February-March, 47% of seawater quality was excellent, 36% of seawater quality was normal, 11% of seawater quality was bad. The area of water pollution was around inner gulf of Thailand in 4 main estuaries. There are 3 important crisis in 2002 such as the declination of seawater quality, solid waste, and oil leak (Department of Pollution Control, 2002).

In 2003, the coastal water quality monitoring data of Thailand from 240 stations in 23 provinces and shows that 7 percent of the stations had excellent water quality, 61 percent had good water quality, 29 percent had fair water quality and 3 percent had deteriorated water quality. The most of the monitoring data showed that the water quality in the area was within the coastal marine water quality standards. The exceptions were Charn Damri Beach (Ranong Province) and Naiharn Beach (Phuket Province) which had low dissolved oxygen concentrations (2.8-3.0 mg/l). High counts of total coliform bacteria (16,000 units) were detected in the areas of Charn Damri Beach (Ranong Province), Naiharn Beach, Patong Beach, Rawai Beach (Phuket Province), Ban Laemsak (Phang-Nga Province), Tonsai Bay, Phi Phi Island and Nopparatara Beach (Krabi Province). Iron concentrations were high in most areas. There were high total bacteria concentrations at the pier on Tonsai Bay, Phi Phi Island. Suspended solids values (3-43 mg/l) were lower than other regions. When compared to data from previous years areas with excellent water quality had decreased from 47% to 7%, areas with good water quality has increased from 36% to 61%, areas with fair water quality had increased from 11 % to 29% and areas with deteriorated water quality has decreased from 6% to 3% (Pollution Control Department, 2003).

In 2004, the coastal marine water quality monitoring data of Thailand from 240 stations (23 provinces) in 2 seasons: dry season (April-May) and rainy season (July-August) 2004, and the situation assessment by means of Marine Water Quality Index showed that the stations, with excellent, good, fair, deteriorated, and highly deteriorated water quality conditions, were at the rates of 3%, 43%, 45%, 5%, and 4% respectively. The exceptions, Charn Damri Beach (Ranong Province), Naiyang Beach, Naiharn Beach, Patong Beach, Rawai Beach, Karon Beach, the estuary of Tah Jeen Canal, Bahn Kor Siray, Bang Rong Bay (Phuket Province), Nopparatara Beach, Tanode Headland (Lanta Island), Ban Saladan (Lanta Island), Tonsai Bay, Yow Beach, Phi Phi Island (Krabi Province), Pakmeng Beach, Samran Beach (Trang Province), and Pak Bara Beach (Satul Province) high counts of total coliform bacteria (1,100-160,000 units) were detected and Ban Saladan (Lanta island) was the highest.

Enterococci were detected at Ban Saladan, Tanode Headland (Lanta Island), Rawai Beach, Nopparatara Beach, and Pakmeng Beach as 460, 170, 920, 130 and 120 units, respectively.

Iron concentrations were found at Bang Ben beach (Ranong Province), Bahn Khao Pilai (Phang-Nga Province), the estuary of Tah Jeen Canal (Phuket Province), Pakmeng Beach, Samran Beach, and Bahn Bor Muang (Trang Province) higher than the coastal marine water quality standards (310-10,000 µg/l). The highest concentration was at Bang Ben Beach (Ranong Province), which sand was dark color. (Pollution Control Department, 2004).

After the tsunami flooded coastal areas up to two kilometers inland in Phang-Nga Province, the water samples were collected from Takua Pa District, Phang-Nga Province at Ban Nam Khem, Ban Bangsak, Kuk Khak Beach, Ban Kuk Khak, Ban Bannieng, and Khao Lak Merlin. The values of salinity were detected as 24.5 ppt, 17.9 ppt, 3.70 ppt, 24.8 ppt, 28.1 ppt, and 32.9 ppt, respectively, dissolve oxygen were recorded as 4.02 mg/l, 6.75 mg/l, 4.42 mg/l, 7.17 mg/l, 4.59 mg/l, and 4.90 mg/l respectively, and pH of water samples were reported as 8.19, 8.35, 7.68, 8.62, 8.39, and 8.06 respectively (Thanawood et al., 2006).

In 2005, the coastal marine water monitoring data from 242 stations during spring season (March-April) and rainy season (August-September), classified by the assessment of Marine Water Quality Index showed that 3, 43, 44, 9, and 1 percent of the stations had excellent, good, fair, poor and very poor water quality respectively.

Andaman coast, from Ranong to Satul provinces, marine water quality was mainly between good and fair. Compared to data in 2004, water quality in general was poorer. Several water quality monitoring stations downgraded from good to fair According to the data, water quality of Andaman coast was mainly within standards except some which were not within the standards and draft standards as follows:

Nitrate-N: between <1-102 μg/l. The concentration was greater than standards draft at Chan Damri Beach, the estuary of Ranong River (Ranong Province), Bang Sak, Bahn Nam Kem and Phra Thong Island (Phangnga Province), Patong Beach, and Rawai Beach (Phuket Province), Tanode Headland (Lanta Island), Bahn Klong Nin (Lanta Island, Krabi Province), Bahn Pak Bara Beach, Bahn Pak Bang, ferry pier at

Pak Bara, and Bahn Tung Rin (Satul Province). The highest concentration was found at Bahn Pak Bang.

Ammonia-N: between <1-676 μg/l. The concentration was greater than standards at the estuary of Ranong River, Bang Ben Beach, and Prapas Beach (Ranong Province), Bang Sak, Pak Bang Canal (Khao Lak), Bahn Bang Nieng, Bahn Khao Pi Lai, Bahn Tab Lamu, Tai Mhuang, Phra Thong island, Bahn Kor Khor Khao, Bahn Nam Kem, and Bahn Kuek Kuck (Phang-Nga Province), Naiyang Beach, Bang Thao Beach, Surin Beach, Kamala Beach, Patong Beach, Karon Beach, Kata Noi Beach, Kata Yai Beach, Rawai Beach, Nai Han Beach, Ma Kham Bay (in front of Marine Fisheries Office of Phuket), the estuary of Tah Jeen Canal, Bahn Kor Siray, Bang Rong Bay, and Chalong Bay (Phuket Province), Nopparat Tara Beach, Lanta Island Southern Kor Kwang Beach (Bahn Klong Nin and Bahn Saladan), Phi Phi Island (Tong Headland, Lo Ba Kao, Lo Da Lum Bay, Yow Beach), Mayah Bay, and Railay Bay (Krabi Province), Pakmeng Beach (Bahn Bor Muang), Chao Mhai Beach, Yong Ling Beach, Yow Beach, and Chao Samran Beach (Trang Province), Pak Bara Beach, Bahn Tung Rin, Bahn Pak Bang, and Pak Bara ferry pier (Satul Province). The highest concentration was found at Rawai Beach.

Phosphate-P: between <1-104 μg/l. The concentration was greater than standards draft at Chan Damri Beach, the estuary of Ranong River (Ranong Province), Prapas Beach, and Bang Sak (Phang-Nga Province), Patong Beach, Kata Noi Beach, Rawai Beach, and Nai Han Beach (Phuket Province), Railay Bay (Krabi Province). The highest concentration was found at Prapas Beach.

Total Coliform Bacteria: between <2-24,000 units. The concentration was greater than standards at Chan Damri Beach, the estuary of Ranong River (Ranong

Province), Bahn Nam Kem (Phang-Nga Province), Rawai Beach (Phuket Province), Nopparat Tara Beach, Lo Da Lum Bay (Phi Phi Island), and Mayah Bay (Krabi Province). The highest concentration was found at Nopparat Tara Beach.

Fecal Coliform Bacteria: between <2-13,000 units. High concentration was found at Chan Damri Beach, the estuary of Ranong River (Ranong Province), Bahn Bang Nieng, Bahn Khao Pilai, Bhan Tab Lamu, Bahn Nam Kem, and Bahn Kuek Kuck (Phang-Nga Province), Naiyang Beach, Patong Beach, Rawai Beach, the estuary of Tah Jeen Canal, Bahn Kor Siray, and Bang Rong Bay (Phuket Province), Nopparat Tara Beach, Ta Node (Lanta Island), Bahn Klong Nin (Lanta Island), Ma Yah Bay, Railay Bay, Loh Dalam Bay (Phi Phi Island), and Yow Beach (Phi Phi Island, Krabi Province). The highest concentration was found at Rawai Beach.

Enterococci Bacteria: between <6->1,600 units. High concentration was found at Bang Ben Beach and Prapas Beach (Ranong Province), Bahn Khao Pilai, Tai Mhuang, and Phra Thong Island (Phang-Nga Province), Naiyang Beach, Bang Thao Beach, Surin Beach, Kamala Beach, Patong Beach, Karon Beach, Kata Noi Beach, Rawai Beach, Nai Han Beach, and Ma Kham Bay (in front of Marine Fisheries Office of Phuket), Phuket Island, Nopparat Tara Beach, Railay Bay, Phi Phi Island, Tong Headland, Lo Ba Kao, Loh Dalam Bay, Yow Beach (Krabi Province), Chaomai Beach, Yong Ling Beach, and Chao Samran Beach (Trang Province), Bahn Pak Bara Beach, and Bahn Tung Rin (Satul Province). The highest concentration was found at Bahn Khao Pilai, Phra Thong Island, Naiyang Beach, Bang Thao Beach, Surin Beach, and Nopparat Tara Beach. These areas having bacteria higher than draft standards were mainly tourist spots with dense stores, restaurants, hotels and resorts.

Iron: between <0.1-2,226 μg/l. The concentration was greater than standards at Chan Damri Beach, the estuary of Ranong River (Ranong Province), Pak Bang Canal (Khao Lak), Bahn Khao Pilai, and Tai Mhuang (Phang-Nga Province), Bang Thao Beach, Patong Beach, Nai Han Beach, the estuary of Tah Jeen Canal, Bahn Khor Siray (Phuket Province), Southern Kor Kwang Beach (Lanta Island), Loh Dalam Bay (Phi Phi Island), and Yow Beach (Phi Phi Island, Krabi Province), Pakmeng Beach, Bahn Bor Muang, and Samran Beach (Trang Province), Bahn Pak Bara Beach, Pak Bara Ferry Pier, and Bahn Tung Rin (Satul Province). The highest concentration was found at Bang Thao Beach.

Zinc: between <0.1-136 μg/l. The concentration was greater than standards at Chan Damri Beach, the estuary of Ranong River and Bang Ben Beach (Ranong Province), Bahn Khao Pilai and Tai Mhuang (Phangnga Province), Bang Thao Beach, Patong Beach, Karon Beach, and Bang Rong Bay (Phuket Province). The highest concentration was found at Tai Mhuang.

Tributyltin: between <10-36 ng/l. The concentration was greater than draft standards around Chan Damri Beach, the estuary of Ranong River (Ranong Province), Bang Rong Bay (Phuket Province). The last area had the highest concentration (Pollution Control Department, 2005).

In 2007, the coastal water-monitoring data analyzed from 240 stations during dry season (February-March) and rainy season (June-July) and classified by the assessment of Coastal Water Quality Index, showed that 12%, 49%, 36%, 2%, and 1% of the monitoring stations had excellent, good, fair, deteriorated and highly deteriorated conditions respectively. In comparison of last three years, it was found that coastal water quality was better with the decrease of water in deteriorated and highly deteriorated conditions.

The parameters, that the water quality was deteriorated, was Total Coliform Bacteria, Nitrate-N, Phosphate-P, Amonia-Nitrate, including Zinc (Zn), Iron (Fe), Suspended Solids, Floating Material, Oil, and Grease. The high contamination was found at the river mouth, tourist sites, and community areas. Waste and oil were also found along the coastline.

Coastal water quality in Andaman coast at 65 monitoring stations, from Ranong to Satul, the quality of water was in good to fair. Compared with 2006, the water quality generally decreased. The quality of water in several stations changed from excellent to good and from good to fair. The parameters which did not meet the standards were enterococci, fecal coliform bacteria and floating materials (Pollution Control Department, 2007).

2.11 Marine water quality standard (Marine Environment Division, 2006)

The Thailand National Environment Board issued the 7th decree (B.E. 2537) for the control of coastal water quality. According to the decree, Thailand established the original Coastal Water Quality Standard, which has been used to govern and manage coastal water for ten years. When taking into consideration the current state of the economy and environmental awareness as well as the rapid advancement of technologies it has become clear that the original standard is outdated. National Environment Board reconsidered the original standard and agreed that the amendment of the original standard was needed. Subsequently, the 7th decree was renounced on

January 20, B.E. 2537 and the new marine water quality standard were designated as follows:

2.11.1 Definitions

2.11.1.1 Marine water means all waters within Thai territorial waters, excluding water in the surface water under the Notifications of National Environment Board on the Water Quality Standards for Surface Waters.

2.11.1.2 Thai waters mean all territorial waters under the sovereignty of Thailand according to the Maritime Law Vessel Act of Thailand.

2.11.1.3 Minimum transparency level means the lowest level of transparency of water that measured and collected from the same station in the past a year during the same tides and seasons.

2.11.1.4 Minimum salinity level means the minimum salinity of water that measured and collected from the same station in the past a year during the same tides and seasons.

2.11.1.5 Buffer zone means the joint areas between different types of marine water utilization. The zone is defined based on the parallel distance of 500 meters from the water that has lower water quality.

2.11.2 The marine water quality standard for recreation areas

The marine water quality standard for recreation areas must be inline with the water quality standard for natural resource preservation areas, except:

2.11.2.1 Temperature changes shall not exceed 2 ^{o}C from nature.

2.11.2.2 Petroleum hydrocarbon shall not exceed 1 microgram per liter.

2.11.2.3 Fecal coliform bacteria shall not exceed 100 CFU per 100 millimeters.

2.11.2.4 Enterococci bacteria shall not exceed 35 CFU per 100 millimeters.

2.11.2.5 Nitrate-Nitrogen shall not exceed 60 micrograms-Nitrogen per liter.

In case, industrial or ports zone or residential areas are overlapped with the coral reef conservation areas, aquaculture areas or recreation areas, as the case may be, the strictest standard of marine water quality shall be applied for the overlapped zone.

2.11.3 Classification of marine water quality standard in Thai waters

Classification of marine water quality standard in Thai waters, the water quality can be classified into 6 types as follows:

Class 1 The marine water quality standard for natural resource preservation areas cover to the water that is not reserved for a particular use and is naturally suitable for breeding or nurturing newborn marine organisms as well as being able to serve as food sources and natural habitats for marine animals, plants and seagrasses.

Class 2 The marine water quality standard for coral reef conservation areas cover to the water densely inhabited by coral reefs, covering the area with 1,000 meters extension from the most exterior ridge of the coral reef.

Class 3 The marine water quality standard for aquaculture areas cover to the water designated as to be utilized for aquaculture by the fisheries laws.

Class 4 The marine water quality standard for recreation areas cover to the water declared by the local administrative organizations for swimming or other recreational activities.

Class 5 The marine water quality standard for industrial or ports zone cover to the water that is adjacent to an industrial estate, which conformed to the law governing the Industrial Estate Authority of Thailand; adjacent to port zones governed by any ports and maritime laws; governed by the standard shall extend from the lowest tide line up to 1,000 meters.

Class 6 The marine water quality standard for residential areas cover to the water that is close to residential areas under the municipal laws, Pattaya Municipality or Bangkok Municipality; the standard shall be applicable specifically to the parts of Pattaya, Bangkok and other municipalities whose borders are attached to the coastal area and extend from the lowest tide line up to 1,000 meters.

2.11.4 The marine water quality standard for natural resource preservation areas

2.11.4.1 No unpleasant objects floating on the water surface.

2.11.4.2 No oil or visible fat floating on the water surface.

2.11.4.3 The color of marine water is in the range from 1-22 in the scale of Forel-Ule solution.

2.11.4.4 The odor must not be obnoxious; no odors of oil, hydrogen sulfide, chemicals, garbage, etc.

2.11.4.5 The temperature can be increased for not more than 1 ^{o}C compared with natural background condition.

2.11.4.6 The pH must be in the range of 7.0-8.5.

2.11.4.7 The reduction of water transparency from natural background conditions shall not exceed 10 percent, compared with the minimum transparency level.

2.11.4.8 Increase of suspended solids shall not exceed the summation of average daily, monthly, or annual value and their standard deviation; the average daily value calculated from the measurements of every hour or at least five times a day and the interval time sampling should be equal; the average monthly value calculated from the measurements of every day or at least four times a month in the same station and the interval time sampling should be equal; the average annual value calculated from the measurements of every month in the same station and sampling time.

2.11.4.9 Salinity change shall not exceed 10 percent of minimum salinity.

2.11.4.10 Petroleum hydrocarbon shall not exceeded 0.5 micrograms per liter.

2.11.4.11 Dissolved oxygen is not less than 4 milligrams per liter.

2.11.4.12 Total coliform bacteria shall not exceed 1,000 MPN per 100 millimeters.

2.11.4.13 Fecal coliform bacteria shall not exceed 70 CFU per 100 millimeters.

2.11.4.14 Nitrate-Nitrogen shall not exceed 20 micrograms-Nitrogen per liter.

2.11.4.15 Phosphate-Phosphorus shall not exceed 15 micrograms-Phosphorus per liter.

2.11.4.16 Ammonia-Nitrogen (Unionized ammonia) shall not exceed 70 micrograms-Nitrogen per liter.

2.11.4.17 Total mercury shall not exceed 0.1 micrograms per liter.

2.11.4.18 Cadmium shall not exceed 5 micrograms per liter.

2.11.4.19 Total chromium shall not exceed 100 micrograms per liter.

2.11.4.20 Chromium Hexavalent shall not exceed 50 micrograms per liter.

2.11.4.21 Lead shall not exceed 8.5 micrograms per liter.

2.11.4.22 Copper shall not exceed 8 micrograms per liter.

2.11.4.23 Manganese shall not exceed 100 micrograms per liter.

2.11.4.24 Zinc shall not exceed 50 micrograms per liter.

2.11.4.25 Iron shall not exceed 300 micrograms per liter.

2.11.4.26 Fluoride shall not exceed 1 microgram per liter.

2.11.4.27 Phenol shall not exceed 0.03 micrograms per liter.

2.11.4.28 Sulfide shall not exceed 10 micrograms per liter.

2.11.4.29 Cyanide shall not exceed 7 micrograms per liter.

2.11.4.30 Polychlorinated Biphenyl (PCB) must not be detected.

2.11.4.31 Arsenic shall not exceed 10 micrograms per liter.

2.11.4.32 Radioactivity in the form of *alpha* shall not exceed 0.1 Becquerel per liter, in the form of *beta* shall not exceed 1.0 Becquerel per liter.

