アセアン諸国海域におけるアオウミガメの大回遊機構解明

（課題番号１３３７５００８）

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はしがき

ウミガメ類は今から 2 億年以上前の中生代ジュラ紀ごろに地球上に現れ、現在はオサガメ科（オサガメ）とウミガメ科（アカウミガメ、クロウミガメ、アオウミガメ、タイマイ、ヒメウミガメ、ケンプヒメウミガメ、ヒラタウミガメ）が世界の海に生息している。その分布域は亜熱帯から熱帯域を中心に世界中に広がり、大規模な摂餌・産卵回遊を行っている。ウミガメ類はその生息頭数が減少していると言われており、全種がワシントン条約（CITES）の附属書 I にリストアップされている。

ウミガメ類の減少は、海洋環境の変動などの自然要因に加え、リゾート開発等に伴う砂浜の減少、プラスチック類の誤食並びに漁業による混獲など人為的な要因も大きいと考えられている。特にトロール漁業（底引き網）による混獲が問題とされ、アメリカ合衆国メキシコ湾ではケンプヒメウミガメの減少はエビトロール漁業による混獲が主な原因として、ウミガメ類混獲防止装置（Turtle Excluder Device:　TED）の装着が義務付けられている。

1996 年、アメリカ合衆国は、TED 未装着漁船で漁獲されたエビ類の輸入禁止措置をタイ国などに通告してきた。タイ国にとってアメリカ合衆国はエビ類輸出の最大国であったため、この通告がタイ国漁業界に与えた衝撃は強烈であった。アセアン諸国のエビトロール漁船はメキシコ湾の漁船と比べて小規模な漁船であるため、メキシコ湾で装着されている TED をそのまま導入して装着することは、操業の安全性、効率等から不可能であった。このためタイ国などはアメリカ合衆国の措置に対して世界貿易機関（WTO）に撤回を求める提訴を行った。一方、ウミガメ類の混獲を回避するための努力もアセアン諸国で構成されている東南アジア漁業開発センター（Southeast Asia Fisheries Development Center: SEAFDEC）との協力の下に行われ、タイ式ウミガメ類混獲防止装置（Thai Turtle Free Device: TTFD）の開発と装着が進められてきた。

国際共同研究　SEASTAR2000

アメリカ合衆国からの TED 装着の通告を受けたタイ国政府は、TTFD の普及を図ると同時に、アオウミガメの回遊生態を調査するための研究協力を京都大学へ求めてきた。京都大学では坂本亘教授の下、日本で産卵を行うアカウミガメの調査・研究を 10 年以上に亘って継続的に実施してきており、すでに多くの成果と多くの研究者が育っている。我々京都大学の研究グループは 1999 年 3 月にタイ国水産局の研究者たちと協議を行い、研究課題を整理するとともに、タイ国研究者の強い要望があった人工衛星によるバイオテレメトリー（アルゴスシステム）を行うこととした。2000 年 2 月にアルゴス送信機の試験的装着及び

放流をプーケット海洋生物学センターにて行った。

この予備実験の結果を踏まえ、科学研究費補助金の申請に踏み切り 2001 年度の海外学術調査の新規課題として採択され、「アセアン諸国海域におけるアオウミガメの大回遊機構解明」（基盤研究(A)海外学術調査：研究代表者　荒井修亮）として、2001 年度から 3 カ年の研究を開始した。

本報告書には 3 カ年の研究によって得られた成果を下に執筆された博士学位論文 1 編、修士論文 1 編並びに 2003 年 12 月に開催した第 4 回 SEASTAR2000 ワークショップのプロシーディングス 20 編から構成されている。

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研究成果による工業所有権の出願・取得状況

該当なし

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Biology and Conservation of Green Turtle *Chelonia mydas* in Thailand

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Chapter 1

REVIEW OF RESEARCHES AND CONSERVATION OF SEA TURTLES IN THAILAND

INTRODUCTION

History of sea turtles researches in Thailand was dated back to 1916 when 3 species of sea turtles were documented (Smith 1916). Recently, 5 species (ranked from the highest relative abundance to the lowest) *i.e.* green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), leatherback turtle (*Dermochelys coriacea*), and loggerhead turtle (*Caretta caretta*) have been reported. All species except loggerhead turtle nest along the coast or islands in Thailand.

In the past, sea turtles and their eggs were consumed locally without any regulations or laws enforcement. Until 1947, sea turtles have been proclaimed as conserved animals. During 1950-1983, concessions of sea turtles' eggs collection had been permitted with a condition that concessionaires had to keep part of the collected eggs, incubated and released sea turtle hatchlings back to the sea. Direct take of sea turtles tremendous increased during 1973-1985 due to the high demand for export. In addition, introducing of trawling in 1964 adversely affected to the number of sea turtles. Nesting statistic showed that the number of sea turtles has dramatically decreased over the last 50 years.

Attempts to protect and to increase the number of sea turtles have been launched in several ways. Four national Acts (Fisheries Act 1947, National Park Act 1961, Export and import Act 1979, Wildlife Reservation and Protection Act 1992) were enacted to direct protect sea turtles as well as to protect their feeding, internesting and nesting grounds. Along with the law enforcement, various aspects of biological studies (from nesting behavior, embryonic development, to rearing technique) have been carried out to get better understanding of sea turtle conservation. Captive rearing and breeding project has been started and later on adopted by Her

Majestic Queen of Thailand. Sea turtles hatchlings from the project have been released every year. Public awareness building program has been deployed as an additional means for conservation of sea turtles in Thailand.

Despite of the present conservation efforts, nesting statistics still indicate the decreasing trends of all species. With the present scenario, nesting populations of *Chelonia mydas* and *Eretmochelys imbricata* might be wiped out from the Gulf of Thailand within 87 years, while ones of *Lepidochelys olivacea* and *Dermochelys coriacea* in the west coast of Thailand may disappear as soon as 2008. It is now or never that we have to reconsider the ways to conserve and protect these animals. In the past, conservation was limited to "on the beach" protection. However, it is known that sea turtles are migratory species from hatchling to adult (Bolten 2003). Thus, conservation plan is needed to protect the whole life cycles. In stead of traditional studies which have been confined to captive animals or "on the beach" data, further "beyond the beach" information is required to answer questions *i.e.*

1) Where do the sea turtles stay during nesting?

2) How long does it takes for nesting season?

3) What is the behavior of sea turtles during nesting?

4) Where do the sea turtles go after the nesting period?

Additionally, genetic information will reveal population structure of sea turtles in the region. These new scientific findings together with strengthened enforcement would secure the presence of sea turtles of the region.

SPECIES AND DISTRIBUTION

A list of sea turtles species in Thailand was firstly documented by Smith (1916). He reported 3 species of sea turtles as well as their relative abundance in the Gulf of Thailand. The species were green turtle (species name was written as *Chelone mydas*, very common), hawksbill turtle (*Chelone imbricata,* common), and possibly loggerhead turtle

(*Thalassochelys caretta* Linnaeus, with doubt). In 1950, the present of loggerhead turtle (*Caretta caretta*) in Thai waters was confirmed and additional species, leatherback turtle *Dermochelys coriacea* was reported (Kanjanadul 1950; Suvatti 1950b; Suvatti 1950a). Up to date, Olive ridley turtle (*Lepidochelys olivacea*) have only been observed along the west coast of Thailand (Chantrapornsyl 1992), but not in the Gulf of Thailand. Even though, olive ridley was claimed to be observed in the Gulf (Anonymous 1964), the detail described in the text "*scutes were like those of hawksbill turtle, but not imbricate*" is likely to be loggerhead turtle. The finding of true olive ridley may be firstly recorded in "Proposal for studying sea turtles and sea snakes in Malayan Sea and adjacent waters" (Anonymous 1964). It mentioned an unknown species named "Red eyes" sea turtle hatchlings from the west coast of Phang-Nga province which is well known now a day as an important nesting ground of olive ridley. Till recently, 5 species of sea turtles have been reported in Thai waters (Taylor 1970; Phasuk & Rongmuangsart 1973). Identification of sea turtles in Thailand is shown as Figure 1.

Family Cheloniidae

Common name: Green turtle

Scientific name: *Chelonia mydas* (Linnaeus, 1758)

Thai name: Tao Ta-Noo (เต่าตนุ)

Distribution: Green turtle is found in both west and east coasts of Thailand particularly in the sea grass beds. Juvenile green turtles distribute along shallow coastal areas.

Common name: Hawksbill turtle

Scientific name: *Erethmochelys imbricata* (Linnaeus, 1766)

Thai name: Tao Kra (เต่ากระ)

Distribution: Hawksbill turtle is found in both west and east coasts of Thailand. This species distributes around the islands far from the main land such as Surin Islands, Racha Islands (in the west coast) and Kra Island, Tao Island, Khram Island (in the east coast).

Common name: Olive ridley turtle

Scientific name: *Lepidochelys olivacea* (Eschscholtz, 1829)

Thai name: Tao Yah (เต่าหญ้า)

Distribution: This species can only be found along the west coast of Thailand. Juvenile olive ridley turtles distribute in shallow water areas on the west coast from Ranong to Phuket. Satellite tracking of a nesting olive ridley turtle from Prathong Island showed that her feeding ground is around Murgui Achipelago (Kittiwattanawong & Chantrapornsyl *In press*).

Common name: Loggerhead turtle

Scientific name: *Caretta caretta* (Vandelli, 1761)

Thai name: Tao Hua-Korn (เต่าหัวค้อน)

Distribution: There were few records of loggerhead turtle incidentally caught by fishing gears from the both sides of Thailand. It is believed that Thailand is neither feeding nor nesting grounds for this species. Most of specimens caught were adult or near adult sizes. Charuchinda *et al.* (In press) tracked a loggerhead turtle caught by gill net in Thailand with satellite transmitter. The result showed that the turtle passed over Malaysia Peninsula to the south of Borneo Island, and finally ended at Bali Sea of Indonesia.

Family Dermochelyidae

Common name: Leatherback turtle

Scientific name: *Dermochelys coriacea* (Linnaeus, 1766)

Thai name: Tao Ma-Fuang (เต่ามะเฟือง)

Distribution: Leatherback turtle is recently found only in the Andaman Sea. An adult leatherback turtle was incidentally caught in gill net at Rayong province, the Gulf of Thailand (Monanunsap & Charuchinda 1994).

Unconfirmed nesting of this species was reported in Narathiwat and Pattani which are the provinces located in the east coast of Thailand (Penyapol 1957; Phasuk 1992a).

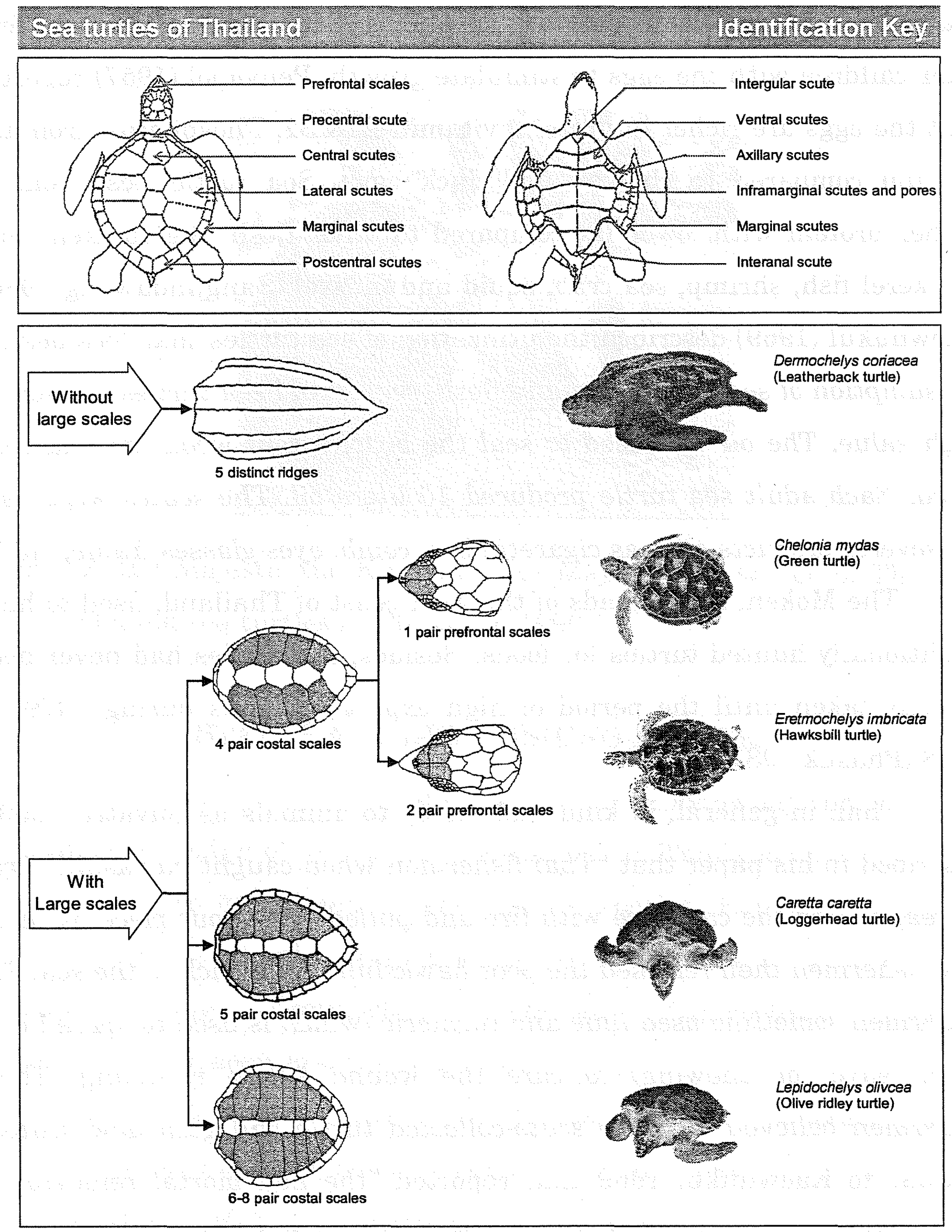


Figure 1. Illustrated glossary of technical terms and identification key of sea turtles in Thailand (modified from Marquez 1990 and Limpus 1992).

CULTURAL BACKGROUND

Sea turtles have been long recognized by Thai. In the past, sea turtles were locally consumed in various ways. Sea turtle eggs (used to be called "Kai Cha-Ra-Med" Suvatti 1950b) served as a food sources for local villagers. It was believed among Thai and Chinese living in Thailand that the eggs could help increasing sexual ability. Some parents liked to feed their children with the eggs to stimulate growth. Penyapol (1957) reported that the eggs are richer in protein, vitamin B1&B2, Phosphorus, iron and calcium compared to chicken and duck eggs. Sea turtle flesh contain higher protein with lower fat compared to other flesh like chicken, cow, mackerel fish, shrimp, sea crab, squid and mussel (Sangjindawong 1980). Kaewnukul (1969) described the utilization of sea turtles that "*besides the consumption of sea turtle eggs and flesh, scutes and sea turtles oil were of high value. The oil was used to seal the boat, extent wood life and color wood. Each adult sea turtle produced 10 liters oil. The scutes were used for several products such as cigarette box, comb, eyes glasses frame, etc.*"

The Moken, sea nomads of the west coast of Thailand, used to have traditionally hunted turtles for foods. Besides, sea turtles had never been directly taken until the period of high export demands during 1979 till 1988 (Phasuk 1981).

Thai, in general, is kind and mercy to animals as Suvatti (1950b) described in his paper that "*Thai fishermen when caught hawksbill turtle at sea, heated the carapace with fire and pulled scutes out piece by piece. The fishermen then released the poor hawksbill turtle back to the sea. The fishermen sometime used lime and turmeric (which is used to spread over betel leave for chewing) to cure the wound before releasing. Those fishermen believed that the scute-collected turtle will gain new scutes*". Similar to Kaewnukul 1969 that reported "*the non mortal removing of scutes by using coconut leave to insert in between a scute and carapace. Then pull the leave to the other end. A scute will be removed, the turtle would be safely released to the sea and the removed scute will be replaced with a new one. By the culture and tradition Thai like to release turtles are believed*".

Turtle releasing is a popular culture among Thai society. It is believed that such an activity would get rid of bad luck and extends the releasers' life. The ceremony of mass releasing sea turtles is often performed in Thai New Year (Apr, 13th) and other important days such as H.M. the King's Birthday and H.M. the Queen's Birthday, *etc.* (Figure 2).

Figure 2. His Majestic the King and Her Majestic the Queen of Thailand released sea turtles at Phuket in 1990.

STATUS AND DEMINISHING FACTORS

Nesting statistics (*see* "nesting statistics" topic in following) indicated the dramatic decreasing of sea turtles populations in Thailand since 1950. All species now are considered as endangered species. Ranking of relative abundance of sea turtles from the highest to the lowest at present is *Chelonia mydas, Eretmochelys imbricata, Lepidochelys olivacea, Dermochelys coriacea,* and *Caretta caretta.*

Caretta caretta is recently not considered as local population. Less than 4 specimens have been recorded over the past 30 yeas (Supot Chantrapornsyl, Mickmin Charuchinda and Somchai Monanansup, per. comu.) These turtles might just wander to Thai waters. Satellite tracking of a loggerhead turtle incidentally caught in the Gulf of Thailand indicated that she might come from Indonesian-North Australian waters (Charuchinda *et al.* In press). The species nesting along the coastal mainland such as *Lepidochelys olivacea* and *Dermochelys coriacea* have been suffered from the rapid development especially along the west coast of Phang-Nga and Phuket. Nesting statistic of these two species revealed very high potential of being wiped out from the area (*see* "Nesting statistic" topic). Although the species, Chelonia mydas and Eretmochelys imbricata, commonly nesting along the beaches of the islands are affected by human activities to reduce their populations, they remain relatively higher abundance.

Diminishing factors can be summarized as three major factors *i.e.* direct take, incidental catch, and habitat degradation.

Direct take

Sea turtle eggs had been directly taken for more than 100 years. Before 1950, the eggs were consumed only in such local areas where sea turtles nested as Phuket, Phang-Nga in the Gulf of Thailand and Sattahip, Rayong, Trad in the Gulf of Thailand. During concession period (1950-1983), the eggs had been harvested and sold to wider markets. The eggs cost ranged from 0.40-0.60 Baht in 1950 (Kanjanadul 1950) to 10-15 Baht in 1983 (Supot Chantrapornsyl, *per. com.*). Additionally, sea turtles were caught directly and exported as flesh and tortoiseshell consumptions. Thailand Customs Statistics revealed that 333,495 kg of tortoiseshell (*Chelonia mydas* and *Eretmochelys imbricata*) had been exported to Hong Kong, Taiwan, Singapore, China, Japan, *etc.* during 1973-1985 (Figure 3, *in* Groombridge & Luxmoore 1989). Assuming that each sea turtle has 20 kg tortoiseshell, it was estimated that 16,674 individuals of *Chelonia mydas* and *Eretmochelys imbricata* were killed for export. These resulted in rapidly dropped (more than 500%) of yearly nesting statistics (Figure 9).

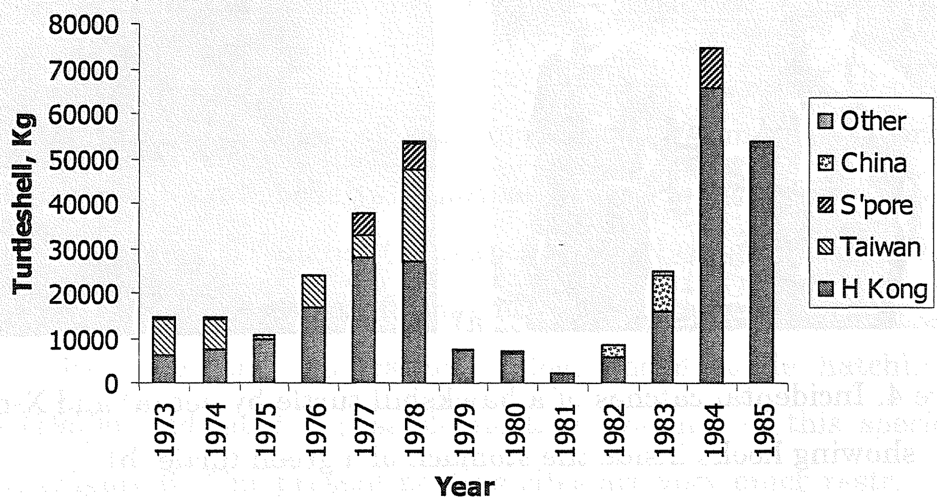


Figure 3. Domestic exports of unworked tortoiseshell (kg) from Thailand to various countries of destination reported in Thailand Custom Statistic (*data retrieved from* Groombridge & Luxmoore 1989).

Phasuk 1981 reported that during 1973-1978, Thailand exported sea turtles to Singapore Hong Kong, Taiwan and Japan 35,000 kg per year

Incidental catch

No direct investigation of incidental catch has been reported. The number of sea turtles, size and species incidentally caught by fishing gears were unknown. Interview of local fishermen often leaded to under estimation or bias data. Adulyanukosol & Ruangkaew (In press) reported 26.2% of stranded sea turtles were caught by gill net, 7% by miscellaneous fishing gears (*e.g.* trap net, hook and line), and about 61.7% washed ashore as unknown course. Introducing of trawling since 1964 has adversely affected to the number of sea turtles (Chantrapornsyl 1993b). Some of fishing gears incidentally caught sea turtles are shown in Figure 4.


a)

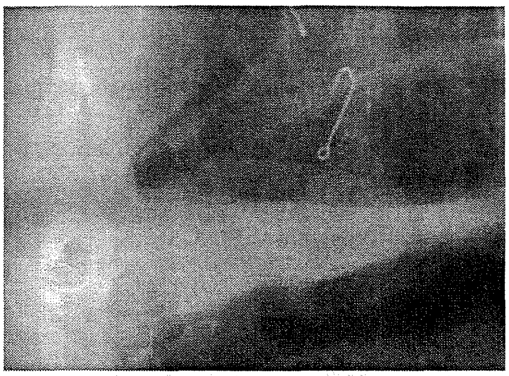

b)

Figure 4. Incidental catches of a hawksbill turtle by net (a) and X-ray film showing hooks inside the stomach of a green turtle (b).

Habitat degradation

Several important nesting beaches in the past have been developed to serve for tourisms and households (Figure 5). Lightings, constructions, and human activities disturb the nesting of sea turtles especially those species that nest on the main land (*i.e. Dermochelys coriacea* and *Lepidochelys olivacea*). Such areas can be found along the west coast of Phuket and Phang-Nga provinces in the Andaman Sea. The same scenery has happened to islands such as Samui Island, Krut Island, Chang Island, *etc.*, resulted in scarcely nesting of sea turtles.

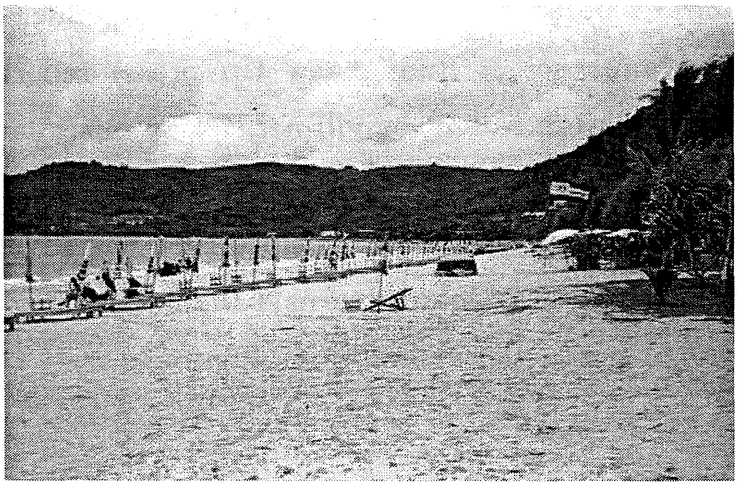


Figure 5. Lightning, constructions and human activities along nesting beaches prohibit nesting of sea turtles.

NESTING

Nesting species and sites

There are only four species of sea turtles (*i.e. Dermochelys coriacea, Chelonia mydas, Eretmochelys imbricata,* and *Lepidochelys olivacea*) reported to nest in Thailand (Penyapol 1957; Lekagul 1965; Phasuk 1992a). Nesting of *Caretta caratta* has never been recorded for more than 50 years. However, the illustration of loggerhead turtle hatchling in Suvatti (1950b) indicated a possible nesting evidence of this species in Thailand (Figure 6). The present nesting sites are very much restricted as protected areas such as national parks, Royal Thai Navy bases (Figure 7). In the past, wider nesting ranges have been reported as Table 1.

Table 1. Nesting sites of sea turtles in Thailand previously reported (Kanjanadul 1950; Petchpaisit 1953; Kaewnukul 1969; Phasuk 1992a).

Sea/Province	Nesting site
The Gulf of Thailand	
Chonburi	Khram Island, Samasarn Island, Lan Island, Lin Island King-Pedarn Island, Chan Island, Chuang Island, Kharm Island, Rad Island, Yor Island, Ra Island, and Song Island.
Trad	Krut Island and Chang Island.
Prachuabkirikhan	Juang Island and Prachuabkirikhan Gulf,.
Nakornsrithammarat	Kra Island.
Suratthani	Samui Island, Pha-Ngan Island, and Tao Island.
Pattani	Marod beach, Por-Ming beach, Panare beach, Talokapor beach, Taluban beach, Maikaen beach, and Pasoiver beach.
Narathiwat	The beaches of Bang-Nak district, Kaluwor district, Priwan district, and Jehe district.
Andaman Sea	
Phang-Nga	Similan Islands, Surin Island, Prathong Islands, Ta-Noon beach, Bang-Pri beach, Na-Teui beach, Tai-Muang beach, and Lam-Kaen beach
Phuket	Kata beach, Karon beach, Patong beach, Nai-Yang beach, Mai-Khao beach, and Maprao beach.
Satun	Tarutao Islands and Adang-Rawi Islands.

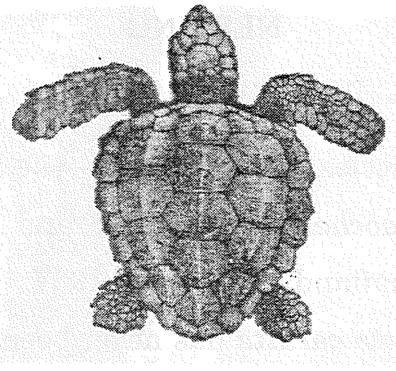


Figure 6. Illustration of a loggerhead turtle *Caretta caretta* hatchling from Thailand (*after* Achara Sahachatmanop *in* Suvatti 1950b).

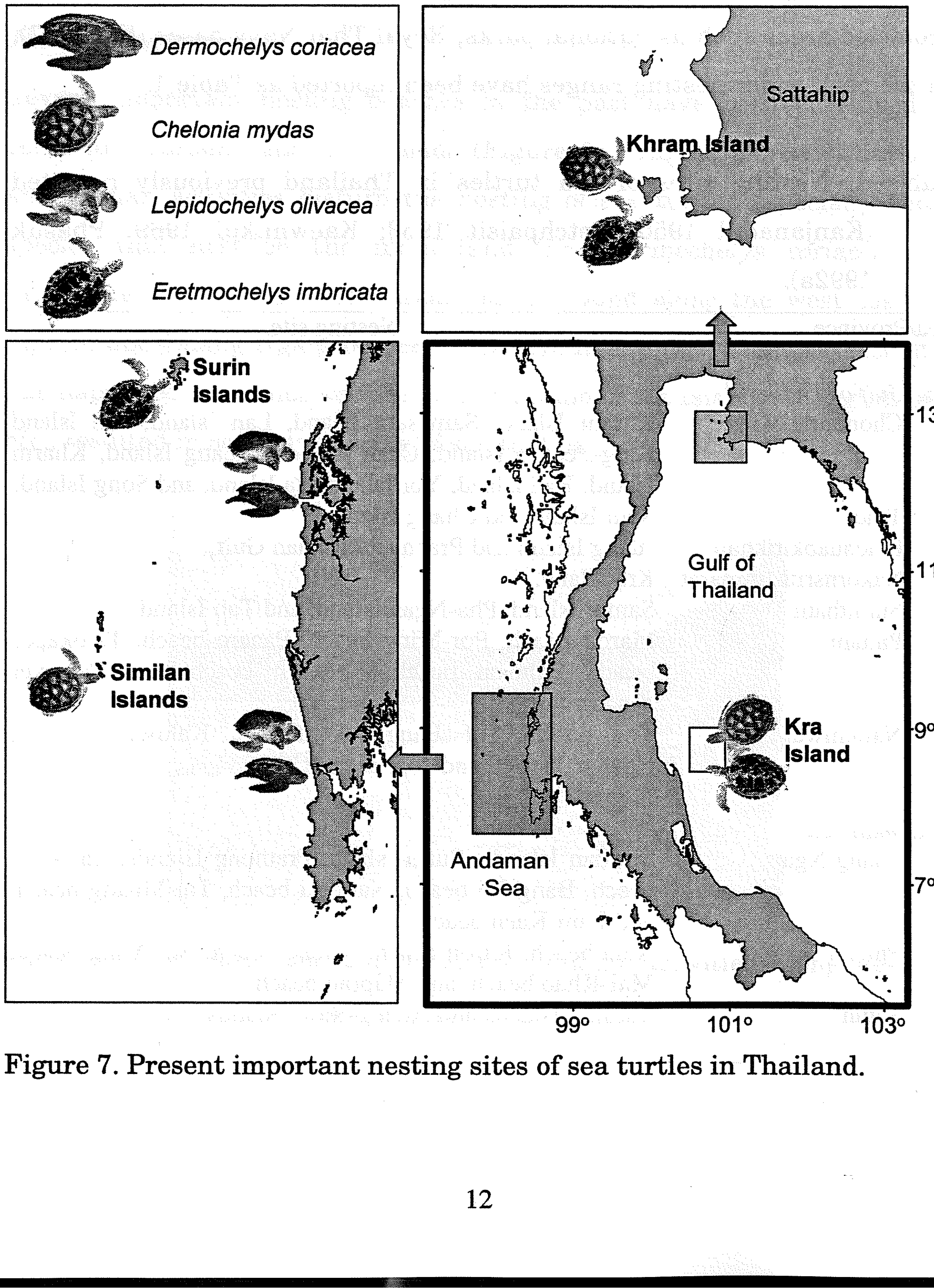


Figure 7. Present important nesting sites of sea turtles in Thailand.

Nesting behavior

Nesting occurs at night during high tide (Phasuk 1992a; Monanunsap & Charuchinda 1994). Klom-in (In press) described the nesting behavior of *Chelonia mydas* at the Huyong Island that *"A nester crept across the sand shore to find suitable places near to a grove, grass, or a tree. When a suitable place was found, she dug a pit big enough for her body to be inside. This step took about 30 minutes. A nester then used her hide limps to dig a small jar-liked hole by swapping hide limps to draw sand and throw to the front. A depth of a hole was between 50-80 cm. A nester spent about 10 minutes to lay the first egg till the last one. During eggs laying, she stayed calmly with posterior end moving up and down. When the last egg was laid, she used her hind limps to bury and compact a hole and used flippers to sweep sand to posterior area along with slowly moved upward. This process took about 1 hour and covered the area of 3-5 square meters. The average of the whole processes took 2 hours".*

Chelonia mydas and *Eretmochelys imbricata* nest all year round with the peak from May to August (Phasuk 1992a; Monanunsap & Charuchinda 1994). *Lepidochelys olivacea* and *Dermochelys coriacea* nest from September to February with the peak between Novembers to January (Chantrapornsyl 1992; Phasuk 1992a). Multiple nesting per season ranges from 5 to 10 times has been reported (Kanjanadul 1950; Monanunsap & Charuchinda 1994). In *Chelonia mydas*, nesters stayed within 5-6 km from the nesting site for 3-4 months (Kittiwattanawong In press). Copulations were observed near to the nesting beaches (Figure 8, Monanunsap & Charuchinda 1994; Klom-in 2002).

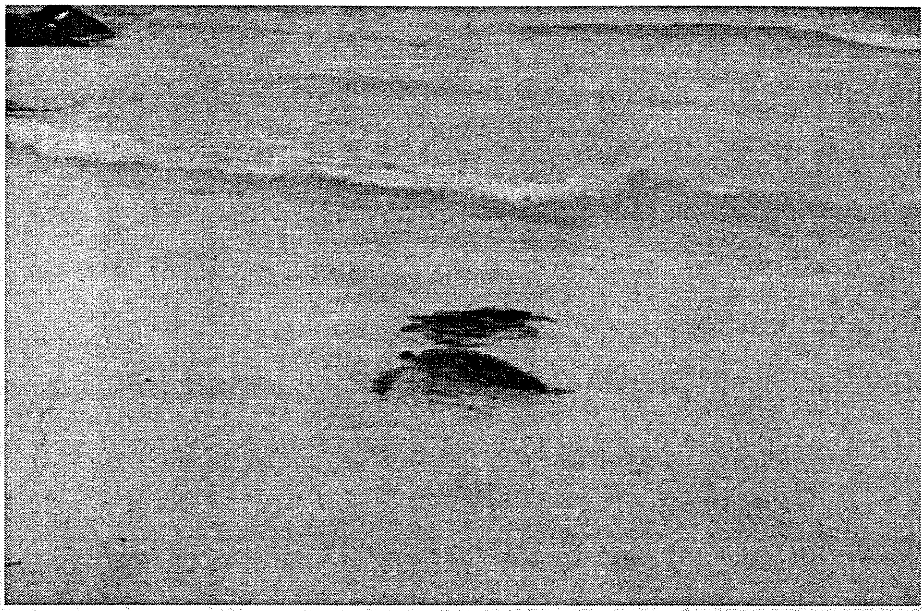


Figure 8. Mating of *Chelonia mydas* in front of nesting beach of Huyong Island on the West of Thailand (*photos courtesy of* Capt. Winai Klom-In)

Nesting statistics

Nesting statistics of *Chelonia mydas* and *Eretmochelys imbricata* at Khram Island have been recorded since 1955 (Penyapol 1957). Continuously recording of nesting statistics make it the most complete nesting data in Thailand (Figure 9, Penyapol 1957; Phasuk 1992b; Monanunsap & Charuchinda 1994 and Somchai Monanansup, unpublished data). Regression analysis revealed that under the present scenario, nesting populations of *Chelonia mydas* and *Eretmochelys imbricata* in the Gulf of Thailand may disappear within 87 years.