2.11.4.33 Tributyltin compounds shall not exceed 10 micrograms per liter.

2.11.4.34 Chlorinated Chemicals used as pesticides include:

(a) Aldrin shall not exceed 1.3 micrograms per liter.

(b) Chlordane shall not exceed 0.04 micrograms per liter.

(c) DDT shall not exceed 0.01 micrograms per liter.

(d) Dieldrin shall not exceed 0.0019 micrograms per liter.

(e) Endrin shall not exceed 0.0023 micrograms per liter.

(f) Endosulfan shall not exceed 0.0087 micrograms per liter.

(g) Heptachlor shall not exceed 0.0036 micrograms per liter.

(h) Lindane shall not exceed 0.16 micrograms per liter.

2.11.4.35 The chemicals used as pesticides and herbicides include Alachlor, Ametryn, Atrazine, Carbaryl, Carbendazim, Chlorpyrifos, Cypermethrin, 2,4-D, Diuron, Glyphosate, Malathion, Mancozeb, Methyl Parathion, Parathion, and Propanil, shall be undetectable.

2.11.5 The marine water quality standard for coral reef conservation areas

The marine water quality standard for coral reef conservation areas must be in line with the water quality standard for natural resource preservation areas, except:

2.11.5.1 Temperature shall not be changed from nature background conditions.

2.11.5.2 Dissolved oxygen shall not be less than 6 milligrams per liter.

2.11.5.3 Enterococci bacteria shall not exceed 35 CFU per 100 milliliters.

2.11.6 The marine water quality standard for aquaculture areas

The marine water quality standard for aquaculture areas must be in line with the water quality standard for natural resource preservation areas, except:

2.11.6.1 Nitrate-Nitrogen shall not exceed 60 micrograms-Nitrogen per liter.

2.11.6.2 Phosphate-Phosphorus shall not exceed 45 micrograms-Phosphorus per liter.

2.11.6.3 Ammonia-Nitrogen (Unionized ammonia) shall not exceed 100 micrograms-Nitrogen per liter.

2.11.7 The marine water quality standard for recreation areas

The marine water quality standard for recreation areas must be in line with the water quality standard for natural resource preservation areas, except:

2.11.7.1 Temperature changes shall not exceed 2 ^{o}C from nature.

2.11.7.2 Petroleum hydrocarbon shall not exceed 1 microgram per liter.

2.11.7.3 Fecal coliform bacteria shall not exceed 100 CFU per 100 millimeters.

2.11.7.4 Enterococci bacteria shall not exceed 35 CFU per 100 millimeters.

2.11.7.5 Nitrate-Nitrogen shall not exceed 60 micrograms-Nitrogen per liter.

In case, industrial or ports zone or residential areas is overlapped with the coral reef conservation areas, aquaculture areas or recreation areas, as the case may be, the strictest standard of marine water quality shall be applied for the overlapped zone.

CHAPTER III

MATERIALS AND METHODS

3.1 Duration and locations of water sample collection

Water samples were detected and collected during January to December 2008 from nine stations around local fishery piers in three districts; Khura Buri, Takua Pa, and Tai Meung of Phang-Nga province. The geographical positions were marked by GPS of Garmin Model: GPSMAP 60CSX on Geographic Coordinate System, which each station was shown below on details as follow Table 3.1 and Figures 3.1-3.10.

3.2 Water sample collection and analysis

3.2.1 Sample collection

The collection of water samples was performed every month on the highest tide's day of the month at nine stations (St.1-St.9). The water sampling was started from the northern parts to the southern part of the South, that began from Khura Buri district (St.1, St.2, St.3, and St.4), followed by Takua Pa district (St. 5, St. 6, and St.7) and Tai Meung district (St.8 and St.9). Samples were collected by water sampler under sea surface at 1 meter. Three replications were made of each station by pouring 1 liter of seawater into the plastic bottles and reserved in the ice tank before preserving in the freezer with exception of water samples that were preserved to detect biological property (phytoplanktons and zooplanktons) and to investigate the heavy metals were preserved by special method.

Table 3.1 The locations of water sample collection at nine stations around fishery piers in Phang-Nga province.

Station	Location	Latitude - Longitude
1	Khura Buri district, Khura sub-district, Ban Hin Lad, village 3	09°13′51.93″N 098°23′05.34″E
2	Khura Buri district, Khura sub-district, Ban Bang La, village 10	09°13′30.48″N 098°22′55.39″E
3	Khura Buri district, Mae Nang Khao sub-district, Ban Bang Dad, village 7	09°07′53.80″N 098°21′31.80″E
4	Khura Buri district, Bang Wan sub-district, Ban Thung La Aong, village 4	09°02′35.76″N 098°19′18.16″E
5	Takua Pa district, Koh Khor Khao sub-district, Ban Pak Koh village 3	08°52′24.63″N 098°16′23.39″E
6	Takua Pa district, Bang Muang sub-district, Ban Nam Kem, village 2	08°51′35.46″N 098°15′56.59″E
7	Takua Pa district, Khuek Khak dub-district, Laem Pakarang, village 2	08°44′10.70″N 098°13′20.80″E
8	Tai Meung district, Tung Ma Prao sub-district, Ban Klong Chalern, village 2	08°31′54.90″N 098°15′42.70″E
9	Tai Meung_district, Na Toey sub-district, Ban Bor Dan, village 7	08°18′57.71″N 098°16′24.12″E

Figure 3.1 Map of the nine water sample collection stations at nine local fishery piers in areas of eight sub-districts in Phang-Nga province.

Figure 3.2 Khura Buri district, Khura sub-district, village 3 (Ban Hin Lad; **St.1**).

Figure 3.3 Khura Buri district, Khura sub-district, village 10 (Ban Bang La; **St.2**).

Figure 3.4 Khura Buri district, Mae Nang Khao sub-district, village 7 (Ban Bang Dad; **St.3**).

Figure 3.5 Khura Buri district, Bang Wan sub-district, village 4 (Ban Thung La Aong; **St. 4**).

Figure 3.6 Takua Pa district, Koh Khor Khao sub-district, village 3 (Ban Pak Koh; **St.5**).

Figure 3.7 Takua Pa district, Bang Muang sub-district, village 2 (Ban Nam Kem; **St.6**).

Figure 3.8 Takua Pa district, Khuek Khak sub-district, village 2 (Laem Pakarang; **St.7**).

Figure 3.9 Tai Meung district, Tung Ma Prao sub-district, village 2 (Ban Klong Chalern; **St.8**).

Figure 3.10 Tai Meung district, Na Toey sub-district, village 7 (Ban Bor Dan; **St.9**).

3.2.2 Water analysis

The general parameters such as transparency, temperature, salinity, hydrogen ion concentration, dissolved oxygen, electrical conductivity and total dissolved solid were evaluated by the portable instruments in the fields. Water samples for analysis of biochemical oxygen demand, chemical oxygen demand and heavy metal concentrations were collected in the plastic bottles and then preserved in the ice tank. After that they were transferred to laboratory for further analysis. Each parameter was examined with the specific instruments and methods as follow:

3.2.2.1 Transparency (Tran.) was determined by using a 30-centimeter diameter white Secchi disc and the depth was measured by tape ruler on centimeter (cm.) scale.

3.2.2.2 The temperature (Temp.) was measured on Degree Celsius (^{o}C) unit, salinity (Sal.) was measured on part per thousand (ppt.) unit and dissolved oxygen (DO) was measured on milligram per litter (mg/l) at 1 meter under the seawater surface. These parameters were detected by using DO Meter Model: YSI 57 D.O Meter.

3.2.2.3 The potential hydrogen ion (pH) of the seawater was measured directly at stations using a hydrogen ion selective electrode by using Pocket pH Tester Model: ID-1000.

3.2.2.4 The electrical conductivity (EC) was measured on milli Siemens per centimeter (mS/cm) and total dissolved solid (TDS) in the seawater was measured on milligram per litter (mg/l) directly at stations using a portable probe. These parameters were detected by using Conductivity Meter Model: YSI 33 S-C-T Meter.

3.2.2.5 The biochemical oxygen demand (BOD) of the seawater was analyzed according to the Standard Method 18th edition, Procedure 5210 B. (5- day BOD Test) (APHA, AWWA, WEF, 1999).

3.2.2.6 The chemical oxygen demand (COD) of the water was examined according to Standard Method 5520 C. (Closed Reflux, Titrimetric Method) (APHA, AWWA, WEF, 1997).

3.2.2.7 The heavy metal concentrations of lead, manganese, iron and chromium (Pb, Mn, Fe and Cr) of the seawater were collected in pre cleaned and nitric acid washed plastic bottles and they were filtered in millipore filter paper (mesh size 0.45μ). The samples were preconcentrated and extracted procedure following the Standard Method for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) and these traces were determined by using an atomic absorption spectrophotometer (Model: Perkin Elmer 2100).

3.2.2.8 Phytoplanktons: The sample collection and preservation field procedures for phytoplanktons were performed as following:

1) Sample collection, preservation and preparation sample for phytoplankton analysis:

- Preparation of Lugol's solution was performed in a fume hood, dissolve, 100 g of KI and 50 g of I_2 in approximately 800 ml of reagent water in a 1 litter volumetric flask. Mix until the chemicals were completely dissolved. Add 100 ml of glacial acetic acid and bring volume up to 1 litter with reagent water (prepared at least one week prior to survey). This preservative was stored in an opaque bottle labeled with the contents, date of preparation, and preparer's initials.

- Water sample was collected of two 1iters by water sampler (must be taken for each station) and poured through No.25 plankton net with a mesh size of 60 µm and preserved the phytoplankton samples in plastic bottles at each station, two 1 litter samples must be taken for each station due to the low numbers of organisms in the sea water.

- In the laboratory, added 10 ml of Lugol' s solution to each 1 litter water sample within 2 hours of sample collection to obtain a final concentration of 1%.

- The neck of the bottles was wrapped several times with parafilm to preclude spillage and evaporation.

- Samples were stored in the dark and under refrigeration for quantitative and qualitative analysis.

2) Phytoplankton analysis

- One thousand ml per each sample were concentrated by the sedimentation method using 10 ml of Lugol's solution to a final volume of 10 ml and preserved with 1 ml Lugol's solution and stored in the dark, following the methods of Benson-Evan et al. (1985). Phytoplankton were identified and counted under a compound light microscope by the Drop microtransect method (Benson-Evans et al., 1985; Traichaiyaporn, 2000). The text books of Cox (1996), Desikachary (1959), Krammer and Lange-Bertalot (1991), Prescott (1978), Smith (1950), and Wongrat, (2001) were used to identify the phytoplankton. Phytoplankton species number and quantity were examined.

3.2.2.9 Zooplanktons: The sample collection and preservation field procedures for zooplanktons were performed following the methods of Goswami (2004):

1) Sample collection, preservation and preparation sample for zooplankton analysis:

- Sea water sample was collected two 1iters by water sampler and filtered through No.10 plankton net with a mesh size of 158 μm for species number and quantity analysis of zooplanktons. The zooplankton samples were immediately conserved by formaldehyde to the final concentration of 4% in plastic bottles at each station.

2) Enumeration and identification species:

- In the laboratory: For enumeration of zooplankton the subsample or aliquot of 10 to 25% was examined. The percentage of aliquot could be increased or decreased depending on the abundance of zooplanktons in the sample.

- Subsample (aliquot): Folsom plankton splitter was used. The zooplankton sample to be subsampled was poured into the drum and the drum was rotated slowly back and forth. Internal partitions divided the samples into equal fractions. The fraction might be poured again into the drum for further splitting. The process was repeated until a suitable subsample was obtained for counting. The splitter was thoroughly rinsed to recover the organisms, which might be sticking onto the wall of the drum. The subsample was used for counting the specimens of common taxa. Glass pipettes were also used to take the subsample for counting. The micropipette was used to obtain a certain volume (0.1 to 10 ml). The zooplankton sample in a glass container was diluted to a known volume and was stirred gently. The micropipette was then used to remove the subsample or aliquot for counting.

- Counting: After splitting, the next step in the analysis was to sort and count the specimens. The common taxa were observed. The counting should be done under the microscope and when the specimen of a particular group was seen, a tally mark was made on the sheet. When different groups were to be counted simultaneously the multiple counters was used. All the specimens present in the subsample were counted with proper records on the data sheet. The total numbers of specimens were later calculated for the whole sample depending on the percentage of subsamples examined.

- Species identification: Species was defined as a group of individuals capable of interbreeding. For identification of species a stereoscopic dissecting microscope, good quality glass slides, cover slips, stainless steel fine forceps, dissecting needles, pipettes and chemical reagents were required. Absolute number of present taxons was expressed as the number of individual taxons per ml. For taxonomic identification and quantity calculator were performed by following the method of Wongrat (2000) and (2003).

3.3 Data analysis

3.3.1 Some data were recorded in the fields at each station and the remain data were calculated and recorded after final analysis.

3.3.2 Data of the most parameters were statistically analyzed with Analysis of Variance and then they were shown on average value by tables and graph figures in each station.

3.3.3 All information was conducted to compare sea water qualities among locations that were severely attacked by Tsunami 2004.

3.4 Location of the research

3.4.1 Local fishery piers in three districts of Phang-Nga province were Khura Buri district (Khura sub-district; village 3 and 10, Mae Nang Khao sub-district; village 7 and Bang Wan sub-district; village 4), Takua Pa district (Koh Khor Khao sub-district; village 3, Bang Muang sub-district; village 2 and Khuek Khak sub-district; village 2) and Tai Meung district (Tung Ma Prao sub-district; village 2 and Na Toey sub-district; village 7). The nine stations of sample collection were Ban Hin Lad (St.1), Ban Bang La (St.2), Ban Bang Dad (St.3), Ban Thung La Aong (St.4), Ban Pak Koh (St.5), Ban Nam Kem (St.6), Laem Pakarang (St.7), Ban Klong Chalern (St.8), and Ban Bor Dan (St.9) (Figures 3.2-3.10).

3.4.2 Faculty of Science and Fishery Technology, Rajamangala University of Technology Srivijaya, Trang Campus, Suranaree University of Technology and Department of Chemistry, Faculty of Science, Thaksin University, Phatthalung Campus were the three main institutions where data were analyzed.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Results and discussions

The results of this research indicated the properties of seawater from around coastal fisheries, coastal aquacultures and coastal communities which were mainly affected areas after disaster tsunami 2004 (in three districts of Phang-Nga province; Khura Buri district (St.1, St.2, St.3, and St.4), Takua Pa district (St.5, St.6, and St.7) and Tai Meung district (St.8 and St.9)) between January to December 2008. The results varied among nine stations (local fishery piers). The properties of seawater were reported on the average value of physical parameters, chemical parameters, biological parameters and heavy metal as following:

4.1.1 Physical parameters

The parameters of physical seawater qualities were considered on temperature (Tem.), transparency (Trans.), total dissolved solids (TDS) and electrical conductivity (EC). Those are indeed a fundamental factor for seawater quality.

The maximum temperature was 31.29 ^{o}C at St.7 (Laem Pakarang) and the minimum value was 29.84 ^{o}C at St.1 (Ban Hin Lad), when those were compared with the coastal water quality standards, the temperature was poorly fluctuated to less exceed 1 ^{o}C. That followed to Marine Environment Division (2008) design to an increase should not exceed 1 ^{o}C from the natural temperature, which were the optimum of temperature for Coral Conservation (Class 2), Marine Conservation (Class

3) and Water for Coastal Farms (Class 4) that to less than 33 ^{o}C (Pollution Control Department, 2007). Besides, they were preferred for the marine aquacultures that vary between 25-32 ^{o}C (Boyd, 1998). The values in every location were found to be normal for coastal seawater.

The transparency was checked at the areas by the depth less than 5 meters. The lowest of average transparency value was 49 cm. at St.5 (Ban Pak Koh) and St.7 (Laem Pakarang) and the highest value was 108 cm. at St.4. They were changed normally at all stations, compared with coastal water quality standards which was limited to less than 10% of water depth (Marine Environment Division, 2008).

The average of total dissolved solids value ranged between 17,060 mg/l at St.8 (Ban Klong Chalern) and 26,240 mg/l at St.7 (Laem Pakarang), which were usual level when compared with the value of total dissolved solids in marine water that suggested by Boyd (1998) with the ranged > 5,000 mg/l.

The lowest electrical conductivity value was 34.12 mS/cm at St.8 (Ban Klong Chalern) and the highest value was 52.48 mS/cm at St.7 (Laem Pakarang). The electrical conductivity was not fixed in seawater quality but the usual electrical conductivity value of seawater was approximately 50.00 mS/cm (Boyd, 1998).

All physical parameters values of this study were shown in the Table 4.1 and Figures 4.1, 4.2, 4.3, and 4.4.

Table 4.1 Average physical properties of seawater on nine stations between January and December 2008.

Station	Tem. (°C)	± SE	Tran. (cm)	± SE	TDS (mg/l)	± SE	EC (mS/cm)	± SE
St.1	29.84	0.47	66	8	21,775	125	43.55	2.38
St.2	30.08	0.42	75	10	22,995	115	45.99	2.33
St.3	30.23	0.31	68	10	22,260	138	44.52	2.54
St.4	30.38	0.25	108	7	24,190	84	48.38	1.66
St.5	30.57	0.24	49	7	22,275	151	44.55	2.70
St.6	30.52	0.23	60	10	25,445	55	50.89	1.18
St.7	31.29	0.27	49	7	26,240	68	52.48	1.62
St.8	30.44	0.22	99	9	17,060	162	34.12	3.48
St.9	30.79	0.38	104	13	22,170	77	44.34	2.99

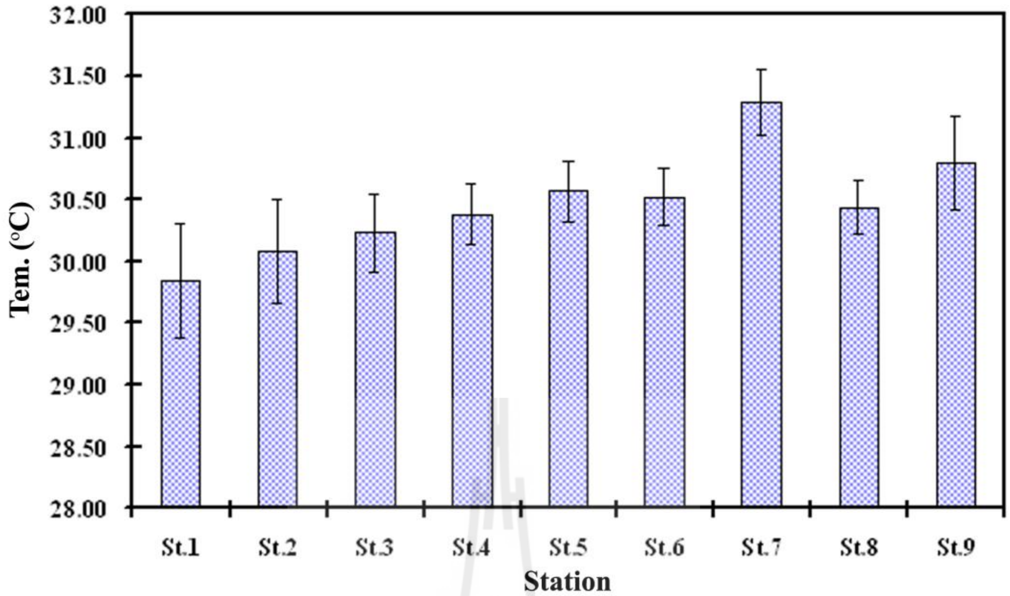

Figure 4.1 Average temperature (°C) of seawater on nine stations between January and December 2008.

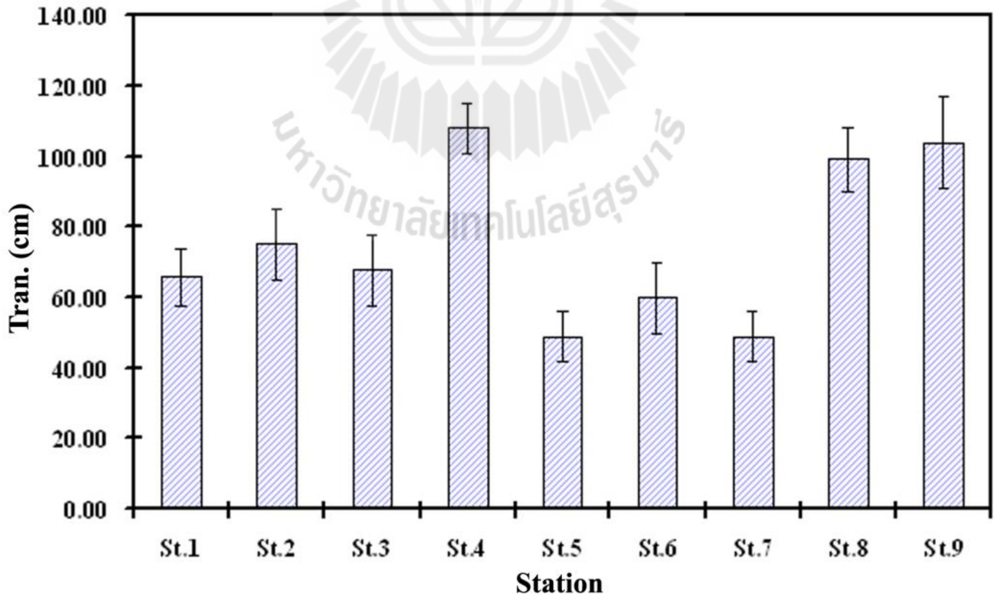

Figure 4.2 Average transparency (cm) of seawater on nine stations between January and December 2008.

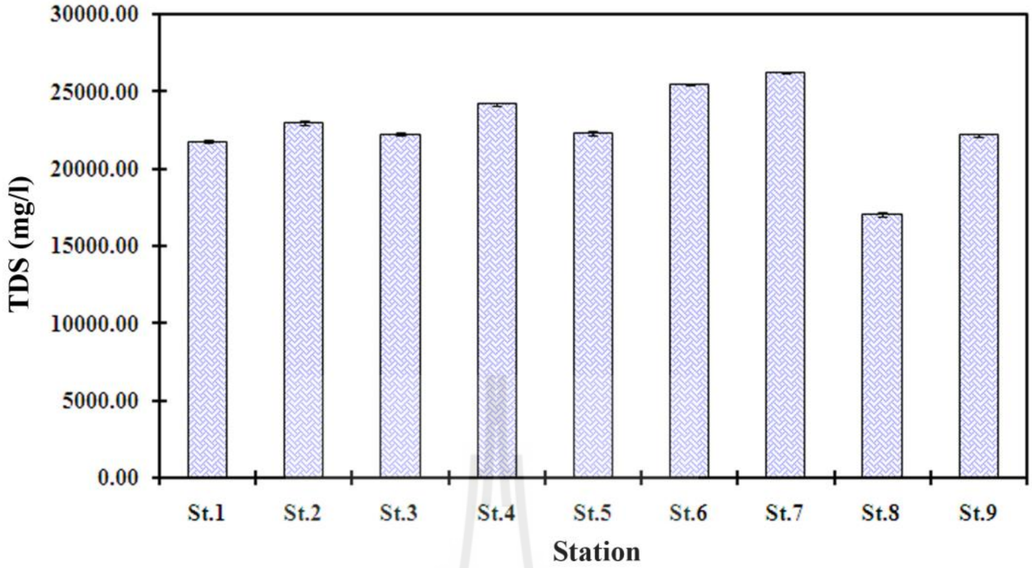

Figure 4.3 Average total dissolved solid (mg/l) of seawater on nine stations between January and December 2008.

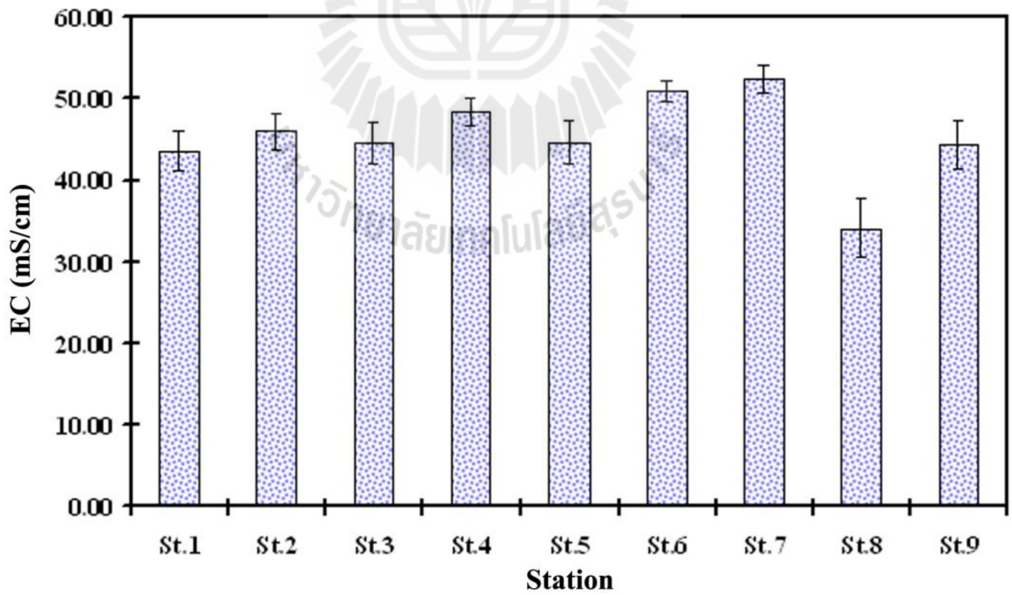

Figure 4.4 Average electrical conductivity (mS/cm) of seawater on nine stations between January and December 2008.

4.1.2 Chemical parameters

In general, the chemical of seawater qualities were detected on hydrogen ion concentration (pH), salinity (Sal.), dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

The hydrogen ion concentration (pH) values ranged between 6.69 and 7.94, which the lowest was at St.2 (Ban Bang La) and the highest was at St.7 (Laem Pakarang). In all stations, the hydrogen ion concentrations (pH) were normal value when compared with coastal water quality standards (7.5-8.5) (Marine Environment Division, 2008). However, these recorded values were acceptable range for coastal aquaculture which pH was usually between 6.5 to pH 9.0 (Boyd, 1998).

The salinity value in nine stations was fluctuated between 19.48 ppt. to 30.28 ppt., which the highest value (30.28 ppt.) was recorded at Laem Pakarang (St.7) and the lowest value (19.48 ppt.) was detected at Ban Klong Charern (St.8). The other areas were found to be normal for coastal seawater when compared with coastal water quality standards (25 ppt.-35 ppt.) (Marine Environment Division, 2008).

The dissolved oxygen (DO) ranged from 6.36 to 7.49 mg/l and at St.3 (Ban Bang Dad) was the minimum value. Interestingly, the value of dissolved oxygen in nine locations was higher than the strict values (> 4 mg/l) of coastal water quality standards.

The value of biochemical oxygen demand (BOD) in Ban Klong Charern (St.8) was recorded the highest (3.80 mg/l) and the lowest was 2.04 mg/l at St.5 (Ban Pak Koh) and St.7 (Laem Pakarang). All locations, the biochemical oxygen demand value seemed to be low when compared to the biochemical oxygen demand value in fish pond (< 5 mg/l) that was suggested by Boyd (1998). However, the biochemical oxygen demand value was very low when compared with the biochemical oxygen demand value of effluent standard for coastal aquaculture (maximum permitted values 20 mg/l) that was limited by Pollution Control Department (2007).

The average value of chemical oxygen demand (COD) at nine severe areas varied between 34.0 mg/l and 63.3 mg/l. The highest COD value was showed at Ban Klong Charern (St.8) and the lowest was presented at Ban Pak Koh and Laem Pakarang, which related to the BOD value. However, the COD concentration was very rare investigated when compared with industrial effluent standards that were fixed not more than 120 mg/l (Pollution Control Department, 2007).

The results of chemical parameters values were presented the details in the Table 4.2 and Figures 4.5, 4.6, 4.7, 4.8., and 4.9.

Table 4.2 Average chemical properties of seawater on nine stations between January and December 2008.

Station	pH	± SE	Sal. (ppt.)	± SE	DO (mg/l)	± SE	BOD (mg/l)	± SE	COD (mg/l)	± SE
St.1	6.78	0.09	25.23	1.54	6.44	0.36	2.99	0.27	49.9	0.25
St.2	6.69	0.13	26.51	1.18	6.61	0.39	3.43	0.05	57.2	0.66
St.3	7.07	0.38	26.12	1.15	6.36	0.35	2.26	0.27	37.5	0.19
St.4	7.56	0.10	28.23	0.65	7.00	0.34	2.83	0.23	47.3	0.21
St.5	7.62	0.11	26.11	1.43	6.88	0.35	2.04	0.22	34.0	0.95
St.6	7.76	0.08	30.08	0.32	7.07	0.39	2.54	0.23	42.3	0.95
St.7	7.94	0.07	30.28	0.44	7.49	0.35	2.04	0.25	34.0	0.12
St.8	7.43	0.11	19.48	1.78	6.65	0.33	3.80	0.20	63.3	0.84
St.9	7.76	0.07	25.35	1.86	7.33	0.37	3.63	0.12	60.5	0.33

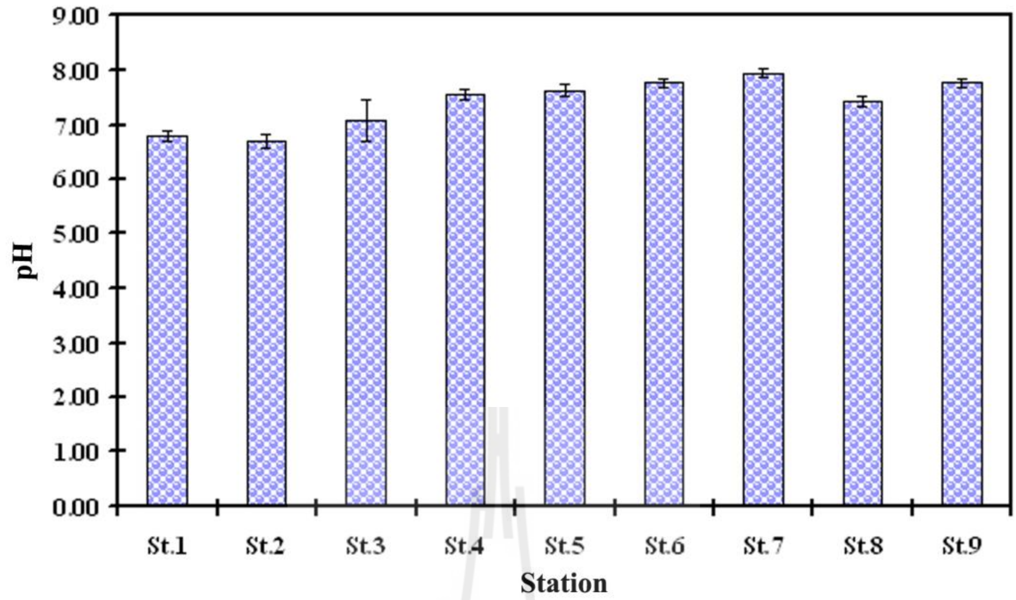

Figure 4.5 Average pH of seawater on nine stations between January and December 2008.

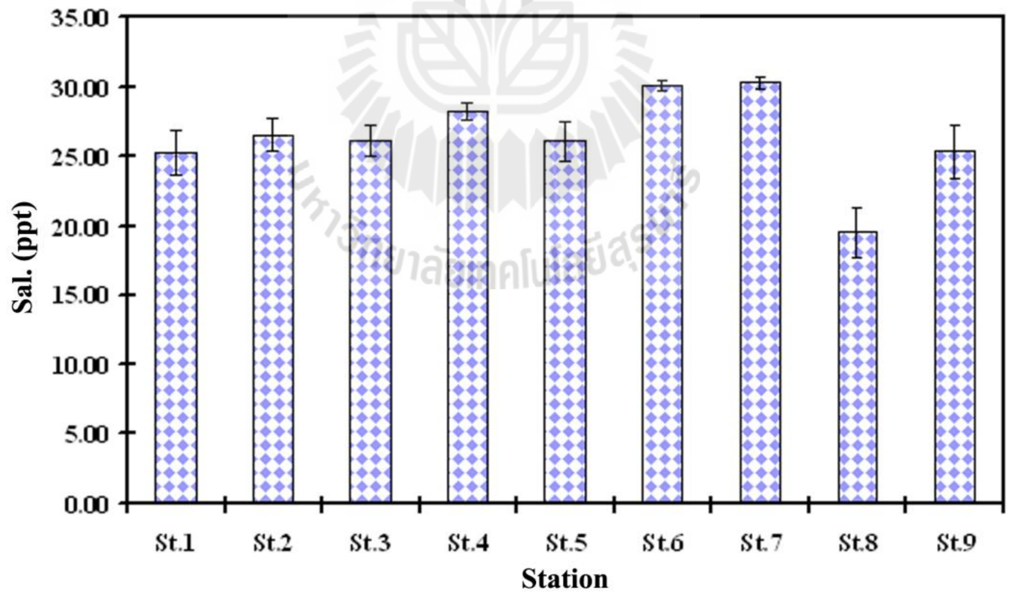

Figure 4.6 Average salinity (ppt.) of seawater on nine stations between January and December 2008.

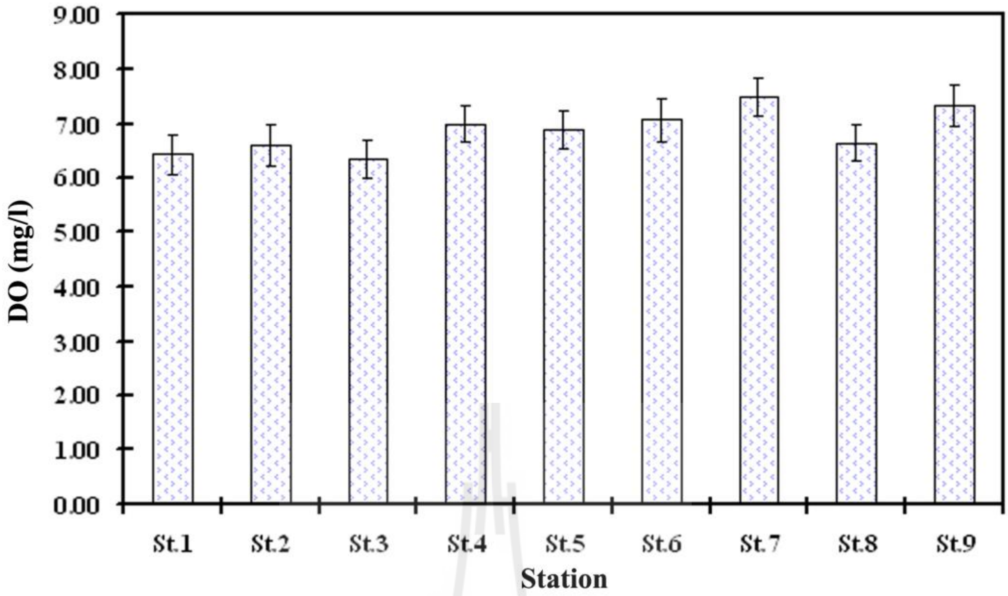

Figure 4.7 Average dissolved oxygen (mg/l) of seawater on nine stations between January and December 2008.