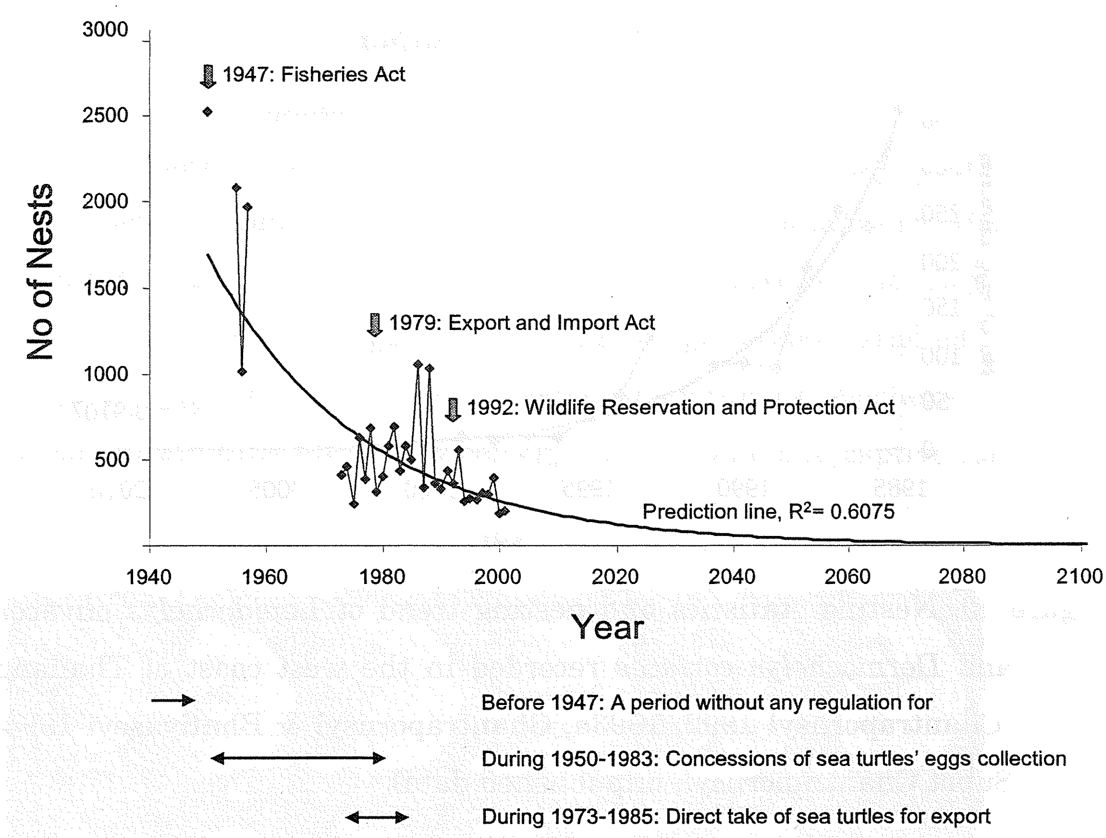


Figure 9. Nesting statistics of *Chelonia mydas* and *Eretmochelys imbricata* at Khram Island in the Gulf of Thailand and nesting trend. The figure is superimposed with chronological launching of sea turtle protection laws as well as major diminishing factors (*data compiled from* Penyapol 1957; Phasuk 1992b; Monanunsap & Charuchinda 1994 and Somchai Monanansup, unpublished data).

In the west coast of Thailand, accumulated data published by Chantrapornsyl 1992, 1993a; Chantrapornsyl & Bhatiyasevi 1994; and Supot Chantrapornsyl, unpublished data indicated very critical status of *Lepidochelys olivacea* and *Dermochelys coriacea* (Figure 10). Regression analysis revealed that under the present scenario, nesting populations of the two species may be wiped out by the year 2008.

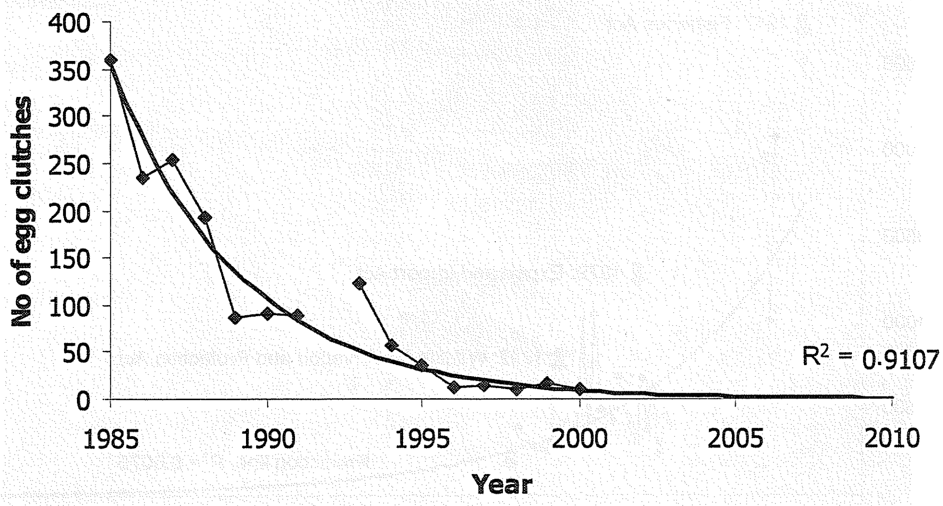


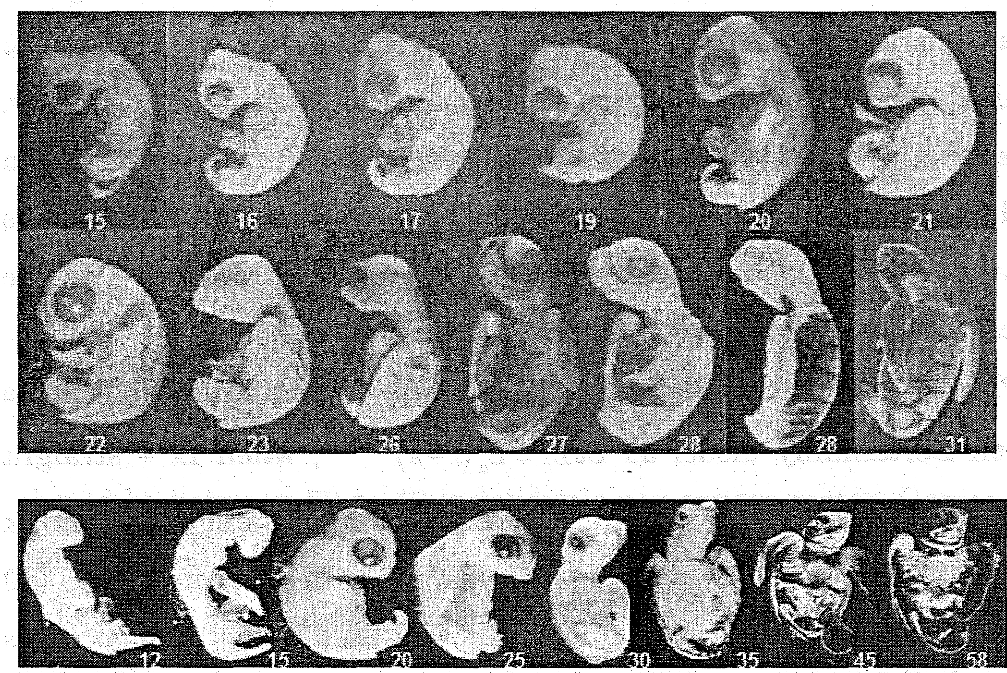
Figure 10. Nesting statistics and nesting trend of *Lepidochelys olivacea* and *Dermochelys coriacea* recorded in the west coast of Thailand (Chantrapornsyl 1992, 1993a; Chantrapornsyl & Bhatiyasevi 1994; Supot Chantrapornsyl, unpublished data).

INCUBATION TECHNIQUE

Sometime, the turtle eggs may not be safe *in situ* because of poachers or natural factors such as reaching of the sea water, roots penetration, ants, lizards, *etc.* Translocation and artificial incubation of eggs may be needed. Success of incubation of sea turtle eggs in Styrofoam box has been reported (Chantrapornsyl 1980; Phasuk 1992a). The method began with filling 10 cm sand layer to the bottom of a 34.5x46.5x30 cm Styrofoam box. Lay 50-100 sea turtle eggs, which were collected within 6 hours after nesting, onto the sand layer, then buried with sand. Keep a Styrofoam box with eggs outdoor. Spray sand with water from time to time if sand was too dry. The hatching successes were between 70-83% (58-64 incubation days at 26.6-30.1 °C). Charuchinda (1995) obtained 84.2% hatching rate of green turtle eggs using a crocodile eggs hatching room at the controlled temperature 30-31 °C and 95-99% air humidity. Tatsukawa *et al.* (In press) reported the pivotal temperature (a temperature that each eggs clutch have 50% male and female) of 30.44 °C for *Chelonia mydas* in Thailand.

EMBRYONIC ONTOGENY

Embryonic developments of *Chelonia mydas* (Penyapol 1957; Monanunsap *et al.* 1987), *Lepidochelys olivacea* (Chantrapornsyl 1985), and *Eretmochelys imbricata* (Ganjanamavint & Rongmuangsart 1987) were reported. Development stages of *Chelonia mydas* and *Lepidochelys olivacea* are shown in Figure 11. Wangkulangkul (2000) studied thickness of calcareous and fibrous layers of olive ridley turtles' eggshells and found no significant differences between eggs laid by wild and captive turtles.



a

b

Figure 11. Embryonic development of (a) *Chelonia mydas* (*modified from* Penyapol 1957) and (b) *Lepidochelys imbricata* (*photos courtesy of* Supot Chantrapornsyl). The numbers indicate ages in day.

REARING

The ideas to release sea turtles back to nature have diverted into two schools: head-started and releasing after hatch. Headstart program required the rearing of sea turtles hatchling for a period of time prior to release into the sea. This program claimed that the bigger size of hatchlings would enhance the survival rate. In a mean time, it helps building up public awareness. The opponent school pointed out the failure of headstart program such as loss of natural instinct, poor rearing condition, *etc.* (*read further information from* Mortimer 1988; 1995). Fighting between the two schools of idea is still going on without any scientific judgment.

In Thailand, the idea of head-started turtles has had been overwhelmed. Most of the hatchlings that are produced in Thailand are reared in captivity for 3-12 months prior to their release. Attempts to rear sea turtles hatchling have been conducted as early as 1938 when Boon Intharampan (*in* Suvatti 1950b) noted that "*it took one year to rear green and hawksbill turtles from 5 cm to 15 cm*". In 1973, Phasuk & Rongmuangsart reported a feasibility of rearing sea turtles in captivity. This leaded to the sea turtle conservation project which later on has been adopted by Her Majestic the Queen of Thailand. Mannai Sea Turtles Conservation Station and "*Sea Turtle Program*" at Phuket Marine Biological Center were initiated to serve this project.

Phasuk (1992c) calculated the growth rate of *Lepidochelys olivacea* using von Bertanlanfy model as Lt $L_t = L_\alpha(1-e)^{-k(t-t_0)}$, when L_t = straight carapace length in cm; L_∞ = maximum straight carapace length (85 cm); k = growth efficiency (0.1915); t = age in year; t_o = incubation period (60 days or 0.16 year). The growth equation showed that reared *Lepidochelys olivacea* reached maximum length in 15 years. Bhatia (1985) found faster growth rate of *Eretmochelys imbricata* reared from hatchling to 22-month old was observed compared to the one of *Lepidochelys olivacea.*

Food preference and requirement have been studied. Phasuk & Rongmuangsart (1973) experimented on feeding of hatchling and 1-year old *Lepidochelys olivacea* with various type of foods *i.e.* live planktons (scooped with 55 micron mesh size net), green algae (*Enteromorpha intestinalis*), sea grass (*Thalassia testudinum*), plant (*Ipomoeapes caprae*), Oysters (*Ostrea* spp.), cockle (*Anadara* sp.), shrimp (*Metapenaeopsis* sp.), and trash fish (mixture of small fish of no economic value). They found that the most preferred food for both of hatchling and 1-year old turtle was oysters, followed by fish and shrimp. They noted that all the three types of plant food were consumed only in negligible amount. Ganjanamavint *et al.* (1993b) fed 2-month old *Chelonia mydas* with 5 diets. They found that the survival rates were 90, 95, 100, 80, and 30% when fed with fish, commercial pellet for shrimp, bivalve, commercial pellet for bird, and commercial pellet for goldfish, respectively. The highest growth rate was observed in the turtles fed with fish, while the commercial pellet for goldfish gave the worst growth rate. Monanunsap *et al.* (1987a) reported that the 4-month old *Chelonia mydas* and *Eretmochelys imbricata* could eat up to 3.6% of their body weight, while they were able to eat up 1.6% and 2.0% respectively. The minimum growth compensation levels were 0.7% and 1.3% of their body weight for the 4-month old *Chelonia mydas* and *Eretmochelys imbricata*, while the 3-month old of the two species required the same at 1%.

Optimal stocking density for sea turtle hatchling has been studied. Monanunsap *et al.* (1987b) had reared green turtle hatchlings for 8 weeks in round concrete tanks (1 m diameter) and cages (2x2x0.5 m) with different stocking densities. They found that the optimal stocking density should be between 20 to 40 individuals per square meter. Ganjanamavint *et al.* (1993a) reported that 3-week old green turtle hatchlings reared at 21 individuals per square meter for 4 weeks had highest growth rate compared to ones stocked at 34 and 48 individuals per square meter.

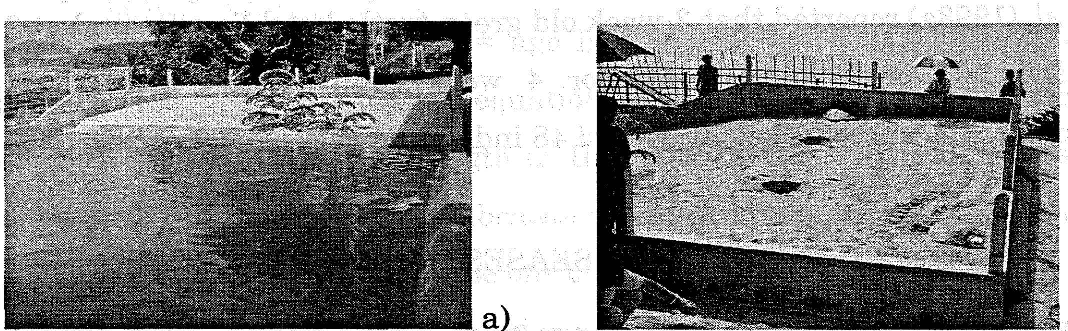
DISEASES

Studies of diseases in sea turtles have been confined to captive populations. Gray patch like disease and treatments were reported by Kanjanamavint *et al.* (1988; 1989; 1991; 1992). The disease was observed in 2-5 months old green turtles at Mannai Sea Turtle Conservation Station during 1989-1990. The symptoms showed ulcerative skin lesions at eyes, head, neck, tail, and flippers. *Aeromonas hydrophila* and *Vibrio alginolyticus* were the two dominant bacterial species isolated from the ulcerative skin lesions. The turtles were dull, lethargy, sunken eyes, plastron shrinkage, inactive movement, unable to dive, anorexia, emaciated, purulent inside the nasal passage, and ulcerative stomatitis. The infected turtles died within 1-5 weeks. Treatment with acriflavin, nalidicxic acid, or oxytetracyclin showed the turtles recovered within 14 days.

Several other diseases have been observed at Phuket Marine Biological Center and Mannai Sea Turtle Conservation Station such as shell rot, fibropapillomatosis, lung infection, *etc.* Further intensive investigation on pathology of sea turtles in Thailand is required.

CAPTIVE BREEDING

Depletion of natural sea turtle populations has leaded to a captive breeding program. The programs aimed to succeed in captive breeding of *Lepidochelys olivacea* was reported by Chantrapornsyl & Bhatiyasevi (1994). A large pond was built with artificial sand beach on one side (Figure 12). Six males and 14 females were released into the pond after having been in captivity at the center for 16 years. The first egg clutch was laid in December 1992. The eggs were incubated *in situ* for 56 days. Hatch success was 89.6%.



a) b)

Figure 12. Captive breeding pond at Phuket Marine Biological Center (a) and nesting of *Lepidochelys olivacea* on the artificial sand beach (b).

CONSERVATION EFFORTS

Three major efforts have been employed, *i.e.* laws & regulations, protective areas, and awareness building.

Laws and regulations

Up to 1947, there were no laws or regulations controlling the hunting of sea turtles and the collection of their eggs in Thai waters. This resulted in a noticeable decline in the sea turtle population. The Fisheries Act 1947 was therefore proclaimed by the government as a conservation measure. According to this law no one allowed to catch, trap, ambush, harm or kill sea turtles. The sea turtles must be released when incidentally caught by any fishing gears. Egg collection along certain (but not all) beaches required a yearly license issued to concessionaires who were required to hatch a certain percentage of the eggs and released the hatchlings into the sea. These duties were supervised by the provincial fisheries offices. Each beach was leased to one licensee and the eggs of all sea turtles nested on the same beach. Approximately 10,000 hatchlings of all species were released yearly during 1960-1972 (Phasuk 1983). This reflects a marked decline in the number of nesting. In addition, the decline may be attributed to the rapid development of commercial trawling operations in the Gulf of Thailand and along the west coast. The sea turtle migrating to the shallow areas for nesting and copulation might be caught in the nets during trawling operations where they become entangled and die. The Fisheries Act 1972 then was launched. The Act prohibits trawling and push net boats equipped with engines to operate with 3 km from shore line.

In 1980, Ministry of Commercial proclaimed that any person who wants to export sea turtles carcasses must be requested permission. In 1992, Wildlife Reservation and Protection Act, B.E. 2535 was enacted. This leads to totally protection of all sea turtle species in Thailand. In addition, National Park Act B.E. 2504 (1961) has help protecting nesting populations as well as nesting habitats since most of nesting sites at present located within national parks.

Protective areas

Most of important nesting sites in Thailand are under jurisdiction of 1) national parks (*i.e.* Similan Islands, Surin Islands, Adang-Rawi Islands, Tarutao Islands, part of Tai-Muang beach on the west coast of Phang-Nga province), 2) Royal Thai Navy (*i.e.* Khram Island), and 3) local conservationists (*i.e.* Mai-Khao beach on the west coast of Phuket province, Prathong Islands on the west coast of Phang-Nga province).

Awareness building

Awareness building program is relatively new compared to others conservation means. It is known that law enforcement is often a weak point due to either lacking of man power (government staffs) or willingness to enforce. In despite, awareness building program has tried to promote a group of local conservationists to protect their "*in front of the house*" natural resources. The stimulus for conservation is paid back by other non destructive income such as a launching of eco-tour to watch turtle nesting. Education and training courses on natural resources including sea turtles have been provided to school children, volunteers as well as government staffs (Figure 13).

Figure 13. A group of sea turtle conservation at the Prathong Island which is one of important nesting beaches in Thailand.

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APPENDIX I

NATIONAL LIGISLATION CONCERNING TURTLES PROTECTION

(1) Fisheries Act, B.E. 2490 (1947)

(2) Export and import Act, B.E. 2522 (1979)

(3) Wildlife Reservation and Protection Act, B.E. 2535 (1992)

(4) National Park Act B.E. 2504 (1961)

1) Fisheries Act, B.E, 2490 (1947)

Fisheries Act, B.E. 2490 has been drawn up in 1947 before the development of marine fisheries in Thailand. Some provisions in the Act have been revised twice in 1953 and 1984. Under this Act, all turtle species shall be protected by the provision of Section 32, which states that:

"Section 32: The Minister or Provincial Governor in his jurisdiction and with the approval of the Minister, is empowered to make notification determining

(1) the size of mesh and dimension of any fishing implement, and size, kind, number and parts of fishing implement, which is permitted in fisheries;

(2) any kind of fishing implement which is absolutely forbidden to be used in fisheries;

(3) the distance between each stationary gear;

(4) the methods of using every kind of fishing implement;

(5) the spawning and breeding seasons, fishing implement; and methods of fishing in any fisheries during the given seasons;

(6) The species, size and maximum number of aquatic animals the fishing of which is permissible;

(7) certain species of aquatic animals the fishing of which is absolutely forbidden."

The Minister of Agriculture and Cooperatives or the Provincial Governor within his jurisdiction subject to the approval of the Minister is empowered to impose any fishery regulation in accordance with this provision by proclaiming the Ministerial Notification. For protection of turtles, there is the Ministerial Notification issued in 1947. The content of such notification is summarized as follow:

"By the power of Section 32 (7) of the Fisheries Act, B.E. 2490, the Minister of Agriculture and Cooperatives has proclaimed that:

(1) No person shall catch, take, trap, lure, injure, or kill any sea turtle or sea terrapin. If sea turtle or sea terrapin has been trapped by any fishing implement, such sea turtle or sea terrapin shall be released into the sea promptly.

(2) No person shall take or damage the eggs of any sea turtle or sea terrapin, unless otherwise the permission from the competent authority has been granted.

This notification shall come into force on April 14,2490 (1947).

Given on April 14,2490 (1947)
(Signed) Charoon Saubsaeng
Minister of Agriculture and Cooperatives"

The violation of notification shall be penalized by the power of Section 65 of the Fisheries Act, B.E. 2490 (1947) which states that:

"Section 65 Whoever violates the notification of the Ministry or the Provincial governor issued in pursuance of Section 32 shall be punished with fine from 5,000 - 10,000 baht, or imprisonment not exceeding 1 year, or both"

In order to control the import and export of turtles and their products, Section 54 of the Fisheries Act, B.E. 2490 states that:

"*<u>Section 54</u> No person shall, without permission from the competent official, bring into the Kingdom such kind of aquatic animals as specified by a Royal Decree.*"

In 1993, the Department of Fisheries proclaimed a Royal Decree (No 2), B.E. 2536 under Section 54 of the Fisheries Act, B.E. 2490. The Royal Decree proclaimed the list of all turtle species to be prohibited for importing into Thailand. The list of turtle species in the Royal Decree includes all turtle species listed in the CITES appendices.

However, the provision of Section 54 controls only the importation of aquatic animals. It does not control the exportation of aquatic animals from Thailand. Therefore, there is a loophole for controlling the exportation of aquatic animals by the power of the Fisheries Act, B.E. 2490. In order to solve this problem, the Department of Fisheries requested the Ministry of Commerce to use its law **"the Export and Import Act, B.E. 2522"** to control exportation of all aquatic animals listed in the CITES appendices including turtles and their products.

2) Export and Import Act, B.E. 2522 (1979)

This Act is under the jurisdiction of the Ministry of Commerce with the purposes of controlling the import and export of goods. Section 5 of the Export and Import Act, B.E. 2522 divides goods into many categories. However, turtles and their products are categorized as goods which require permission for export and import. All marine turtles found in Thai waters are listed as goods which require permission for exporting.

The Ministry of Commerce which proclaimed the Ministerial Notification in 1980 laid down the list of turtles and their products which require permission before exporting. Example of turtle species in the Notification includes:

Eretmochelys imbricata bissa

Chelonia mydas Japonica

Caretta caretta gigas

Platysternum megacephalum pequense Grey

Dermochelys coriacea

Testudo emys Schleg and Mull

3) Wildlife Reservation and Protection Act, B.E. 2535 (1992)

This Act was enacted in 1992. It is under the jurisdiction of the Department of Fisheries (DOF) and the Royal Forestry Department (RFD). The Act empowers the Department of Fisheries to be responsible for aquatic animals and the Royal Forestry Department to be responsible for terrestrial animals as specified in Section 4.

"Section 4: "Director-general" means the Director-General of Royal Forestry Department for terrestrial animals, and the Director-General of Fisheries Department for aquatic animals"

Under this Act, there are two lists of animals (1) List of Reserved Species, and (2) List of Protected Species. The List of Reserved Species shall be done by Royal Decree. The List of Protected species shall be done by Ministerial Notification which is specified in Section 6.

"Section 6 The assignment of any particular kind of animals into the List of Protected Species shall be done only through the formal proclamation of Ministerial Notification with the consent of the Committee."

In 1994, there has been the proclamation of Ministerial Notification specified wild animals in the List of Protected Species. Within this List, there are numerous species of turtles and tortoises being listed. The Department of Fisheries is responsible for the turtles in this list as follows:

Turtles

1 Hawksbill Turtle (*Eretmochelys imbricata*)

2 Southern Salt-Water Terrapin (*Batagur baska*)

3 Green Turtle (*Chelonia mydas*)

4 Loggerhead Turtle (*Caretta caretta*)

5 Malayan Snail-Eating Terrapin (*Malayemys subtrijuga*)

6 Leatherback Turtle (Dermochel_ys coriacea)

7 Painted Batagur Terrapin (*Callagur boneoensis*)

8 Ridley Turtle (*Lepidochelys olivacea*)

9 Batagur (*Batagur baska ranongensis*)

10 Brown Giant Tortoise (*Manouria emys*)

<u>Soft-Shelled Turtle</u>

1 Commom Slarmese Soft-Shelled Turtle (Amyda cartilaginea)

2 Red-Cheeked Soft-Shelled Turtle (Dogania subplana)

3 Yellow-Spotted Soft-Shelled Turtle (Amyda cartilaginea nakornsritarnaratensis)

4 Burmese Soft-Shelled TurtIe (Nissonia formosa)

5 Kanburien Giant Soft-Shelled Turtle (Chitra chitra)

6 Blunt-Headed Giant Soft-Shelled Turtle (Pelochelys bubroni)

In accordance with this Act, any species included in the List of Protected Species shall be protected from hunting, breeding, possessing, trading, exporting and importing. The provisions related to these activities are described as follows.

"<u>Section 16</u>: No person shall hunt or attempt to hunt wild animals listed in the Lists of Reserved Species and Protected Species except the act is part of official activities which are exempted by the provision of Section 26."

"<u>Section 18</u>: No person shall undertake breeding activities of species listed in the List of Reserved Species and Protected Species unless ...."

"<u>Section 19</u>: No person shall be in possession of reserved wild animals, protected wild animals, or carcass of protected wild animals, except the protected wild animals in Section 17 categorized as species bred in

captivity and carcass thereof, in which case the possessor is required to have a license from the Director-General and to observe the rules set by the Ministerial Notification and conditions prescribed in the license. ....
............"

"Section 20: No person shall engage in trading of reserved wild animals, protected wild animals, carcass of reserved and protected wild animals, and products thereof, except that of protected wild anima Is specified in Section 17 which were obtained from breeding in captivity, carcass and products thereof, in which case permission by the Director-General is a prerequisite.."

"Section 21: No person shall collect, harm, or keep in possession of the nests of reserved and protected wild animals.

"Section 23: Subject to the provision of Section 24, no person shall engage in the importation, exportation and transitory movement of wild animals or carcass thereof appearing on the prohibition list of the Minister without permission from the Director-..."

"Section 24: The importation, exportation and transitory movement of wild animals and carcass thereof, which require accompanying permit in accordance with the International Convention on International Trade in wild animals and carcass thereof, are permissible only with permission by the Director-General" ...."

Section 23 and Section 24 are the provisions applied to the implementation of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Therefore, the provisions of this Act protect all activities which will affect the survival of wild animals in Thailand. The penalty of this Act is described as follows.

"<u>Section 47</u>: Violators of Section 16, Section 19, Section 20 Clause 1, or Section 23 Clause 1 shall be punished with imprisonment not exceeding four years or fined not exceeding forty-thousand baht, or both"

"<u>Section 48</u>: Violators of Section 18 and Section 23 Clause 2, and persons neglecting to observe Section29 shall be punished with imprisonment not exceeding three years or fined not exceeding thirty-thousand baht, or both"

It can be concluded that the Wildlife Reservation and Protection Act, B.E. 2535 contains the most effective legal instrument for turtle protection in Thailand. From now on, the Department of Fisheries will use the power of this Act to protect all aquatic animals found in Thai waters in addition to the Fisheries Act, B.E. 2490.

4) National Park Act B.E. 2504 (1961)

This Act is responsible by Forestry Department. Many nesting sites are found located within national parks such as part of Tai-Muang beach in Phang-Nga province, Similan Islands, and Surin Islands. The Act helps protecting sea turtles during nesting within Nation Parks which often be patrolled by national parks' staffs. The Acts also protects nesting habitat.

<u>Section 6</u>: Declaration of national parks

"<u>Section 16</u>: Within national parks, it is prohibited to...

1) hold or occupy a plot of land as well as to build, to lay the groundwork, or to burn the forest.

2) collect, bring out, or do anything that may destroy or degenerate to wood, sap, wood oil, mineral or other natural resources.

3) bring out animals or do anything that may harm animals.

4) do anything that may destroy or degenerate to soil, rock, gravel, or sand.

5) change water way or do anything that may cause drought or flood of river, canal, swamp, or pond.

6) close or create an obstruction to water and land

7) collect or bring out or do anything that may harm or degenerate to orchids, honey, lac, wood charcoal, bark, or bat's excretion.

8) collect or bring out or do anything that may harm flowers, leaves, or fruits.

9) drive or ride any vehicles in and out, or drive or ride off road, except being permitted by an authorized staff.

10) take off or landing, except being permitted by an authorized staff.

11) let in or release livestock.

12) let domestic animals or beasts of burden, except following the protocol of Director-general and authorized by a minister.

13) run any activities to earn profit, except being permitted by an authorized staff.

14) post any notification, propaganda, or write & draw any where

15) bring any tools or weapons to catch or to hunt, except being permitted by an authorized staff and follow the protocol of an authorized staff.

16) shoot a gun, ignite a bomb, or ignite a firework.

17) shout or do anything that may annoy or bother other people or animals.

18) discard any garbage or anything outside the prepared are.

19) abandon anything that may cause fire."

"Section 24: Violators of Section 16 clause 1, 2, 3, 4, or 5 shall be punished with imprisonment not exceeding five years or fined not exceeding twenty-thousand baht, or both"

"Section 25: Violators of Section 16 clause 6, 7, 9, 10, or 11, or Section 17, or Section 18 shall be punished with imprisonment not exceeding one month or fined not exceeding one-thousand baht, or both"

Chapter 2

NESTING BIOLOGY OF GREEN TURTLE

INTRODUCTION

Green turtle *Chelonia mydas* is one of the four sea turtles found nesting in Thailand. Recently, it is known as relatively the most abundant species. Despite of wider nesting sites in the past reported by Penyapol (1957), Polunin (1975), and Phasuk (1992a), present significant nesting has been restrained to two sites *i.e.* Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea (Figure 1).

Khram Island is located in the inner Gulf of Thailand (12^{o} 39'N, 100^{o} 47.4'E). The 14-km^2 Island is under jurisdiction of Royal Thai Navy since 1950. It possesses 14 beaches with the beach length vary from 100-750 meters. Monanunsap & Charuchinda (1994) found that the beach slopes were between 8.5 to 15.6 degrees and the grain sizes ranged 0.32-0.81 millimeter. They described the beaches at Khram Island into 3 categories.

1) The beach with obstacles such as submerged rock, rocky or coral debris fore shore. This type of beach remains lesser than 60% of sandy beach. The beaches of this type are Jeck, Po, Kruat, Yor, and Tal.

2) Inundated beaches such as Nanarn and Lieb beaches. Sea turtles have difficulty to nest along these beaches due to beach erosion.

3) The beach without any obstacles. This type of beach (*i.e.* Kham, Nuan, Krathing, Sadao, Phutsawan, Toei, and Intaphalum) is appropriate for nesting of sea turtles.

Khram Island does not only serve as the highest abundant nesting site for *Chelonia mydas*, but for hawksbill turtle *Eretmochelys imbricata* as well. An average of 72 egg clutches of *E. imbricata* was reported by Monanunsap & Charuchinda (1994) during 1988-1993.

Huyong Island (8^{o} 28.8'N, 97^{o} 38.4'E, 1.63 km^2) was recently discovered by the Royal Thai Navy as the second highest abundant nesting site of *Chelonia mydas* in Thailand. It is a part of Similan Islands'

National Park which is well known as heaven of scuba divers. Every year, there are over 70,000 tourists visiting Similan Islands. Among Similan Islands group, Huyong Island is the most restricted islands due to sea turtles conservation plan. Limited number of tourists and boats is allowed to ashore or to dive around the Huyong Island. The tourists are not permitted to stay over night and lighting is not allowed when anchor in front of this island at night. Huyong Island has only one 800 m nesting beach. The beach profile changes seasonally with the steep seawater-borne beach erosion at the northern part of the beach during northeast monsoon and at the southern part of the beach during southwest monsoon. Only green turtles have been recorded to nest at Huyong Island.

This study revealed long term population trend as well as reproductive biology of *Chelonia mydas* in Thailand. The results will be used for management and conservation plan.

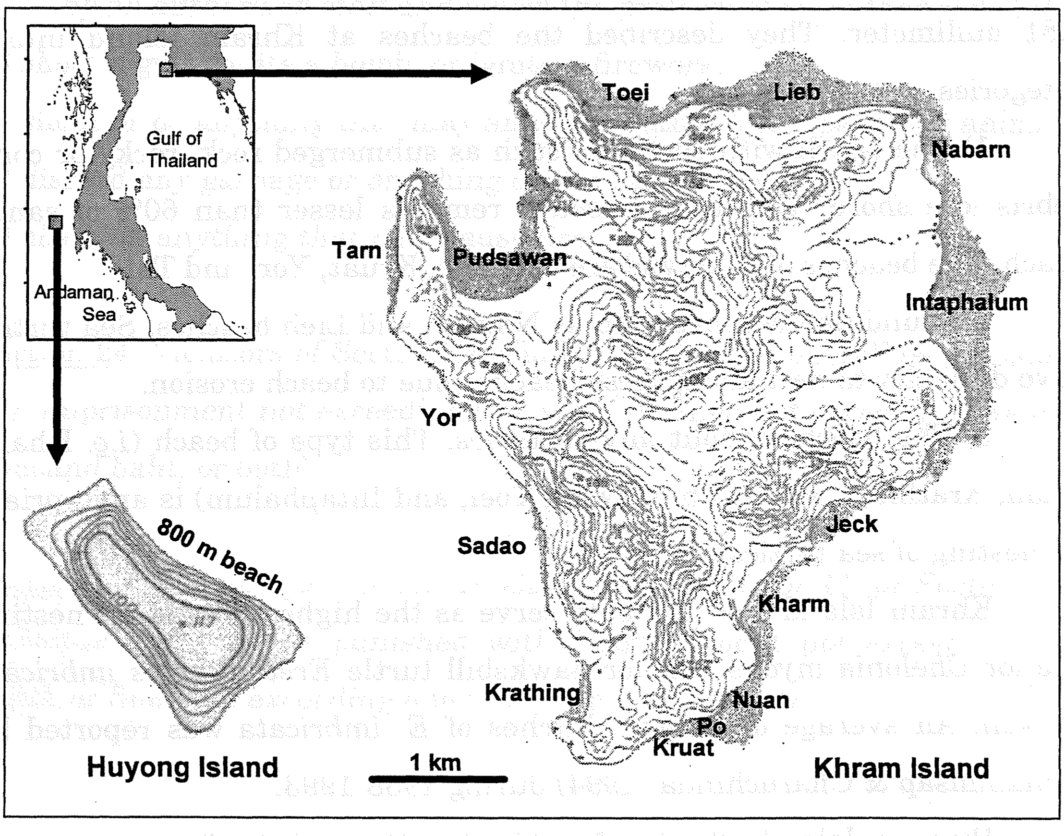


Figure 1. Nesting sites of green turtle *Chelonia mydas* in Thailand *i.e.* Khram Island and Huyong Island.

MATERIAL AND METHODS

Nesting statistics data of *Chelonia mydas* from the two most important nesting sites *i.e.* Khram Island and Huyong Island have been analyzed. Analyses were performed for abundance trends, nesters' size, fecundity, nesting season, nesting cycles within and between nesting seasons. The average values *i.e.* modes and means with confidence limit at 95% were calculated for nonparametric and parametric data, respectively. T-test was used to compare the difference of the two means. Significance test of the regression line was performed as Fowler & Cohen (1997).

The nesting data (dated back to 1950) at Khram Island was compiled from Kanjanadul (1950), Penyapol (1957), Polunin (1975), Phasuk (1992b), Monanunsap & Charuchinda (1994), Charuchinda & Monanunsap (1998), Monanunsap (1999), and Somchai Monanansap (unpublished data). The data collecting protocol varied over time. A common protocol was to patrol each beach every morning. When the walking tracks were found, the navy staffs counted number of eggs, egg clutches, date and nesting beach. The species of each egg clutch was identified by the diameter of eggs *i.e.* larger size egg was identified as *Chelonia mydas* and smaller one was *Eretmochelys imbricata* (Supot Chantrapornsyl, per. commu.). Additional protocols were performed from time to time. Phasuk (1992a) measured the straight carapace length and width as well as weighed and attached fiberglass tags (Figure 2a) to 54 *Chelonia mydas* nesters in 1981 to observe nesting behavior. Monanunsap & Charuchinda (1994) sent staffs to patrol the beach at night from January to August between 1986-1992. After eggs were laid, each nester was measured for curved carapace length and width. The weight was occasionally recorded with a hanging balance. Then, external tag was attached to the first lateral left scute with water-resistant glue (Figure 2b). Internal Avid™ microchip tag together with external stainless tag were employed during 1994-1996 (Charuchinda & Monanunsap 1998).