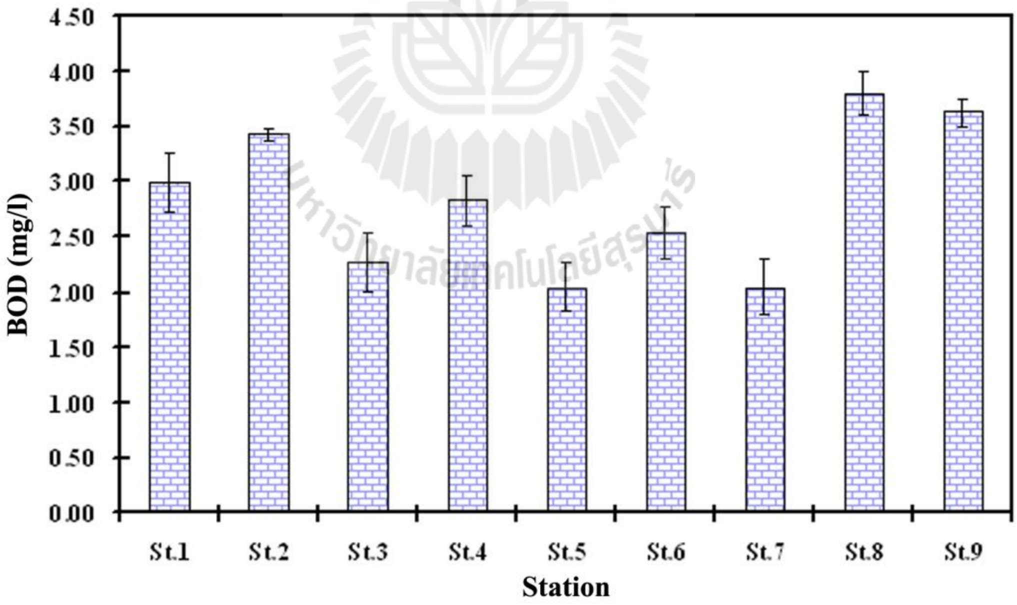

Figure 4.8 Average biochemical oxygen demand (mg/l) of seawater on nine stations between January and December 2008.

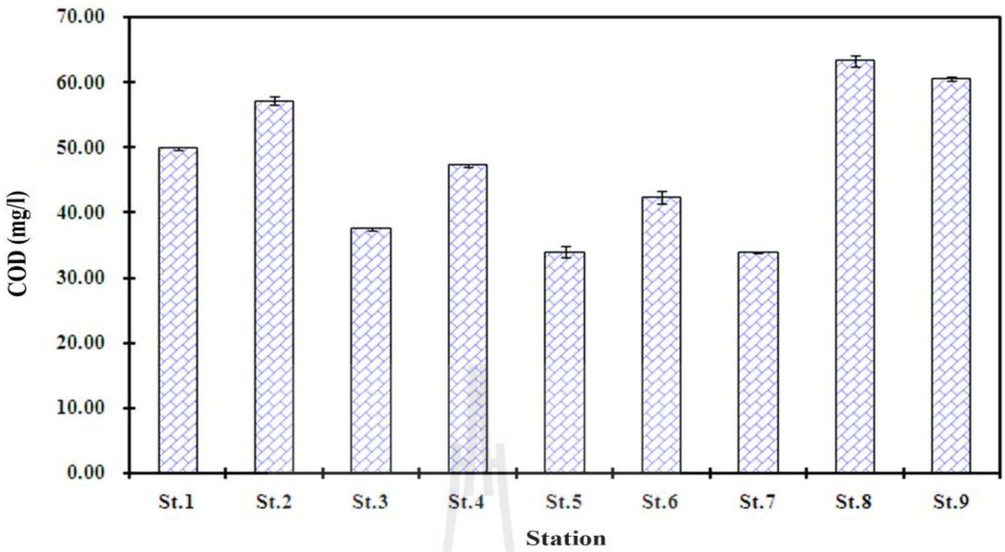

Figure 4.9 Average chemical oxygen demand (mg/l) of seawater on nine stations between January and December 2008.

4.1.3 Biological parameters

4.1.3.1 Phytoplankton

Phytoplankton communities were determined as five divisions, which consisted of Euglenophyta, Chlorophyta, Chrysophyta, Cyanophyta and Pyrrhophyta. The Euglenophyta was found in 1 genus (Euglena) at St.1 to St.8. However, this genus did not occur at St.9. The Chlorophyta was also found only 1 genus (Chlorella) at seven stations, but did not find at St.1 and St.9. The highest species of Chrysophyta corresponded to 10 genera (Actinocyclus, Asterionellopsis, Chaetoceros, Chrococcus, Diatoma, Frafilaria, Naviccula, Pinnularia, Thalassinema and Thalassiosira) at Ban Thung La Aong (St.4) and the lowest species were in 3 genera of Chaetoceros, Cossinodiscus and Nitzschia) at Ban Hin Lad (St.1) and Ban

Bor Dan (St.9). The Cyanophyta was classified to 4 genera (Oscillatoria, Spirulina, Trichodesmium and Urothrix) at St.1 and St.9, whereas other locations detected only 1 genus (*Oscillatoria*). And then, the Division Pyrrhophyta was found 1 genus (*Ceratium*) at several locations, but it was completely absented at St.5 and St.7. The details of them were shown in Table 4.3 and Figure 4.10-4.14. But, from the study result of phytoplankton communities in the vicinity of Ban Nam Kem by Nittharatana et al. (2009) found that consisted of 100 genera; 5 genera of cyanobacteria, 15 genera of dinoflagellates, 69 genera of diatoms, 7 genera of chlorophytes, 3 genera of Dictychopphyceae and 1 genus of Euglenoids. Along Bang Rong mangrove creek was consisted of 80 genera, including 7 genera of cyanobacteria, 11 genera of dinoflagellates, 60 genera of diatoms, and 1 genus of silicoflagellate and chlorophyte. Which compared with the number of species that found at this study area was difference.

Phytoplankton densities from nine locations were examined to Euglenophyta, Chlorophyta, Chrysophyta, Cyanophyta and Pyrrhophyta. In general, the density was varied among locations. The Euglenophyta dominated at St.7 as 40 x 10^3 cells/l, but none at St.9. The highest of Chlorophyta was 245 x 10^3 cells/l found in St.8, but was not found at St.1 and St.6. The Chrysophyta was recorded highest at Ban Thung La Aong (St.4) as 1,255 x 10^3 cells/l and the lowest as 425 x 10^3 cells/l at Ban Nam Kem (St.6). Maximum Cyanophyta values stood at 1,875 x 10^3 cells/l at St.9, and minimum values at 5 x 10^3 cells/l at St.5. Then the quantity of Pyrrhophyta was poorly represented at all locations, that ranged between 0-25 x 10^3 cells/l, did not appeared at St.5 and St.7, and the highest occurrence was at Ban Pak Koh as 25 x 10^3 cells/l (Table 4.4 and Figures 4.15-4.19). However, Nittharatana et al.

(2009) that reported the density of phytoplankton in Ban Nam Kem ranged from 1.2×10^4 cells/l to 4.1×10^4 cells/l. The cyanobacteria, *Anabeana* sp., with an average density of 1,001-10,000 cells/l was the most dominant genera and along Bang Rong mangrove creek, the cyanobacteria, *Oscillatoria* spp. was the most abundant genera with a density ranging between 1,001->10,001 cells/l.

The phytoplankton communities and phytoplankton densities were demonstrated the details in the Tables 4.3- 4.4 and Figures 4.10- 4.19.

Table 4.3 Phytoplankton communities in seawater on nine stations between January and December 2008.

Station	Divisions									
	Euglenophyta (genera)	± SE	Chlorophyta (genera)	± SE	Chrysophyta (genera)	± SE	Cyanophyta (genera)	± SE	Pyrrhophyta (genera)	± SE
St.1	1	0.1	0	0.0	3	1.0	4	0.1	1	0.2
St.2	1	0.1	1	0.1	4	1.0	1	0.2	1	0.1
St.3	1	0.1	1	0.1	6	1.2	1	0.1	1	0.2
St.4	1	0.1	1	0.1	10	1.9	1	0.1	1	0.3
St.5	1	0.1	1	0.1	5	1.0	1	0.1	0	0.0
St.6	1	0.1	0	0.0	4	0.9	1	0.1	1	0.1
St.7	1	0.1	1	0.1	6	1.0	1	0.1	0	0.0
St.8	1	0.1	1	0.1	6	1.4	1	0.1	1	0.1
St.9	0	0.0	1	0.1	3	0.5	4	1.0	1	0.1

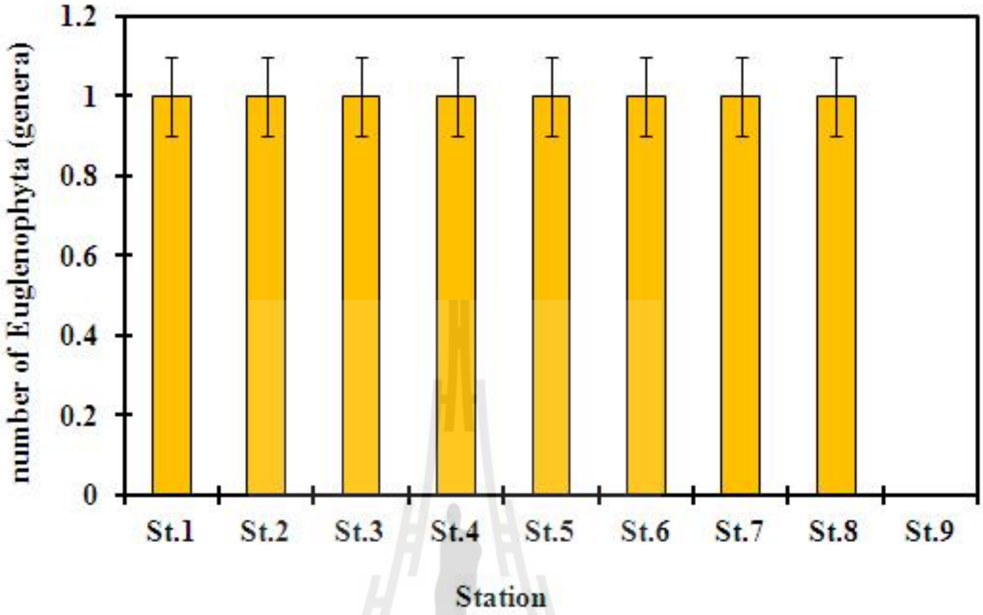

Figure 4.10 Number of Euglenophyta (genera) in seawater on nine stations between January and December 2008.

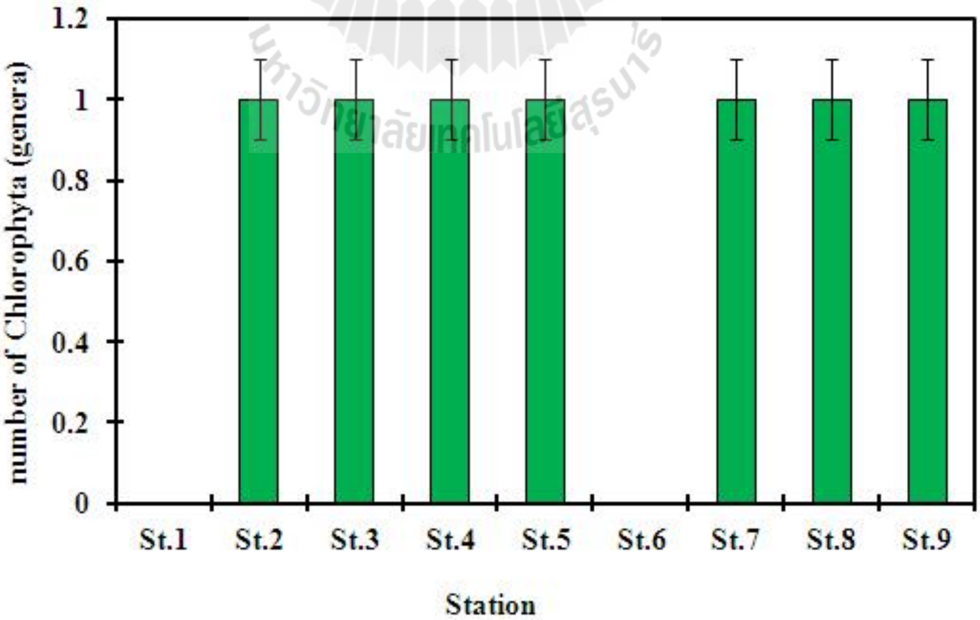

Figure 4.11 Number of Chlorophyta (genera) in seawater on nine stations between January and December 2008.

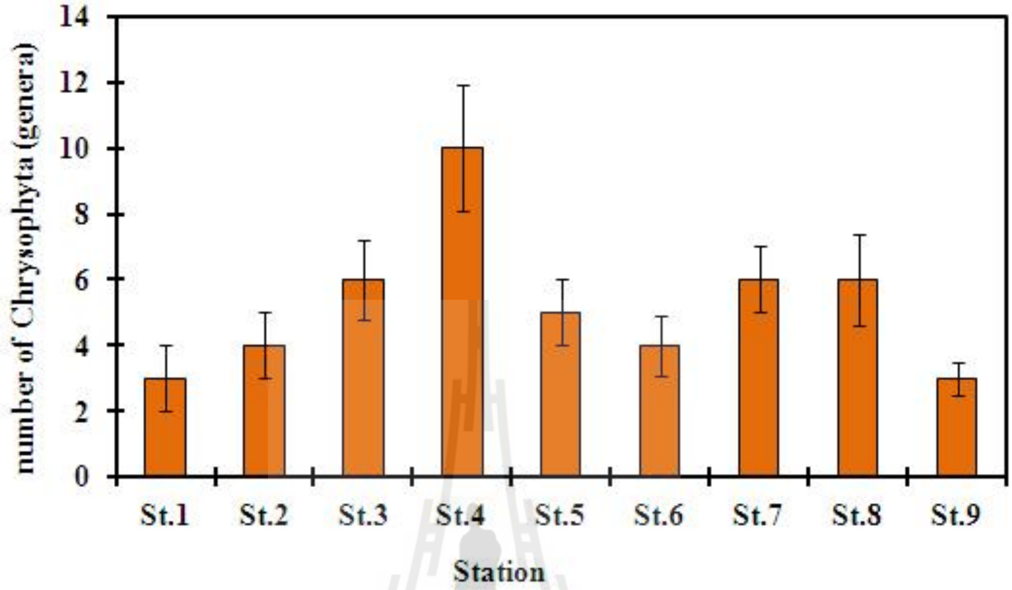

Figure 4.12 Number of Chrysophyta (genera) in seawater on nine stations between January and December 2008.

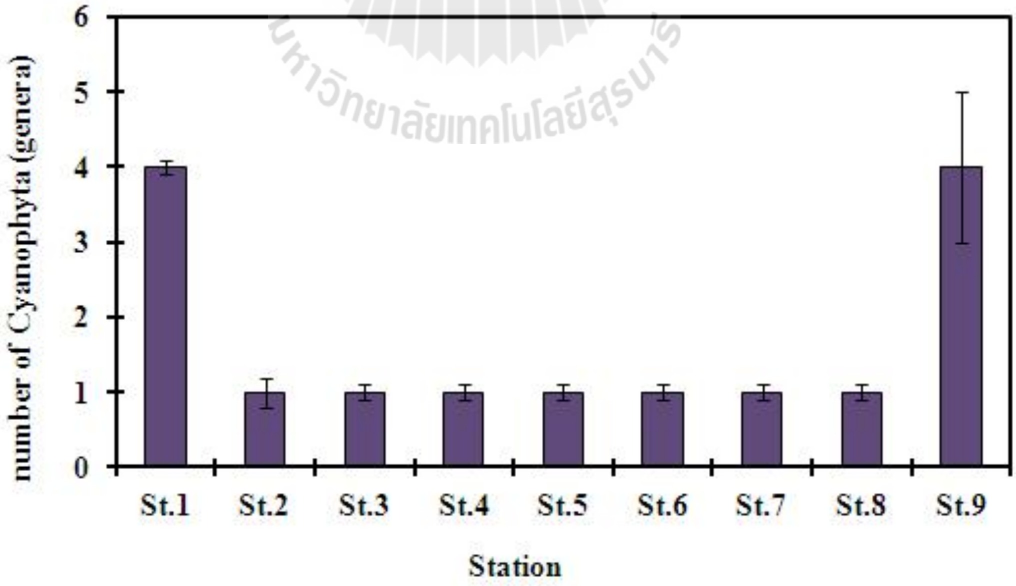

Figure 4.13 Number of Cyanophyta (genera) in seawater on nine stations between January and December 2008.