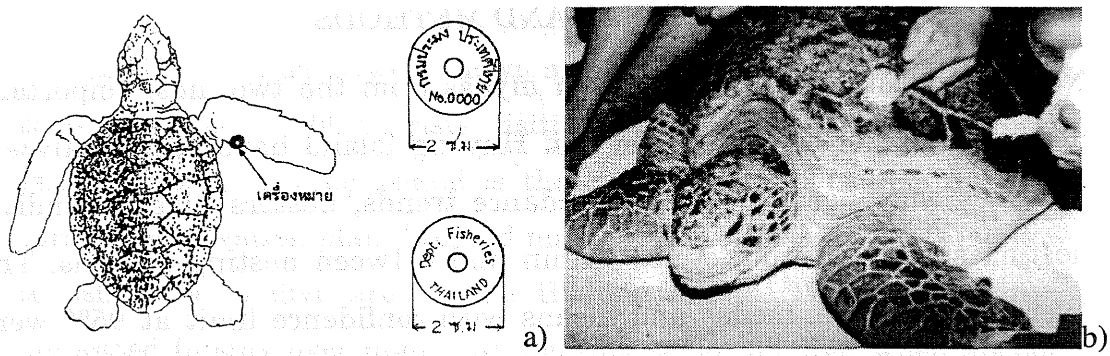


Figure 2. a) Fiberglass tag and tagged sites (*after* Phasuk 1992a) and b) Glued tag (*after* Monanunsap & Charuchinda 1994).

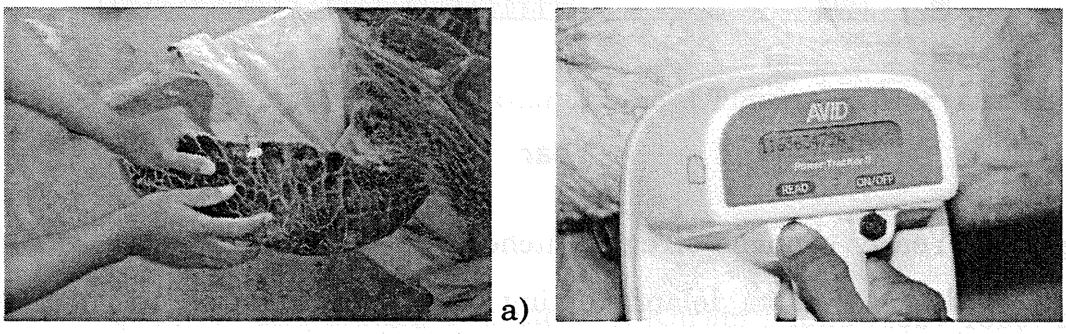
Nesting statistic of green turtle at Huyong Island has been monitored whole year since March 1995 by Royal Thai Navy staffs. Three staffs were set to stay on the island every 15 days. These staffs guarded the island from poachers and minimized other threatened factors such as anchoring, lighting at night, *etc.* In the mean time, they collected biological data of sea turtles. During day, the staffs removed any woods or materials that might obstruct the beach-walking of sea turtles. At night the staffs patrolled along beach on feet every 1-2 hours during high tide. No light sources were employed during patrolling. When nesters were observed, they waited until the turtles finished egg laying and then started the following protocol. The data were recorded in forms as shown in Appendix I. Since, the beach has only 800 m long, nearly all of nesters were expected to be discovered. The data analyzed in this paper was collected from March 1995 to July 2003.

1. Find the external (Inconel stainless tag, (Gerosa 1996) and internal (Avid™ microchip, 8 and 10 mm lengths) tags. If none of them were observed, new tags would be added to the nesters at the both flippers (Figure 3a and 3b). Each identified turtle would be named by the observers. These sea turtle' names were used as identification key for individual tracking of nesting behavior. Additional marking such as shortened appendages, body marks or present of barnacles were taken note.

2. Measure the greatest curved carapace length and width with ribbon tape. Photos of the carapace were occasionally taken.

3. Take note of nesting distance from the northern margin of the beach.

4. Count the number of the eggs and transfer to the incubation site which was located near to the camp on the island.



a) b)

Figure 3. *Chelonia mydas* tagged with stainless tag (a), microchip scanning for identification number (b).

RESULTS

Nesting trend

Decreasing of *Chelonia mydas* population in the Gulf of Thailand was revealed by dramatic reduction of number of egg clutches during 1950-1972 (Figure 4). Relatively little on-going decline has existed from 1973 onward (Figure 5). The reduction in number of egg clutches was as much as 15 times compared between the year 1950 and 2002. Exponential fitting ($y = 1629.3e^{-0.0406x}$, $R^2 = 0.6053$) indicated that, under the present scenario, the population may disappear from the area in 2073. At Huyong Island, the temporal nesting data during 1996-2003 could not be fitted significantly with any regression lines (Figure 6). However, accumulated nesters over time indicated slightly decreasing of new nesters during 2001-2003 (Figure 7). The average number of egg clutches per year during 1997-2002 was 218±80 and 54±30 at Khram Island and Huyong Island, respectively.

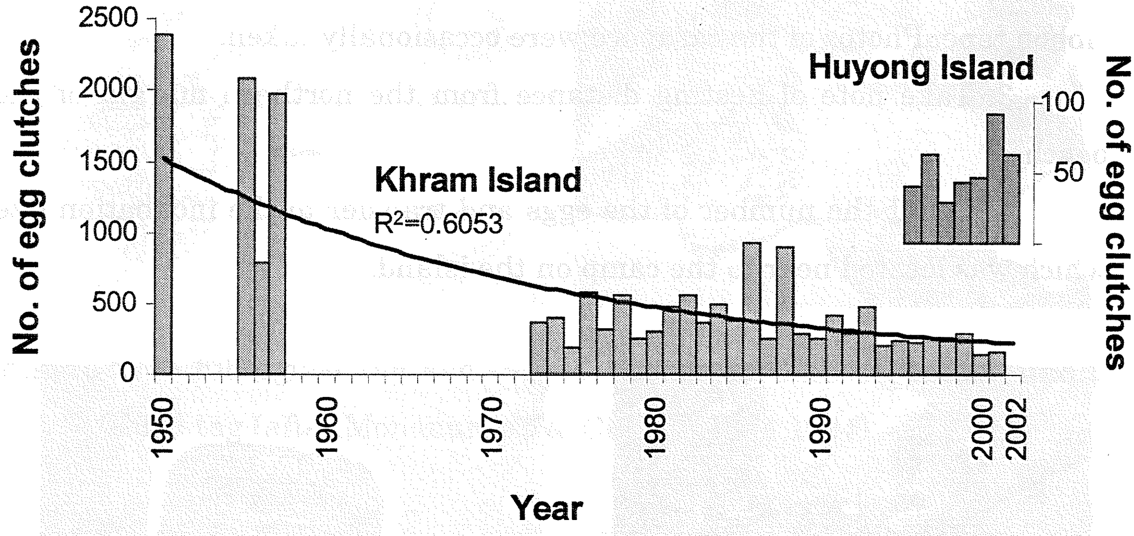


Figure 4. Yearly changes of egg clutches laid by green turtle *Chelonia mydas* at Khram Island (fitting with exponential function, y = $1629.3e^{-0.0406x}$) and Huyong Island.

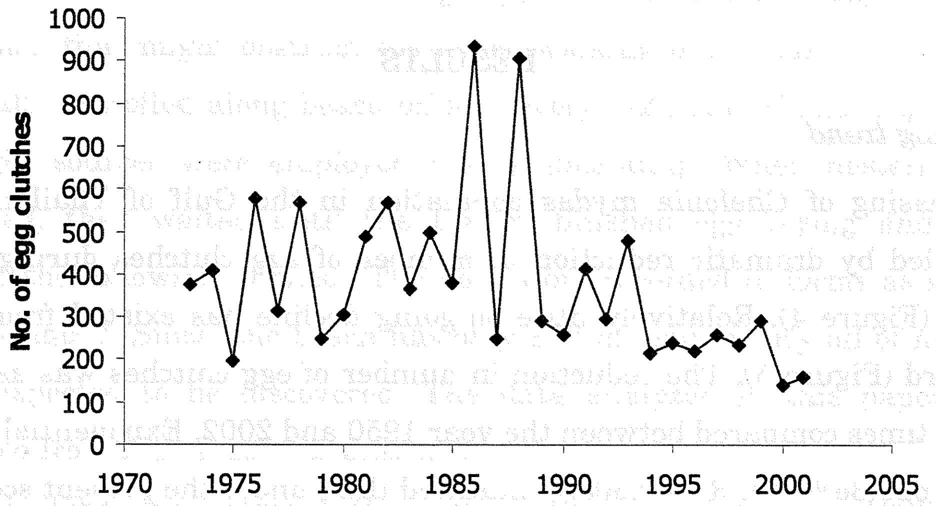


Figure 5. Yearly changes of egg clutches laid by green turtle *Chelonia mydas* at Khram Island during 1973-2001.

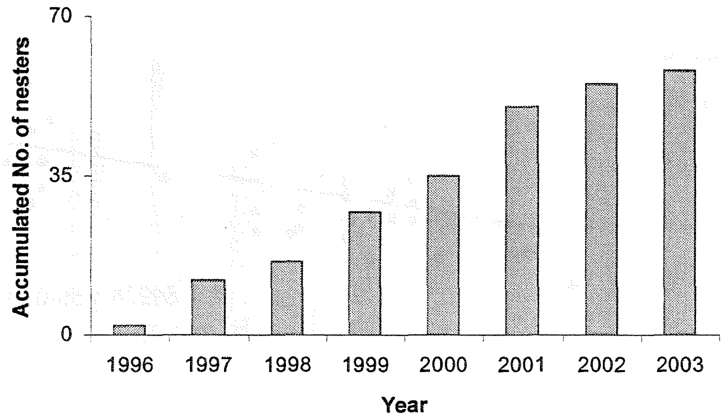


Figure 6. Increment trend of accumulated *Chelonia mydas* nesters at Huyong Island.

Nesters' size

Size frequencies distribution of nesters at Khram Island (1997-1999) and Huyong Island (1995-2003) is shown as Figure 7. The nester curved carapace length (CCL) ranged from 85-109 and 80-119 cm at Khram Island and Huyong Island, respectively. There was no significant difference in CCL between the two nesting populations. The average CCL was 97.5±1.3 cm. A weak positive correlation (but significance) between curved carapace length (CCL, cm) and average number of eggs per clutch of *Chelonia mydas* nested at Huyong Island during 1995-2003 was detected (Figure 8).

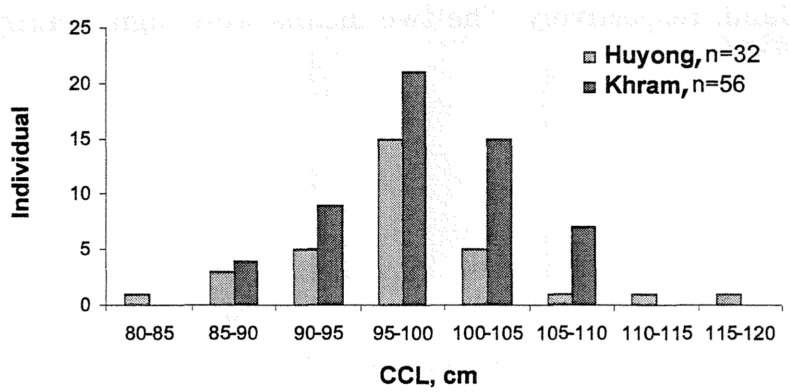


Figure 7. Size (curved carapace length, CCL) frequencies distribution of *Chelonia mydas* nesters at Khram Island (1997-1999) and Huyong Island (1995-2003).

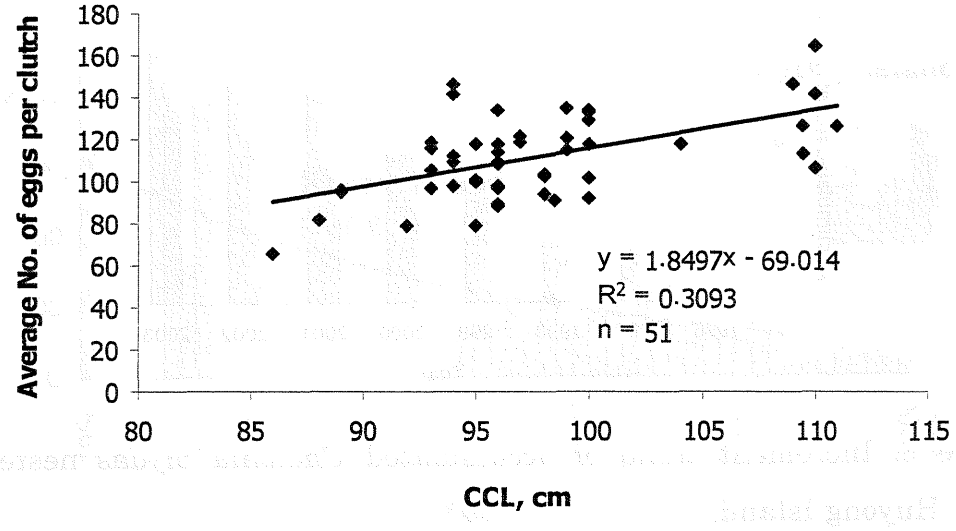


Figure 8. Correlation between curved carapace length (CCL, cm) and average number of eggs per clutch of *Chelonia mydas* nested at Huyong Island during 1995-2003.

Fecundity

Each nesting season, *Chelonia mydas* at Huyong Island laid eggs 1-9 times with the mode at 5 clutches while Khram Island population laid eggs 1-5 times with the mode at 2 clutches (Figure 9). Total number of eggs per nesting season at Huyong Island ranged from 89-1067 with the mode between 451-610 eggs (Figure 10). The distribution of number of eggs per clutch at Huyong Island was shown in Figure 11. The mean number of eggs per clutch was 95±3 and 111±3 eggs at Khram Island and Huyong Island, respectively. The two means were significantly difference at 95%.

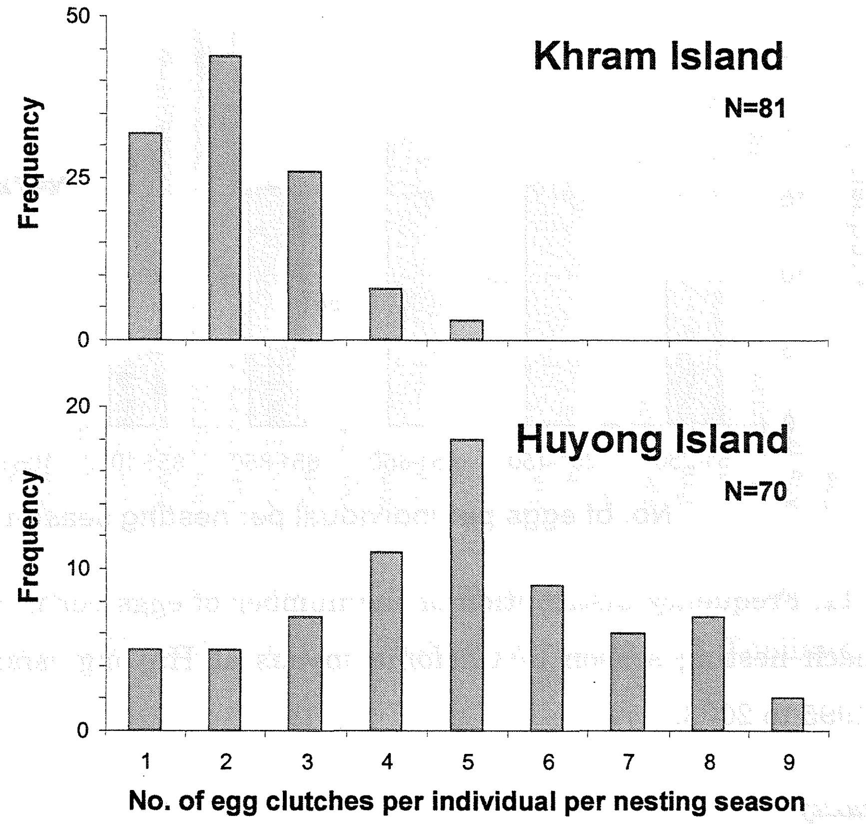


Figure 9. Frequency distribution of the number of eggs clutches per nester in each nesting season of *Chelonia mydas* at Khram Island during 1988-1992 & 1994-1996 and Huyong Island during 1995-2003.

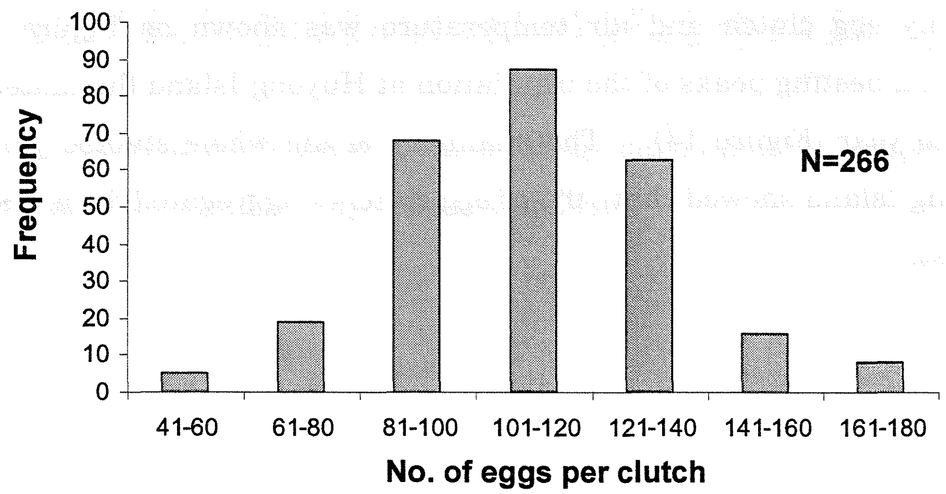


Figure 10. Frequency distribution of the number of eggs per clutch laid by *Chelonia mydas* at Huyong Island during 1995-2003.

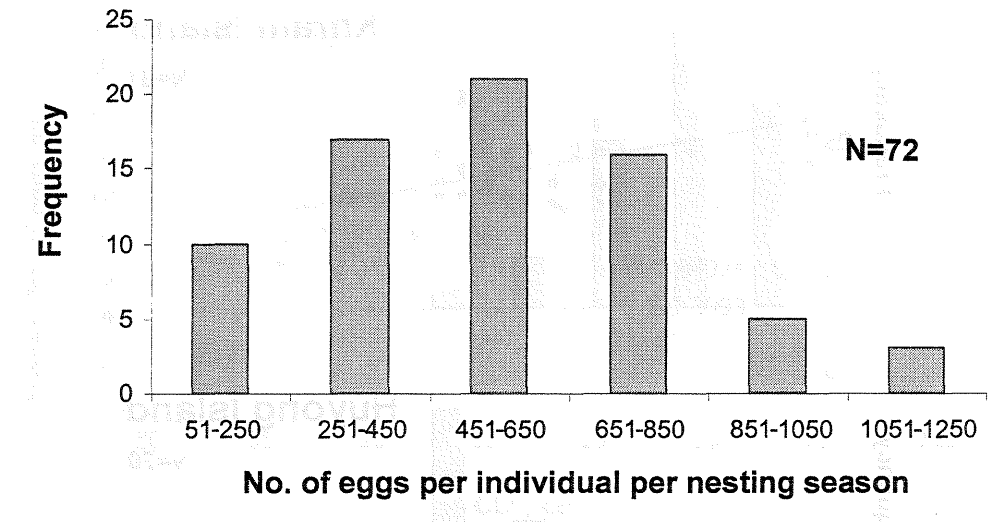


Figure 11. Frequency distribution of the number of eggs per individual in each nesting season of *Chelonia mydas* at Huyong Island during 1995 to 2003.

Seasonality

Nesting populations of the both the Gulf of Thailand and the Andaman Sea laid eggs all year round. At Khram Island, monthly nesting statistic exhibited mono-modal distribution. The peak was from May to August which accounted as 72% of the whole yearly production. The nesting peaks were constant over studied period (Figure 12). The correlation between monthly egg clutch and air temperature was shown as Figure 13. In contrast, nesting peaks of the population at Huyong Island fluctuated from year to year (Figure 14). The summary of the whole studied period at Huyong Island showed that 70% of egg clutches aggregated from March to August.

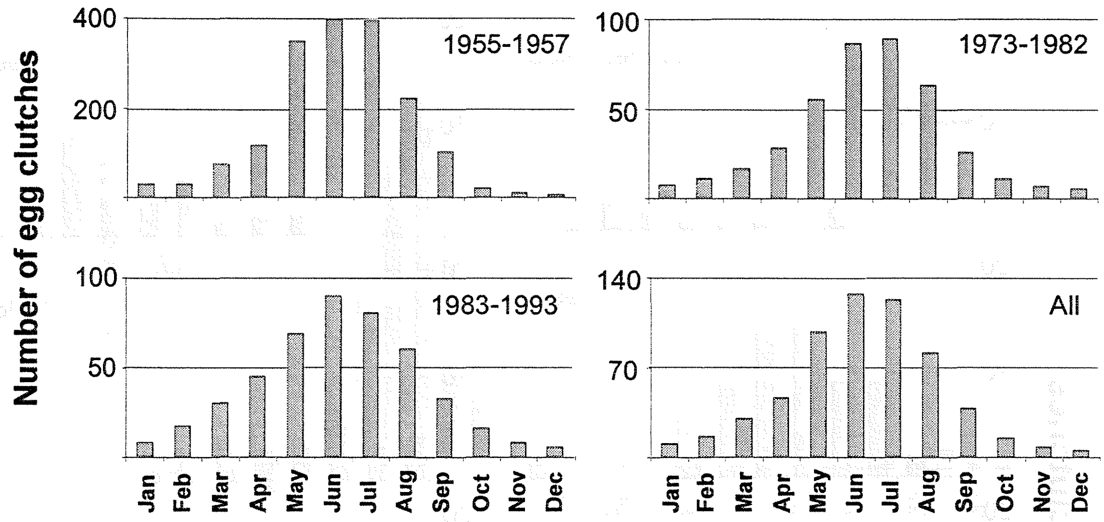


Figure 12. Monthly variation in the number of egg clutches observed during 1955-1957 and 1073-1993 at Khram Island, Thailand.

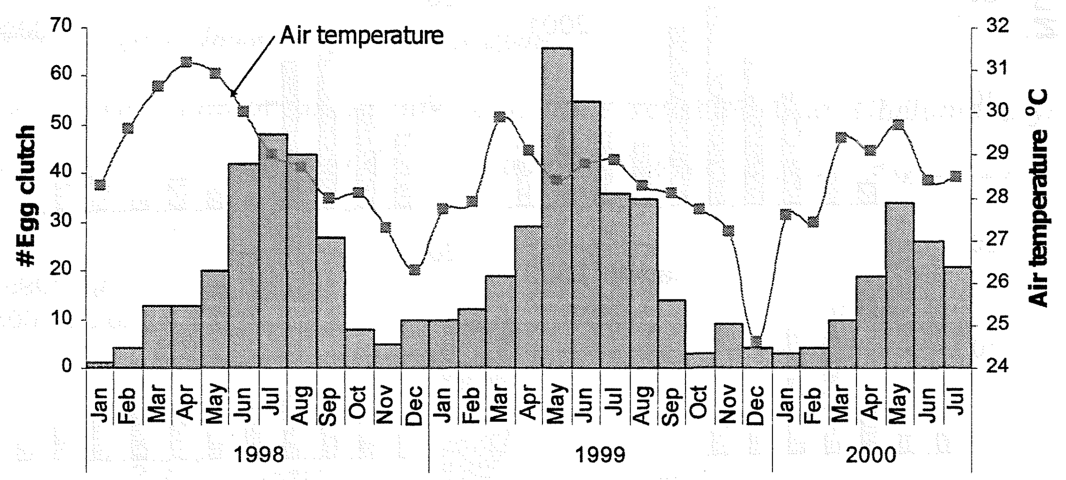


Figure 13. Correlation between number of egg clutch and air temperature at Khram Island during 1998 to Jul 2000.

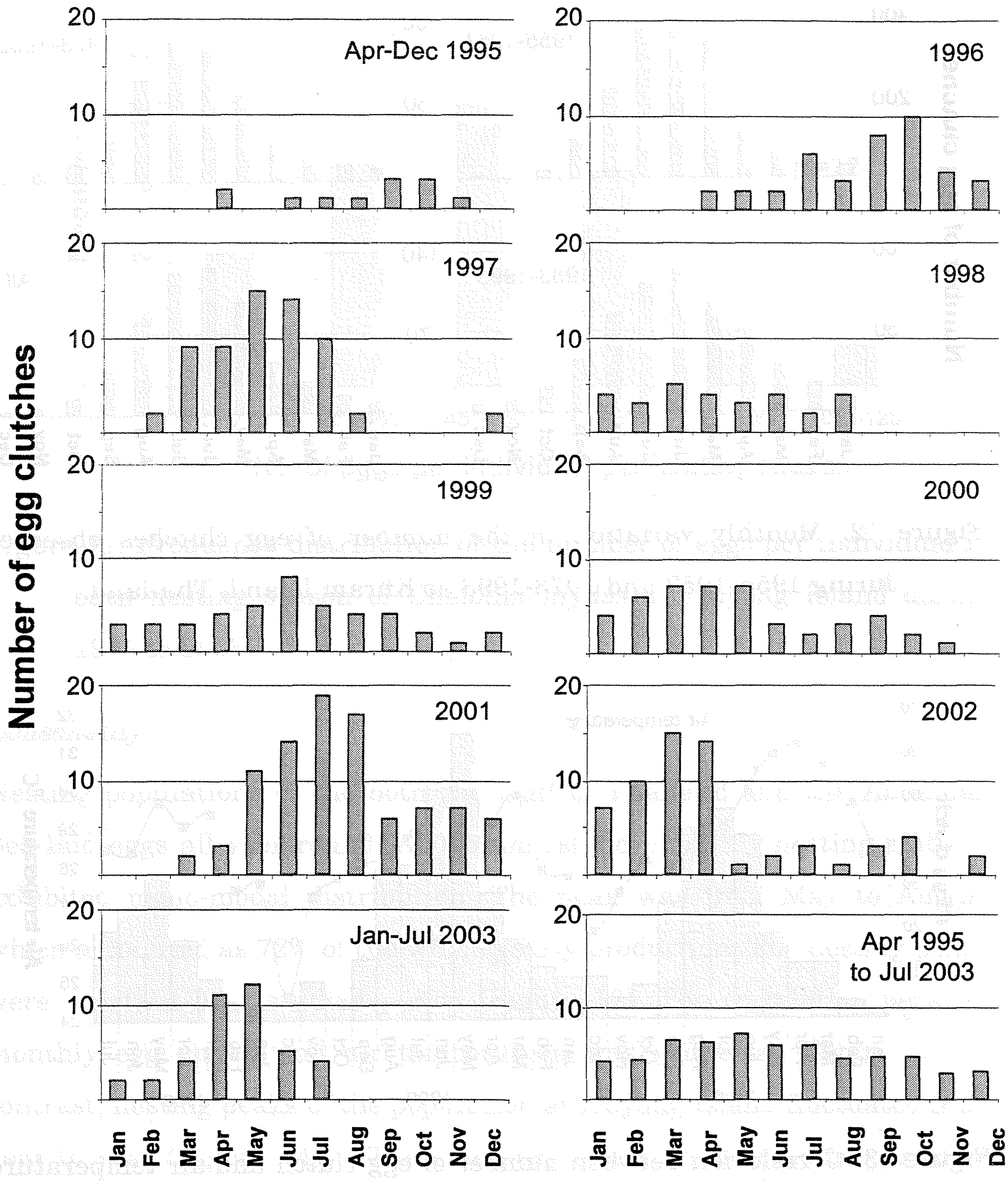


Figure 14. Monthly variations in the number of egg clutches observed during April 1995 to Jul 2003 on the 800 m beach of Huyong Island, Thailand.

Nesting cycle: within nesting season

Mark and recaptured of the nesters at Khram Island revealed that nesting interval ranged 9-16 days. At Huyong, the interval mode was 12 days (Figure 15) with the range from 6-39 days.

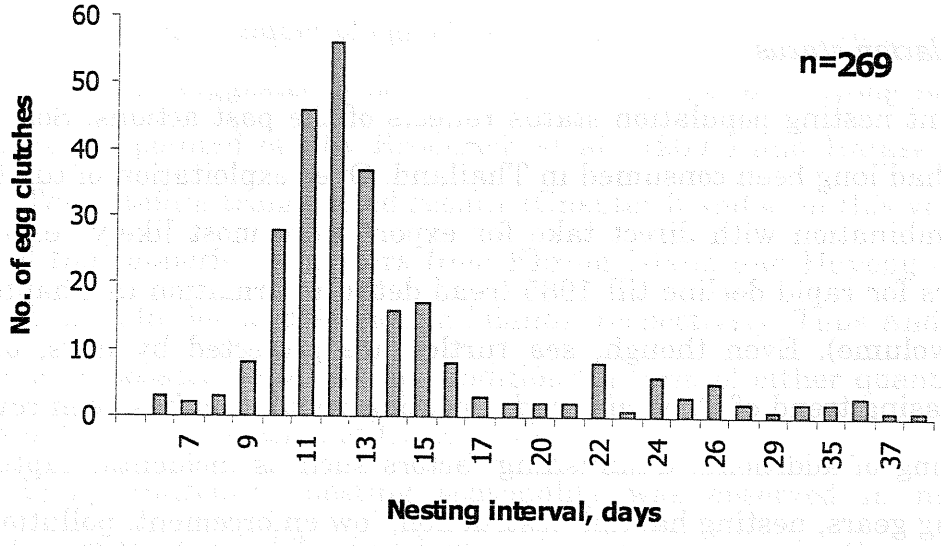


Figure 15. Nesting interval frequencies of *Chelonia mydas* laid eggs along the 800 m beach of Huyong Island, Thailand.

Nesting cycle: between nesting season

Long term monitor using microchip tags revealed that *Chelonia mydas* laid eggs at Huyong Island re-migrated back every 2 years (Figure 16).

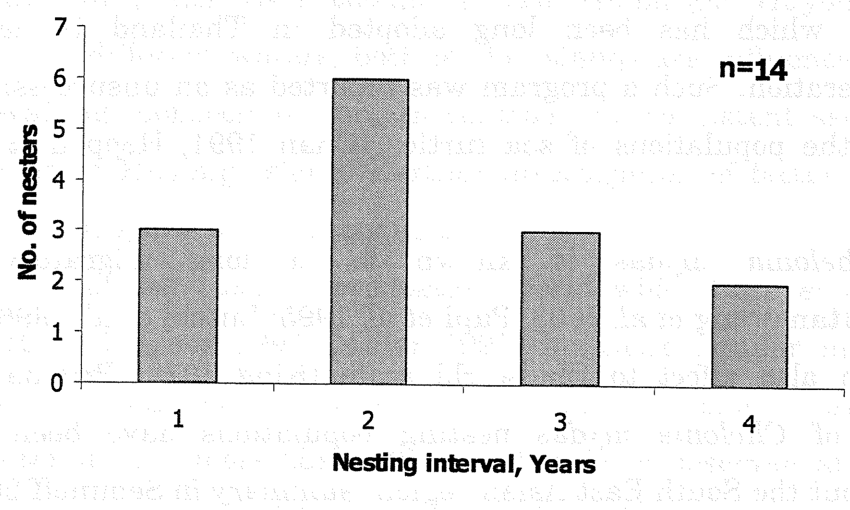


Figure 16. Nesting interval of green turtles that re-migrated to lay eggs along the 800 m beach of Huyong Island, Thailand.

DISCUSSION

Population status

Present nesting population status reflects of the past actions. Sea turtles eggs had long been consumed in Thailand. Over exploitation of turtle eggs in combination with direct take for export were most likely responsible factors for rapid decline till 1985 (read detail information in Chapter 1 of this volume). Even though, sea turtles are protected by laws, ongoing decreasing trend of *Chelonia mydas* nesting population has been revealed. Existing of additional diminishing factors such as incidental captures in fishing gears, nesting habitat destruction, low enforcement, pollutions has depleted the recover of sea turtles.

Low number of present breeding stock may lead to failure to produce recruitment of breeding generations. Before 1985, lesser than 10% of turtles eggs were hatched and released (Penyapol 1957; Polunin 1975; Phasuk 1983, 1992c). While, Tow & Moll (1995) estimated that 15% of the total egg production could provide the necessary recruitment. As high as 70% was recommended by C. Limpus (*in* Chan 1991). Head-started program which has been long adopted in Thailand is needed for reconsideration. Such a program was reported as an unsuccessful tool to sustain the populations of sea turtles (Chan 1991; Heppell & Crowder 1998).

Chelonia mydas is known as a long migratory species (Kittiwattanawong *et al.* 2003, Papi *et al.* 1995; Luschi *et al.* 1996). Locally depletion also affect to the world scale (King 1979; Pritchard 1997). Decline of *Chelonia mydas* nesting populations have been reported throughout the South East Asian region (*summary in* Seminoff 2002). It is not each country to protect sea turtles but the responsible of whole region.

Nesting biology

The size ranges of the two populations were within the global range reported for the species (Hirth 1980; Miller 1997; Whiting *et al.* 2000). While, nesters' size did not different significantly between the two populations, intra-annual reproductive output of both average number of eggs per clutch and number of egg clutches were higher at Huyong nesting population. This suggested a better feeding condition of Huyong nesting population as pointed out by Broderick *et al.* (2001) and Hatase *et al.* (2002). The satellite transmitted results (Chapter 3 and 4, in this volume) revealed that majority of nesters from Khram Island and Huyong Island migrated to Sulu Sea and Andaman Islands, respectively. Thus Andaman Islands may possess better living condition (in term of either quantity or quality of food sources) than at the Sulu Sea.

Highly consistent nesting seasonality was observed in nesting population of the Gulf of Thailand which is in common with other studies (Godley *et al.* 2001; Cruz 2002; Godley *et al.* 2002). Godley *et al.* (2001) pointed out that nesting seasonality was predominant in the period with relatively high air temperature (which also found strongly positively correlate to sand temperature, Hays *et al.* 1999). In this study, monthly variation of the number of egg clutches did not response directly to the high temperature period (Figure 13). There was about 2-month time lag between the two peaks. Even though, Khram Island and Huyong Island located in the different waters, both of the islands are influenced by the same prevailing monsoon season. In contrast, no consistent seasonality was detected at Huyong Island. Further investigation of factor affecting seasonality at Huyong Island is required.

Review of sea turtle reproduction world wide (Carr *et al.* 1978; Ehrhart 1995; Hughes 1995; Miller 1997) indicated similar intra- and inter-annual nesting intervals as found in this study. Prolong intra-annual nesting interval (*i.e.* more than 20 days) has been observed at Huyong Island. This can be caused by the observed turtles nested at the other beaches or missing to observe re-nesting. However, it is not likely to be the case since the Royal Thai Navy staffs patrolled the 800-m beach every night. In addition, a relatively small nesting number (lesser than 5%) were found at nearby islands. Sato *et al.* 1998 pointed out that this prolonged nesting interval occurred when sea turtles experienced low water temperature.

The way ahead

On-going decline of nesting trends in both Khram Island and Huyong Island suggested failure of previous conservation plans. Understanding of on-beach nesting behaviors supports part of conservation and management plan. Nevertheless, life history of *Chelonia mydas* is not confined to nesting areas (Miller 1997; Bolten 2003), further information of beyond the beach knowledge is required to fulfill the conservation strategies.

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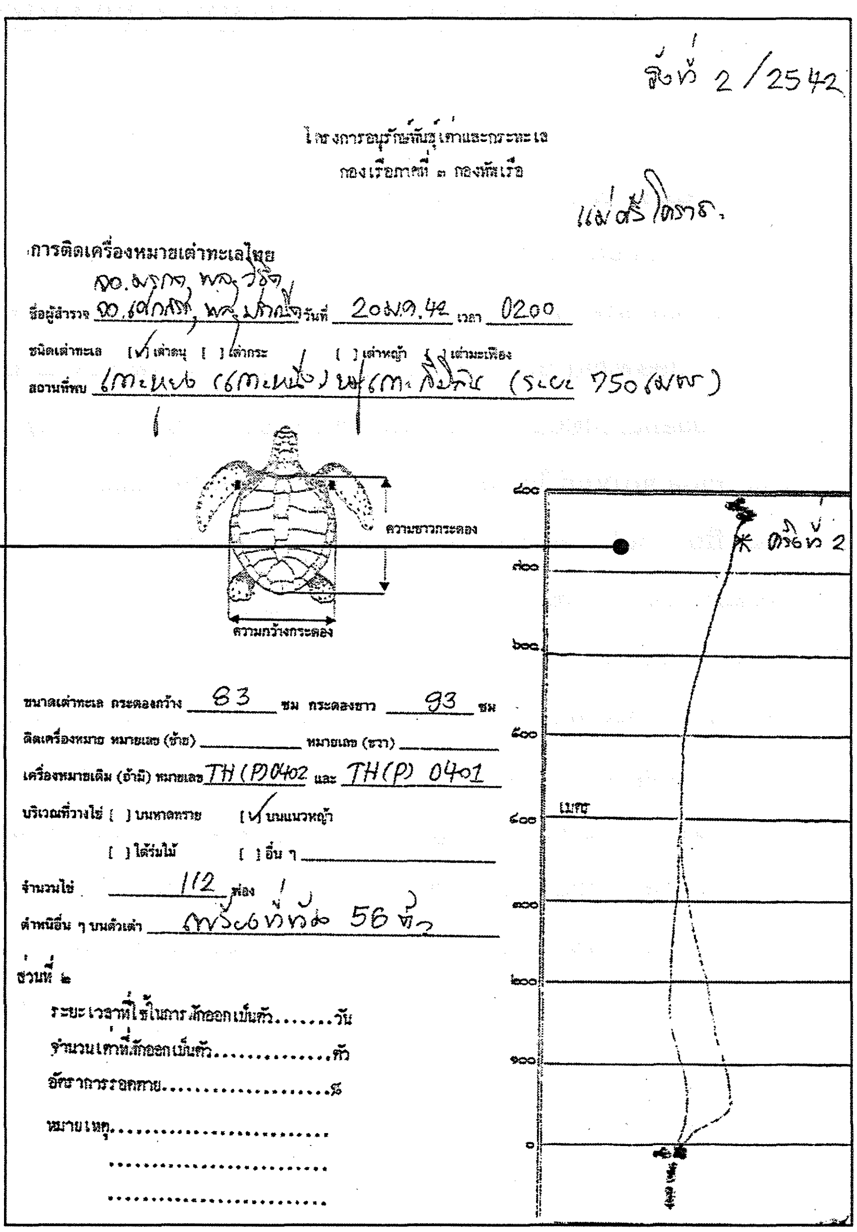
APPENDIX I

A form employed to collect sea turtle nesting data at Huyong Island (created by Caption Winai Klom-In, Royal Thai Navy).



ครั้งที่ 2/2542

โครงการอนุรักษ์พันธุ์เต่าและกระทะเล
กองเรือภาคที่ ๓ กองทัพเรือ

การติดเครื่องหมายเต่าทะเลไทย

ชื่อผู้สำรวจ ______ วันที่ 20 ม.ค. 42 เวลา 0200

ชนิดเต่าทะเล [✓] เต่าตนุ [ ] เต่ากระ [ ] เต่าหญ้า [ ] เต่ามะเฟือง

สถานที่พบ เกาะหูยง ______ (ระยะ 750 เมตร)

ความยาวกระดอง

ความกว้างกระดอง

๘๐๐ ๗๐๐ ๖๐๐ ๕๐๐ ๔๐๐ ๓๐๐ ๒๐๐ ๑๐๐ ๐

ขนาดเต่าทะเล กระดองกว้าง 83 ซม กระดองยาว 93 ซม

ติดเครื่องหมาย หมายเลข (ซ้าย) ______ หมายเลข (ขวา) ______

เครื่องหมายเดิม (ถ้ามี) หมายเลข TH (P) 0402 และ TH(P) 0401

บริเวณที่วางไข่ [ ] บนหาดทราย [✓] บนแนวหญ้า

[ ] ใต้ร่มไม้ [ ] อื่น ๆ ______

จำนวนไข่ 112 ฟอง

ตำหนิอื่น ๆ บนตัวเต่า ______ 56 ______

ส่วนที่ ๒

ระยะเวลาที่ใช้ในการฟักออกเป็นตัว.......วัน

จำนวนเต่าที่ฟักออกเป็นตัว..............ตัว

อัตราการรอดตาย....................%

หมายเหตุ..........................

....

....

-Turtle name
-Observer name, date and time
-Turtle species
-Nesting location

-Top profile of the nesting beach with distance scales every 100 m for marking of nesting position

-Curved carapace length &width
-Tag information
-Nesting location
-No. of eggs
-Natural marks

-Incubation period
-No. of hatchlings
-% mortality
-Remark

Chapter 3

DETERMINE OF INTERNESTING GROUNDS, POSTNESTING MIGRATIONS, AND FEEDING GROUNDS OF GREEN TURTLES *CHELONIA MYDAS* IN THE ANDAMAN SEA AND THE GULF OF THAILAND USING PLATFORM TRANSMITTED TERMINALS

INTRODUCTION

Green turtle *Chelonia mydas* distributes in tropical and subtropical waters of the Atlantic, Pacific, and Indian Oceans (Plotkin 2003). Nesting sites of this species locate along the beaches of both islands and continents (Figure 1). The species is known to possess long migration between nesting and feeding rookeries (Balazs 1976, 1994; Balazs *et al.* 1995; Luschi *et al.* 1996; Luschi *et al.* 1998; Luschi *et al.* 2001). The result of having such long migrations leads to collaboration among countries for efficient conservation of sea turtles in each region (Liew *et al.* 1995). Life history pattern shown as Figure 2 reveals that a single nesting population may be contributed from several feeding populations. Migration pattern is known as an important knowledge for conservation and management of sea turtles. However, most of the knowledge on the green turtle migration is confined within the Atlantic and Pacific oceans. Few of such a study have been reported in the South East Asia (*i.e.* Liew *et al.* 1995; Papi *et al.* 1995; Luschi *et al.* 1996).

In Thailand, the *Chelonia mydas* is one of four species which are found nesting. Two major nesting sites of green turtles are Huyong Island on the west coast and Khram Island in the Gulf of Thailand (*see* the map in Figure 1 from Chapter 2, this volume). Both nesting islands are patrolled by the Royal Thai Navy all year round. Therefore, it is secure for the nesters and their eggs on the nesting beaches. Each nesting season, green turtle spends 2-4 months to lay up to 9 consecutive clutches and re-migrate to the same nesting sites every 2-5 years (Chapter 2 in this volume). During internesting period, the nesters stayed near to the nesting beach (Carr *et al.* 1974; Dizon & Balazs 1982).

In 1995, the first trial of a Platform Transmitter Terminal (PTT) in Thailand was conducted at Phuket Marine Biological Center with the supervision of Professor Wataru SAKAMOTO from Kyoto University. The result lead to the launch of the South East Asia Sea Turtle Associate Research program (SEASTAR2000) sponsored by Kyoto University in year 2000. The program provided PTTs for studying postnesting migrations and behaviors of green turtles nested at Khram Island and Huyong Island. Various analyses have been performed throughout the data set. This chapter revealed internesting grounds, postnesting migratory paths, and feeding grounds of the two nesting green turtle populations (Khram Island and Huyong Island). Additional information such as swimming behavior, surface time and sea surface temperature were also reported. The results will be further proposed as a part of conservation and management plans for green turtles in Thailand.

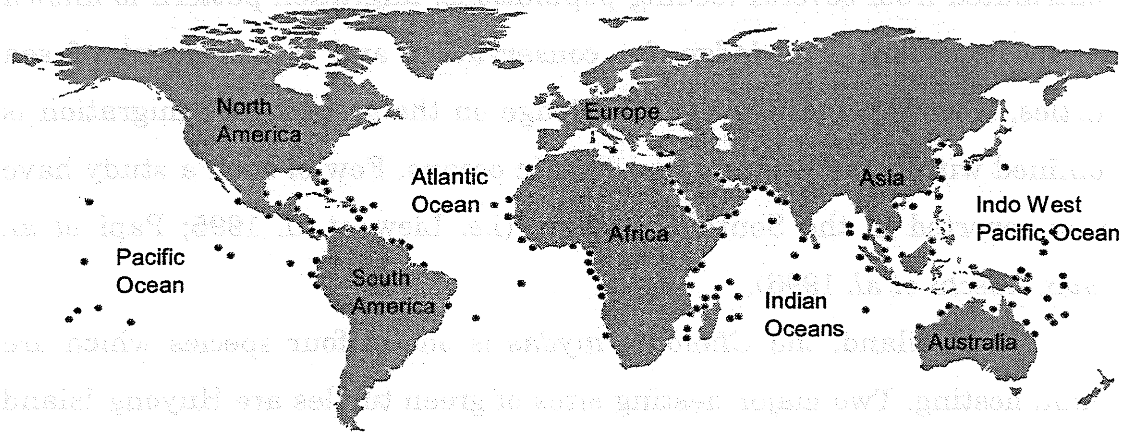


Figure 1. Nesting sites of green turtle *Chelonia mydas* in the world (data source: The worldwide distribution of sea turtle nesting beaches, Center of Marine Conservation, 1981).

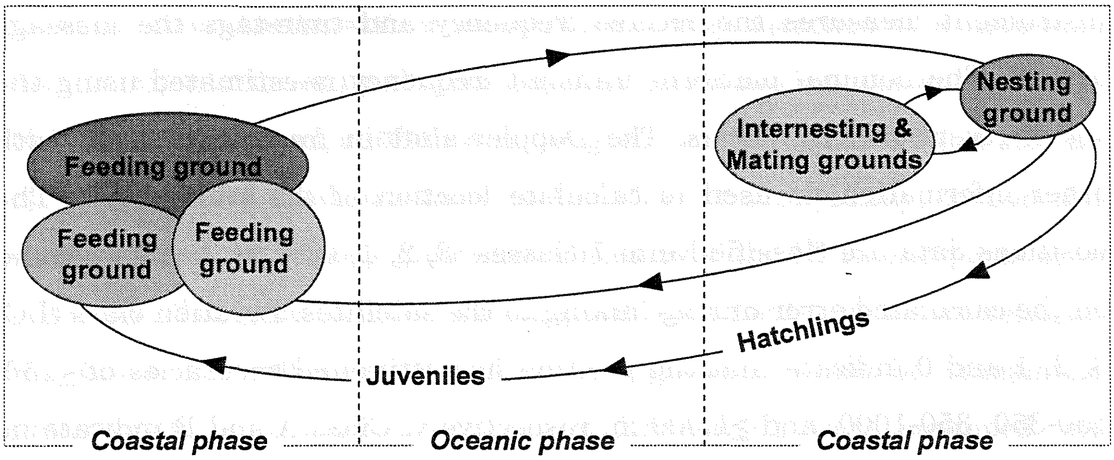


Figure 2. Schematic life cycle of *Chelonia mydas* (modified from Miller 1997; Musick & Limpus 1997; Bolten 2003; Kittiwattanawong *et al.* 2003). The model is based on a single nesting population in which each adult individual may migrate from different feeding grounds.

MATERIALS AND METHODS

The Argos system

The position signals from the PTTs were obtained via the Argos system (www.argosinc.com). The Argos is a satellite-based location and data collection system. The system comprises three components *i.e.* 1) Platform Transmitter Terminals (PTTs); 2) The Space Segment; and 3) The Ground Segment. Briefly, PTTs uplink the coded radio signals to the Argos instruments attached to the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites and relay and store them to the ground stations in real time (Figure 3). Three main system ground stations located at Wallops Island, Virginia, USA; Fairbanks, Alaska, USA; and Lannion, France.

Argos locations are calculated by measuring the "Doppler shift" on the platform transmissions. This enables the use of robust, and simple to operate field equipment (PTTs). Relative to the transmit frequency (nominal frequency), the frequency measured by the satellite instrument is shifted upward as a satellite "approaches" a PTT, and downward as the satellite moves away. Each time a message is received, the satellite instrument measures the receive frequency and time-tags the message arrival. The nominal platform transmit frequency is estimated using the set of reception frequencies. The Doppler shift in frequency, along with other information, is used to calculate location of the transmitter. The positions data are classified into 7 classes (3, 2, 1, 0, A, B, and Z) depend on the calculated error during linking to the satellites. Location class (LC) 3, 2, 1 and 0 indicate that the position has estimated accuracies of ≤150, 150-350, 350-1000, and ≥1,000 m, respectively. Class A and B indicate no accuracy estimation. Class Z means no position is assigned. Location data was retrieved via the Internet system.

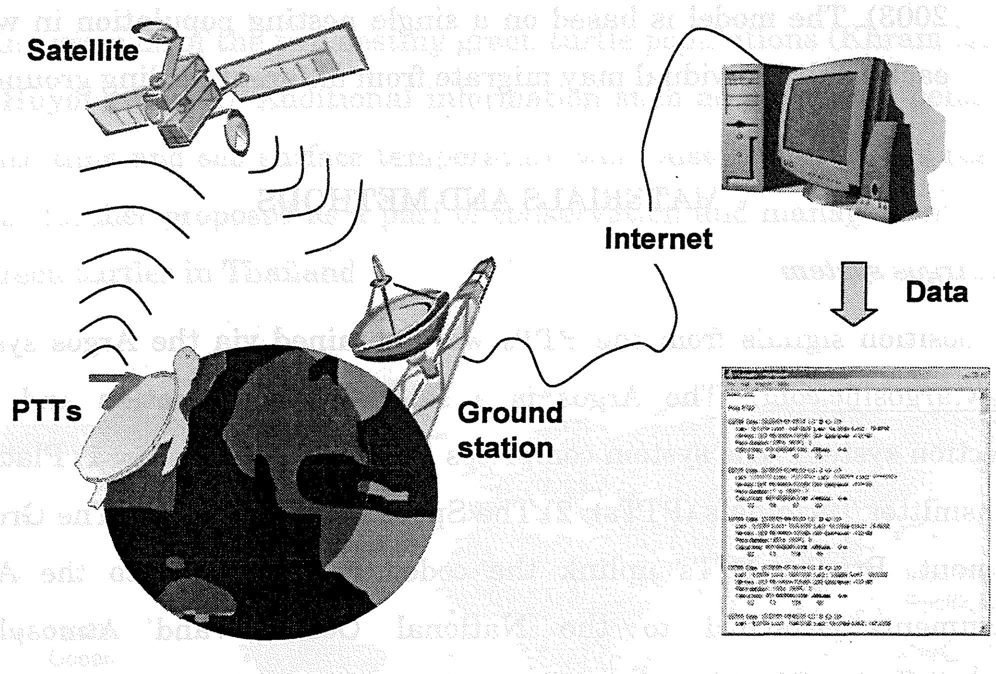


Figure 3. The Argos satellite-based location and data collection system. The PTTs attached sea turtles transmit the signals only during emerging.

Trial of PTTs

In 1995 and 2000, three models of PTTs (*i.e.* the Trial, Telonics ST18 and Kiwisat101, Figure 4) were preliminary tested on the sea turtles at Phuket Marine Biological Center and Huyong Island. The specification of those trial PTTs is listed in Table 1. The Trial PTT was connected to the juvenile green turtle with a monofilament that attached to a man-made hole on a posterior scute (Figure 5a). The other two models were attached to the cleaned second mid-scute of the green turtles (Figure 5b). Putty and epoxy glue were used to adhere to the PTTs. Subsequently, carbon fiber cloths soaked with epoxy glue were placed over the PTTs and parts of the mid-scute. The green turtles were kept at least for 1-2 hr before releasing to harden the adhesive. Because the signals can not be transmitted underwater, both Telonics ST18 and Kiwisat101 were equipped with saltwater switch for energy saving underwater.

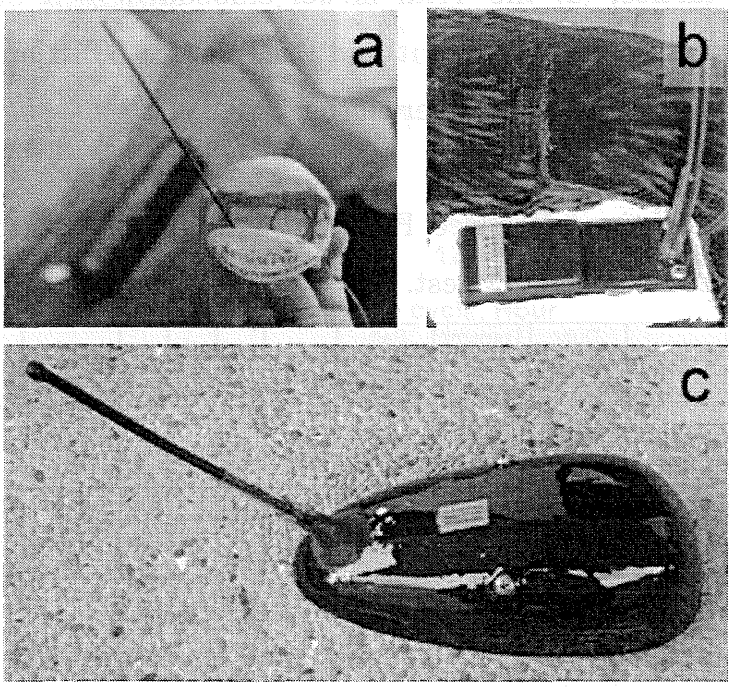


Figure 4. Platform Transmitter Terminals (PTTs) employed; the Trial by NTT Docomo and Kyoto University (a), model ST18 by Telonics USA (b), and model Kiwisat 101, Sirtrack limited New Zealand (c).

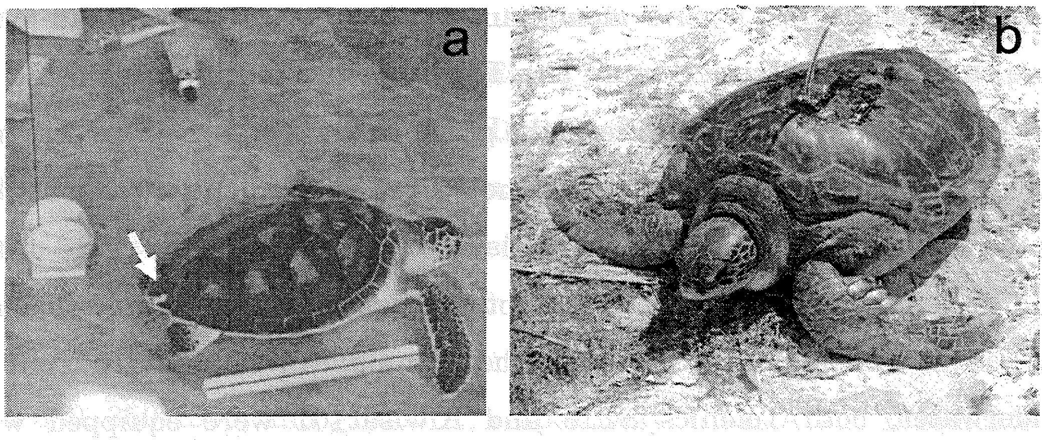


Figure 5. Attachment of Platform Transmitter Terminals (PTTs) to the green turtles; (a) the Trial model embedded in a Styrofoam ball connect via a monofilament and (b) Telonics ST18 and Kiwisat101 using glue with carbon fiber cloths.

Table 1. Specifications of three Platform Transmitter Terminals (PTTs) employed for efficiency test.

Developer	Model	Duty cycle (hr/day)	Transmit Power (watt)	Salt-water switch	L cm	W cm	H cm	WT g	Battery life, day	Obtained information
NTT Docomo and Kyoto University	The Trial	24	NA	No	4	3			180	Position
Telonics, USA	ST18	8	0.5	Yes	13.4	4.7	2.1	200	255	Position
Sirtrack Limited, New Zealand	Kiwisat101	24	1.0	Yes	18	8.5	5	610	150	Position, surface time and surface temperature

The number of data per day retrieved from the Trial PTT was the lowest (0.7 times/day) among the three PTTs models. Comparison between Kiwisat101 and Telonics ST18 showed that Kiwisat101 sent two times higher number of data per day than Telonics ST18 (4.0±0.9 times/day VS 1.6±0.3 times/day). This is because Kiwisat101 has higher transmitting power (1 watt) compared to Telonics ST18 (0.5 watt). Besides, Kiwisat101 was set to 24-hr on while Telonics ST18 was set to 8-hr on-off cycle. The number of signals was high during 4:00–11:00 and 16:00–21:00 (local time, Figure 6). Despite lower numbers of signals, the smaller size of the Trial PTTs allows a chance to tag on a small size turtle (*i.e.* 20–30 cm curved carapace length). Further development of the Trial PTTs, thus, offers a possibility to track the feeding grounds of those juvenile turtles.

The proportion of location classes obtained from Kiwisat101 and Telonics ST18 is shown in Figure 7. The proportion of good signals (*i.e.* LC 3, 2, 1, and 0) obtained from Kiwisat101 was higher compared to Telonics ST18. Kiwisat101 proved to have higher performance than Telonics ST18 in both quantity and quality location information.

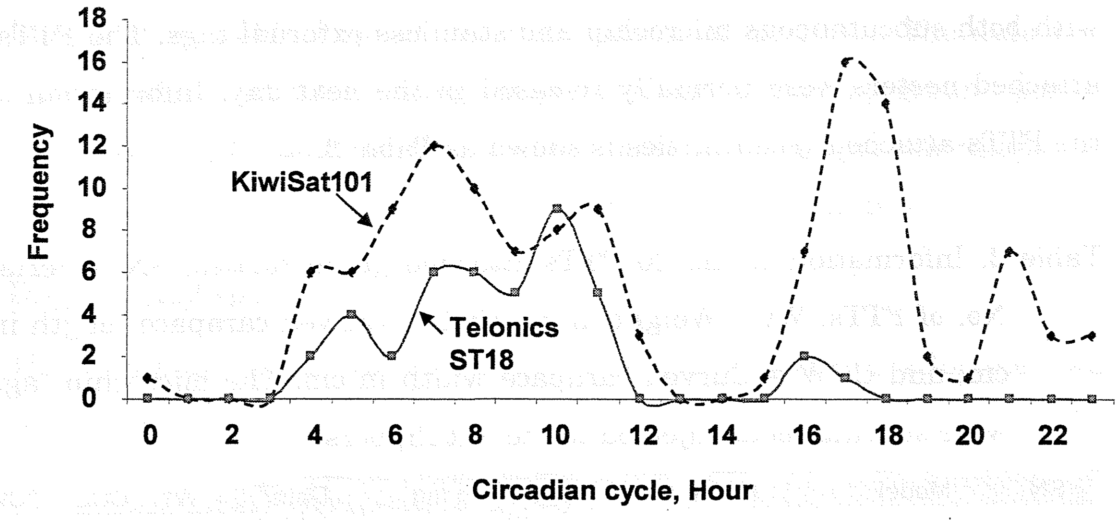


Figure 6. Circadian pattern of signals obtained from Kiwisat101 and Telonics ST18.

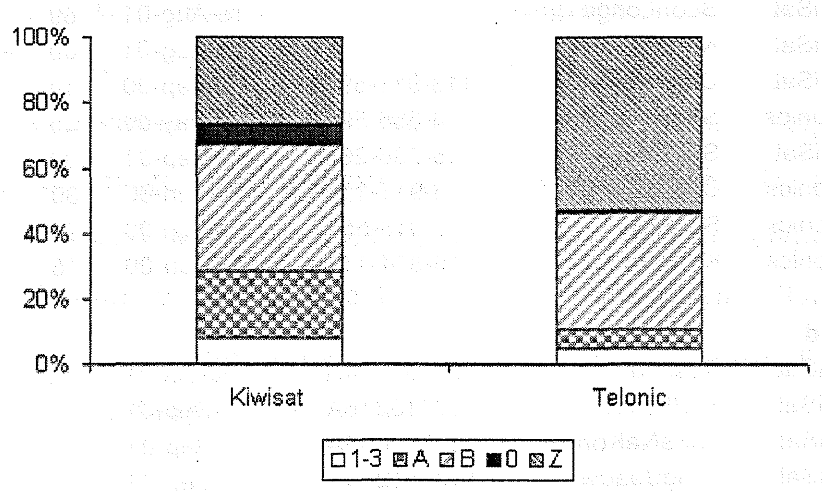


Figure 7. Signals quality comparison of the two PTTs model (Kiwisat101 and Telonics ST18). The retrieved data was classified as 7 location classes ranged from the best to the worst: 3, 2, 1, 0, A, B, and Z.

The turtles

The green turtles nested at Khram Island (11 individuals) and Huyong Island (9 individuals) were attached with PTTs during 2000-2003. The PTTs employed were model Kiwisat101 and Telonics ST18 produced by Sirtrack Co, Ltd., New Zealand and Telonics Inc., USA, respectively. Attachments of the PTTs were performed after the nesters laid eggs as the attachment method described earlier. Each turtle was named and tagged with both subcutaneous microchip and stainless external tags. The PTTs-attached nesters were normally released in the next day. Information of the PTTs-attached green turtles is shown as Table 2.

Table 2. Information of the 20 PTTs-attached green turtles. SN = Serial No. of PTTs, Wt = Weight in kg, CCL = Curved carapace length in cm, and CCW = Curved carapace width in cm. The microchip tags were subcutaneous injected to the left flippers.

SN	Model	Name	Microchip tag	Date	Wt	CCL	CCW
Khram Island							
9785	KiwiSat	KhramNoi		10-Aug-01	86	95.8	89.7
9786	KiwiSat	NgamTa		8-Aug-01	80	95.7	81.4
9787	KiwiSat	SriAnan		10-Aug-01	94	88.9	80.7
9788	KiwiSat	BoonLonge		15-Aug-01	69		
9804	KiwiSat	KhramYai		10-Aug-01	100	98.5	90
16723	KiwiSat	ChaoSamut	113-911-594A	12-Sep-00	110	98	86
16724	Telonics	SamPrieng	116-835-593A	8-May-00	125	104	91
17682	KiwiSat	SriKhram	116-736-265	3-Sep-01	100	95	85
28532	Telonics	Chonburi	116-911-111A	28-Jun-00	130	100	89
28533	Telonics	Sattahip	116-918-551A	23-Jun-00	90	94	86
28534	Telonics	KoKram	116-874-117A	14-Jun-00	115	98	85
Huyong Island							
9729	KiwiSat	Rusana	122761714A	30-Jul-01	-	99	88.5
9730	KiwiSat	SriPhuket	122715216A	17-Sep-01	-	96	84
9780	KiwiSat	SriFaNaKorn	122711635A	3-Sep-01	-	88	96
9784	KiwiSat	TongBeauw	112751274A	2-Sep-01	-	101	90.4
13062	KiwiSat	Burapa	TN015610875	10-Jun-01	-	-	-
18683	KiwiSat	Kayano	116479195A	5-Sep-00	-	110	90
19278	Telonics	SriNuan00	017-864-343	10-Jun-00		119	100
24438	Kiwisat	SriNuan02	017-864-343	6-Mar-03	140	110	97.5
27445	Telonics	RachDhamNern	12278655A	11-Jun-01		96	86

Data analyses

The location data was plotted on GIS software with 1: 50,000 to 1: 1,000,000 reference maps. The data with location classes 3, 2, 1, and 0 were utilized directly. Location class A and B were visual inspected over spatial projection. The suspected errors were tested and rule out using criteria that shifting speed of the two consecutive locations was not higher than criterion sea turtle swimming speed at 5 km/hr (Wyneken 1997; Luschi *et al.* 1998; Papi *et al.* 2000; Luschi *et al.* 2001). The data then were classified as internesting, migratory, and at feeding ground periods by visual adjustment of the location data over geographic maps. All sampling errors were calculated as confidence interval at 95%.

Distance and speed

The minimum accumulated migrating distance (D_m) in kilometer was calculated as

$$A \times \sum_{i=1}^{n} \sqrt{(y_{i+1} - y_i)^2 + (x_{i+1} - x_i)^2}$$

where, A = Conversion constant from a degree to km

= 111.12

Yi = Latitude in decimal degrees

Xi = Longitude in decimal degrees

The swimming speeds were interpreted from slopes between accumulated migrating distance and time (Figure 8). In addition, the swimming speed was classified as during cruising or feeding using the visual judgment of the plotted locations in GIS system. The speed unit was reported as km/day instead of km/hr since there may be a difference between day and night.

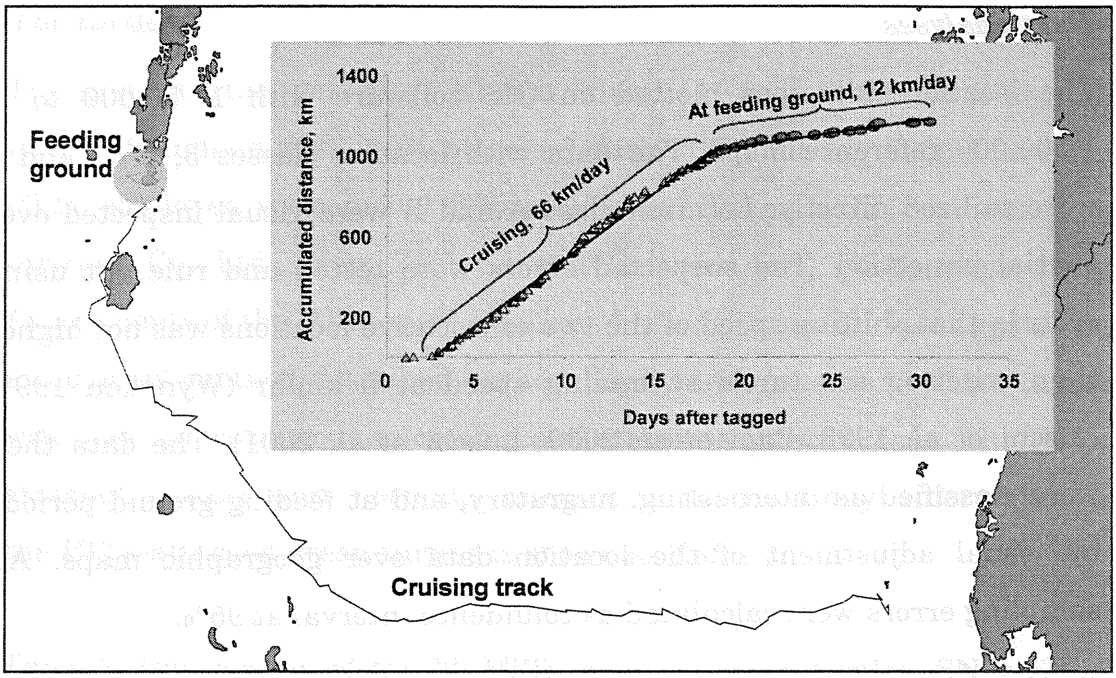


Figure 8. A calculation of swimming speeds using slopes between accumulated migrating distance and time. The slopes were assigned as either cruising or "at feeding ground" periods by spatial visualization.

Home range

Kernel home range analysis (Worton 1989) was applied to the location data assigned as internesting and "at feeding ground" periods using Animal Movement extension software for Arcview® (Hooge & Eichenlaub 1997). The location data of each PTTs attached turtles were pooled according to the nesting sites (*i.e.* Khram Island and Huyong Island). Distribution probability range at 95% was used as a significant level for the boundaries. Existent protected boundaries of Khram Island, (no trawling within 3 km from the shore, Fisheries Act 1947), Huyong Island (conservation area within 5 km, Natural Park Act 1961) were buffered from the coastal lines of each island and its adjacent area. The boundaries were plotted 1 km interval until covering the internesting ranges and proposed as protective areas for nesting green turtles.

RESULTS

Monitored duration

The monitored durations of the PTTs attached green turtles (9-126 days) were shorter than expected battery lives (150-255 days, Figure 9). Average PTTs lives experimented in the Gulf of Thailand (68±21 days) was not significantly difference compared to the ones employed in the Andaman Sea (73±30 days).

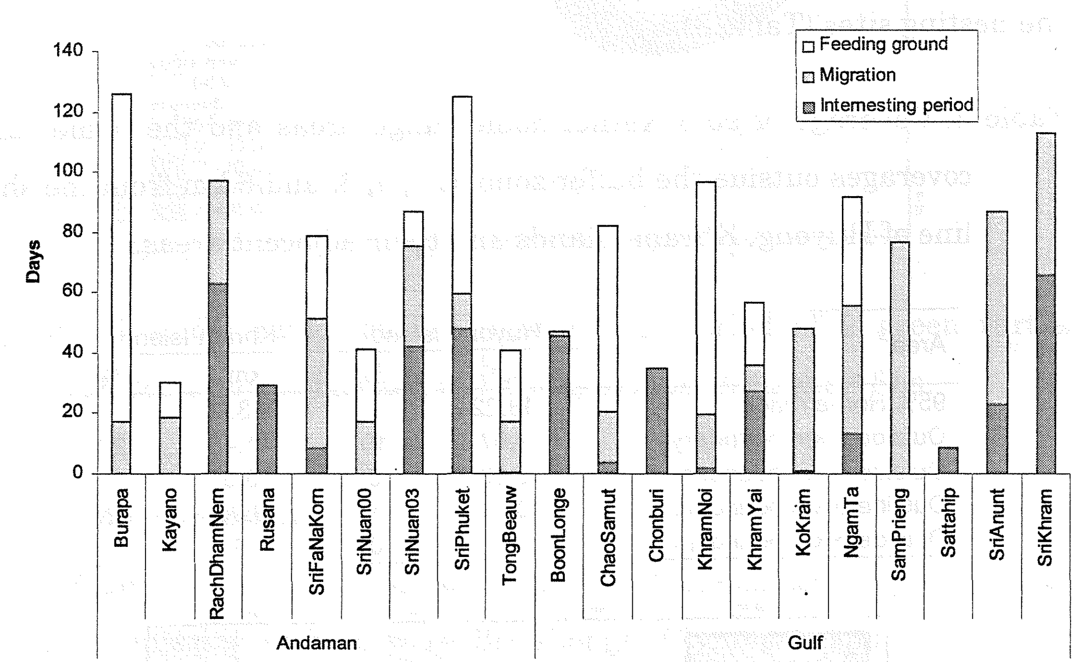


Figure 9. Monitored periods (Y-axis) of PTTs attached green turtles (*Chelonia mydas*) nested at Huyong (9 individuals) and Khram Islands (11 individuals). Each turtles were named as shown in X-axis. The periods were classified as internesting, postnesting migratory and at feeding ground periods.

Internesting grounds

There were 9 individuals (BoonLonge, ChaoSamut, Chonburi, KhramNoi, KhramYai, NgamTa, Sattahip, SriAnan, and SriKhram) from Khram Island and 5 individuals (RachDhamnern, Rusana, SriFaNaKorn, SriNuan, and SriPhuket) from Huyong Island that possessed internesting location data. Home ranges during internesting period of monitored turtles nested at Khram Island and Huyong Island are shown as Figure 10 and 11, respectively. During internesting period, the green turtles distributed within 5-6 km from the nesting islands. At Huyong Island, the turtles distributed within smaller area compared to the distribution at Khram Island (Table 3). The result revealed that average 71.5 % of the home range coverage was within 3 km boundary at the both nesting sites. The coverage decreased in same trend with the increasing distance from the nesting sites (Table 3).