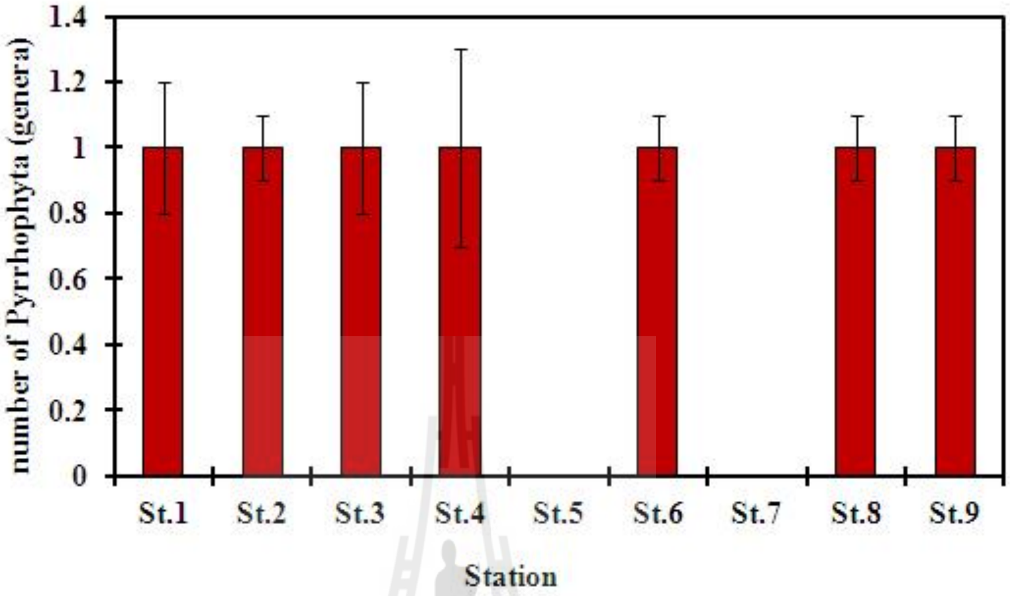

Figure 4.14 Number of Pyrrhophyta (genera) in seawater on nine stations between January and December 2008.

Table 4.4 Phytoplankton densities in seawater on nine stations between January and December 2008.

Station	Divisions									
	Euglenophyta ($x10^3$ cells/l)	± SE	Chlorophyta ($x10^3$ cells/l)	± SE	Chrysophyta ($x10^3$ cells/l)	± SE	Cyanophyta ($x10^3$ cells/l)	± SE	Pyrrhophyta ($x10^3$ cells/l)	± SE
St.1	30	7.4	0	0.0	745	259.7	105	89.0	15	13.4
St.2	25	6.5	15	10.0	535	160.2	40	17.3	5	2.1
St.3	15	5.4	5	2.3	700	181.0	30	14.7	5	3.5
St.4	10	7.4	15	7.4	1,255	248.1	25	23.2	5	3.4
St.5	20	11.6	5	3.4	475	117.1	5	3.2	0	0.0
St.6	10	7.4	0	0.0	425	113.3	10	3.4	10	7.4
St.7	40	14.5	5	2.4	550	107.3	35	14.5	0	0.0
St.8	5	3.4	245	163.7	825	350.6	40	23.2	5	4.4
St.9	0	0.0	5	2.7	825	383.0	1,875	837.6	25	14.5

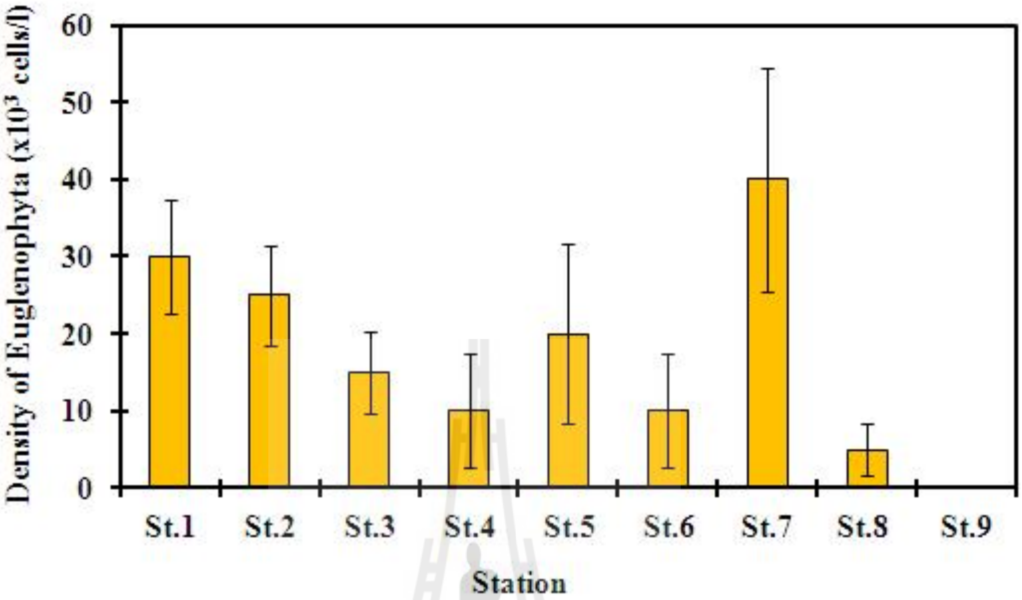

Figure 4.15 Densities of Euglenophyta (x10^3cells/l) of in seawater on nine stations between January and December 2008.

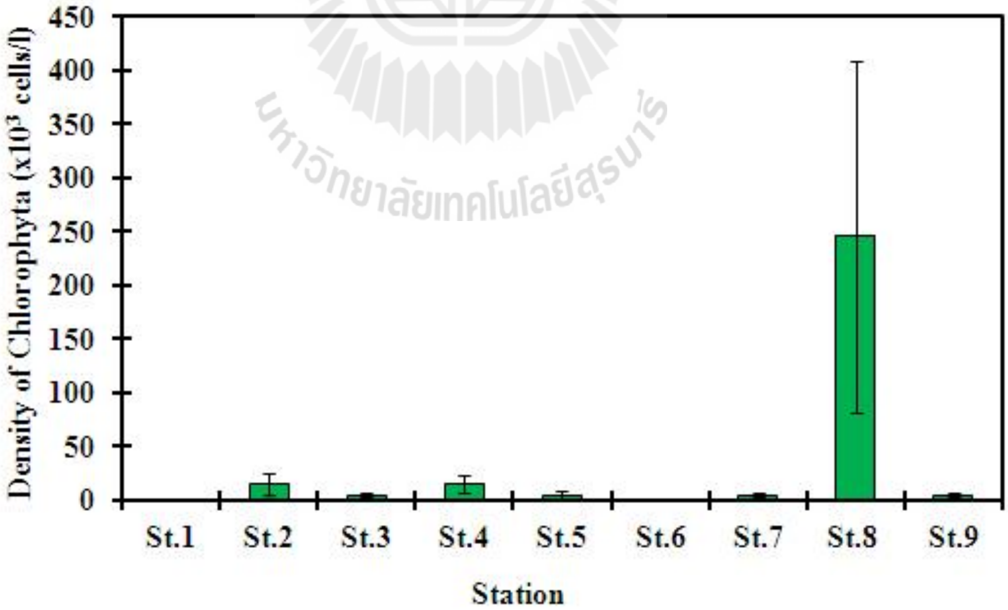

Figure 4.16 Densities of Chlorophyta (x10^3cells/l) of in seawater on nine stations between January and December 2008.

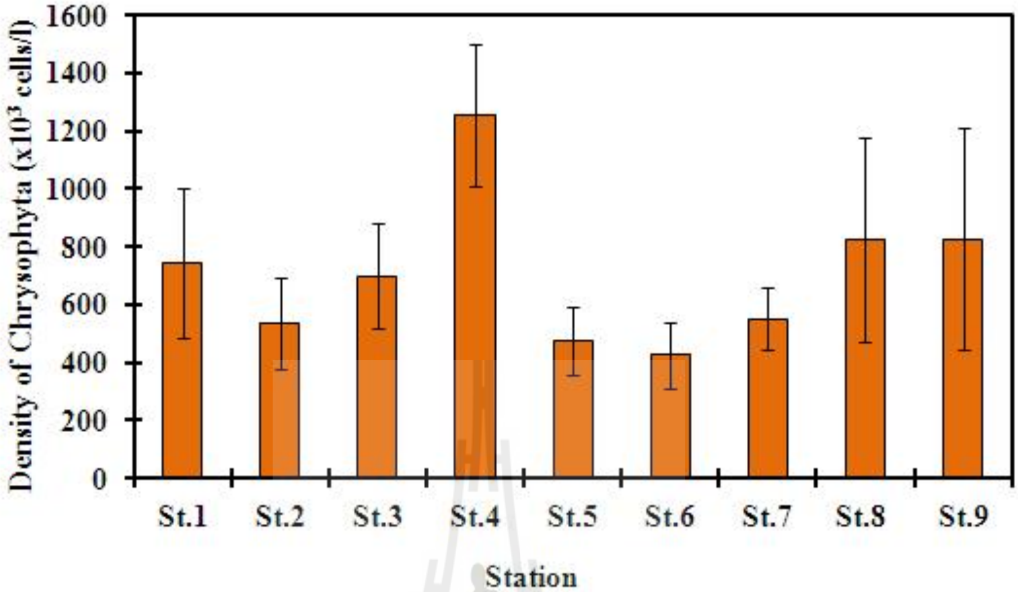

Figure 4.17 Densities of Chrysophyta (x10^3cells/l) of in seawater on nine stations between January and December 2008.

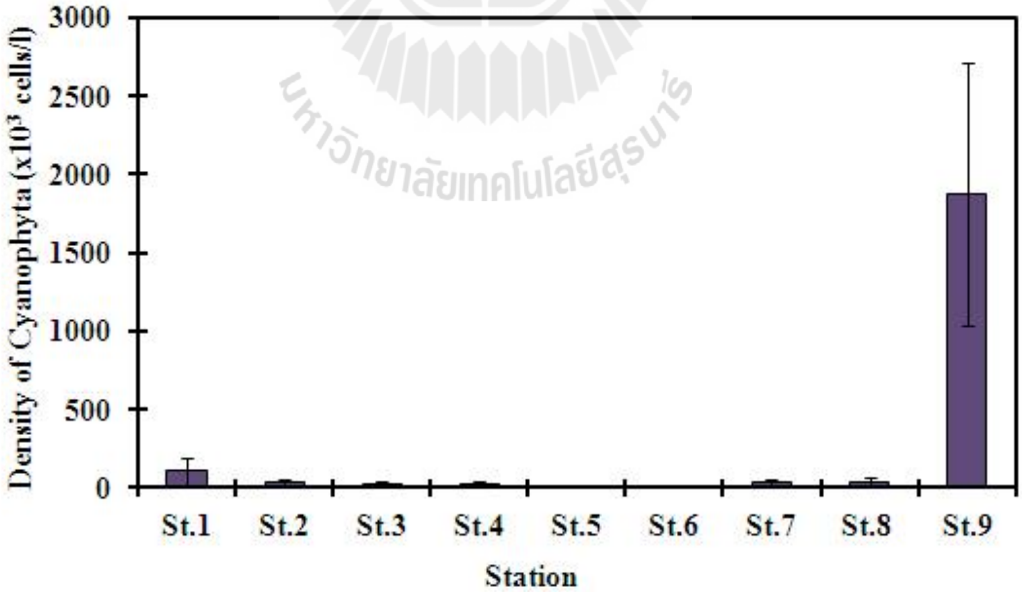

Figure 4.18 Densities of Cyanophyta (x10^3cells/l) of in seawater on nine stations between January and December 2008.

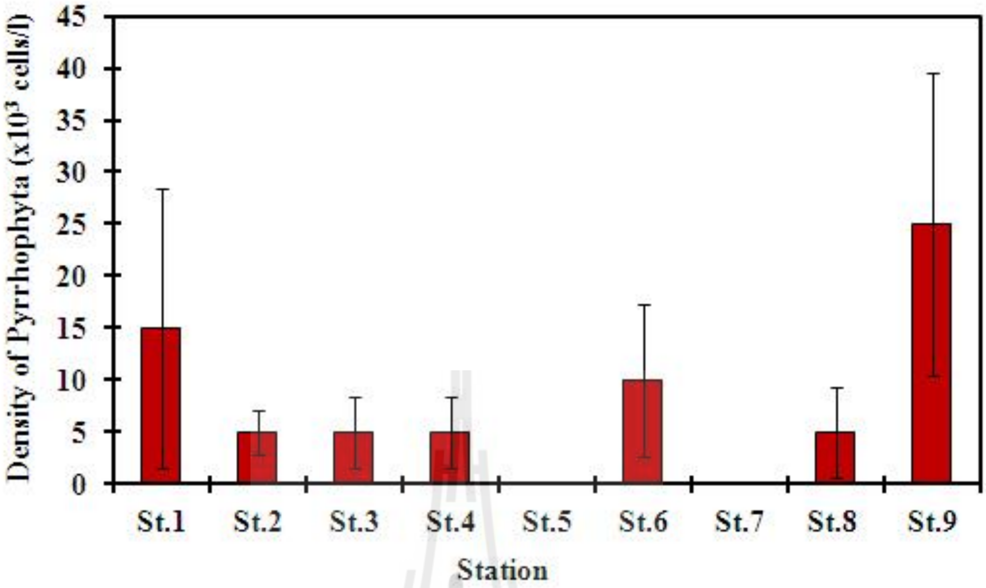

Figure 4.19 Densities of Pyrrhophyta (x10^{3}cells/l) of in seawater on nine stations between January and December 2008.

4.1.3.2 Zooplankton

Zooplankton communities were classified to six Phylum (Chordata, Annelida, Arthropoda, Rotifera, Mollusca and Protozoa). Phylum Chordata was detected only in 1 group of Tunicate at St.1, St.2, St.3, St.4, St.6, and St.9, but was absent at St.5, St.7 and St.8. Phylum Annelida was also determined only in 1 group of Polycheate at St.3, St.4, St.7, and St.9. Phylum Arthropoda was the highest group in all locations, which St.4 and St.8 found the maximum groups of cycloploid copepod, calanoid copepod, cladocera, harpacticoid copepod, balanus nauplius, nauplius crustacean and zoea larvae of Brachyura. The highest genera of Phylum Rotifera found at St.9, it consisted of 2 genera (Keratella and Rotifer). A single genus (Rotifer) was observed at St.1 and St.5. All stations had mollusks. Two groups (bivalve larvae and gastropod larvae) were probed at five locations (St.2, St.4, St.5, St.6, and St.7) and bivalve larvae was detected at St.1, St.3, St.8, and St.9. Two genera (Tintinnopsis and Foraminifera) of Phylum Protozoa were discovered the highest at St.4, St.6, St.7, and St.9, whereas 1 genus (Foraminifera) was found at St.2, St.3, St.5, and St.8. Station 1 was an exception. The details of them were presented in Table 4.5 and Figures 4.20-4.25. Similarly, zooplankton communities in Klong Pak Ko, a water channel between Ban Nam Kem and Kho Khao island that were determined by Nittharatana et al. (2009), which were dominated by calnoid copepods, followed by cycloploid copepods, harpacticoids and copepod, bivalve larvae, polychaete larvae, foraminiferans and arrow worms.

Zooplanktons (Chordata, Annelida, Arthropoda, Rotifera, Mollusca and Protozoa) densities were studied from nine stations. Phylum Chordata was the highest at St.1 and St.6 and showed 8 inds/l. Station 2, St.3, St.4, and St.9 showed 3 inds/l, 7 inds/l, 4 inds/l and 4 inds/l respectively, but failed to appear at St.5, St.7 and St.8. At station 3, the highest of Phylum Annelida was 8 inds/l, the secondary was St.4 as 7 inds/l and St.7 and St.9 were found as 4 inds/l, whereas St.1, St.2, St.5, St.6, and St.8 had no members of Phylum Annelida. The maximum quantity of Phylum Arthropoda was determined everywhere, which ranged between 30-470 inds/l. Phylum Arthropoda was recorded the highest at St.9 (470 inds/l) secondly was St.7 (168 inds/l) and the lowest as 30 inds/l at St.6. Phylum Rotifera were examined at three locations (St.1, St.5, and St.9) and at maximum of 8 inds/l was recorded at St.9. Station.1 and 5 appeared as 4 inds/l and 7 inds/l, respectively. The quantity of Phylum Mollusca was recoeded at all locations, that showed maximum at St.7 (84 inds/l) and minimum at St.1 (4 inds/l). Protozoa was highly recorded in several areas except at St.1. The maximum of of 22 inds/l was recorded at St.4 (Table 4.6 and Figures 4.26-

4.31). However, Nittharatana et al. (2009) found that zooplankton densities were high in the upper part of Klong Pak Ko with the highest density of 9.87 x 10^6 inds/100 m^3 and the lowest densities of zooplankton were found at the low part of Klong Pak Ko with density less than 2.0 x 10^6 inds/100 m^3.

The detail of zooplankton communities and zooplankton densities were described in the Tables 4.5-4.6 and Figures 4.20-4.31.

Table 4.5 Zooplankton communities in seawater on nine stations between January and December 2008.