Table 3. Coverage of 95% Kernel home range areas and the home range coverages outside the buffer zone at 3, 4, 5, and 6 km from the shore line of Huyong, Khram Islands and their adjacent areas.

Area	Huyong Island		Khram Island	
	km^2	%	km^2	%
95% Home range	48.22	-	203.05	-
Outside 3 km boundary	9.07	19	41.46	20
Outside 4 km boundary	3.63	8	13.57	7
Outside 5 km boundary	0.71	1	3.05	2
Outside 6 km boundary	0	0	0	0

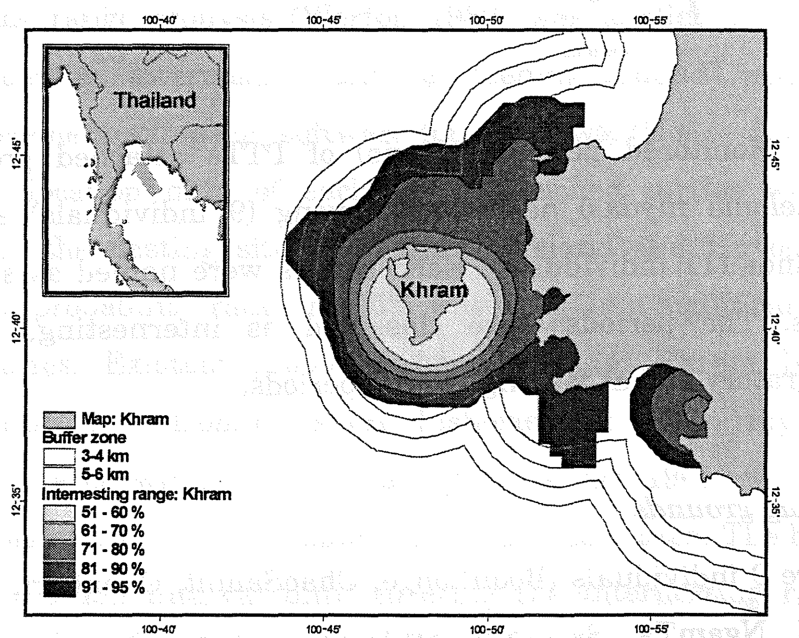


Figure 10. Home range during internesting period of 9 green turtles (*Chelonia mydas*) nested at Khram Island, the Gulf of Thailand.

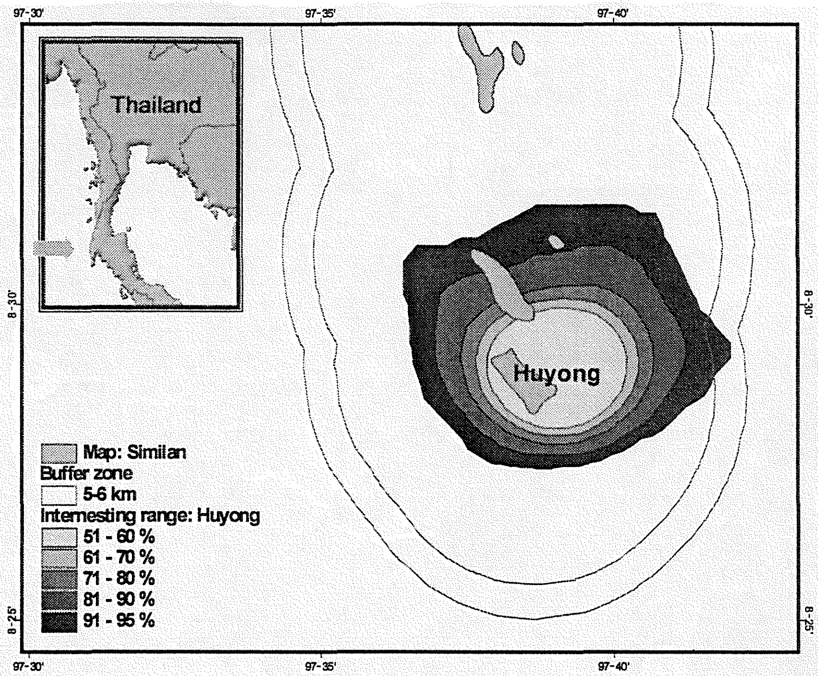


Figure 11. Home range during internesting period of 5 green turtles (*Chelonia mydas*) nested at Huyong Island, Andaman Sea.

Postnesting migrations

In the Gulf of Thailand, 8 out of 11 nesters transmitted migratory data. The three missing nesters were BoonLonge, Chonburi, and Sattahip. In the Andaman Sea, 8 out of 9 nesters possessed migratory data. The missing nester was Rusana which was attached with the PTT 9729 on Jul 30th, 2001. Due to the malfunction of the PTT, it was removed when she returned for re-nesting on Aug 28th, 2001. The migratory paths were revealed as Figure 12 and 13 for the nesters in the Gulf of Thailand and the Andaman Sea, respectively. The migratory paths of the both populations did not correlate with monthly surface current published by Mathew Fontaine Maury (Pilot Chart of the Indian Ocean, YEAR).

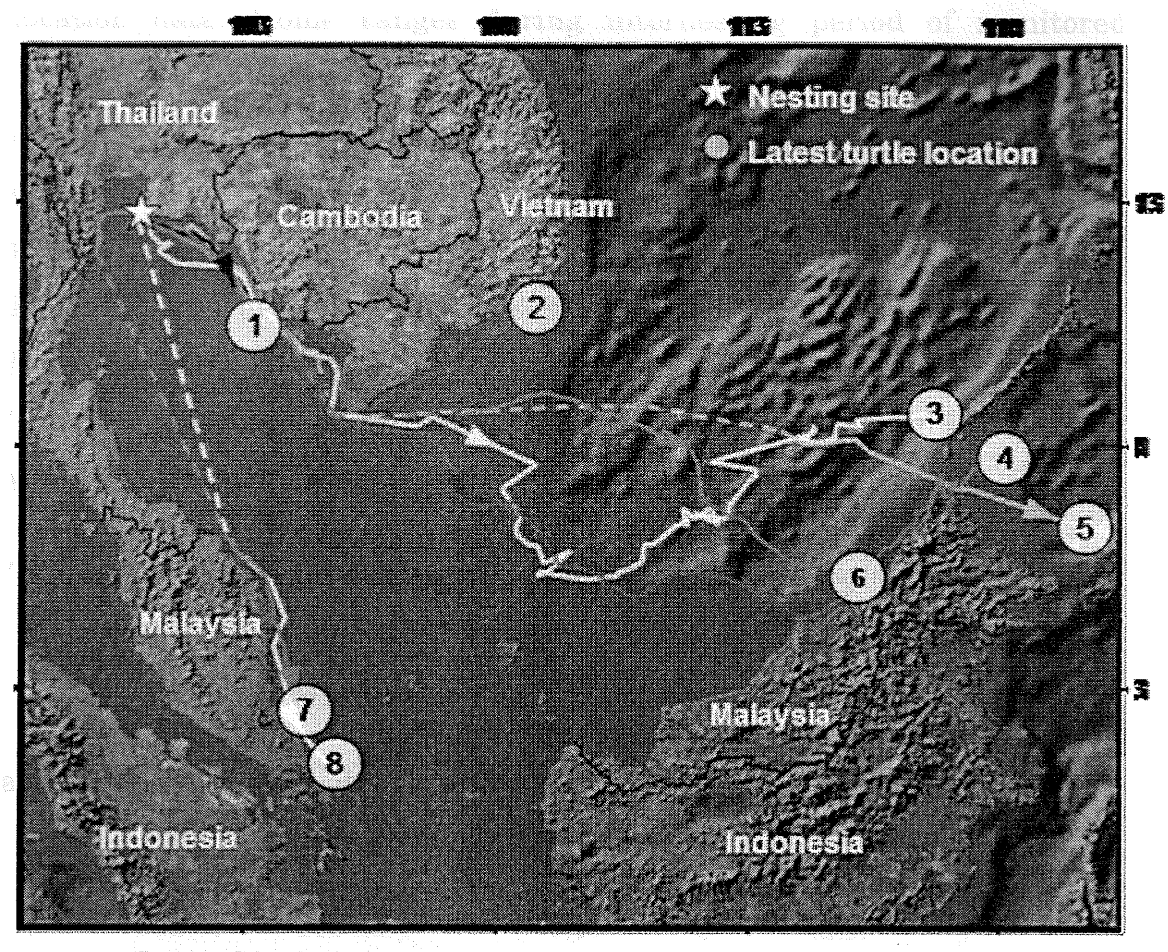


Figure 12. Post migratory paths of green turtle *Chelonia mydas* nested at Khram Island, Gulf of Thailand. The turtles were named as 1= Chaosamut, 2= KhramNoi, 3= SriKhram, 4= Ngamta, 5= KoKhram, 6= SriAnan, 7= KhramYai, and 8= Samprieng. The broken lines indicated tentative point to point routes.

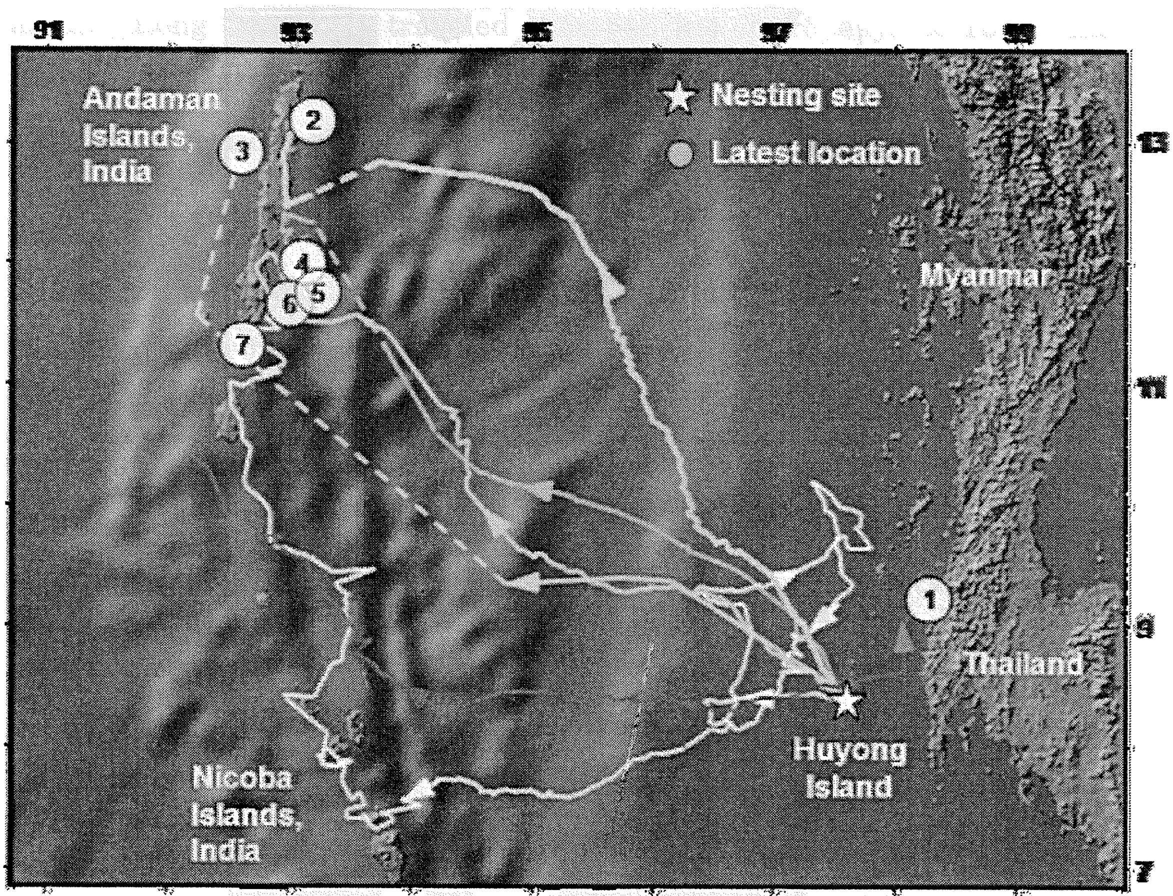


Figure 13. Post migratory paths of green turtle *Chelonia mydas* nested at Huyong Island, Andaman Sea. The turtles were named as 1= SriNuan, 2= Burapa, 3= Rachadamnern, 4= SriPhuket, 5= Tong Beaow, 6= SriFanakorn, and 7= Kayano. The broken lines indicated tentative point to point routes.

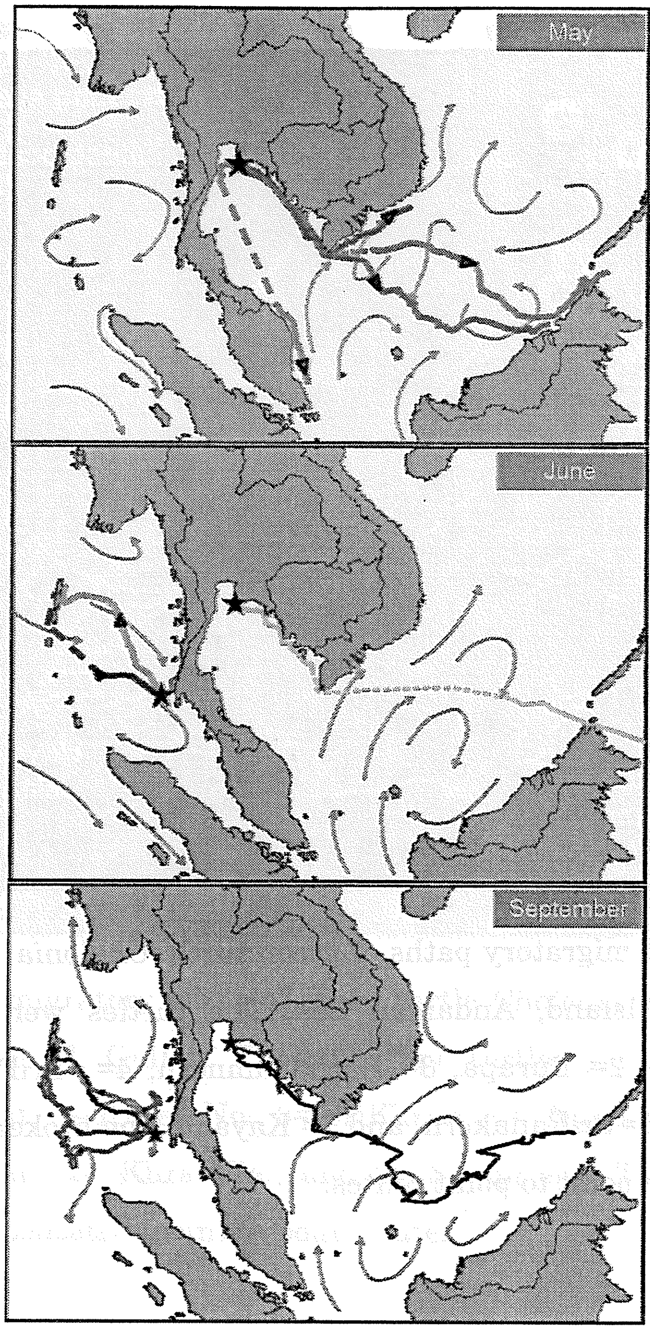


Figure 14. Migratory paths of the PTTs attached green turtles and monthly sea surface current (redrawn from Pilot Chart of the Indian Ocean, Mathew Fontaine Maury).

The Gulf of Thailand

Chaosamut was released from Khram Island on Aug 12th, 2000. She stayed 2 days nearby the island before migrating with the speed of 33.9±0.9 km/day along the E coast to the S of Cambodia, and stayed around Rong Island. It traveled over 648 km in 18 days to reach this destiny. She stayed near by Rong Island for 62 days until the signal ended. The last location signal was retrieved on Dec 4th, 2000 (10°23.4´N 103°50.4´E).

KhramNoi was transferred from Khram Island to release at Sattahip bay on Aug 10th, 2001. She migrated with the relatively fast speed of 79.8±0.6 km/day in the same direction with Chaosamut and further migrated along the coast to the vicinity of Pu-Quoc Island in the SE coast of Vietnam. She traveled over 1,373 km in 18 days. She was further observed for 79 days before ending of the signals on Sep 14th, 2001. Her last location was at 10°47.4´N 108°5.4´E.

SriKhram, after released on Sep 3rd, 2001, migrated (39.3±0.8 km/day) along the eastern coast passing coast line of Cambodia to the S of Vietnam. Thereafter, she migrated with significantly higher speed of 112.8±3.1 km/day across the ocean to the N of Borneo. Her signal ended (before feeding ground was confirmed) at the sea between Borneo and Philippines on Dec 30th, 2001 (8°28.6´N 116°39.6´E). The journey was 3,370 km in 45 days. Her travel direction suggested that she was heading to the Sulu Sea.

Ngamta was attached with the PTT on Aug 8th, 2001. She migrated at relatively constant speed at 58.2±0.6 km/day along the eastern coast passing Cambodia to the south of Vietnam as SriKhram and crossed the ocean to Sulu Sea. Ngamta reached her feeding ground at the island in the N of Borneo (in the Sulu Sea). The signals ended on Nov 9th, 2001 (7°19.9´N 116°51´E). The travel distance was over 2,604 km in 42 days.

KoKhram was released on Jun 14th, 2000. She had similar track to SriKhram and Ngamta. The average migratory speed was 57.6±2.5 km/day. The signal ended before reaching the feeding ground. However, it was likely that her feeding ground was in the Sulu Sea. Her journey covered 2,448 km in 48 days. The last observed location was recorded at 6°9.1´N 119°51.6´E on Aug 17th, 2000.

SriAnan was released from Khram Island on Aug 10th, 2001. Her route passed the coastline of Cambodia and Vietnam. Thereafter, she crossed the ocean along the continental shelf to the N of Borneo. The average migratory speed was 68.6±0.6 km/day. The latest signal on Nov 12th, 2001 indicated that her feeding ground was at the N of Brunei (5°16.3´N 115°E). She spent 49 days to travel over 2,559 km.

KhramYai was nested on Khram Island. After PTT attachment, she was transferred to release at the Sattahip Navy Base on Aug 10th, 2001. She had spent 27 days in the inner part of the Gulf of Thailand before making her journey in the S direction. Unfortunately, the contact was lost for 16 days. The signals were retrieved again on Aug 4th, 2001 where she was located at the NE of Malaysia peninsula. She was heading along the W coast of Malaysia peninsula. On Aug 20th, 2001, she was found at her feeding ground in the SE of Malaysia peninsula. KhramYai was observed wandering around that area until the signal ceased on Aug 23rd, 2001 (2°14.6´N 103°55.2´E). The total migratory distance was 1,360 km in 16 days.

SamPrieng was found nested on Mannai Island, Rayong province. The PTT was attached on Apr 25th, 2000.. The location signal had lost after deployment for 44 days. There were only 5 locations recorded after May 8th, 2000. When observed, she was heading to the S with the average least speed of 32.9±5.9 km/day. Jun 23rd, 2000, she was found in vicinity of the NE coast of Malaysia peninsula. She probably migrated S along the coastal area. Jul 11th, 2000, she was observed for the last time at the SE of Malaysia peninsula (1°20.5´N 104°36´E). The total migratory distance was 1,299 km in over 78 days.

The Andaman Sea

SriNuan was tracked with the PTTs two times (PTT 19278 on Jun 10th, 2000 named as Srinuan00 and PTT 24438 on Mar 6th, 2003 named as SriNuan02). Srinuan00 went in the NE direction from Huyong Island and reached to a sea grass habitat (the N of Ra Island) in 3 days. She had spent about 7 days. It is suspected that she was feeding in the area which was reported as a sea grass bed (Chansang & Poovachiranon 1994; Poovachiranon & Chansang 1994). There after, she returned to lay eggs for the 7th time in year 2000 nesting season at Similan Island (13 days after the previous eggs laying). Thereafter, she went to the same feeding ground. Her last position was detected at 98°13´N 7°27´E. SriNuan00 swam 35–46 km/day when cruising between nesting and feeding grounds. During staying at feeding ground, she swam 2–4 km/day. D_m was 524 km in 27 days.

Location data retrieved from SriNuan02 confirmed that she had the consistent feeding ground with the previous experiment. The PTT was attached after her 2nd nesting of the season. She was staying near by the island and laid 3 more times before coming back to the N or Ra Island. At this time migratory speed could not be calculated due to too few number of location data. SriNuan02 kept sending data until Sep 9th, 2003. The last location was recorded at 9°15.2'N 98°4.1'E.

Burapa was recorded to nest 4 clutches on the Huyong Island in 1997. The PTT was attached on Jun 10th, 2001 which was her 5th clutch (and the last clutch) for this nesting season. She took NW course heading to Andaman Islands, India. She reached her destination at the NE of Andaman Islands in 17 days. The travel distance was 963 km with the speed of 56±0.7 km/day. The location signals had been sent until Oct 16th, 2001. The last location was recorded at 13°11.34´N 93°2.5´E.

Kayano came to lay egg for the first time on Sep 4th, 2000. She was kept overnight for the attachment of the PTT. After releasing, she traveled directly in the E direction and made turn in the NW direction near to Nicoba Islands. She reached her destination at the S of Andaman Islands

(Woodmason bay, Rutland Island). It took her 19 days to swim over 1003 km with the average migratory speed of 64.3±1.3 km/day. She had stayed there until the signal ceased at 11°23.4´N 92°35.7´E on Sep 24th, 2000.

Rachadamnern was attached with the PTT on Jun 11th, 2001 which was her second nesting in that year. After released, she had stayed nearby Huyong Island and had laid 4 more clutches on Jul 6th, 17th, 30th, and Aug 15th, 2001. Thereafter, she headed to the S of Andaman Islands, passed the S of Andaman Islands and headed up in the N direction. There were too few location records to calculate reliable migratory speed. It was most likely that the location signal ceased before she reach her destination.

Tongbeaow had been reported to nest 5 clutches on Huyong Island in 1998. She was observed to lay eggs again in 2001. On Sep 3rd, 2001 which was her last nesting (the 8th clutch), she was attached with the PTT. After releasing, she took a direct course to the SE of the Andaman Islands. The journey to her destination took 17 days with a distance of 688 km. The average speed was 62.4±0.7 km/day. Her last location signal ended on Oct 14th, 2001 at 12°11.4´N 93°16.6´E.

SriPhuket was firstly observed to lay eggs on Huyong Island in 1996. In that season, she had laid 7 clutches. She was attached the PTT on Sep 17th, 2001 which was her 3rd intra-annual nesting. She had continued to lay 4 more clutches before leaving Huyong Island for the SE coast of the Andaman Islands. It took 13 days over 823 km with the average speed of 72.4±1.5 km/day. At feeding ground, the PTT kept sending for 66 more days and ended on Jan 22nd, 2002. The last location was at 11°59.4´N 92°49.3´E.

SriFanakorn was reported to lay her first nest on Aug 22nd, 2001. After her 2nd nesting on Sep 3rd, 2001, the PTT 9780 was attached. Subsequently, she seemed to lose her way home wandering around for 24 days. On Sep 28th, 2001, she started tracking back home by taking the SW course via

Nicobar Islands, India and heading N to reach her destination at the SE coast of the Andaman Islands. The average cruising speed was 68±0.5 km/day. It took her 43days and cover the distance of 2848 km. The last location was reported on Nov 23rd, 2001 (11°52.2'N 92°59.4E).

Feeding grounds

There were only 4 out of 11 nesters (Chaosamut, KhramNoi, KhramYai, and NgamTa) that possessed "at feeding ground" data. In the Andaman Sea, 7 out of 9 nesters were able to be tracked for feeding grounds (*i.e.* Burapa, Kayano, RachDhamNern, Rusana, SriNuan00, SriNuan02, SriFaNaKorn, SriPhuket, and TongBeauw). The signal duration at feeding ground ranged between 12-108 days with the mean of 41±23 days.

The study revealed that the turtles from Khram Island came from four feeding grounds *i.e.* (1) Sulu Sea, a common territory of Malaysia, Indonesia and Philippines; (2) the SE of Malaysia peninsula; (3) the SE of Vietnam; (4) the S of Cambodia (Figure 15), while the ones nested at Huyong Island derived from two feeding habitats *i.e.* (1) the Andaman Islands, India; (2) the N of Ra Island PhangNga province, Thailand (Figure 16). Among these, two major feeding grounds were observed at Sulu Sea and Andaman Islands for the nesting populations from Khram Island and Huyong Island, respectively. The average home range of feeding ground was 140±68 km^2.

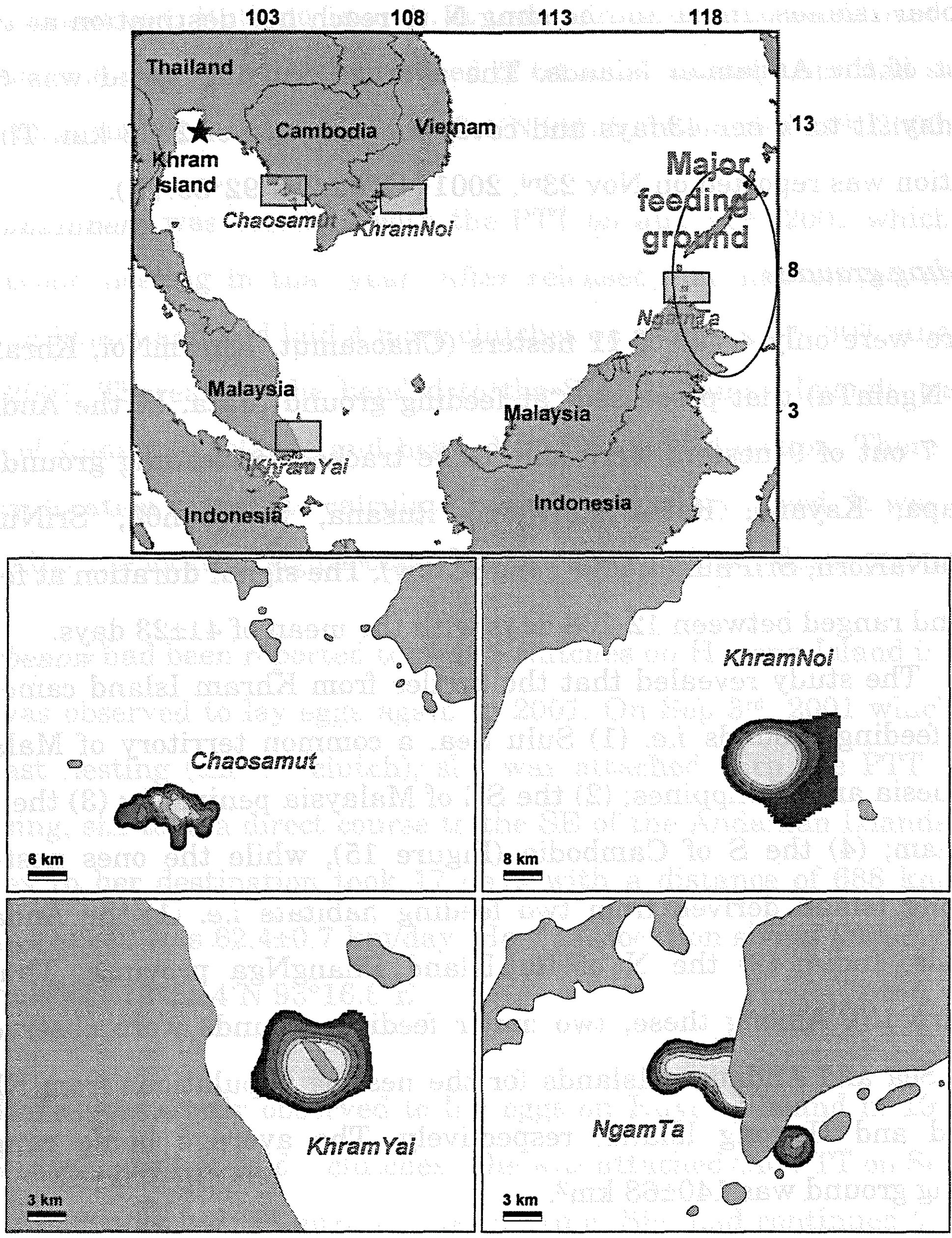


Figure 15. Feeding ground of the green turtles nested at Khram Island

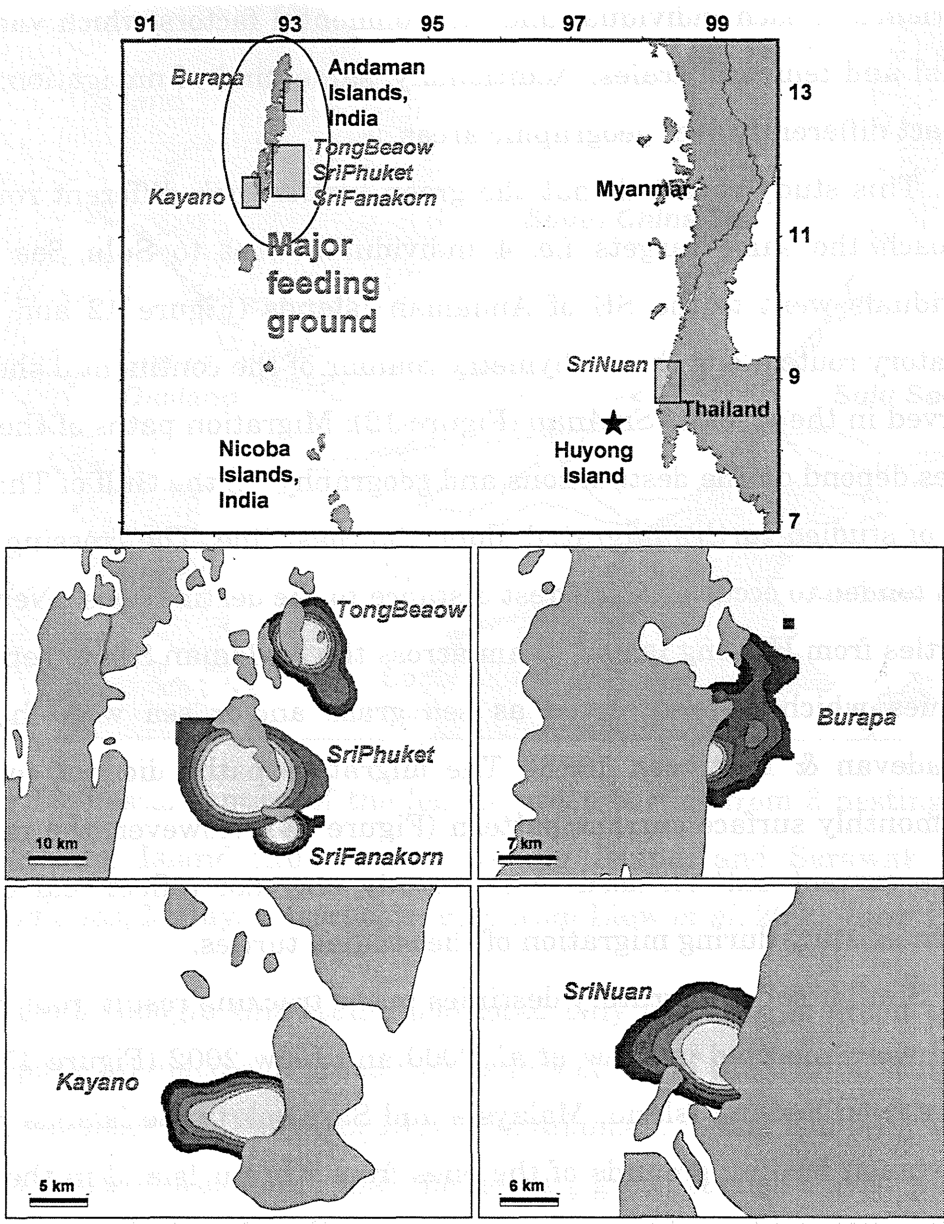


Figure 16. Feeding grounds of the green turtles nested at Huyong Island.

DISCUSSION

Several mechanisms driving migratory patterns have been reported such as magnetic, ocean current, ocean front, windborne, bathymetric features, sea surface temperature, chemosensory (Pritchard 1976; Morreale 1996; Lohmann *et al.* 1997; Sakamoto *et al.* 1997; Luschi *et al.* 1998; Lohmann *et al.* 2001; Luschi *et al.* 2001, read further information of unsuccessful tests of these cues from Papi *et al.* 2000; Hays *et al.* 2001). It is postulated that different choices of navigational cues can be adopted depending on experience of each individual and environmental factors which vary over spatial and temporal scales. Additionally, same kind of navigational cues may act differently over geographic areas.

This study revealed that the green turtles took different routes to approach the same targets *i.e.* 4 individuals went to Sulu Sea and 3 individuals went to the SE of Andaman Islands (Figure 12 and 13). A migratory route along the bathymetry contour of the continental shelf was observed in the track of *SriAnan* (Figure 12). Migration paths of the green turtles depend on the destinations and geography. In the Gulf of Thailand, most of studied turtles migrated along the coast line. The crossing of the ocean tended to occur as a shortest distance to the destinations. Nearly all of turtles from Huyong Island swam across the Andaman Sea to separated destinies which were reported as sea grass and/or sea weed habitats (Mahadevan & Easterson 1983). The migratory paths did not correlate with monthly surface current pattern (Figure 14). However, the monthly surface current pattern used in this study may not reflect real current pattern existing during migration of the studied turtles.

Similar set of migratory destinies to the tracking result from Khram Island were reported in Liew *et al.* 2000 and Liew 2002 (Figure 17). The nesters from Redang Island, Malaysia and Sarawak turtle Islands shared the common feeding grounds of the ones from Khram Island in the SE of Malaysia peninsula and the Sulu Sea/Celebes Sea. The findings suggested relatively high food abundance in the Sulu Sea/Celebes Sea.

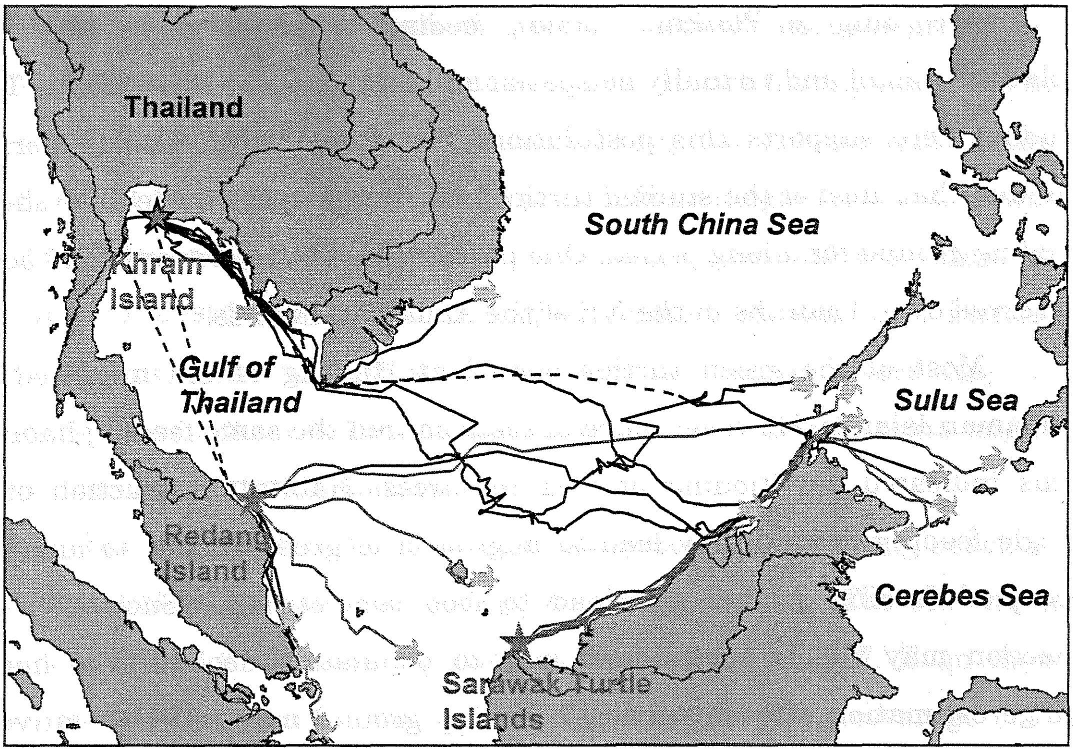


Figure 17. Postmigration of the female green turtles from 3 nesting sites: Khram Island (this study), Redang Island, and Sarawak Turtle Islands, Malaysia (reconstructed from Liew *et al.* 2000; Liew 2002).