Station	Phylum											
	Chordata (groups)	± SE	Annelida (groups)	± SE	Arthropoda (groups)	± SE	Rotifera (genera)	± SE	Mollusca (groups)	± SE	Protozoa (genera)	± SE
St.1	1	0.1	0	0.0	5	0.3	1	0.1	1	0.1	0	0.0
St.2	1	0.1	0	0.0	6	0.4	0	0.0	2	0.2	1	0.1
St.3	1	0.1	1	0.1	6	0.3	0	0.0	1	0.1	1	0.1
St.4	1	0.1	1	0.1	7	0.3	0	0.0	2	0.1	2	0.2
St.5	0	0.0	0	0.0	5	0.2	1	0.1	2	0.2	1	0.1
St.6	1	0.1	0	0.0	3	0.3	0	0.0	2	0.1	2	0.1
St.7	0	0.0	1	0.1	6	0.4	0	0.0	2	0.2	2	0.1
St.8	0	0.0	0	0.0	7	1.4	0	0.0	1	0.5	1	0.5
St.9	1	0.1	1	0.1	6	0.4	2	0.1	1	0.1	2	0.1

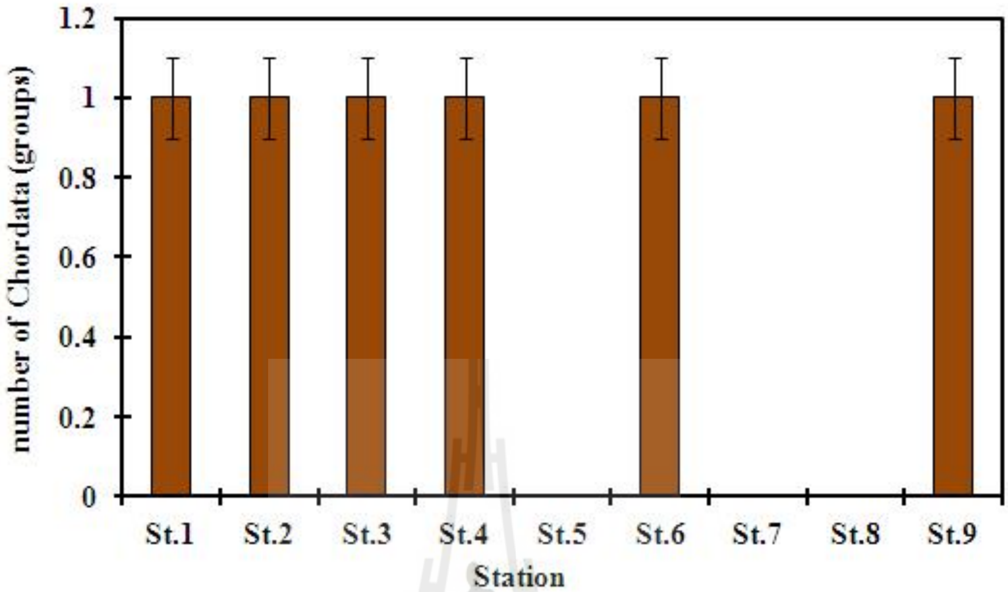

Figure 4.20 Number of Chordata (groups) in seawater on nine stations between January and December 2008.

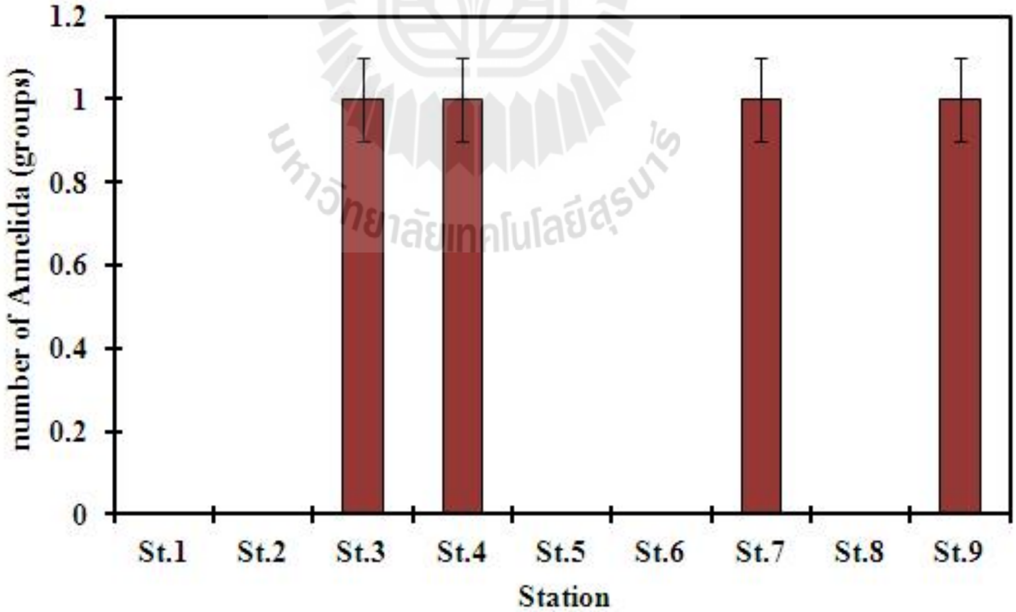

Figure 4.21 Number of Annelida (groups) in seawater on nine stationsbetween January and December 2008.

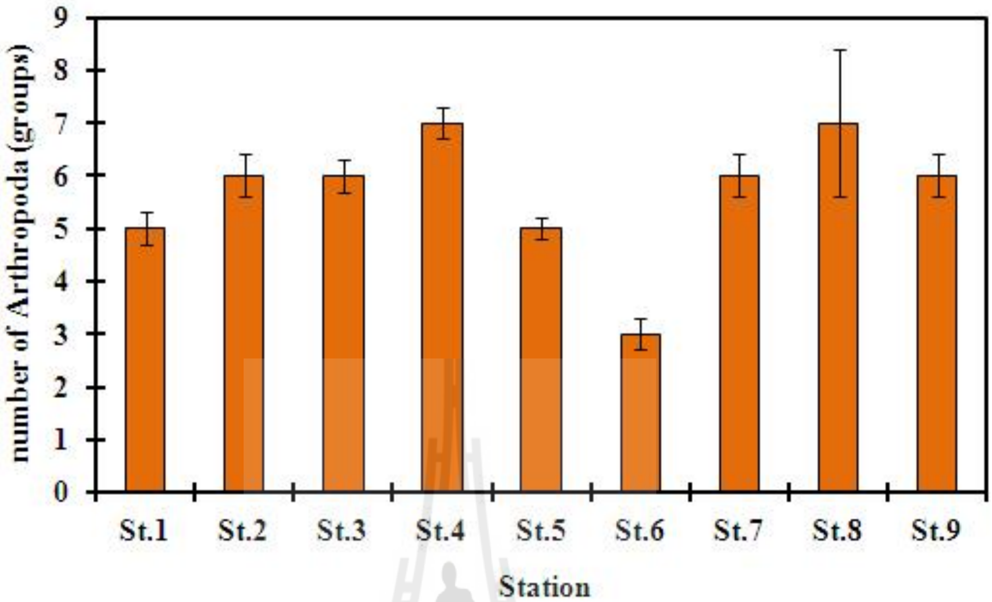

Figure 4.22 Number of Arthropoda (groups) in seawater on nine stations between January and December 2008.

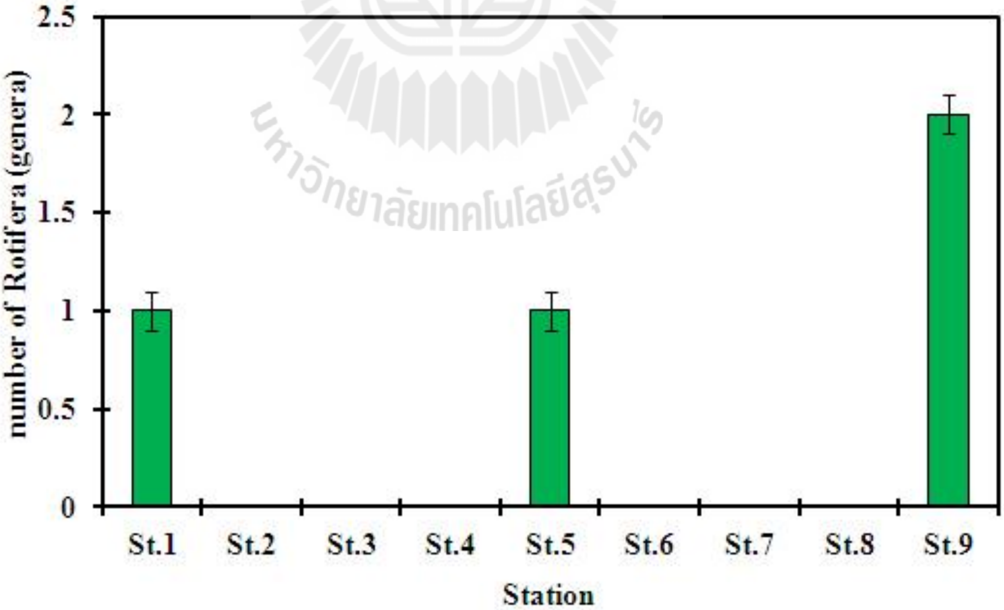

Figure 4.23 Number of Rotifera (genera) in seawater on nine stationsbetween January and December 2008.

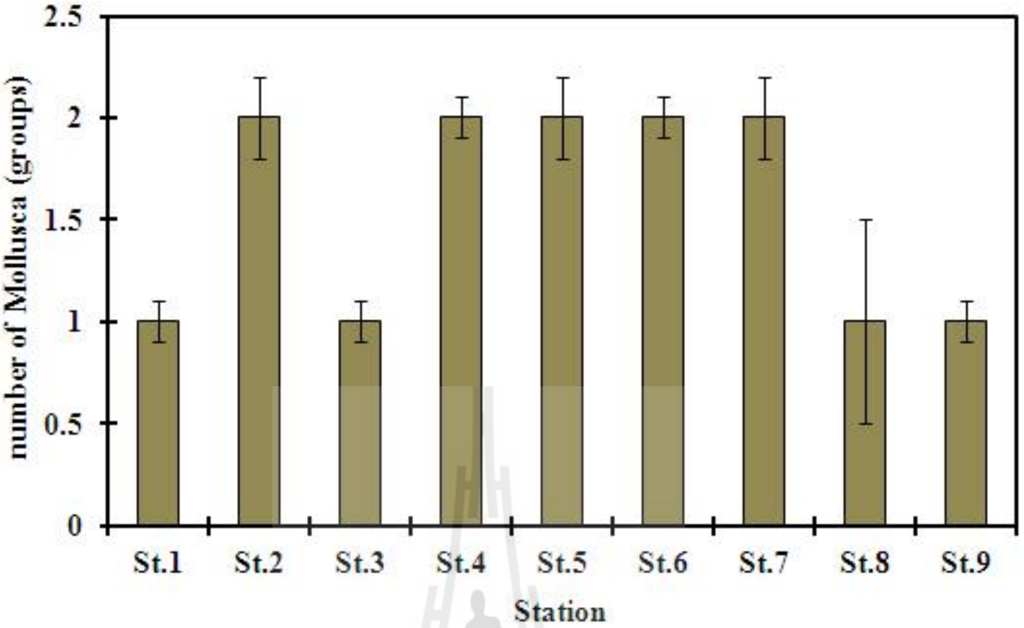

Figure 4.24 Number of Mollusca (groups) in seawater on nine stations between January and December 2008.

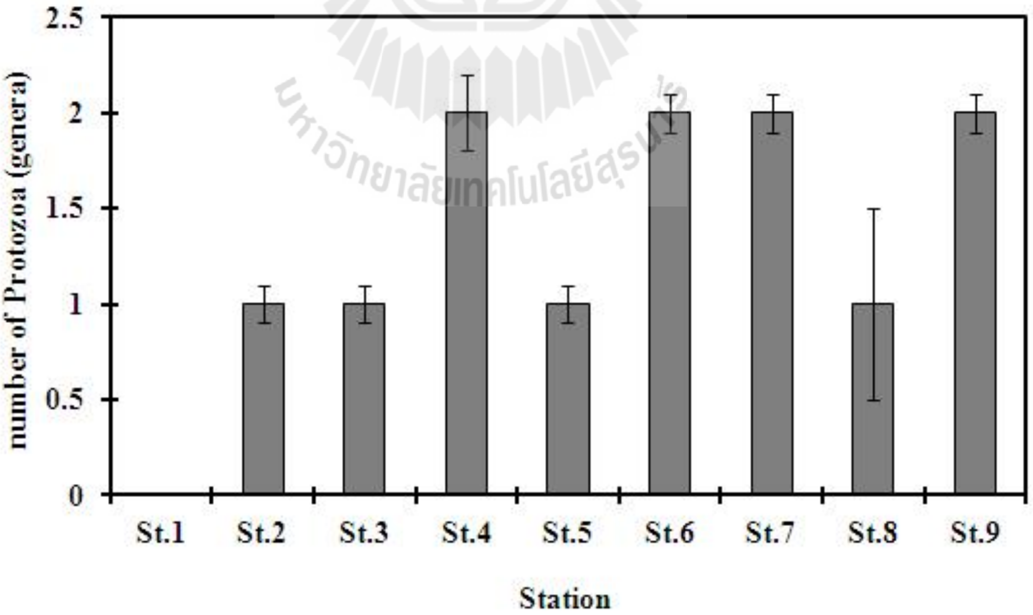

Figure 4.25 Number of Protozoa (genera) in seawater on nine stations between January and December 2008.

Table 4.6 Zooplankton densities in seawater on nine stations between January and December 2008.

Station	Phylum											
	Chordata (inds/l)	± SE	Annelida (inds/l)	± SE	Arthropoda (inds/l)	± SE	Rotifera (inds/l)	± SE	Mollusca (inds/l)	± SE	Protozoa (inds/l)	± SE
St.1	8	7.5	0	0.0	59	17.1	4	3.8	4	3.5	0	0.0
St.2	3	2.4	0	0.0	85	20.9	0	0.0	11	10.1	14	6.0
St.3	7	4.8	8	5.0	83	16.5	0	0.0	4	3.7	19	8.7
St.4	4	3.9	7	4.8	122	30.2	0	0.0	10	5.4	22	8.2
St.5	0	0.0	0	0.0	52	13.9	7	5.0	8	7.8	8	5.0
St.6	8	5.0	0	0.0	30	11.5	0	0.0	22	6.5	7	4.8
St.7	0	0.0	4	3.5	168	61.7	0	0.0	84	50.3	14	10.6
St.8	0	0.0	0	0.0	86	20.9	0	0.0	14	8.0	14	5.6
St.9	4	3.7	4	2.3	470	84.6	8	5.0	15	6.2	11	7.8

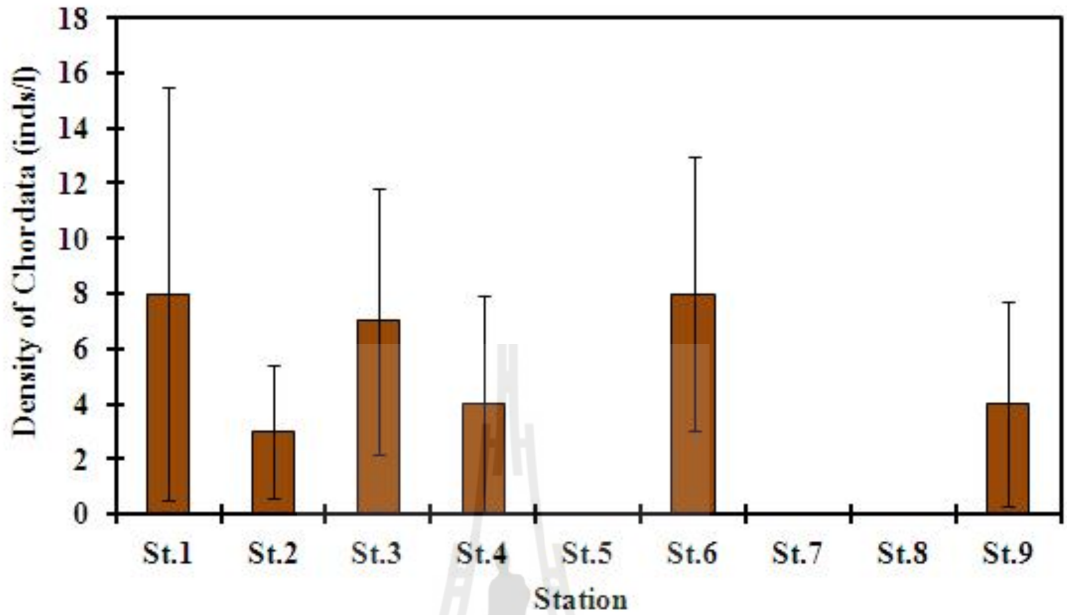

Figure 4.26 Densities of Chordata (inds/l) in seawater on nine stations between January and December 2008.

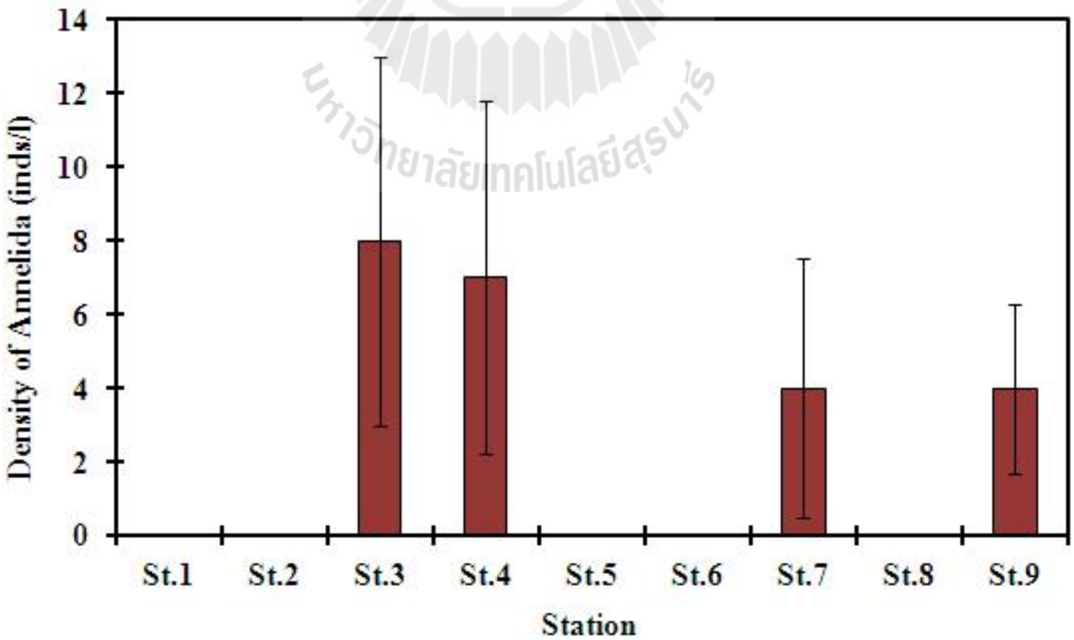

Figure 4.27 Densities of Annelida (inds/l) in seawater on nine stations between January and December 2008.