Even though, this study monitored only the nesting green turtles. The reports on mating of green turtles in vicinity of the both nesting sites have been observed (Penyapol 1957, Monanansap, S. and Klom-In, W., per. comm.). Since it was found that the nesting green turtles stayed within 6 km from the nesting sites, it is postulated that the adult males stay within the same boundary during nesting seasons. Satellite transmitted tracking of the adult male loggerhead turtle *Caretta caretta* showed that adult male did migrate in and out of the same nesting site (Sakamoto *et al.* 1997). Balazs (1980) reported that male green turtles appear to migrate more frequently to breeding grounds than female ones. Data from both tagging (Dizon & Balazs 1982; Limpus 1993, repeated tracking of *SriNuan* in this study revealed the strong nesting site fidelity) and mitochondrial DNA (Fitzsimmons *et al.* 1997) in the green turtles, suggested that fidelity to specific feeding and breeding grounds occur in the both sexes.

According to Plotkin (2003), feeding range of green turtle is relatively small and virtually no spatial and temporal variation exists. The finding here supports this postulation. The data during feeding period showed that most of the studied turtles had stayed in the same near shore feeding ground for a long period. One postnesting turtle, *Burapa*, had been observed over 3 months in the NE of the Andaman Islands.

Most of the green turtles nested at Huyong Island migrated to Andaman Islands. However, none of them shared the same feeding habitat. This indicated partitioning of food resources. Habitat destruction of a single feeding ground may lead to migration of green turtles to another occupied feeding ground and lead to food competition. Such a chain reaction may widely spread and lead to population decline. The home range estimation of each turtle at feeding ground may reflect relatively quantitative abundance of the food source in such an area. This requires further investigation. A technique such as remote sensing with ground truth may be useful to evaluate potential of each feeding habitat remotely and quickly. By this way, any destructive change of the feeding grounds then can be rapidly recognized and solved before affecting to sea turtles population.

This study revealed the wide geographic life history of green turtles nested in Thailand. It was proved that theses green turtles were not only belong to Thai but also the whole region. Depleting of a single geographic population would directly affect to other parts. Cooperative among regional countries is necessary to ensure the survival of green turtle populations in South East Asia. In addition, the knowledge of geographic population structure would enhance a proper conservation and management of sea turtles in a large scale (Dutton *et al.* 2002).

Implementations of the study in Thailand

Nesting grounds

Since Huyong Island was a part of national parks, the sea within 5 km has been claimed as no take zone by Natural Park Act 1961. The internesting coverage of revealed that there was only 1 % chance that the green turtles would distribute outside the protected area. Hence fishing activities seem not to be a diminishing factor, if there is regular enforcement. Artificial reef might be a possible solution to protect from illegal trawlers. However, the activities of tourist visiting the island might cause adverse effect to the number of nesters. For instance, higher number of boats may increase a risk to injure sea turtles with propellers or tourist divers may scare nesters. Restriction of the number of tourist and tourist boats might be considered to minimize disturbance.

Khram Island is declared as military zone. The nesting beach is, in general, entirely saved from an egg collecting poacher. The sea within 3 km is claimed as no trawling zone by Fisheries Act 1947. Even though, this boundary covered a major part of the internesting coverage (71 %), extending of the protected area to 6 km will exclusively secure the survival of nesters.

Feeding grounds

This study revealed only one feeding ground in the N of Ra Island, PhangNga province. The area was recognized as a big sea grass habitat (Chansang & Poovachiranon 1994; Poovachiranon & Chansang 1994). Thus, declaration of protecting area around the N of Ra Island will not only help for sea turtles but also sea grass bed which plays an important role to marine ecology. Additionally, a risk of being captured incidentally by intensive trawling in the area (Nuthmon *et al.* 1998, Figure 18) would be minimized.

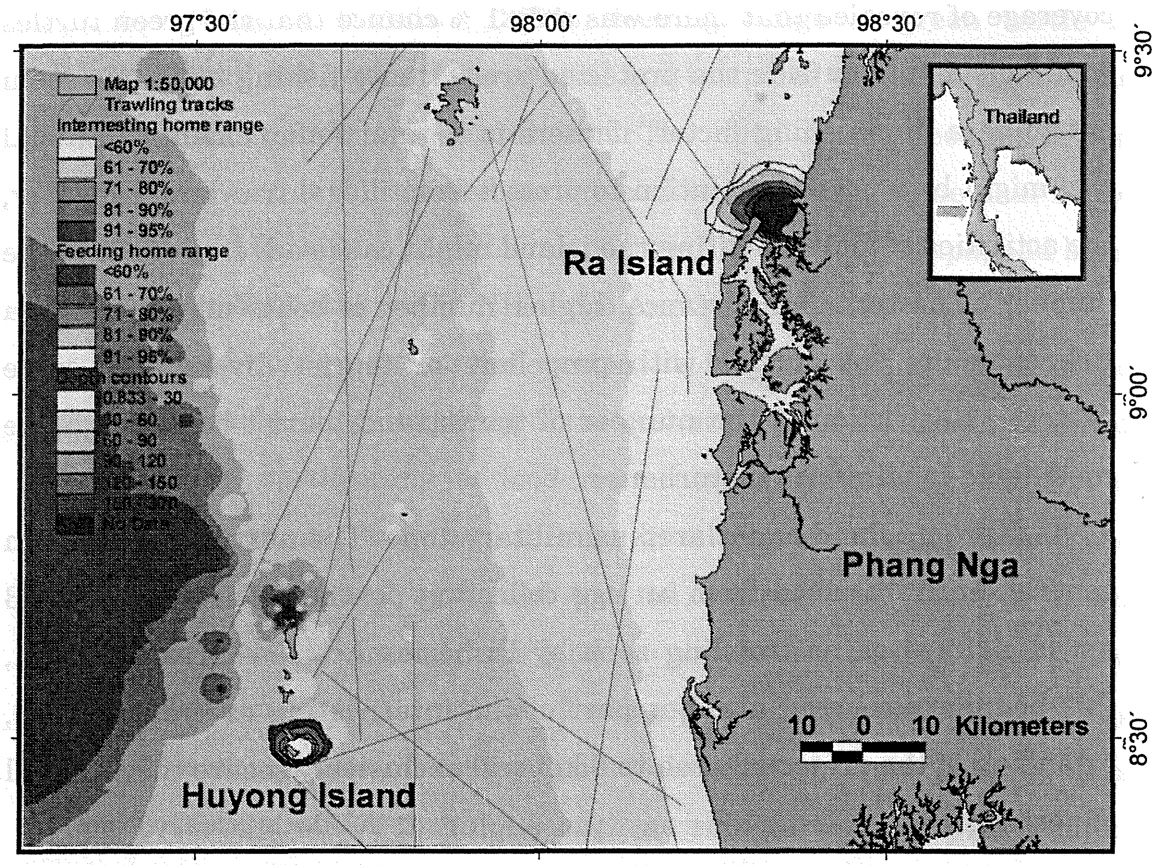


Figure 18. Internesting and feeding home ranges of nesting *Chelonia mydas* from Huyong Island overlaid with trawling tracks and depth contours (trawling tracks were reconstructed from Nuthmon *et al.* 1998).

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Chapter 4

NO GENETIC DIVERGENCE BETWEEN GREEN TURTLE *CHELONIA MYDAS* NESTING POPULATIONS FROM THE ANDAMAN SEA AND THE GULF OF THAILAND

INTRODUCTION

Thailand faces two seas *i.e.* the Gulf of Thailand and the Andaman Sea. The two seas are separated by the southern part of Thailand through Malaysian peninsular and further semi-separated by Indonesia (Figure 1). These geological barriers act effectively to limit geneflow among conspecific populations from the two seas as revealed in several marine organisms *e.g.* banana prawn *Peneaus monodon* (Supungul *et al.* 2000; Klinbunga *et al.* 2001), giant clams *Tridacna squamosa, Tridacna maxima* (Kittiwattanawong 1999; Kittiwattanawong *et al.* 2001), starfish Benzie 1999), rock oysters *Crassostria* spp. (Bussarawit 2003). Additionally, separation at community level was detected (coral reef fish communities, Sattapumin 2001). At the larger scale, this geological barrier may serve as a door to separate marine organisms between Indian and Pacific oceans.

A green turtle is another organism distributes in both the Gulf of Thailand and the Andaman Sea (Phasuk 1992). This allows a possibility to test the effectiveness of this geological barrier. Recently, satellite transmitted tracking of the nesting green turtle populations from the Andaman Sea and the Gulf of Thailand (Chapter 3 in this volume) suggested contemporary allopathic life cycles (Figure 1). However, such a only reflects the present scenario. An improved understanding may be further obtained by research on population genetic structure. Several kinds of genetic materials vary from proteins to nucleic acids can be employed (Avise 1994). Since, genetic materials are inherited from one generation to another, information obtained from research on these genetic materials reflects from the summary of natural history the past till present (Futuyma 1986; Page & Holmes 1998).

This study was an analysis of nucleotide sequence from mitochondrial DNA (mtDNA) at control region or D-loop which is recognized as highly polymorphic site (Norman *et al.* 1994). Within the d-loop, the mutation rate is approximately five to ten times that of the rest of the mitochondrial genome, (Aquedro & Greenberg 1983). The genetic diversities and divergence of the two green turtle nesting sites *i.e.* Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea are revealed (Figure 1).

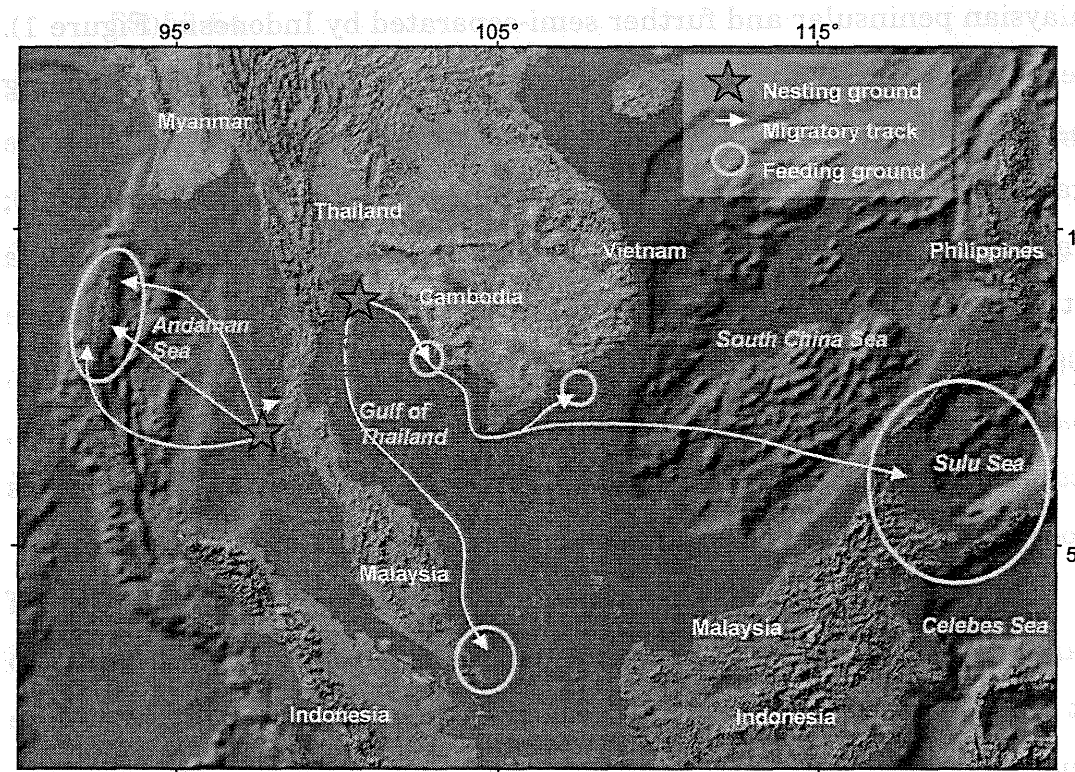

Figure 1. The two major nesting grounds of green turtles *Chelonia mydas* in Thailand (Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea) with the satellite transmitted results showing the simplified migratory routes and their feeding grounds.

MATERIALS AND METHODS

The tissues

The samples were collected with supports from the Royal Thai Navy during 2001-2002. Generally, the staffs patrolled the beaches at night during high tide. After a turtle had laid eggs, the staffs scanned for a microchip tag at the both flippers (a new one would be inserted subcutaneously to the left flipper when it was not found). Thereafter, a small piece of skin tissue (approximately 0.3x0.3 cm^2) at the inner flipper was cut with a sterile surgery knife and put into a 2-ml microcentrifuge tube filled with sodium chloride saturated DMSO or TNES (a mixture of 150 mM NaCl, 10 mM Tris-HCl pH 7.5-8.0, 25 mM EDTA, and 0.5% SDS) solutions and stored at room temperature. The medicines such as Gentian Violet, Povidoiodine, or tetracycline oilment were placed to the wounds before releasing of the green turtles. Twenty-seven samples were collected from Khram Island in the Gulf of Thailand and nineteen samples were from Huyong Island in the Andaman Sea. All samples were brought to analyze at Graduate School of Agriculture, Kyoto University. All the samples were exported under the permission of the CITES.

DNA analysis protocol

The detail analysis protocol of the control region mtDNA is shown in Appendix 1. In brief, the tissues were digested with Proteinase K. The DNA solutions were obtained by a standard phenol/chloroform extraction (Sambrook *et al.* 2001) and precipitation. The forward primers *i.e.* Green15552F (FGTGT C CACA CAAAC TAACT ACCT), Green15579F (CTGCC GTGCC CAACA GAACA) and reward primers *i.e.* Green16300R (GTCTC GGATT TAGGG GTTTG GCG), Green16087R (CCAGT TTCAC TGAAT CGGCA) were used to obtain the specific nucleotide sequences in the control region mtDNA (Figure 2). Afterward, the selected sequences were amplified with a PCR machine. The PCR products then were run on the Argarose gels to identify the successful of PCR amplification. Finally, the PCR products were sequenced with an automated sequencer to obtain direct reading of the nucleotide sequences.

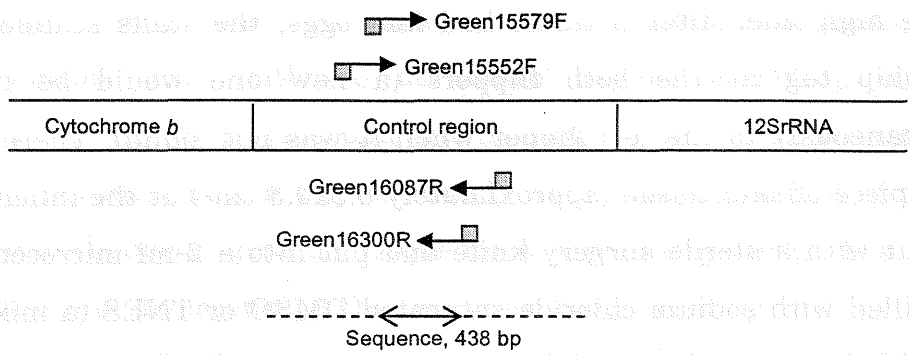

Figure 2. Location of the primers employed in the study overlaid to a none-scale mtDNA of *Chelonia mydas*. Arrows indicate the nucleotide synthesis directions. The line with both ends arrows indicates proximal length of nucleotide sequence (438 bp).

Data Analysis

The nucleotide sequences were aligned and cut using the computer program CLUSTAL W 1.7 multiple sequence alignment (Thompson *et al.* 1994). Haplotypes were determined by examining the aligned sequences. Haplotypes were assigned when one or more base changes differed from the consensus or conserved sequence. Haplotype (*h*) and nucleotide (π) diversities (Nei 1987) were calculated. Divergences between the two populations were calculated as Gst (based on haplotype frequencies, Hudson *et al.* 1992), Nst (based on nucleotide sequences, Lynch & Crease 1990), and Tamura-Nei's genetic distance (D_{TN}, Tamura & Nei 1993). Nst is similar to Fixation indices (Fst) described in Weir & Cockerham 1984. The difference is that Nst uses the Jukes & Cantor 1969 correction. Additionally, the differences in haplotype frequency among populations and the nucleotide divergence among haplotypes are both taken into account in the calculation of Nst (Ramey II 1995). Gst and Nst values range from 0 to 1 which indicate non existence of population subdivision to well defined sub population. A chi-square test (Hudson *et al.* 1992) based on pair-wise comparisons of haplotype frequency data was also conducted to test for any significant genetic differentiation between populations. Gene flow (Nm) between the two populations was estimated from Nst and

Gst values using the formula Nm=0.5(1/Nst or Gst–1)(Wright 1951). Nm can be interpreted as the absolute number of individuals exchanged between populations per generation (Avise 1994). All calculations were performed using the program DnaSP version 3.99.5 (Rozas & Rozas 1999) and MEGA version 2.1 (Phylogenetic and molecular evolutionary analyses, Kumar *et al.* 2001). The nucleotide sites with gaps or missing data were completely excluded from the analysis. All sampling errors were reported as standard error (SE) calculated by the mentioned programs with 1,000 bootstrap replicates (Nei & Kumar 2000). A chi-square test was conducted to test for a significant genetic divergence between the two populations (Nei 1987; Hudson *et al.* 1992).

RESULTS

Diversity

The aligned sequences contained 438 base pairs (bp) with 254 polymorphic sites. There were 8 haplotypes assigned from the 49 green turtles sampled from the Andaman Sea and the Gulf of Thailand (Table 1). The two most dominant haplotypes (B1 and A1) were observed in common in the both waters. The number of haplotypes was higher in the samples from the Gulf of Thailand (7 haplotypes *i.e.* A1, A2, A3, B1, B3, B4, B5, and B6) compared to the ones from the Andaman Sea (3 haplotypes *i.e.* A1, B1, and B3). The haplotype A2, A3, B4, B5, and B6 tended to endemic to the Gulf of Thailand, while there was only B3 that tended to restrict to the Andaman Sea.

Table 1. Distribution of the mtDNA control region haplotypes between the nesting populations of the Andaman Sea and the Gulf of Thailand.

Haplotype	Andaman	Gulf	Total
A1	8	8	16
A2	-	1	1
A3	-	1	1
B1	10	15	25
B3	1	-	1
B4	-	1	1
B5	-	1	1
B6	-	3	3
Total	19	30	49

Overall haplotype diversity (Andaman Sea and Gulf of Thailand combined) for the green turtle nesting populations of Thailand was high (h=0.640; Table 2). The Gulf of Thailand had a slightly higher degree of haplotype diversity than the Andaman Sea. On the contrary, nucleotide diversity was higher in the population from the Andaman Sea compared to the one in the Gulf of Thailand. However, nucleotide and haplotype diversities in all cases might be slightly less than the actual value due to the calculations excluded gaps in the aligned sequences.

Table 2. Haplotype diversity (*h*), Nucleotide diversity (π), number of polymorphic nucleotide, and average number of nucleotide difference for the green turtle nesting populations from the Andaman Sea and the Gulf of Thailand. Diversity indices were calculated by DnaSp ver.3.99.5 (Rozas and Rozas 1999) and MEGA ver 2.1 (Kumar et al. 2001).

	Andaman	Gulf	Overall
Haplotypes diversity (*h*)	0.573±0.014	0.687±0.016	0.640±0.011
Nucleotide diversity (π)	0.294±0.068	0.264±0.008	0.272±0.005
No of polymorphic nucleotide	251	254	254
Average No of nucleotide difference	129	116	119

Divergence and geneflow

Low genetic divergence between the nesting green turtle populations of the Gulf of Thailand and the Andaman Sea was detected in both haplotypic (Gst=0.00311) and nucleotide levels (Nst=0.02838) as well as genetic distance (D_{TN}=0.016±0.003). The estimated female mediated gene flows (Nm) from haplotype and nucleotide data were 161 and 17, respectively. This implied a lack of population subdivision between the nesting populations of the Andaman Sea and the Gulf of Thailand and a sufficient degree of gene flow to prevent genetic differentiation between the two populations. The chi-square tests of genetic divergence of both Gst and Nst, revealed no significant differentiation ($P>0.05$) between the nesting populations of the Gulf of Thailand and the Andaman Sea.

DISCUSSION

Genetic information obtained from this study pointed out that the two nesting green turtle populations between the Gulf of Thailand and the Andaman Sea was well mixed. The present geological boundary (the part of the Southern continent from Thailand to Malaysia peninsula down to Indonesia) seems not to effectively prevent the geneflow between the two populations as observed in invertebrate species (Kittiwattanawong 1999; Supungul *et al.* 2000; Kittiwattanawong *et al.* 2001; Klinbunga *et al.* 2001 Benzie 1999; Bussarawit 2003). Moreover, this finding was not in agreement with the satellite transmitted tracking results reported in the Chapter 3 that the two nesting populations possessed separated feeding grounds and hence, leading to separated populations. Contradiction between the two findings leads to discussion of two schools of thought *i.e.* (1) tracking trusted postulation and (2) genetic trusted postulation.

In the first case, tracking results reveal a present distribution of green turtle nesting populations, while genetic information does not echo the real time structure due to the high genome conservation. Extremely low genetic divergence rate in sea turtles have been reported in various genetic material levels such as protein (hybridization test, Karl *et al.* 1995), chromosome (banding pattern, Bickham 1981), Single-copy nuclear DNAs (Karl *et al.* 1992), and microsatellite loci (Fitzsimmons *et al.* 1995). In addition, mtDNA evolution in turtles proceeds at a several-fold lower rate than "conventional" vertebrate pace (Avise *et al.* 1992; Bowen *et al.* 1996). Such evidences suggested that a large part of genetic information has been remaining from the past since the founding of the two populations from a common ancestor.

Genetic trusted postulation may argue about the small sample size of the tracking study. Even though, the tracking result was retrieved from only 11 and 9 nesting green turtles from the Khram Island and Huyong Island, respectively, such numbers revealed a good representative compared to the number of yearly nesting green turtles at Khram Island (<100 nesters per year, Monanunsap & Charuchinda 1994) and Huyong Island (12 individuals per year). It can be claimed that the period of tracking period is relatively too short (9-126 days, chapter 3) compared to the life span of the sea turtles (60 years, Seminoff 2002). The tracked turtles might have not stayed at the same feeding ground all the time, but wandering to the wider expected rookeries. Incorporate of this factor with long range migratory ability may break down the barrier and hence leading to a mixing of the populations. Lastly, the evidence from the sea level fluctuation tends to support the genetic-based finding. Geneflow between the two populations is likely to occur by migration across seaways (via stepping stone mechanisms along nesting and feeding grounds existed in the region or directly via long migratory pattern) in-betweens Malaysia peninsula-Sumatra, Sumatra-Java. These seaways have been closed and widen up over the time scale due to sea level fluctuation (Geyh *et al.* 1979). Figure 3a showed that within 140,000 years ago (Potts 1983), there were two periods that sea level were higher than the one at present. These periods with high sea level affected ~~to~~ the topography of the Southeast Asia by widening the Strait of Malacca, seaways in between Sumatra-Java, and consequently allowing higher geneflow of the both nesting turtle populations (Figure 3c). In contrast, the periods with lower sea level would narrow the seaways or even closed them as Figure 3b. Since the geneflow was maximized (hence, create low genetic divergence) in the period with higher sea level since 4,000 years ago and continue till present (Figure 2b, c, and d). This allows sea turtles to disperse back and forth between the two seas making both populations to have essentially become one non-differentiated population.

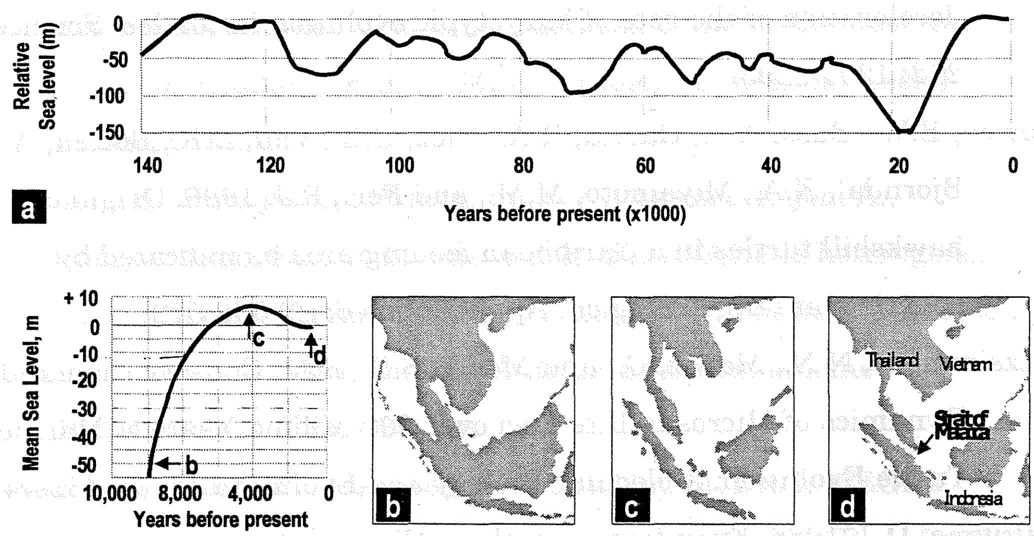

Figure 3. a) Sea level fluctuation over the past 140,000 years ago (Potts 1983). b), c) and d) Sea levels and topographies of SPouth East Asia during 8000, 4000 years ago and at present, respectively (modified from Lekagul & McNeely 1977; Geyh *et al.* 1979).

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APPENDIX 1

DNA ANALYSIS PROTOCOL

Tissue preservative solution

	1.5 ml	New tube
+	1200 μl	TNES solution
✂+	3x3 mm	Skin tissue from an inner flipper
➔		Preserved tissue

Protein digestion

		Remove TNES-Urea solution completely
+	400 μl	TNES solution
+	40 μl	Proteinase K solution (20 mg/ml)
+	32 μl	DTT solution (1 M)
✂		Cut by scissors
		Vortex
		Incubate at 55°C for over night with shaking
➔		Digested sample

DNA extraction

Phenol/chloroform treatment

		Digested sample
+	400 μl	Phenol (Bufferized, pH 8.0)
		Vortex
		15,000 rpm, 30 min, 10°C
		Remove Supernatant to New Tube
+	400 μl	Phenol/Chloroform (1:1)
		Vortex
		15,000 rpm, 15 min, 10°C
		Remove Supernatant to New Tube
+	400 μl	Chloroform
		Vortex
		15,000 rpm, 10 min, 10°C

Precipitation

		New Tube
+	3 μl	Ethachinmate™ (Precipitation enhancer)
+		Supernatant
		Vortex
		Spin down

+	1000 μl	100% EtOH
↓↑		Vortex
⏱☽		-20°C for over night (Alternative)
↻		15,000 rpm, 30 min, 10°C
↺		Remove Supernatant
+	500 μl	70% EtOH
↓↑		Vortex
↻		15,000 rpm, 15 min, 10°C
↺		Remove Supernatant
+	100 μl	70% EtOH
↓↑		Vortex
↻		15,000 rpm, 15 min, 10°C
		Dry up
+	100 μl	H_2O
➔		DNA solution

First PCR amplification

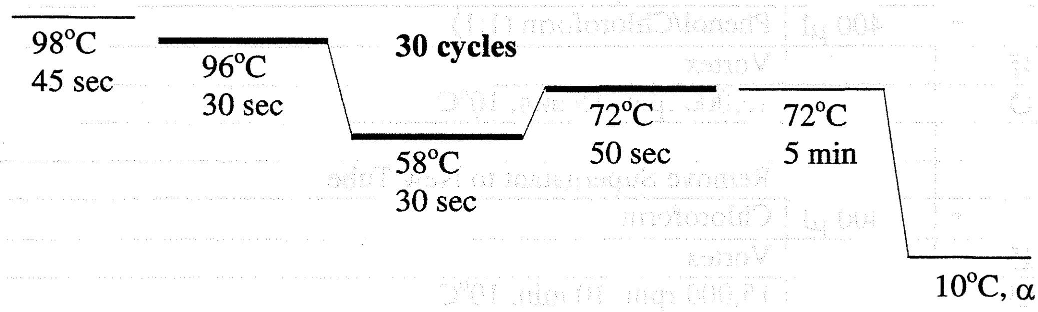
Dilution

🗑		New Tube
		1/10 concentration of DNA solution in H_2O
➔		1°Diluted DNA

PCR reaction mixture

🗑		New Tube
+	2 μl	10x EXTaq buffer
+	1.6 μl	dNTP mix
+	2 μl	5 μM Primer (green 15552F)
+	2 μl	5 μM Primer (green 16120R)
+	11.3 μl	H_2O
+	0.1 μl	EXTaq
+	1 μl	1°Diluted DNA

PCR reaction



➔ 1° PCR product Frig, Freeze

Electrophoresis

Gel preparation

	1.25 g	Argarose	RT
	100 ml	1x TAE buffer	RT
	2.5 μl	Ethidium bromide (10mg/ml)	RT

Loading

	1.5 μl	Loading dye (BPB, OrG)	RT
	3 μl	1° PCR Product	Frig, Freeze

Indicator

	1.5 μl	Loading dye (BPB, OrG)	RT
	3 μl	Lambda DNA Hindill digest	4°C

Running condition

		50 or 100 V	
		Running buffer, 1x TAE buffer	

Check bands under UV light

Second PCR amplification

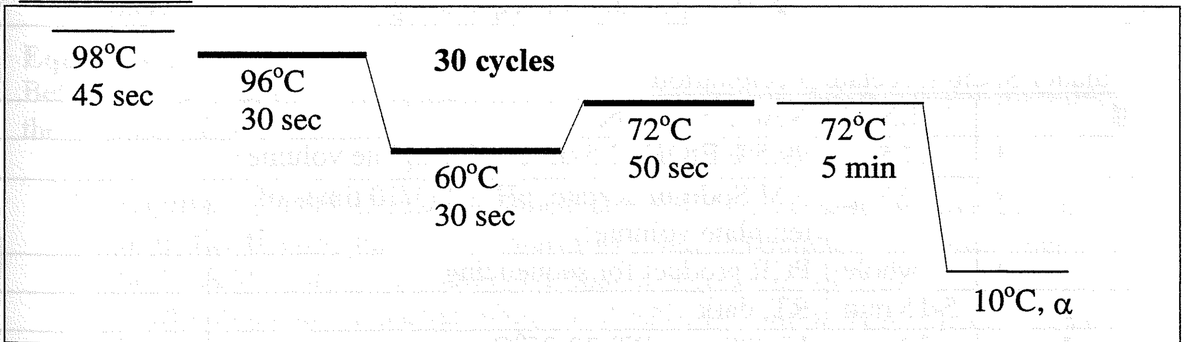
Dilution

		New Tube	
		1/100 concentration of 1° PCR product in H_2O	
→		2°Diluted DNA	Frig, Freeze

PCR reaction mixture

		New Tube	
+	2 μl	10x EXTaq buffer	4°C
+	1.6 μl	dNTP mix	4°C
+	2 μl	5 μM Primer (green 15579F)	4°C
+	2 μl	5 μM Primer (green 16087R)	4°C
+	11.3 μl	H_2O	
+	0.1 μl	EXTaq	4°C
+	1 μl	2° Diluted DNA	Frig, Freeze

PCR reaction



→		2° PCR product	Frig, Freeze

Electrophoresis

Gel preparation

	1.25 g	Argarose	RT
	100 ml	1x TAE buffer	RT
	2.5 μl	Ethidium bromide (10mg/ml)	RT

Loading

	1.5 μl	Loading dye (BPB, OrG)	RT
	3 μl	2° PCR Product	

Indicator

	1.5 μl	Loading dye (BPB, OrG)	RT
	3 μl	Lambda DNA Hindill digest	4°C

Running condition

		50 or 100 V	
		Running buffer, 1x TAE buffer	

Check bands under UV light

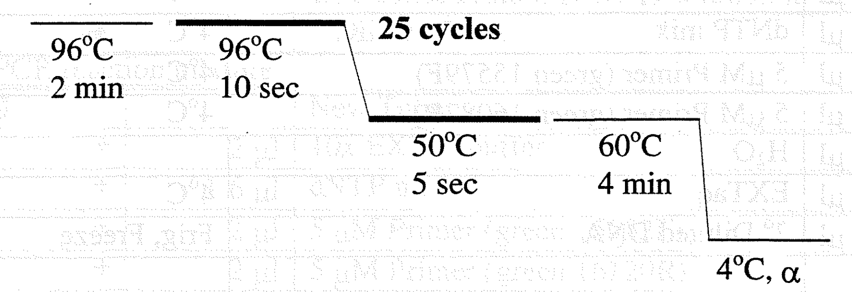
Sequencing

ExoSap™ Treatment

		2° PCR product	
+	1.5 μl	ExoSap: remove excess primers & nucleotides	
⇅ ↺		Mix and spin down	
PCR		37°C, 30 min for treatment	
		80°C, 15 min to inactivate	

PCR for Dye terminator cycle sequencing

PCR reaction



		➔ PCR product for sequencing	Freeze

Ethanol/Sodium acetate precipitation

	1.5 ml	New 1.5 ml tube	
+	17.5 μl	99.5% EtOH (2.5 times of template volume)	
+	0.7 μl	3 M Sodium acetate, pH 5.2 (1/10 times of template volume)	
+	whole	PCR product for sequencing	
	5-15 min	RT, dark	
↻	30 min	15,000 rpm RT(20-25°C)	
		Remove EtOH	
+	125 μl	70% EtOH	
↻	5 min	15,000 rpm RT(20-25°C)	
		Remove EtOH	
	1 min	Dry at 90°C	
+	15 μl	TSR (Loading buffer)	
↺		Spin down	
	2-3 min	Mix with shaker	
	2 min	Denature at 95°C	

		Quick chilling	
	whole	Transfer to 0.5 μl tube	
		→ Sequencing (8 samples per day)	

Solutions preparation

TNES solution

150 mM	NaCl	
10 mM	Tris-HCl, pH 7.5-8.0	
25 mM	EDTA	
0.5 %	SDS	

TAE stock solution (Tris-acetate) 50x

242 g	Tris base	
57 ml	Glacial acetic acid	
100 ml	0.5 M EDTA pH 8.0	

Phenol

Most batches of commercial liquified phenol are clear and colorless and can be used in molecular cloning without redistillation. Occasionally, batches of liquified phenol are pink or yellow, and these should be rejected and returned to the manufacturer. Crystalline phenol is not recommended because it must be distilled at 160°C to remove oxidation products such as quinones that cause the breakdown of phosphodiester bonds or cause cross-linking of RNA and DNA.

Caution: Phenol is highly corrosive and can be cause severe burns. Wear gloves, protective clothing, and safety glasses when handling phenol. All manipulations should be carried out in a chemical hood. Any areas of skin that come in to contact with phenol should be rinsed with a large volume of water and washed with soap and water. Do ***not*** use ethanol.

Equilibration of phenol

Before use, phenol must be equilibrated to pH > 7.8 because DNA will partition into the organic phase at acid pH.