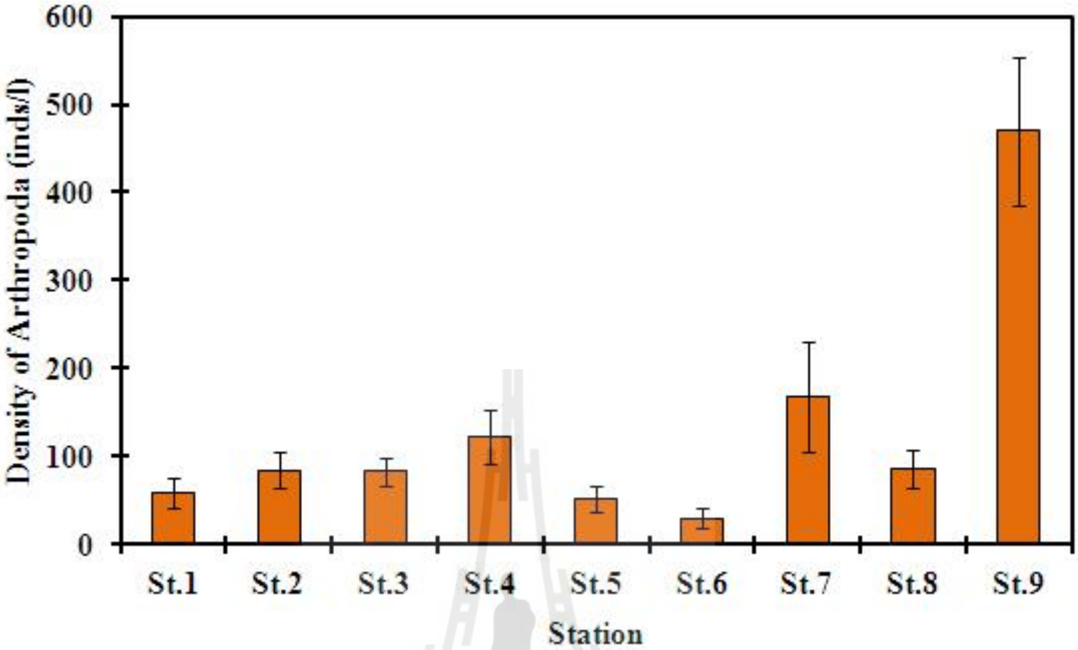

Figure 4.28 Densities of Arthropoda (inds/l) in seawater on nine stations between January and December 2008.

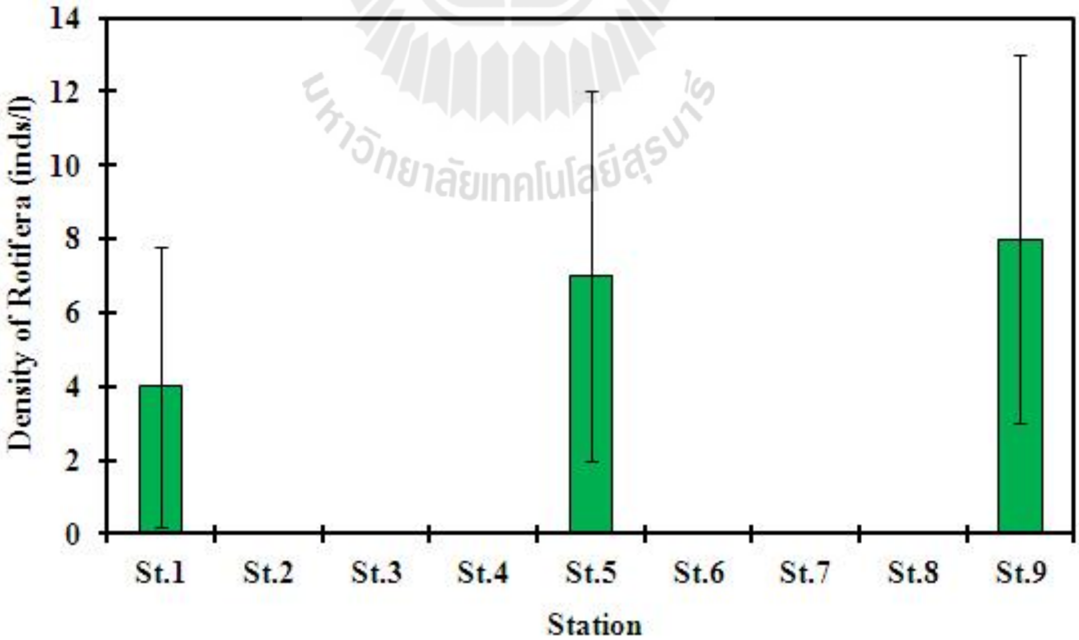

Figure 4.29 Densities of Rotifera (inds/l) in seawater on nine stations between January and December 2008.

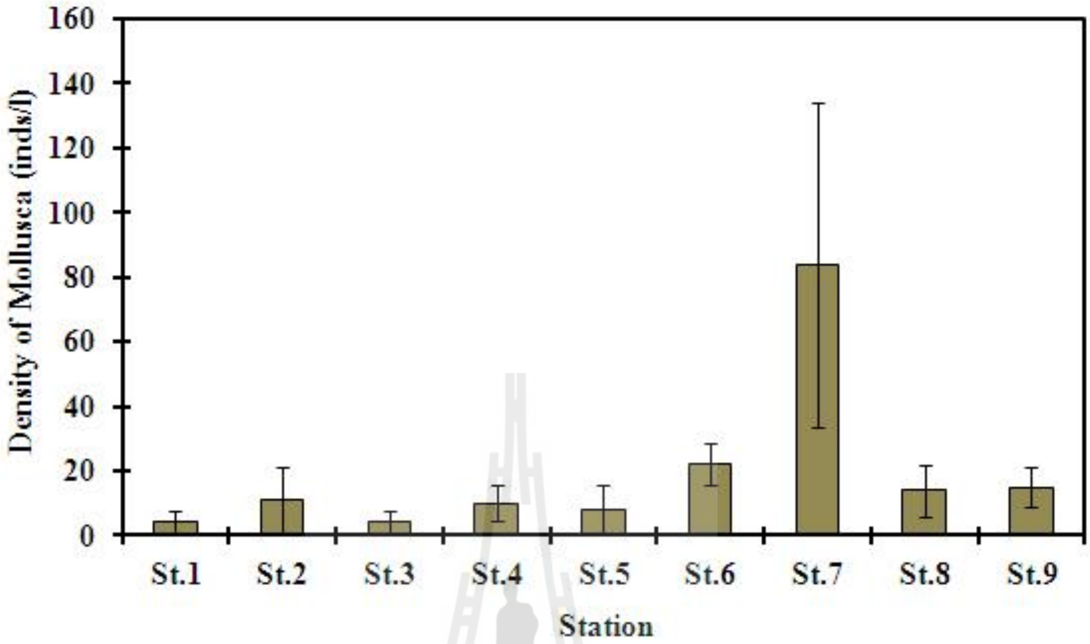

Figure 4.30 Densities of Mollusca (inds/l) in seawater on nine stations between January and December 2008.

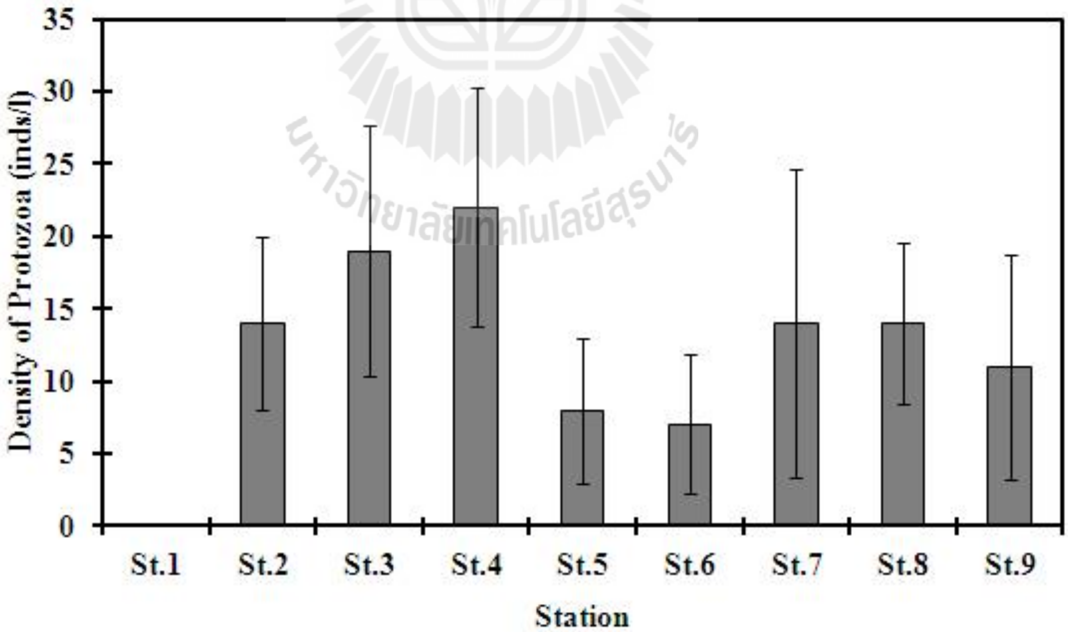

Figure 4.31 Densities of Protozoa (inds/l) in seawater on nine stations between January and December 2008.

4.1.4 Heavy metal

The concentration of lead (Pb), manganese (Mn), iron (Fe) and chromium (Cr) were detected in seawater samples at the severely effected areas in Phang Nga province showed no risk to the impact of residue in seawater.

The concentration of Pb was detected the highest at St.8 as 0.3649 µg/l, secondary was at St.7 as 0.2960 µg/l and the lowest amount 0.1606 µg/l. These were compared with coastal water quality standard too low that Thailand National Environment Board issued the 7th decree (B.E. 2537) specified as not exceed 8.5 µg/l (Marine Environment Division, 2008) and when compared with report of Marine Environment Division, Water Quality Management Bureau (2004b) in May 2004 and July 2004 as <0.05 µg/l in Phang Nga Province before disaster from Tsunami in December 26, 2004 was higher.

The quantity of Mn was examined minimum amount 0.1206 µg/l was at St.8 and maximum was at St.1 as 0.2143 µg/l. All stations, the concentration of Mn were detected very rare when compared with the value that was fixed by Marine Environment Division (2008) as less than 100 µg/l. Moreover, when compared with the value of Mn that was reported by Marine Environment Division, Water Quality Management Bureau (2004b) as 5.5 µg/l in May 2004 and 9.2 µg/l in July 2004 in Phang-Nga Province before disaster from Tsunami in December 26, 2004 which was too low. Beside, the result of this research was likely with the study on the impact of Tsunami on the heavy metal accumulation in water, sediments and fish at Poompuhar Coast, Southeast Coast of India that performed to sample collection in November 28, 2004 (Pre tsunami) and on January 26, 2005 (Post tsunami). This case study was detected concentration of heavy metal in water after Tsunami was higher than all heavy metal, exception Mn was examined less than before Tsunami (Martin Deva Prasath and Hidayathulla Khan, 2008).

The value of Fe was showed the lowest amount 0.0822 µg/l was at St.9 and the highest value 0.1849 µg/l was at St.5, when compared with the value of coastal water quality standard as less than 300 µg/l that was very low. Then, to compare with the Fe concentration that was reported by Marine Environment Division, Water Quality Management Bureau (2004b) as 310 µg/l in May 2004 and 280 µg/l in July 2004 in Phang-Nga Province before disaster from Tsunami in December 26, 2004 which was highly different.

The Cr value was varied between 0.0248- 0.0417 µg/l, the highest value was at St.5 and the lowest amount was at St.8, but the concentration of Cr in this study was a few when compared to the value that was limited by Marine Environment Division (2008) as not exceed 100 µg/l and less than report of Marine Environment Division, Water Quality Management Bureau (2004b) in May 2004 as 2.8 µg/l. and July 2004 as <2.8 µg/l in Phang-Nga Province before disaster from Tsunami in December 26, 2004.

The concentration of heavy metal were presented the details in the Table 4.7 and Figures 4.32-4.35.

Table 4.7 Average concentration of heavy metal in seawater on nine stations between January and December 2008.

Station	Heavy metals							
	Pb (µg/l)	± SE	Mn (µg/l)	± SE	Fe (µg/l)	± SE	Cr (µg/l)	± SE
St.1	0.1606	0.0606	0.2143	0.0652	0.1225	0.0174	0.0333	0.0071
St.2	0.1903	0.0538	0.1915	0.0586	0.0903	0.0149	0.0287	0.0090
St.3	0.1738	0.0518	0.1613	0.0501	0.1215	0.0115	0.0310	0.0098
St.4	0.1610	0.0487	0.1430	0.0512	0.1057	0.0132	0.0260	0.0080
St.5	0.2038	0.0694	0.1956	0.0638	0.1849	0.0790	0.0417	0.0048
St.6	0.2484	0.0546	0.1881	0.0594	0.1302	0.0255	0.0390	0.0054
St.7	0.2960	0.0588	0.1667	0.0544	0.1544	0.0477	0.0383	0.0053
St.8	0.3649	0.0821	0.1206	0.0391	0.1114	0.0210	0.0248	0.0062
St.9	0.2786	0.0657	0.1286	0.0443	0.0822	0.0151	0.0397	0.0045

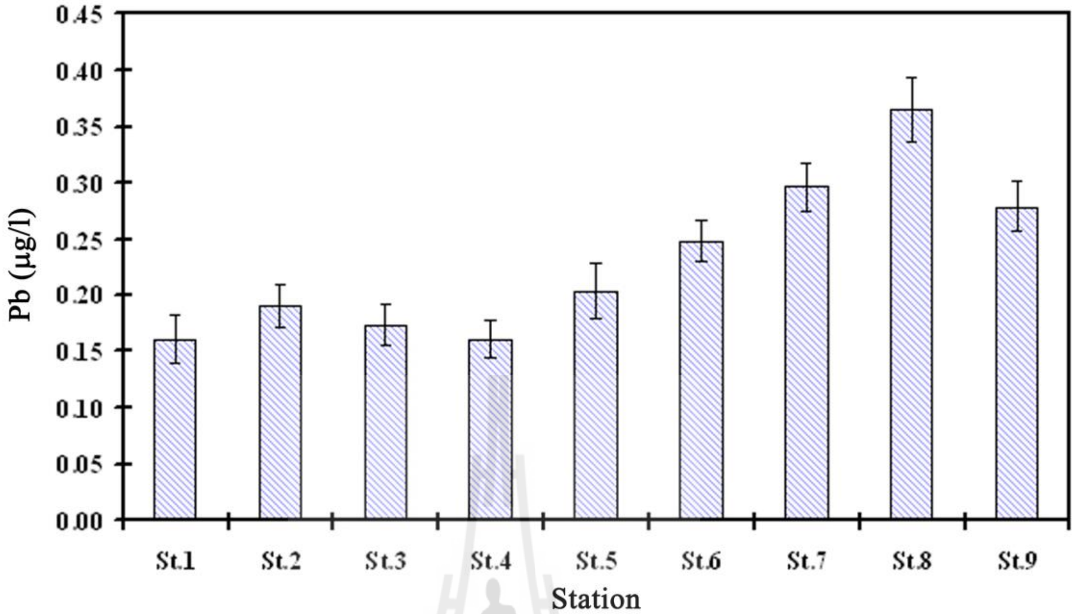

Figure 4.32 Average concentration (μg/l) of lead in seawater on nine stations between January and December 2008.

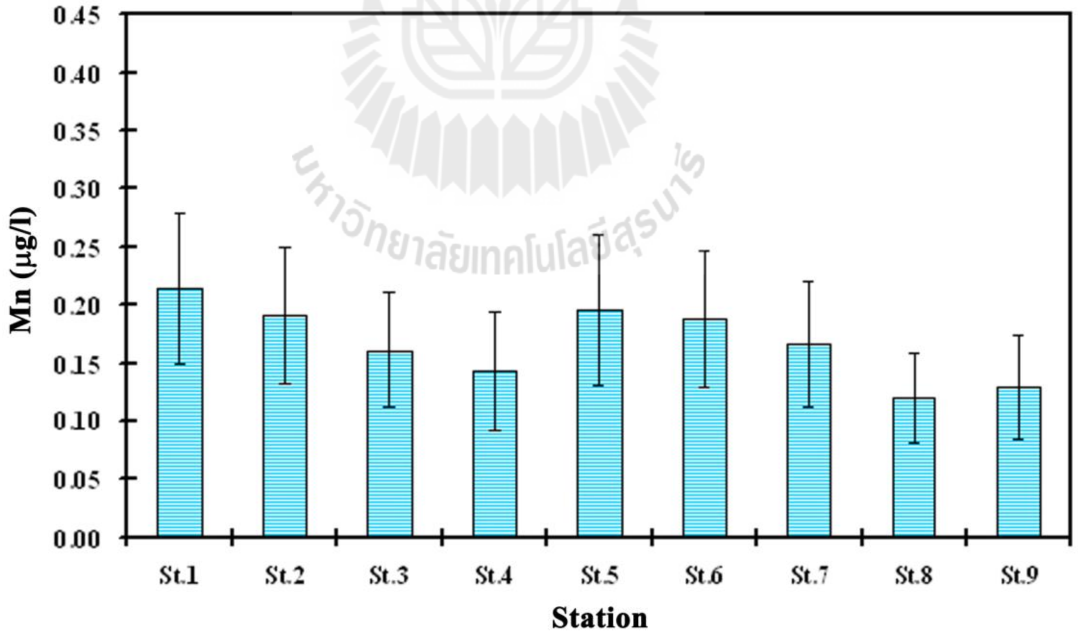

Figure 4.33 Average concentration (μg/l) of manganese in seawater on nine stations between January and December 2008.