1. Liquified phenol should be stored at -20°C. As needed, remove the phenol from the freezer, allow it to warm to room temperature, and then melt it at 68°C. Add hydroxyquinoline to a final concentration of 0.1%. This compound is an antioxidant, a partial inhibitor of RNAase, and a weak chelator of metal ions. In addition, its yellow color provides a convenient way to identify the organic phase.
2. To the melted phenol, add an equal volume of buffer (usually 0.5M Tris-Cl pH 8.0 at room temperature). Stir the mixture on a magnetic stirrer for 15 minutes, and then turn of the stirrer. When the two phases have separated, aspirate as much as possible the upper (aqueous) phase using a glass pipette attached to a vacuum line equipped with traps.
3. Add an equal volume of 0.1M Tris-Cl (pH 8.0) to the phenol. Stir the mixture on a magnetic stirrer for 15 minutes, and then turn off the stirrer. Remove the upper aqueous phase as described in step 2. Repeat the extraction until the pH of the phenolic phase is >7.8 (as measured with pH paper).

4. After the phenol is equilibrated and the final aqueous phase has been removed, add 0.1 volume of 0.1M Tris-Cl (pH 8.0) containing 0.2% b-mercaptoethanol. The phenol solution may be stored in this form under 100 mM Tris-Cl (pH 8.0) in a light-tight bottle at 4°C for periods of up to 1 month.

Chapter 5

CONSERVATION MANAGEMENT OF GREEN TURTLE CHELONIA MYDAS POPULATIONS FOR THAILAND

INTRODUCTION

Since an ongoing decline trend of green turtles is still detected, an immediate master action plan should be setup and adopted by all responsible organizations. This chapter identify remain threats and proposes an initial action plan to the accomplish conservation goal. The action plan concerns the green turtle populations as well as nesting and marine environments. The findings from previous chapters suggested that the management unit of green turtle populations can not be confined to only Thailand, but should be a responsible of the whole Southeast Asian countries.

RESPONSIBLE ORGANIZATIONS

Several organizations from both governmental and nongovernmental sectors have been involving in researches and conservation of sea turtles in Thailand.

Governmental sector

Department of Marine and Coastal Resources (DMCR)

The department is under the Ministry of Natural Resources and Environment which was recently found according to the government reform in 2002. Under DMCR, there are two organizations responsible to sea turtles researches and conservation namely Phuket Marine Biological Center and Mannai Sea Turtle Conservation Station which located in the Andaman Sea and the Gulf of Thailand. The two organizations were previous under Department of Fisheries. More than 30 years, many research aspects have been conducted vary from *in situ* nesting behavior to captive breeding program. The first world success of producing second filial (F2) olive ridley *Lepidochelys olivacea* in captivity was reported

(Chantrapornsyl & Bhatiyasevi 1994). Additionally, DMRC is responsible for the laws enforcement to protect coastal environment and conserved organisms. Marine Coastal Resources Patrol Units (MCRPUs) have been established along the Thai coastline. MCRPUs also search and arrest any illegal sales of sea turtles and their products in the markets and shops.

Department of Fisheries (DOF)

Under the new government reform in 2002, DOF has a major concern on fisheries activities. There are many Fisheries Patrol Units stations located in both the Gulf of Thailand and the Andaman Sea. They guard and capture illegal fishing, particularly within 3-km of no trawling zone. The DOF thus plays an important role in enforcement of protective laws. Cooperation between DOF and DMCR has widened protective eyes along with broadening of stranding alert network.

Department of National Parks (DNP)

Most of sea turtles nesting grounds in Thailand confine within insular and mainland national parks (Chapter 1). KaoLumpee-Thaimuang National Park and Srinath National Park located on the west coast of PhangNga and Phuket provinces are recognized as nesting ground for *Lepidochelys olivacea* and *Dermochelys coriacea*. Occasionally, *Chelonia mydas* nests long these continental beaches. Insular national parks such as Surin Islands, Similan Islands National Parks are important nesting ground for *Chelonia mydas* and *Eretmochelys imbricata*. DNP has helped conserving sea turtles by secure the survivor of nesters and their eggs as well as protecting nesting habitats.

The Royal Thai Navy

The Royal Thai Navy has played an important role in researches and conservation of sea turtles in Thailand since 1955 (Penyapol 1957). The two most important nesting grounds of green turtles (*i.e.* Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea) are under jurisdiction of the Royal Thai Navy. With prompt of man power and discipline, the both nesting grounds are totally protected from any poachers and beach invasion. With the close cooperation between DMCR and the Royal Thai Navy, the long term nesting statistic recorded at Khram Island and Huyong Island provide fruitful information of nesting behavior of *Chelonia mydas* and *Eretmochelys imbricata*. The Royal Thai Navy takes care of nesting beaches protection, head-started releasing program as well as public education and awareness building.

Nongovernmental sector

Nongovernmental Organizations (NGOs) and local villagers

Conservation of sea turtles has been supported by several NGOs such as World Wildlife Fund (WWF) Thailand, Magic Eyes Organization. NGOs have played a role to educate, launch conservation campaign as well as to support founding of local conservationists. At present there are two sea turtle conservation groups in Thailand *i.e.* MaiKhao Sea Turtle Conservation and Phrathong Sea Turtle Conservation.

MaiKhao Sea Turtle Conservation group is driven by villagers at MaiKhao beach Phuket and WWF Thailand. The group patrols the beach located in the NW of Phuket during November to January. The turtle eggs are translocated and incubated at the prepared beach and reared for a few months before releasing.

Prathong Sea Turtle Conservation group comprises of students and villagers at Phrathong Islands which was previously reported as an important nesting beach for *Lepidochelys olivacea* and *Dermochelys coriacea* (Chantrapornsyl 1992). The group was founded as part of sea turtle conservation training by Phuket Marine Biological Center in 2000. The group members help patrolling the beach and report on sea turtle nesting.

Media creators

Conservation awareness of sea turtles has been rapidly given to public through medias such as newspapers, radio, television and the

Internet. Recent advance in computer technology and availability enhances transfer of conservation means.

THE REMAIN THREATS

Even though, the major factors adversely affecting to the decline of sea turtles (direct take of sea turtles and their eggs) is minimized by laws and awareness building campaign, it remains two major threats *i.e.* bycatch and habitats degradation.

Bycatch

Although, there is no direct estimation of the number of bycatch sea turtles in Thailand, the records of stranded sea turtles along the coastal areas indicated high percentage cause of death by fishing gears (Adulyanukosol , in press). Necropsy of the sea turtles carcasses (various size from gravid females to juvenile) revealed that most of the stranded turtles died because of drowning, appendages cut by net, or swallowing fishing hooks (Kittiwattanawong, unpublished data). Trawling and drift/gill net are among the destructive gears that cause mortality or injure of sea turtles (Chan *et al.* 1988; Chantrapornsyl 1993). Illegal trawling has been personally observed in front of nesting beach at Phrathong Island, PhangNga province which is very vulnerable to the survival of sea turtles. The high sea driftnets were reported to catch the sea turtles in the internationals waters (Balazs 1982).

Habitats degradation

Increasing of tourist industry leads to rapid development along the coastal area. This creates both direct and indirect adversely impacts to sea turtles. The construction of hotels, resorts, restaurants, shops have changed once-remote beaches unsuitable for nesting. Lighting and activities on the beaches (beach camping and fire) at night prevent sea turtles to nest. The vehicle driving on the beach causes sand compaction and rutting, and can accelerate erosion. Reduction of feeding habitat (*e.g.*

sea grass bed) caused by pollutants from domestic sewage water and physical damage by push net was reported (Poovachiranon & Chansang 1994). Ingestion of non-degradable debris such as plastic bag and rope was reported as cause of mortality in sea turtles (Kittiwattanawong, unpublished data).

SUGGESTED ACTION PLAN

A common management plan

Lacking of cooperation among responsible organizations has been recognized as one of the failure in conservation management. The common master plan should be adopted and practiced in a harmonic way among responsible organizations. However, in the real world, operation often occurs individually. Each organization rises up its own goals. Further more; inconsistency of the managing policy inside the organization is another problem. A replacement of a new director often leads to new policy which varies upon the experience and vision of each chief. A long term master conservation and management plan should be setup base on agreement of all responsible organizations. An annual meeting should be held for sea turtles status evaluation.

Habitat reserves

An idea of marine reserves has been proved as one of conservation means (Chan 1991; Dethmers 2000). The study employing satellite telemetry (Chapter 3) revealed that the 5 km protective boundary from the nesting beach and feeding ground should be proclaimed. Most of the green turtle nesting sites confined within the insularly national parks. With increasing number of tourists visiting these national parks, the development of these insular national parks to serve for tourisms tends to adversely effect to the nesting of sea turtles. Higher number of visiting boats increases changes to collide to sea turtles during internesting or migration. With these regards aspects, quota on the number of tourists should be issued with the balance of environmental degradation and the business income.

Construction in the national parks should be confined behind the beach front.

Artificial reef may be employed to protect sea turtles from trawling. In a mean time, this would increase shelter for marine life which will in turn increase production in the area. Harmful fishing gear such as drift/gill nets should be minimized within defined feeding and internesting grounds

Increasing law enforcement

Illegal fishing particularly, trawling within 3 km boundary along the nesting sites still occurs frequently. A number and effort for patrolling should be increased especially during nesting season (*e.g.* November – January). Enforcement, judicial and prosecutorial personnel must receive adequate resources as well as instruction about sea turtles and importance of protecting turtle populations. Beach patrol should be performed regularly to prevent egg poaching.

Education and awareness building

While increase law enforcement will be effective in a short term, without support of the local people, regulations will become ineffective. Education of public as to the value of conserving sea turtles is a very effective way of sustaining recovery efforts and providing support for enforcement of management regulations. Education should not be only concerned to sea turtles, but also the importance of preserving their habitats. Personal communication to some coastal villagers suggested that the altitude to consume of sea turtles is still remaining in elder generation. Some people still believed in extraordinary nutritional value of sea turtle eggs (despite of the fact that a turtle egg provide lesser energy compared to a chicken egg, Penyapol 1957). Trained school children and young generation particularly those who live in sea turtle-encountered places would provide conservation feedback to their elder generations. Local villagers who have high potential to encounter with sea turtles should be educated the proper protocols when they find nesting or injured sea turtles.

Conservation education should also be given to tourists. Beach walking to look for sea turtles at night which is adopted traditionally should be performed with the proper guidance. The number of walkers should be limited each night. Fire camping or use of torches should be prohibited. Tourists should be informed not to have activities such as "petting" turtles and chasing them while snorkeling and scuba diving, especially in sensitive and high density foraging and internesting areas. Vessel traffic and anchoring should be regulated or controlled to eliminate negative impacts.

Captive breeding and head started program

Rearing of hatchling for a period of time (usually 3-12 months) before releasing is common in Thailand. Such a program has been adopted for long period and still becomes popular to use as awareness campaign. Public has a chances to encounter juvenile sea turtles and release them back to the sea. Nearly all of hatchlings are head started. However, despite such a long term hatchery operation, all turtle populations trend is going down. The same thing has been happening to Malaysian sea turtle populations (Chan 1991). Hence, it would be suggested to re-evaluate and consider a new way of releasing. At the mean time, a standard protocol should be developed by the appropriate agencies for the care and maintenance of sea turtles including diet, water quality, tank size, and treatment of injury and disease. A manual of this standard protocol should be compiled, published, and distributed to responsible organization.

Stranding network

The responsible organizations should have a common network system to register stranded sea turtles when ever be reported or found. Public should be informed about the existence of such a network so that anybody who encounter a stranded turtle can reported to it. Such a network can be useful for alerting managers to incidents causing mortality such as increased fishery bycatch, pollution, or disease problems, as well as providing some basic biological data. Live stranded sea turtles should be transferred to the organization with "rescue" ability or rescue center should be setup to support these injured or ill sea turtles.

Researches requirement

Several research aspects are required to be fulfilled. A genetic survey to establish signature of each nesting population must be established. The Chapter 4 revealed that mtDNA sequencing may not sensitive enough to distinguish the two green turtle populations in Thailand. Highly variable markers such as Microsatellite technique may be employed. Genetic investigation should also be extended to the regional populations. Once, nesting stocks have been genetically tagged, it is important to pair juvenile, sub-adult, or feeding stocks with their nesting populations. This issue is important to stock management.

Nesting monitor should be performed on regular basis particularly in the major nesting grounds such as Khram Island and Huyong Island. Distribution and abundance of post-hatchlings and juveniles should be observed as well as their migration patterns. Diseases on sea turtles in both captive and natural condition should be studied. Habitat carrying capacity should be evaluated.

Regional cooperation

Since it is found that nesting populations of green turtles migrate outside Thai territorial waters during at least part of their life cycle, an effective conservation plan must be cooperated with other nations to protect the species. The existing cooperation such as CITES, Convention of Migratory Species (CMS) should be adopted through out the region. Information and researches sharing should be setup with a common assessable database system. Regional meeting for a common conservation management should be held regularly.

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Master Thesis

The study on coastal management policy in Rayong, Thailand by system dynamics

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The study on coastal management policy in Rayong, Thailand by system dynamics

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ABSTRACT

It's noted generally that natural environment are getting worse to worse with development of human society. In coastal area especially, we can see often the environmental deterioration. The tourism impact is rapidly increasing recently. For developing countries, a rapid growing tourism industry has proved to be an increasingly important source of foreign exchange inflows. However, the tourism industry is increasingly having an ecological impact on the world's protected areas and the rising number of tourists presents both threats and opportunities. Against this background, many regional managers are beginning to seek the way to establish the regional management system which can realize environment conservation, tourism development, and local community development. This study was conducted in the Rayong coastal area, Thailand. The objectives were to construct the computer simulation model for the coastal management and to suggest the coastal management policy based on the simulation results.

Firstly, in order to grasp the current situation of the local community and to bring to the light the problem of the regional management from the resident's and the tourist's perception and awareness, I conducted the research of the statistical data and the reports, and the questionnaire survey for the residents and the tourists in the Rayong coastal area. In this result, the economic disparity between the fishing household and the worker of tourism industry, and the garbage problem are clarified as the problem for regional management in future.

Secondly, in order to analyze comprehensively the transition of local society in the Rayong coastal area by system dynamics, I constructed the simulation model represented the interlinkages between tourism, local community, and natural environment. The simulation is conducted in scenario which the Rayong coastal area develops on present showing. This result is thought to be a base for future discussion. All correlation coefficient values are generally high, especially the number of visitor and the population of the fishing households. This

implies this simulation model is appropriate to the regional management tool.

This model is based on the assumption that the contaminants from industrial waste currently have a great impact on the ocean environment and the fish resources. Consequently the fish stocks drop off suddenly, the catch landings and the income of the fishing households also drastically decrease. The downturn of fishery in this area makes the fishing households change their jobs or move out to the other places some day. Meanwhile the sign of a slight recovery of the fish resources appears in last term of the simulation period when the effect of the contaminants and the decreasing trend of the fishing households begin to sink down at last. Although the fishery which is the largest factors of the destruction of the coral reef and the plastic garbage fall in decay, the condition of the coral reef and the amount of the garbage could not improve absolutely because many construction of the hotels and a lot of the tourists, excursionists from the development of the tourism industry affect the condition of the coral reef and the amount of the garbage instead of the fishery.

The most important problem in this area is thought there is no means to activate fishery in this area. After the impact of the contaminants is very small, the fish resources recover little by little. On present showing, the recovery of the fish resources takes about 50 years. In reality, the fishing households in consequence, the growth of population of the fishing household with the increment of the fish catch landings gets more impact reversely on the coral condition and the amount of garbage, thus which bring about the decline of the visitors.

These results and considerations proved in practice that this simulation model by system dynamics is effective tool to analyze comprehensively the complex web of local community, and provides the great deal benefit for a regional management. By shifting the parameters in each section of this model, I can observe these variations of the components in the various scenarios. Additionally, on the basis of the results of many simulations in the various scenarios, I will be able to forecast the shift of the Rayong coastal area, and enforce the effective management policy toward all problems. A future issue is to simulate the effect and the ripple effect of introducing ecotourism by System Dynamics, and to feed this result back to the simulation model for regional management.

タイ国ラヨーン県におけるシステム・ダイナミックスを用いた沿岸域管理政策に関する研究

奥山　隼一

内容梗概

近年、人間社会の発展に伴い、自然環境・生活環境が悪化していることは周知の事実である。とりわけ、沿岸域の環境へのインパクトの中で、近年著しく増加を見せているのが観光によるインパクトである。観光産業の急激な発展は、その地域の自然環境を破壊し、観光客の激減を招き、地域の経済は破綻させる可能性がある。このような背景を踏まえて、近年では自然環境の保護と観光産業の発展、さらには地域社会の発展を共に実現する新たな形態の観光、そして地域管理の手法が模索され始めている。本研究では、ケーススタディとしてタイ国ラヨーン県の沿岸地域をとりあげ、コンピュータ・シミュレーション・モデルを適用することにより、観光の発展に伴う地域管理の在り方について考察し、この地域の地域政策・計画について提言を行うことを目的とする。

本研究ではまず地域社会の現状を把握し、地域住民・観光客の意識・認識のレベルからの地域社会の問題点を明らかすることを目的に、タイ国ラヨーン県において、統計資料の収集とアンケート調査を行った。この結果、観光関係者と漁業関係者の間で経済的な格差があることが明らかになった。また、ゴミ問題が観光客、地域住民の間でかなり意識されており、ゴミ問題の放置は、観光客の減少を引き起こす可能性があることが明らかになった。

次に、ラヨーン県沿岸域の社会構造を包括的に分析するため、システム・ダイナミックスを用いた観光・地域社会・自然環境を表したシミュレーション・モデルを作成した。シミュレーションは、ラヨーン県沿岸域が現在の調子で発展した場合について行った。この結果はすべてのシミュレーションの考察に対する基盤となるためである。実測値とモデルによる理論値の相関係数はおおむね高い値を示し、このモデルが沿岸域管理政策に応用するのに適していることを示した。

このモデルは、工業排水による汚染物質がこの地域の水産資源や海洋環境に強い影響を与えていることを前提としている。その結果、水産資源量とそれに伴う漁獲量は急激に減少し、漁業関係者の収入の低下を招いた。長期

にわたる水産業の低迷は、この地域の漁業関係者へ転職や他の場所への移動を強要しかねない。しかし、一方で、汚染物質の影響が少なくなった時分より、僅かながら回復の兆しが見える。水産業は珊瑚礁やゴミ問題に最も大きな打撃を与える要素であるが、水産業が低迷している間も、珊瑚礁の状態が回復することはない。なぜならば、水産業の代わりに旅行者と地域住民の増加が見られるためである。そして、ゴミはシミュレーション期間内において絶えず投棄されているため、増加の一途を辿るばかりである。これらは現状のままこの地域が発展していった場合、回避できる術はなく、現状の問題として捉えることできる。

この地域における管理政策において、最も重要な問題は漁業を活性化させる手段がないことである。汚染物質の影響がなくなって後、漁業資源が回復するのに 50 年を必要とする。しかし、実際には漁業関係者は 50 年も待てるわけはなく、回復するまでの間何かの対策を講じなければならない。一方で 50 年経過し、漁業資源が回復した後、珊瑚礁とゴミの量の増大により、観光客が激減することがわかった。その後、漁業資源と観光客は交互に入れ替わりながら、急激な増減を繰り返すことが明らかになった。また、この繰り返しは終わることはなく、地域社会としてうまくいっていると判断できる。

一度漁業資源が回復すると、地域社会としてうまくいくことができる。ゆえに、50 年後に漁業資源が回復するまで、漁業者に新たな仕事を与える政策を施行しなければならない。新たな地域管理政策として、ラヨーン県沿岸域にエコツーリズムを導入することは、漁業者の収入を増やし、かつ水産資源量の回復を早めることができる。今後、エコツーリズムを導入した場合にどのような波及効果が現れるかを、具体的な現地調査を踏まえて明らかにし、シミュレーション・モデルに組み込んで、その効果を検証することが、さらに地域管理に貢献するための課題となるであろう。

Contents

Chapter 1. Introduction

1.1. Necessity of another regional management system

It's noted generally that natural environment are getting worse to worse with development of human society. In coastal area especially, we can see often the environmental deterioration because coastal zone is a point of contact between the land and the sea. In the various impacts on the coastal area, the tourism impact is rapidly increasing recently. Nature-based tourism is most popular among the tourists, in which marine tourism industry is rapidly growing **[1]**. This trend of tourism development is expanding to the world. For developing countries, a rapid growing tourism industry has proved to be an increasingly important source of foreign exchange inflows. Nature-based tourism is an important tool for generating employment and income in underdeveloped, biodiversity-rich Third World regions because it requires comparatively small investments **[2]**. However, the tourism industry is increasingly having an ecological impact on the world's protected areas and the rising number of tourists presents both threats and opportunities **[3]**.

Against this background, many regional managers and planners are beginning to seek the way to establish the regional management system which can realize environment conservation, tourism development, and local community development at all once. The good example of the regional management system is "Ecotourism".

1.2 Ecotourism and this availability

Ecotourism is defined by H.Ceballos-Lascurain, the World Conservation Union (IUCN) as follows; "environmentally responsible, enlightening travel and visitation to relatively undisturbed natural areas in order to enjoy and appreciate nature (and any accompanying cultural features both past and present) that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of local population"**[4]**. Concretely, ecotourism is commonly recognized as the available tool which can realize the natural conservation, environmental education for tourists, and economic and social contribution to local society. Ecotourism is compounded of many interrelated processes which influence the potential and success of ecotourism within a protected area and links between natural areas, the local people and tourism [5]. As a characteristic of ecotourism, each function of ecotourism promotes the other function each other in ecotourism system. Sustainable ecotourism can be realized only after local society manages economics, sociality and natural conservation by itself.

In the process of development of ecotourism, local perceptions will be an important factor influencing how its development proceeds [6]. Furthermore, if planning and decision-making do not involve local populations, then ecotourism will not succeed, and may even be detrimental to local communities [7]. Therefore, the local perception is important key to consider the possibility of ecotourism success. Additionally, to date, although many studies have been performed about areas which are developing as an ecotourism spot, just a few have assessed how the sustainable ecotourism is realized in the place where the ecotorusim is introduced in the future.

1.3 Availability of the computer simulation model for regional management

Nowadays, in social-economic field, the availability and the usability of computers is get better, because the economical analysis, the objectives of which is regional planning and analysis, is accompanied with the complex problems. Additionally, the case studies which intend to the specific area can apply to the other cases by employing the regional simulation model. Thus, simulation model can be applied to the multiple fields astride among economics, sociology, and ecology.

In the other view points, computer modeling can be used in building consensus between disciplines; science, policy and public. The process of modeling can help build mutual understanding, solicit input from a broad range of stakeholder groups and maintain a substantive dialogue between members of these groups. Therefore computer simulation modeling is available to make the regional management model and planning which consider fully all of tourism, local society, and natural environment [8], which can apply to any other area for regional management. The modeling process must involve ecological, sociological and economic aspects in order to clarify the interlinkages about the way in which the system works. Although as a characteristic of the computer simulation model, the challenge of linking ecological and economic data is not restricted, however all over the world the integration of ecology and economy is posing major challenges, and several studies with the goals have been carried out or under development. So this approach of the simulation model to the regional management is very novelty in this field.

1.4 Objectives

This study employed the Rayong coastal area, Thailand as a case study. The objectives of this study were to construct the computer simulation model for the coastal management and to suggest the coastal management policy based on the simulation results. The regional management model should be on the basis of resident's & tourist's perception to assess some important ecological & economic linkages between environment, tourism, & local society in the Rayong coastal area. In addition, we suggested the ecotourism planning from the result of modeling.

In order to complete these objectives, I set two steps. First was to grasp the current situation of the local community and to bring to the light the problem of the regional management from the resident's and the tourist's perception and awareness, which was described in Chapter 3. On the basis of this result, we considered the way of regional management. Second was to construct the computer simulation model for the coastal management, which was described in Chapter 4. Through the process of modeling, the Rayong coastal area was analyzed quantitatively and in chronology. But the computer simulation model needed to confirm the accuracy of this simulation, because the improper simulation model elicits the completely different results. And erroneous results give only the wrong regional management policy. Simulation was conducted in case the Rayong coastal area develops on present showing. On the basis of this result, I clarified the interlinkages between the components of this model. Thereby I discussed future condition of this area in this scenario, and indicated some problems and key factors for further development in future.

In Chapter 5, I discussed the way to improve the management problems, and the possibility of application of ecotourism as another regional management system. In addition, we suggested the ecotourism planning from the result of modeling. The local perception is important key to consider the possibility of ecotourism success. Additionally, to date, although many studies have been performed about areas which are developing as an ecotourism spot, just a few have assessed how the sustainable ecotourism is realized in the place where the ecotourism is introduced in the future. Therefore, the suggestion of another regional management system by the computer simulation model will be good approach for the appropriate regional management policy.

Chapter 2. The current situation of Rayong coastal area, Thailand

2.1 The current situation as tour spot

Rayong province locates at the southeast, 210 km from Bangkok faces south onto the Gulf of Thailand. Many tourists visit this area to enjoy the marine sports and their relaxation. The number of tourists increases at approximately 4% per year in the past five years. In 2002, there were approximately 2.4 million tourists **[9]** (Fig 2-1). The Rayong coastal area is three integrated area; Ban Phe, Mae Pim Cape, and Samet Island (Fig 2-2). According to the tourism statistical data of these areas, the number of the visitors is about 680,000, which occupies about 51% of all visitors in Rayong.

As to the number of visitors by individual countries, of course first was Thai, the percentage of which was about 80. Second was Japan, about 2.7% of the total. The trend of visitors by individual countries had been to many Western and few Southeast Asia visitors compared with other tour spots in Thailand. As for the average length of stay, all tourists stay at average 2.15 days, Thai tourists stay at average 1.96 days, and foreign tourists stay at average 3.27 days. As to the average expenditure (per 1day, 1 person), all visitors spend average 1462 Baht, all Thai visitors spend average 13676 Baht, and all foreign visitors spend average 2116 Baht. As you know, foreign visitors have a tendency to prefer longer stay and more expensive tour style than Thai visitors.

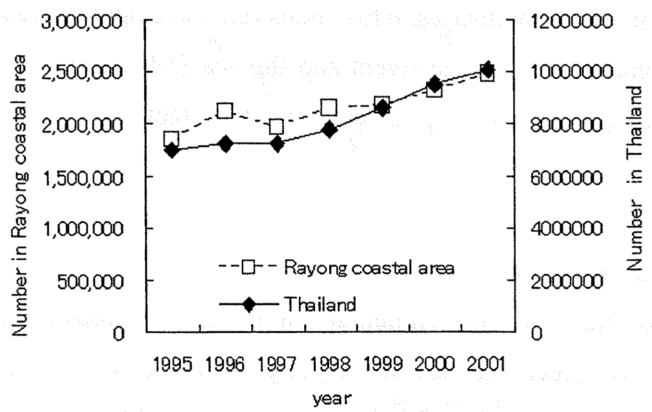

Fig. 2-1. The number of visitors in the Raoyng coastal area and Thailand

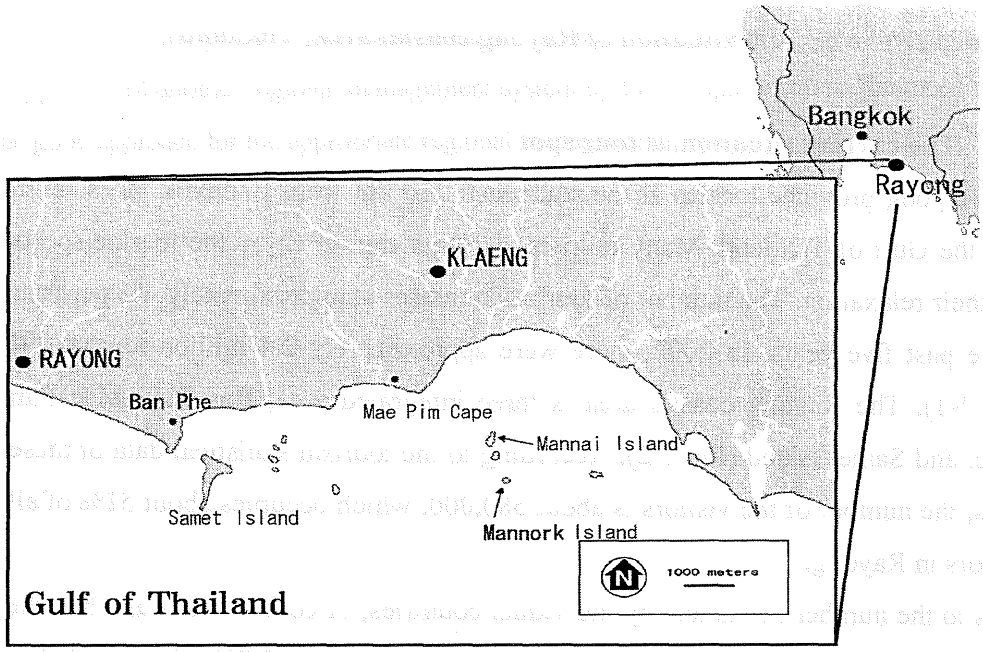

Fig.2-2. The Rayong coastal area.

2.2 The current situation as industrial area

Rayong province has another aspect of industrial area. In 1982, Thailand government has formulated projects for develop coastal area. Rayong province was determined to be an important stronghold for the heavy industrial development. The agricultural areas were replaced by heavy and continuing industries. And more than 6,500 rai (10.26 km^2) of marine areas have reclaimed. In 1991 when Rayong province was also developing as the tourist spot, marine areas were utilized as the reservoir of waste sink for heavy industries. This industrial development caused environmental poor outcome in the air, the rivers and the sea **[10]**. Although the scientific basis is not enough, this development is able to affect the ecological balance of the sea area.

2.3 Ocean pollution and the current situation of fishery

The mostly affected area by environmental pollution was coastal area. Industrial waste is able to affect the sea in Rayong province to deteriorate considerably. The total quality of marine fish landing was 166,270 tons at peak year in 1994, and then was decreasing at 79,943 tons in 1999 **[11, 12]** (Fig. 2-3). So aqua-animals had reduced their number dramatically, and some of species are even extinct. Meanwhile, on even the existing ones, the large amount of toxin has being accumulated. The mentioned situation is able to affect the ecological balance of preserved sea area. Additionally this deterioration of marine situation gets a great impact on local society directly. The main affected matter was related to environment. This caused to collapse the economy of neighborhood in preserved area, where they are inhabitant in the coast.

According to the survey of small boat fishermen's communities in the Rayong coastal area counted altogether 500 families, around 5,000 people. The communities are engaged in activities (95% are fishery alone). Economic division is middle poor class, some are still raising orchard. Annual income around 50,000 to 100,000 Baht, however about 50% of income is spent on repairing fishery equipments which damaged by trawling. Some of them are not land owner, has to raise a flimsy hut at sea shore, watch their boat and fishery equipment. In Mon-soon season they take a rest, each year the off-days are 30-60 days **[10]**. It depends on weather and tide. They had developed to sell catches; fish, squid, crab, and oyster which they have to sell every one for buying everything since they are no producer except fishery **[11, 12]**.

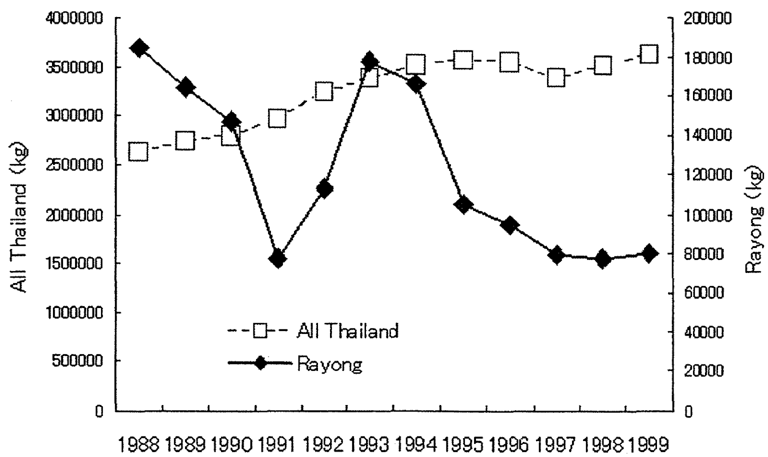

Fig.2-3. Fisheries production in quality in Rayong province and all Thailand

2.4 Necessity of the simulation model for the regional management in the Rayong coastal area

Given the facts related to the situation of tourism, industry, fishery, ocean pollution and local economics in the Rayong coastal area above, we can find the social problems caused by the complex web among tourism, industry, fishery, ocean pollution and local community. Moreover, further tourism development in future will make another problem appear, which is related to the environmental impacts such as the red soil runoff or destruction of coral reef caused by the construction of hotels and the tourists. In order to deal with these problems, we have to perceive and analyze comprehensively the complex web of local community in the Rayong coastal area. On this basis of the analysis, we can make a regional management policy. As previously mentioned in Chapter 1, computer simulation model is the effective tool to analyze comprehensively the complex social problems.

Chapter 3. The current situation and the problems in the Rayong coastal area from the perspectives of residents and tourists

3.1 Backgrounds and Objectives

Local community is compounded of many interrelated processes which influence the potential and success of the regional management within a protected area and links between natural areas, the local people and tourism. In the process of development of the regional management, local perceptions will be an important factor influencing how its development proceeds. Furthermore, if planning and decision-making do not involve local populations, then regional management will not succeed, and may even be detrimental to local communities. Therefore, the local perception is important key to consider the possibility of regional management success.

In this chapter, I conducted the research of the statistical data and the reports, and the questionnaire survey for the residents and the tourists in the Rayong coastal area which locates in the east part of Thailand. The objectives were to grasp the current situation of the local community and to bring to the light the problem of the regional management from the resident's and the tourist's perception and awareness. On the basis of this result, I considered the way of regional management and the appropriate ecotourism planning in the Rayong coastal area.

3.2 Methods

3.2.1 Research of the statistical data and the reports

The large amount of data was collected from the statistics, the reports, and the web pages in the various fields, which were tourism, local community, fishery, coral reef, ocean environment, industry, and garbage. Additionally as many statistical data and reports as possible are also collected in chronology because I can apply these data to the simulation model.

As to tourism, I researched the transition of the number of tourists, and excursionists, and the average expenditure for tour. From the reports about local community, I checked the labor population by the kind of occupation and their income. As for fishery, I researched the amount of fish catch and this average price.

3.2.2 Questionnaire survey

The questionnaire survey was conducted in the Rayong coastal area from 20 February to 10 March 2003. The questionnaire was prepared in Thai and in English. The questionnaire survey for the residents was conducted in villages and towns along the coast. For the tourists, we conducted in 5 points; "Ban Phe", "Mae Pim Cape", "Samet Island", "Mannai Island", "Mannork Island" (Fig. 2-2). We interviewed 172 residential households and 188 tourist groups, of which 171 and 186 were valid respectively. The contents of the questionnaire were the personal evaluation about natural environment, economic condition and social infrastructure in the 10 years ago, at present, and in 10 years respectively, and about the environmental problem in the Rayong coastal area. Furthermore, we asked for respondent's opinion about these contents by open question. For the residents in fishing villages, we interviewed extraordinary about recent fishery. The valid respondents of this questionnaire were 24 households. In the case each question was not filled out or possible to be inadequate, we excluded these responses from consideration.

3.3 Result and Discussion

3.3.1 The current situation of local community form the perspective of the residents

We asked the residents for the personal evaluation about natural environment, economic condition and social infrastructure in the 10 years ago, at present, and in 10 years respectively. The number of valid responses was 170 respectively. Fig.3-1 shows the result of resident's evaluation about natural environment and economic condition.