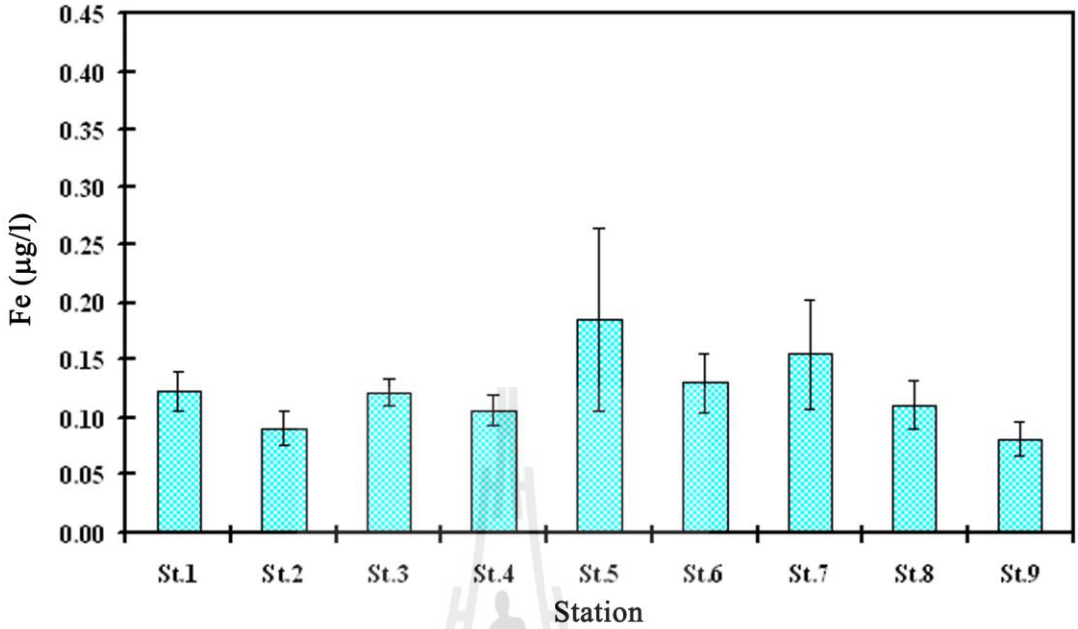

Figure 4.34 Average concentration (μg/l) of iron in seawater on nine stations between January and December 2008.

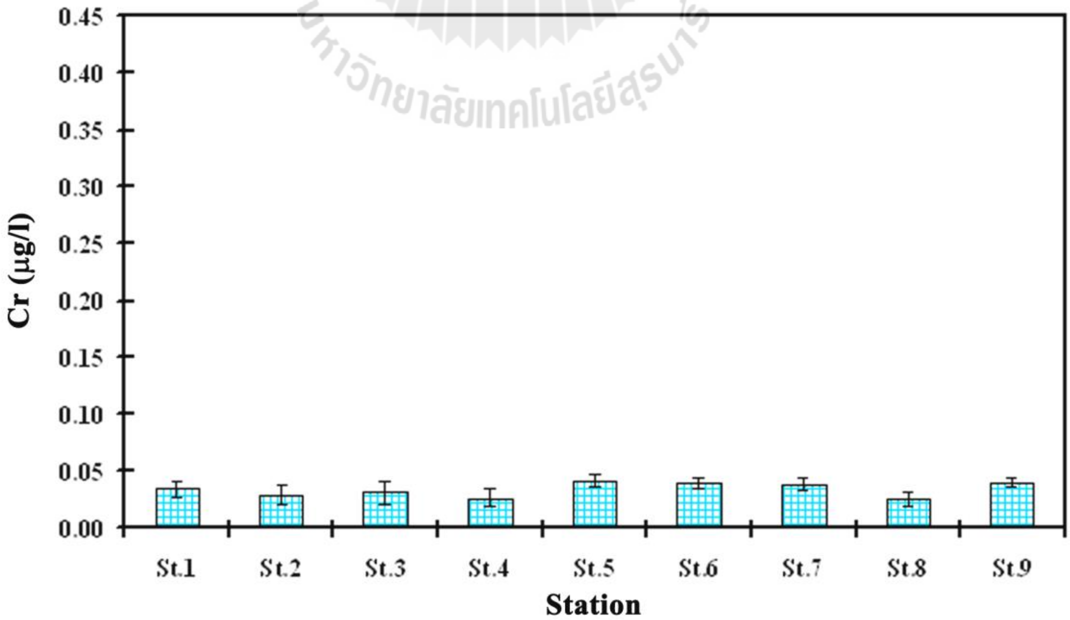

Figure 4.35 Average concentration (μg/l) of chromium in seawater on nine stations between January and December 2008.

CHAPTER V

CONCLUSIONS

From the result of study on physical, chemical and biological properties and heavy metals of seawater around local fishery piers in Phang-Nga province after a devastating tsunami, all parameters of the properties indicated that four years after tsunami (2004-2008), among various concerns of human casualties, sanitary condition, damage of properties and destruction of environment, the seawater quality along the Phang-Nga province coast where was severely affected areas presented normal quality.

The physical parameters were observed that consist of temperature, transparency, total dissolved solids and electrical conductivity showed usual values.

The chemical parameters were detected such as hydrogen ion concentration, salinity, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand indicated fluctuations on the normal situation.

The biological parameters; phytoplankton and zooplankton were recorded variation to locations. The phytoplankton communities were determined to five divisions as Euglenophyta, Chlorophyta, Chrysophyta, Cyanophyta and Pyrrhophyta. The Chrysophyta was the highest of taxonomic group and the Cyanophyta was found the maximum density. For, zooplankton were detected in 6 phylums that consist of Chordata, Annelida, Arthropoda, Rotifera, Mollusca and Protozoa. The most of zooplankton quantity, Phylum Arthropoda was the highest and the subsequence was Phylum mollusca.

The heavy metals such as Lead, Manganese, Iron and Chromium were showed that the concentration of them were detected very low, but some location that full of mariculture cages and parking of local fishing boat was highly determined to Lead. The Manganese was checked the maximum level at a large coastal fisheries community. Then the concentration of Iron and Chromium were found to be extremely at nearly the ferryboat, fishing boats and taxi-boats port.

However, the results of this research all parameters were indicated that the seawater quality conditions of coastal areas of Phang-Nga province particularly in severely affected areas were in good condition.

Although, the result of many cases study were presented to the positive effect after disaster the tsunami 2004. But in the long term, nobody couldn't guarantee that all severely affect areas harmless from these problems. So, the monitoring of environmental parameters in severely effect locations has to be highly significant for protection problem that maybe happened in the future. The long term monitoring of environmental parameters in fixed locations has to be initiated throughout Phang-Nga affected areas in order to have detailed data on various physical, chemical and biological parameters which will enable comparison during such calamities and to make immediate remedial measures and people should be made aware of the effective disaster management measures and coastal protection through conservation and management of natural resources.

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APPENDIX

APPENDIX

MARINE WATER QUALITY STANDARD

A.1 Marine water quality standard (Marine Environment Division, 2008)

The Thailand National Environment Board issued the 7th decree (B.E. 2537) for the control of coastal water quality. According to the decree, Thailand established the original Coastal Water Quality Standard, which has been used to govern and manage coastal water for ten years. When taking into consideration the current state of the economy and environmental awareness as well as the rapid advancement of technologies it has become clear that the original standard is outdated. National Environment Board reconsidered the original standard and agreed that the amendment of the original standard was needed. Subsequently, the 7th decree was renounced on January 20, B.E. 2537 and the new marine water quality standard were designated as follows:

A.1.1 Definition

"Marine water" means that all waters within Thai territorial water, excluding surface waters defined according to the decree regarding the establishment of surface water quality standard issued by the National Environment Board.

"Thai territorial water" means that territorial waters under the sovereignty of Thailand in compliance with Navigation in Thai Waters Act.

"Buffer zones" mean areas between two waters with different uses; its area shall be defined based on the distance of 500 meters from the water that has lower water quality.

A.1.2 Classification of marine water:

Class 1 Natural resource preservation areas shall be applied to the water that is not reserved for a particular use and is naturally suitable for breeding or nurturing newborn marine organisms as well as being able to serve as food sources and natural habitats for marine animals and plants as well as sea grass.

Class 2 Coral reef conservation areas shall be applied to the water densely inhabited by coral reefs, covering the area with 1,000 meter extension from the most exterior ridge of the coral reef.

Class 3 Aquaculture areas shall be applied to the water that is designated by fisheries laws to be used for aquacultural practices.

Class 4 Recreation areas shall be applied to the water allowed by the local administrative organization for swimming or other recreational activities.

Class 5 Industrial or ports zone shall be applicable to the water that is adjacent to an industrial estate whose definition shall conform to the law governing the Industrial Estate Authority of Thailand, or be applicable to port zones, whether it be ports or harbours; the area governed by the standard shall extend from the lowest tide line up to 1,000 meters.

Class 6 Residential districts areas shall applied to the water that is close to residential areas whose definition shall comply with municipal laws, Pattaya Municipality or Bangkok Municipality; the standard shall be applicable specifically to the parts of Pattaya, Bangkok and other municipalities whose borders are attached to the coastal area and extend from the lowest tide line up to 1,000 meters.

A.1.3 Overlapped areas and buffer zones

(a) In the case that there is an overlapping among areas to which different standards are applied, the most stringent standard shall be preferred.

(b) The classification of waters into each type of beneficial use shall proceed with the designation of a buffer zone located between two waters complying with different standards. Besides, water quality standard of a buffer zone shall not exceed the average between different standards of the two waters that have a buffer zone between them, nonetheless, with the following exceptions:

(1) If a buffer zone is situated between the two waters, one of which possesses no standard, the water quality standard of the buffer zone shall not be greater than the standard available.

(2) If the standard of two waters requires that their water quality be the same as it appears in nature, the water quality in a buffer zone shall not exceed half the standard.

A.1.4 Sampling requirements

1) Conduct the water sampling at the depth of 1 meter above the bottom and below the surface, providing that the water has a depth of less than 5 meters.

2) Conduct the water sampling at three different depths including 1 meter above the bottom and below the surface as well as at mid-depth in the water, provided that the water depth ranges from 5 to 20 meters.

3) Conduct the water sampling at five different depths, which are 1, 10, 20, and 30 meters below the surface and 1 meter above the bottom, provided that the water depth ranges from 20 to 40 meters.

4) Conduct the water sampling at five different depths, which are 1, 20, 40, and 80 meters below the surface and 1 meter above the bottom, provided that the water depth ranges from 40 to 100 meters.

5) Conduct the water sampling at the depth of 1 meter below the surface and above the bottom as well as at the depth of every fifty meter, provided that the water depth is greater than 100 meters.

6) Conduct the water sampling at the mid-depth, provided that the water depth is equal to, or less than, 1 meter.

The water sampling shall conform to the six conditions above except for the following circumstances:

a) In the case of the total coliform bacteria, fecal coliform bacteria and enterococci bacteria, the sampling shall be performed at the depth of 30 centimeters below the surface.

b) In the case of floatable solids, colour, transparency, and oil & grease on the surface, the water sampling shall not be required; nonetheless, the measurement of these parameters shall be carried out at the sampling field.

Moreover, if the water be influenced by tides, sampling shall be performed until the lowest level of the tide is reached.

Table A.1 Marine water quality standard.

Parameters	Permitted Value for Marine Water Class Class 1 Natural resource Preservation	Class 2 Coral reef conservation	Class 3 Aquaculture	Class 4 Recreation	Class 5 Industrial or ports zone	Class 6 Residential districts areas
Floatable Solids	not unpleasant					
Colour	not unpleasant[1]					
Odour	not unpleasant[2]					
Temperature ^{o}(C)	an increase shall ^{o} C not exceed 1 from the natural temperature	any change of the natural temperature shall not be allowed	an increase shall not exceed 1 ^{o} C from the natural temperature	an increase shall not exceed 2 ^{o} C from the natural temperature		
pH	7.0-8.5					
Transparency	a decrease shall not be exceed than 10% of the minimum transparency governed by natural condition [3]					
Suspended Solids	an increase shall not exceed the average value within 1 day, 1 month or 1 year added by its corresponding deviation value[4]					
Salinity	any change shall not exceed 10% of the minimum salinity[5]					
Floatable Oil & Grease	not visible to naked eyes					

Table A.1 Marine water quality standard (Continued).

Parameters	Permitted Value for Marine Water Class					
	Class 1 Natural resource Preservation	Class 2 Coral reef conservation	Class 3 Aquaculture	Class 4 Recreation	Class 5 Industrial or ports zone	Class 6 Residential districts areas
Petroleum Hydrocarbon (g/l)	not exceed than 0.5			not exceed than 1	not exceed than 5	
Dissolved Oxygen (mg/l)	not less than 4			not less than 6	not less than 4	
Total Coliform Bacteria (MPN/100 ml)	not exceed 1,000					
Fecal Coliform Bacteria (CFU/100 ml)	not exceed than 70			not exceed than 100		
Enterococci Bacteria (CFU/100 ml)	-	not exceed 35	-	not exceed 35	-	-
Nitrate -Nitrogen (g-N/l)	not exceed 20			not exceed 60		
Phosphate-Phosphorus (g-P/l)	not exceed than 15	not exceed than 45		not exceed than 15	not exceed than 45	
Unionized Ammonia (g-N/l)	not exceed 70		not exceed 100		not exceed 70	

Table A.1 Marine water quality standard (Continued).

Parameters	Permitted Value for Marine Water Class					
	Class 1 Natural resource Preservation	Class 2 Coral reef conservation	Class 3 Aquaculture	Class 4 Recreation	Class 5 Industrial or ports zone	Class 6 Residential districts areas
Total Mercury (µg/l)			not exceed 0.1			
Cadmium (µg/l)			not exceed 5			
Total Chromium (µg/l)			not exceed 100			
Chromium Hexavalent (µg/l)			not exceed 50			
Lead (µg/l)			not exceed 8.5			
Copper (µg/l)			not exceed 8			
Manganese (µg/l)			not exceed 100			
Zinc (µg/l)			not exceed 50			
Iron (µg/l)			not exceed 300			
Arsenic (g/l)			not exceed 10			
Fluoride (mg/l)			not exceed 1			
Residual Chlorine (mg/l)	-	-	-	-		not exceed 0.01
Phenol (mg/l)			not exceed 0.03			
Sulfide (g/l)			not exceed 10			
Cyanide (g/l)			not exceed 7			

Table A.1 Marine water quality standard (Continued).

Parameters	Permitted Value for Marine Water Class					
	Class 1 Natural resource Preservation	Class 2 Coral reef conservation	Class 3 Aquaculture	Class 4 Recreation	Class 5 Industrial or ports zone	Class 6 Residential districts areas
Polychlorinated Biphenyl, PCBs	undetectable					
Radioactivity (Becquerel/l)						
- Alpha	not exceed 0.1					
- Beta (excluding Potassium-40)	not exceed 1.0					
Tributyltin (ng/l)	not exceed 10					
Containing-chlorine pesticides (g/l)						
- Aldrin	not exceed 1.3					
- Chlordane	not exceed 0.004					
- DDT	not exceed 0.001					
- Dieldrin	not exceed 0.0019					
- Endrin	not exceed 0.0023					
- Endosulfan	not exceed 0.0087					
- Heptachlor	not exceed 0.0036					
- Lindane	not exceed 0.16					

Table A.1 Marine water quality standard (Continued).

Parameters	Permitted Value for Marine Water Class					
	Class 1 Natural resource Preservation	Class 2 Coral reef conservation	Class 3 Aquaculture	Class 4 Recreation	Class 5 Industrial or ports zone	Class 6 Residential districts areas
Other pesticides - Alachlor - Ametryn - Atrazine - Carbaryl - Carbendazim - Chlorpyrifos - Cypermethrin - 2,4-D - Diuron - Glyphosate - Malathion - Mancozeb - Methyl Parathion - Parathion	undetectable					

[1] The color of marine water measured in scales of the Forel-Ule solution, ranging from 1 to 22.

[2] No offensive smell from sources, such as, crude oil, “rotten egg”, chemicals, litter and decaying organic matters.

[3] The minimum level of transparency shall be ascertained based on marine water samples taken in the same season and from the same station for 1 year during which occurrence of tides exists.

[4] For 1-day average value, sampling /measurement shall be conducted every hour or, at least, 5 times a day at interval of constant period.

For 1-month average value, sampling /measurement shall be carried out every day or, at least, 4 times a month at interval of constant period.

For 1-year average value, sampling /measurement shall be carried out every month; besides, it shall be conducted on the same day and at the same time throughout the year.

[5] The minimum level of salinity shall be determined based on marine water samples taken in the same season and from the same station for 1 year during which occurrence of tides exists.

CURRICULUM VITAE

Name Mr. Porn-uma Krainara

Date of Birth 09 May 1973

Place of Birth Nakhon Si Thammarat

Education

1995, B.Sc. Aquaculture, Rajamangala University of Technology Srivijaya, Thailand.

2000, M.Sc. (Aquaculture), Kasetsart University, Thailand.

Publications

Thanee, N., and **Krainara, P.** 2011. The quantities of heavy metal in seawater at coastal fisheries areas, Phang-Nga province, Thailand, after the 2004 tsunami. Proceedings International Conference, Toward Enhancement of Economic, Social, Technological and Environmental Development for Welfare Implications in the Greater Mekong Sub-region and Asia-Pacific. Chiagrai Rajabhat University, Chiangrai, Thailand, p.473-481.

Awards Best Practice Award in the International Conference, Toward Enhancement of Economic, Social, Technological and Environmental Development for Welfare Implications in the Greater Mekong Sub-region and Asia-Pacific.

Grants and Fellowships -

Position and Place of Work Lecturer in Environmental Science Program, Department of Environment, Faculty of Science and Fishery Technology, Rajamangala University of Technology Srivijaya, Trang Campus.