As to natural environment, many residents felt the past condition had been bad, and the current condition was better than the past. The perceptions of the future condition tended to vary with each respondent. As concerns of economic condition, the perceptions of the past and the current condition were similar trend to the ones about natural environment. In point of future, residents tended to have optimistic feeling, although the responses varied to some extent. As for social infrastructure, many residents felt that the past condition had been bad, and the current condition

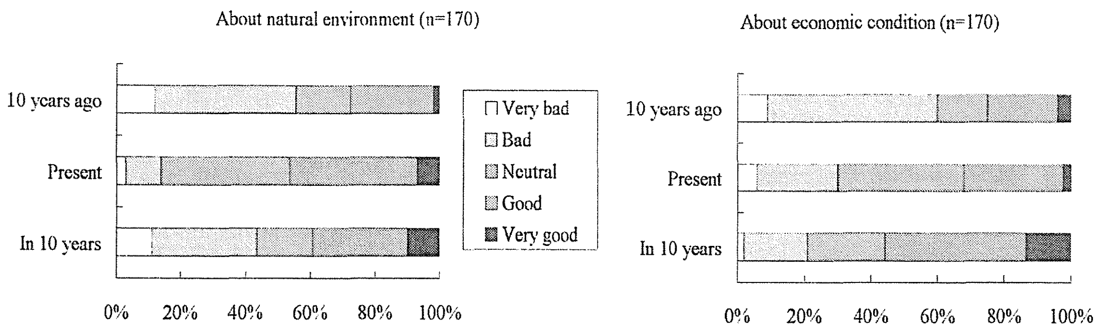

Fig 3-1. Resident's evaluation about natural environment *(left)* and economic condition *(right)*

was better than the past, moreover the future condition would be better than the current. According to these results it was considered that the perception about natural environment and economic condition varied with the individuals. Consequently we considered resident's evaluation additionally on the basis of resident's socio-demographic data.

3.3.2 The difference of the perception between the fishing households and the worker of tourism industry

As a result of the analysis the resident's perception on the basis of each socio-demographic data, it was emerged the difference of the perception between the fishing households and the worker of tourism industry (Fig 3-2). Most resident's jobs in this area were related to either fishery (n=44) or tourism industry (n=90). Many of the workers of the tourism industry tended to have optimistic feeling about natural environment and economic condition at present and in future respectively. On the other hand, many of the fishing households have pessimistic feeling. As for natural environment at present, the chi-square test was significant at 0.5%, and as for natural environment in future and economic condition at present and in future the chi-square test was significant at 0.1%. This difference of resident's perception is supported because the fishery was falling into the decline in this area **[10]**, while the tourism industry was developing **[9]**.

There are many fishermen's opinions concerning the decreasing of the marine

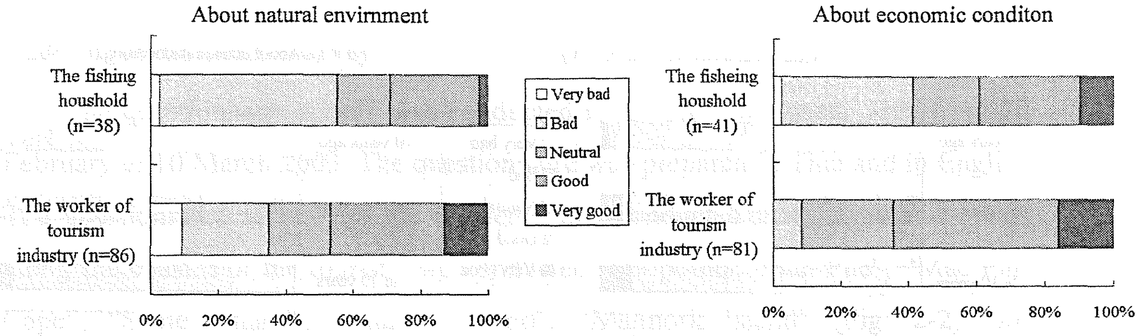

Fig 3-2. The difference of the perception about natural environment *(left)* and economic condition *(right)* in 10 years between the fishing households and the worker of tourism industry (the chi-square tests were significant at 0.1% respectively)

fish landing in the questionnaire. As to the current condition of fishery, 66% (16 of 24 respondents) answered the fish catches were more decreasing than before. Only 1 respondent answered "Unchanged". The others unanswered. As to the fishery in future, 88% (21 of 24 respondents) answered the fish catches will be decreasing. And the other answered "No idea". Additionally we asked 13 respondents who answered the fish catches will be decreasing about fishing in future. According to this result, 62% (8 of 13 respondents) answered they would continue fishing here, from which we can see the fishermen persist in fishing in this area. As for the reason of the decreasing of fish catches, there is a opinion that vessel's trawling have possibility to decline the quality of the marine fish landing.

In the terms of resident's income, the average monthly income per household in Rayong province in 2000 is 14,739 Baht **[17]**.

According to the questionnaire data, the average monthly income of fishing households (n=22) was 12,850 Baht, while the one of the worker of tourism industry was 18,458 Baht. We can see the economic disparity between the fishing households and the worker of tourism industry. It was clarified that the fishing households had anxiety about their living and the fishing in future because of small income compared with the other, the decreasing of the fish catches, and the futureless of the fishing in this area.

3.3.3 The environmental condition form the perspective of the residents and the tourists

The environmental perception of residents had difference between the fishing households and the worker of tourism industry as we had mentioned above. This difference was the most in perception for future.

In addition, we interviewed the residents about the most important environmental problem in this area (Fig 3-3). The valid responses were 151 samples. In the whole, there are 40% of the residents who answered "Garbage / Bad smell". The second and the third opinion were "Air pollution", "Decreasing of marine species", the percentages of which were 21% and 12% respectively. The percentages of respondents answered "Nothing" were 12%. These results show the residents in the Rayong coastal area have high level of awareness about the garbage problem.

For the purpose of the research about the tourist's evaluation of natural environment in the Rayong coastal area, we interviewed the tourists visiting to this area. The valid responses were 176 samples. Although the responses varied with the questionnaire spots, there are more unfavorable responses of "Very bad", "Bad" than "Very good", "Good" in each questionnaire spots except "Samet Island" which is designated as the ocean national park. In the next, we asked them about impression on the Rayong coastal area by open question. As for positive remark (n=102), there were concerned to "Beach", "Clean sea", "Nice climate", "Food", and "Good access". On the other hand, as for negative (n=105), many responses were concerned with the garbage problem, the percentages of which were even 61% of respondents who remarked negatively. In other responses, there were "Too many tourists", "High-priced". These results suggest that the environment in the Rayong coastal area was not good from the perspective of the tourists and the garbage was important problem for developing the tourism industry.

"Garbage" which mattered among the residents and the tourists is scattered along the street, on the beach, over the sea, and around the villages. Except the garbage over the sea, large part was thrown away by the residents. This garbage is much amount, to the extent which we cannot collect or clean up easily. Especially around the fishing villages there are a great deal of much amount of the garbage. Some of the fishing households live in the house built over the garbage. Furthermore, the garbage condition got worse and worse because stray dogs foraged for food.

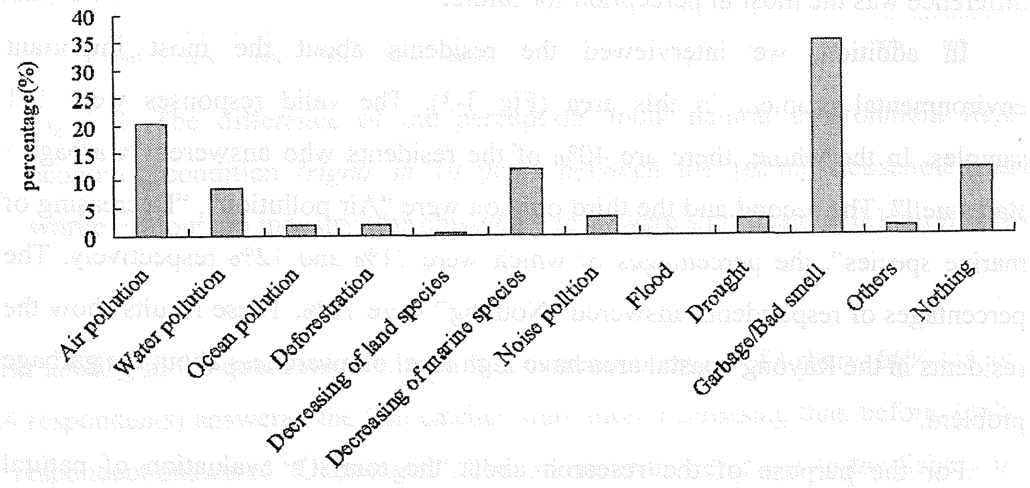

Fig.3-3 The most important environmental problem in this area from the perspective of the residents: n=151

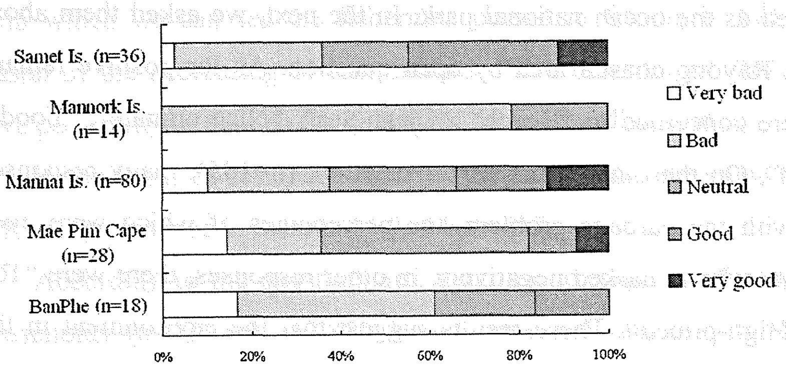

Fig 3-4. The tourist's evaluation of natural environment in the Rayong coastal area

(Samet Island, Mannork Island, Mannai Island, Mae Pim Cape, Ban Phe)

3.4 Conclusion

3.4.1 The regional management model in the Rayong coastal area

Based on these problems & some statistical data, we constructed the regional management model in the Rayong coastal area. This model's components are "Natural environment", "Residents", & "Tourists" (Fig 3-5). As a subclass of "Natural environment", there are "Fishery resources", & "The amount of Garbage". And as a subclass of "Residents", there are "Fishing households", & "Worker of tourism industry".

The current situation of tourism is very well and if the Rayong coastal area develops on present showing, it is expected that the tourism industry grows and with which the number of tourists is increasing for some time in the future. At present half of the tourists take a bus to visit to the Rayong coastal area, and the other take my/ rent-a-car **[13]**. If it is supposed the number of tourists is rapidly increasing, for example a new train route is opened, the residence managers or planners have to pay attention to the environmental pollution and the garbage problem caused by the tourists which is not brought to the light yet. The expansion of tourism has the possibility to promote the price rises which put pressure on the low-income fishing household's living.

Although it is not clear whether the ocean pollution gets better or worse, it is suspected that the decreasing of the fishing catches still remain for a while. Some measures toward the coastal fishery and the fishing households are required quickly.

A lot of tourists, especially foreign tourists, are displeased for the garbage. Recently the eastern coastal area in Thailand is being developed as a tour spot, for example Chanthaburi province and Trat province. The neglect of the garbage problem will cause the drain of the tourists to the other tour spots. The effect of the tourists on environmental doesn't come to the surface yet. But, the region managers or planners have to pay attention to the environmental pollution and the garbage problem caused by the tourists. Therefore, it is considered that the garbage problem was dealt with seriously from the resident level.

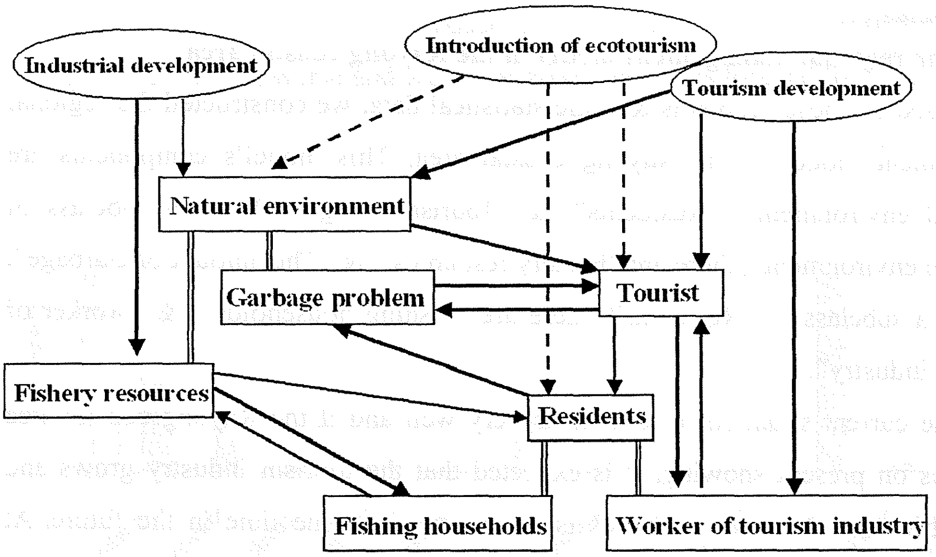

Fig 3-5. The regional management model in the Rayong coastal area

3.4.2 Ecotourism planning in the Rayong coastal area

To date, the definition of Ecotourism has been arranged by a lot scientist **[4, 7, 14]**, and the concept was modeled by S. Ross **[15]**. However, the reality varied with each land characteristic and the main purpose of ecotourism. In this study, considering the ecotourism planning in the coastal area, it was clarified that the local community had some groups which had different aspects. In the case there are some local groups related with ecotourism like the Rayong coastal area, it is considered that the relationships between local groups or their occupations are very important. Additionally in case there are many low-income fishing households like this, even if they are related to ecotourism directly, their livings should not be oppressed with the development of ecotourism. By contrast, we have to make a ecotourism plan which can present new employment opportunities to them.

As Campbell **[6]** said, local perceptions will be important factor in promoting to develop on the ecotourism. On the basis of this concept, the fact that the fisheries households feel good about the environmental and economic condition will fuel their motivation so much to participate in ecotourism. Meanwhile, although the local people tended to have further income, but not want any life-altering risk in this area. Additionally, we can see the fishermen persist in fishing in this area. This implies that the difficulty in introducing ecotourism into the Rayong coastal area, because their hope for not altering the present life could motivate them to avoid new things. To make the fisheries households to be willing to develop ecotourism by themselves, ecotourism will have to be something appealing that they can benefit from. Therefore, when we will introduce ecotourism, whether we can make a program which gives another job that the fishing households want (for example, the short time job which we can employ many people) to them can be the key to the success of ecotourism.

To solve the garbage problem and the economic discrepancy is the best way to manage this regional area. In order that to realize ecotourism, it should make the ecotourism planning including the solution of these problems. Now the Sea Turtle Conservation Station in Mannai Island is promoting the project to gather the tourists (ex. constructing the information center). The prospective scenarios in introducing ecotourism in the Rayong coastal area are as follows;; to increase the tourists because the tourists get another chance to visit to this area, to secure resident's income, especially the fisheries households, because the employment opportunities are increased. Concretely, the employment as a reception in the information center, the boatman to some Islands and the cleaner in the Rayong coastal area are considered as the appropriate ecotourism planning.

Chapter 4 The construction of the simulation model for the regional management in the Rayong coastal area by system dynamics

In this chapter, the objectives were to construct the model represented the interlinkages between tourism, local community, and natural environment on the basis of the questionnaire survey and the research of the statistical data in chapter 3, and to analyze comprehensively the transition of local society in the Rayong coastal area by system dynamics. Firstly the simulation was conducted in scenario which the Rayong coastal area would develop on present showing. This result was thought to be a base for future discussion. Therefore from this result, I indicated the problems for regional management in this area.

The simulation model was composed among tourism, local community, and the fishery. Additionally, the industrial waste, garbage which became problems in Chapter 2 and 3 were incorporated into the simulation model. Therefore this result of simulating was considered to contribute the regional management and policy in the Rayong coastal area.

4.1. Methods

4.1.1. System dynamics [15]

"System Dynamics (SD)" is one of the simulation methods, which created by Prof. Jay W. Forrester, MIT (Massachusetts Institute of Technology) in 1961. At that time, this method was used to predict the transition of the company, thus is called "Industrial Dynamics (ID)". Additionally, he developed "Urban Dynamics (UD)" for the urban and local problem. This method was developed and improved by many scientists, at last the targets of this method was related to the big problems at state level. Since 1980s these methods became to be called "System Dynamics". The SD is applied to the further broad swath of problems which are for the discussion of political problem related to urban management, regional management, the marketing strategy of new products and decision making related to the investment on the research and development, the analysis of the interlinkage between human activity and ecosystem.

4.1.2. Modeling tools for scoping and consensus building

In this study, I employed the simulation software; STELLA (by High Performance System) in order to construct the simulation model based on the perspective from the tourists and the resident in the Rayon coastal area. The STELLA is the software which simulates the SD on the computer. The characteristics of this software is a specific interface which user can construct the simulation model interactively and get the result of simulation automatically when user set the equation or the parameters. Fig. 4-1 shows the block for modeling on the STELLA, which is explained as follows;

1) STOCK

STOCK is used to represent something to accumulate such as the number of individuals, the water of reservoirs.

2) FLOW

FLOW is used to represent some activities, concretely the variation per unit of time

3) CONNECTER

CONNECTER transfers the information for adjustment of FLOW. CONNECTER can connect FLOW and CONVERTER (next block), but not connect STOCK.

4) CONVERTER

In CONVERTER, the equation is defined to generate the output value, and CONVERTER can convert the imported information into another. CONVERTER can reserve the constant value.

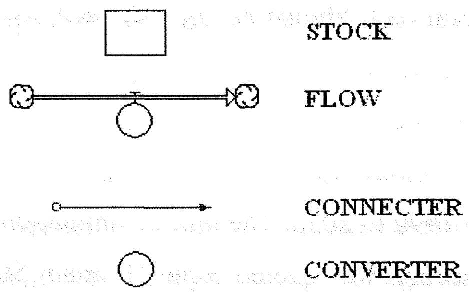

Fig 4-1.
Blocks for modeling by STELLA

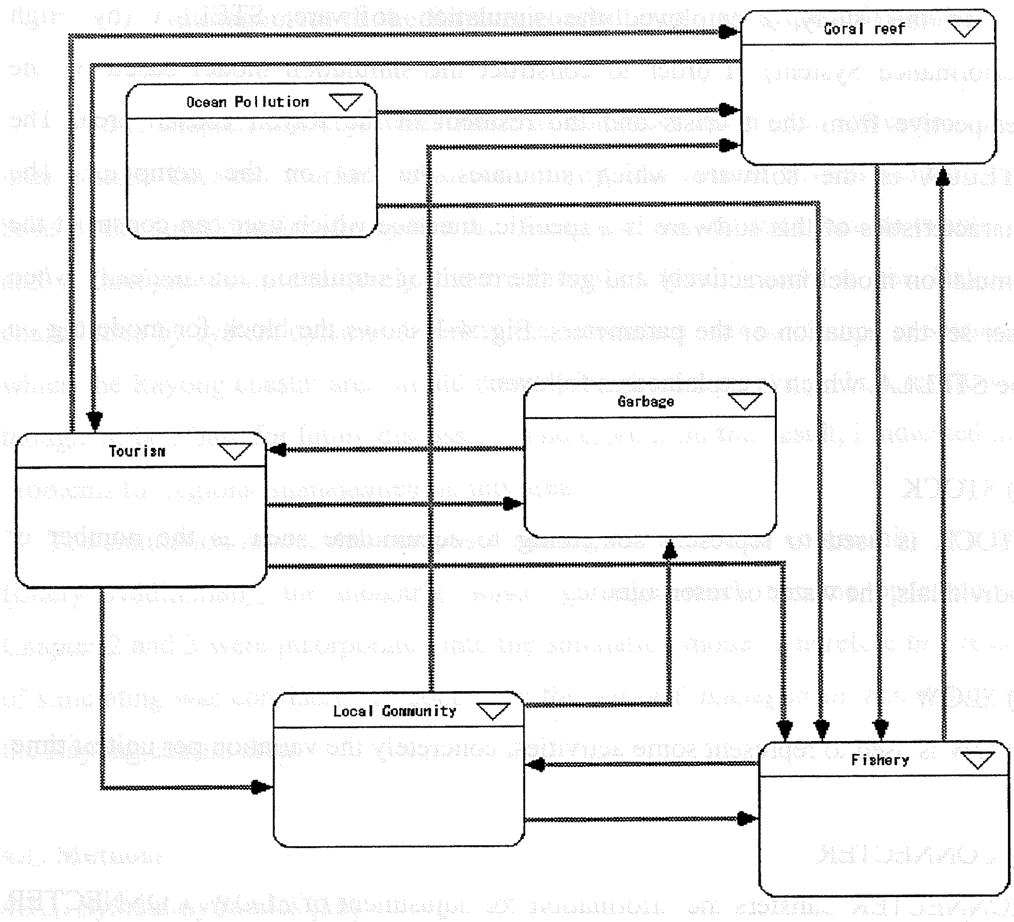

Fig 4-2. The overview of the simulation model in the Rayong coastal area

4.2. Structure of the model

Fig 4-2 shows the overview of the simulation model in the Rayong coastal area. This model is composed of six sections which are tourism, local community, fishery, ocean pollution, garbage, coral reef. Shown in Fig 4-2, each section has a relationship with other sections.

4.2.1. Time frame and Data

This model was set to run from 1990 to 2030. The unit of simulation (dt) was set as 1 year. The data of tourism section was quoted form "Tourism Statistics in Rayong, 1993 – 2002 **[9]** & Statistical Report 2001 **[13]**". As to local community section, I employed "Statistical Report of Changwat. 1992 – 2002 **[16]**". The data of fishery section was quoted from "Fisheries Statistics of Thailand 1995, 1997, 1999 **[11]** & The Landing Place Survey of Thailand 1992, 1994, 1999 **[12]**". As for the data of garbage section and coral reed section was referred to "Study on Actual Situation of Drifted Garbage. Thunyawit Pongpo.2002 **[17]**", and "Coral Map of Gulf of Thailand. 1999 **[18]**", respectively. In this regard of garbage section and coral reef section, I applied subjective values to the initial value and the variation rate because the data was existed in only one year, and I just grasped the transition tendency of the coral reef and the garbage. The data of ocean section was quoted from "International Seminar on Marine Fisheries Environment, Rayong, Thailand **[19]**". In regard of this data, I also applied subjective values to the initial value and the variation rate because the data was existed in two years. Additionally, I collected the further data from interviewing the residents and the public officers of tourism, fishery and ocean environment. Subjective value was set as near real value as possible on the basis of the reports and the interviewing.

Calibration of available data of fishery, tourism, local community from 1991 to 2001 with the results of the model is presented in 4.3.1. In addition, I evaluated the accuracy of this simulation model by calculating the corresponded coefficient between the real value and the theory value.

4.2.2. Tourism Section

The objectives of tourism section are to predict the number of visitors to the Rayong coastal area, and the economic effect of tourism on this area. Given that the trend of tourism is considered, it is better to consider in dividing the visitors into four categories, which are Thai tourists, Thai excursionists, Foreign tourists, Foreign excursionists, because these four categories have each different trend on the number, the length of stay, and the expenditure per 1 day_1 person (Table 4-1). The excursionist means the visitor who does not stay at somewhere. Thereby this model was constructed in dividing the visitors into four categories.

The number of visitors was defined as follows; in each category; Thai tourists, Thai excursionists, Foreign tourists, Foreign excursionists.

Table 4-1. Average number of tourists, Average length of stay & Average expenditure in four categories; Thai tourists, Thai excursionists, Foreign tourists, Foreign excursionists

	Number	Length of stay (Day)	Expenditure (Baht/Person day)
Thai Tourists	1244395	2	1573
Foreign Tourists	211093	3	2294
Thai Excursionists	664755	1	848
Foreign Excursionists	57209	1	1200

Number of visitors (t)

=Number of visitors (t-dt) + Variation of number of visitors ×dt (1)

Variation of number of visitors

= IF (Total number of tourists < Capacity of hotel)

THEN Number of tourists * (Growth rate – Crowds of tourists – Amount of garbage – Coral condition)

ELSE 0 (2)

In this model, the number of tourists is affected by the crowds of the tourists, the amount of garbage, the coral condition and the capacity of hotel. In these days, the growth rate of the number of the tourists is about 4 % per year in the Rayong coastal area. Moreover, Rayong province is developing area. Therefore it is expected that the growth rate is increasing in future. In this model, the growth rate of the number of the tourists is set as constant, and in the viewpoint of the impact of the crowds of the tourists, the amount of garbage, the coral condition and the capacity of hotel on the variation of the tourists, I defined the equation (2).

The economic effect of tourism on the Rayong coastal area, that is, the total income of tourism was defined as follows;

Total income of tourism

= Income from Thai tourists + Income from Thai excursionists + Income from Foreign tourists + Income from Foreign excursionist (3)

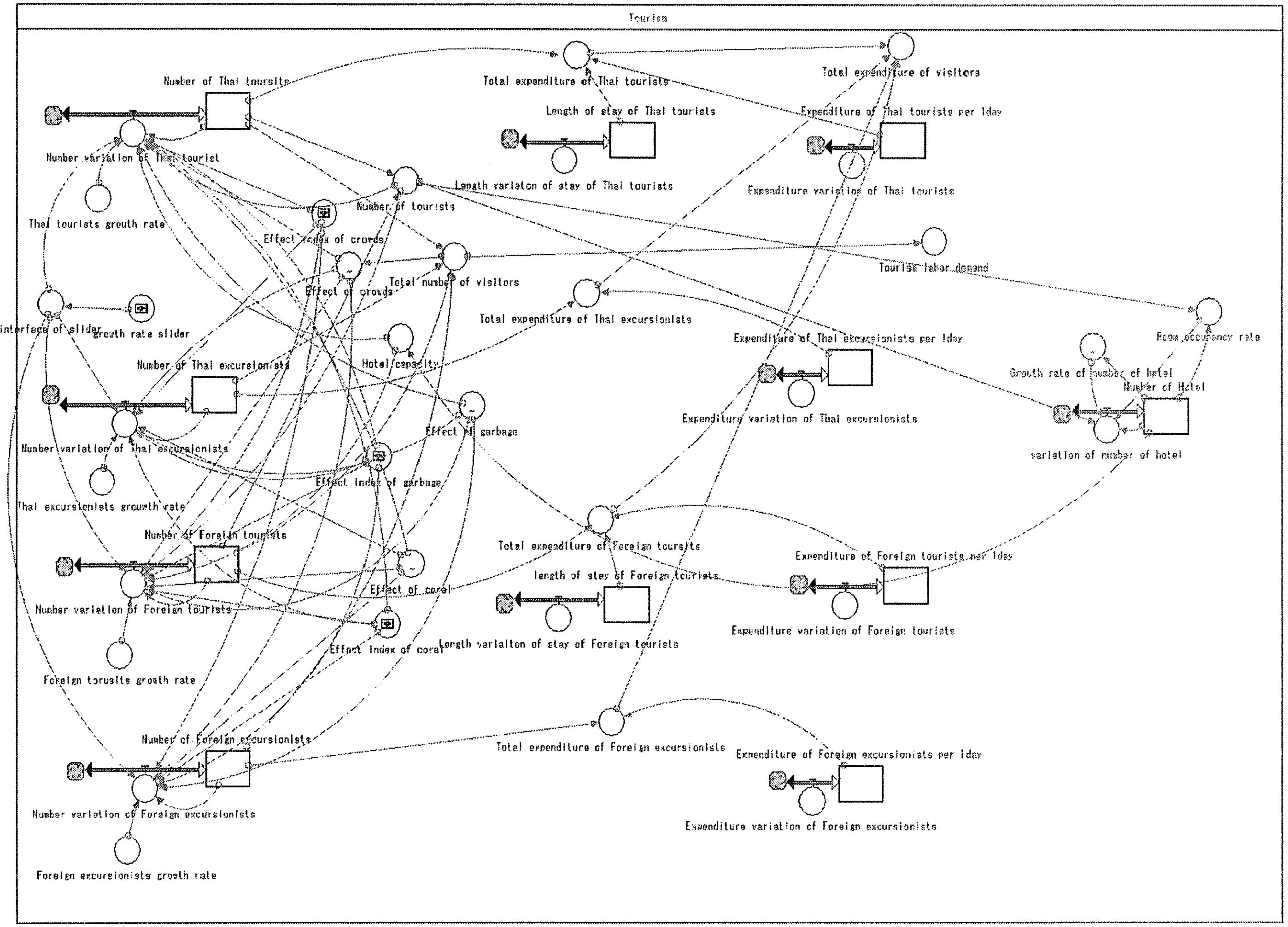

Fig 4-3. Tourism Section

Each income from Thai tourists, Thai excursionists, Foreign tourists, Foreign excursionists was defined as follows;

Income from tourists

= Number of tourists * Length of stay * Expenditure per 1day_1 person (4)

The hotel which has a impact on the tourists is included in tourism section. The variation of the number of the tourists affected the number of hotel, and reversely the number of hotel affects the total number of tourists

4.2.3. Local community Section

Local community section is composed of two categories which are the fishing households and the worker. Because the kinds of resident's occupation in the Rayong coastal area are broadly classified into two; fishery and tourism according to the result of the questionnaire survey in Chapter 3. The objective of this section

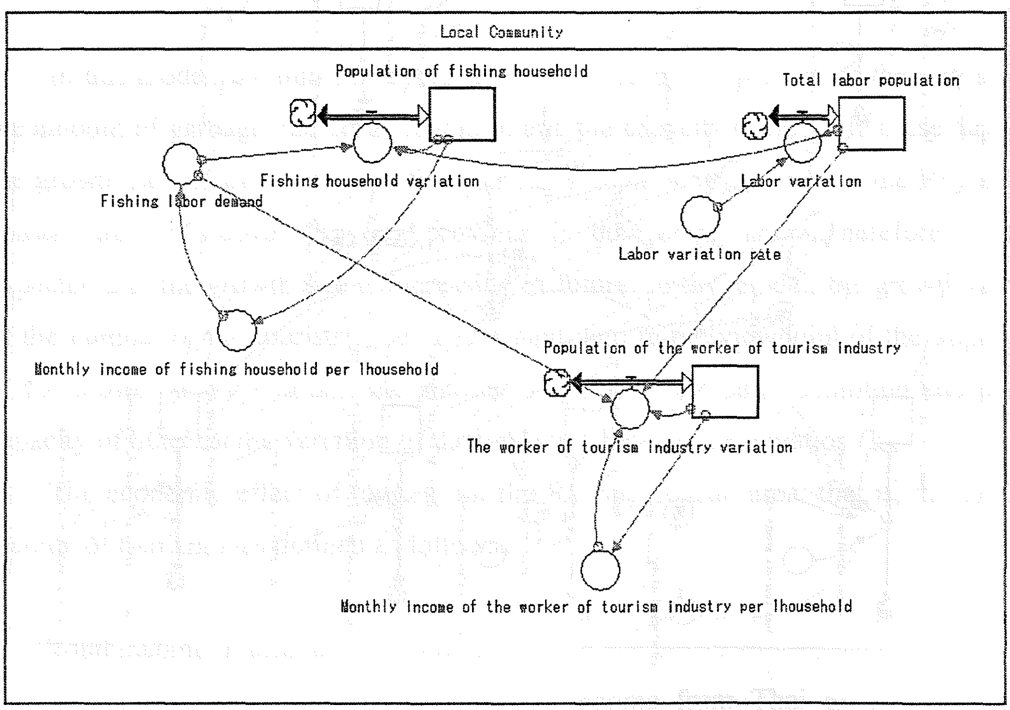

Fig. 4-4. Local community section

is to predict the monthly average income of the fishing households and the worker of the tourism industry per one household.

There are three stocks which are “Population of the fishing households”, “Population of the worker of tourism industry”, and “Total labor population”. “Total labor population” has a effect on the variation of “Population of the fishing households” and “Population of the worker of tourism industry”. Generally, the variation of population is calculated by the number of birth, dead, emigration, and ingression. The numbers of birth, dead are affected by the present population, whereas the numbers of emigration, and ingression, especially in the developing country, depend on the economic condition in the area. So it is very difficult to forecast the variation of population on the basis of the economic consideration. But the labor population in 15 years can be forecasted to a certain degree because the demographic statistics in this area shows the population under 15 years old. Therefore in this model I had a assumption that “Total labor population” increased at a constant rate on the basis of geographic population. The population of the fishing households increases due to birth and emigration for the fishing labor demands, and additionally decreases due to dead and ingression for the tourism labor demands. On the other hand, the population of the worker of the tourism industry increases due to birth and emigration for the tourism labor demands, and additionally decreases due to dead and ingression for the fishing labor demands.

The monthly average income of the fishing households and the worker of tourism industry per one household were defined as the total fishery and tourism incomes per the population of each industry, respectively.

Monthly average income of the fishing households
= Total fishery income / Population of the fishing households (5)

Population of the fishing households (t)
= Population of the fishing households (t-dt) + Variation of the population of the fishing households (dt) (6)

Variation of the population of the fishing households (dt)
= (Population of the fishing households (t-dt) * (Birth rate – Death rate)) + (Total labor population (t-dt) * Fishing labor demands) – (Population of

the worker of tourism industry (t-dt) * Tourism labor demands) (7)

Monthly average income of the worker of tourism industry

= Total tourism income / Population of the worker of tourism industry (8)

Population of the worker of tourism industry (t)

= Population of the worker of tourism industry (t-dt) + Variation of the population of the worker of tourism industry (dt) (9)

Variation of the population of the worker of tourism industry (dt)

= (Population of the worker of tourism industry (t-dt) * (Birth rate – Death rate)) + (Total labor population (t-dt) * Tourism labor demands) – (Population of the fishing households (t-dt) * Fishing labor demands) (10)

4.2.4. Fishery Section

The objectives of fishery section are to predict the amount of the fish catch and the total fishery income. In the Rayong coastal area, there are some

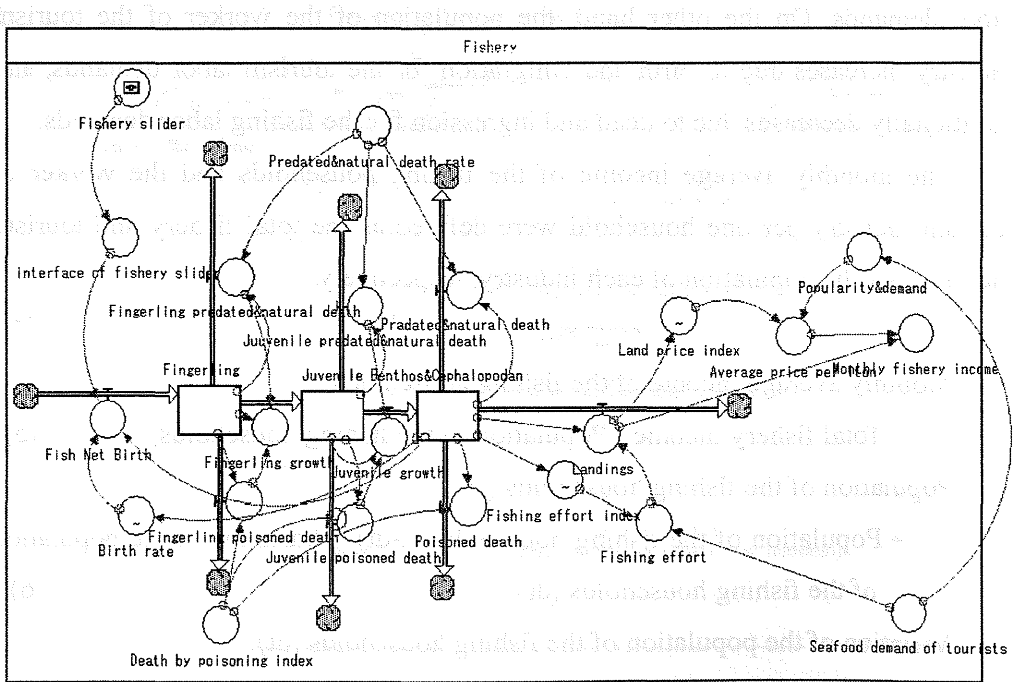

Fig 4-5. Fishery section

fishing households who live near the fishing village by fishing mainly the benthos, the squids, the cuttlefish and some demersal fishes by the small boat, by using the gill nets and the bamboo traps. According to **[12]**, the fish catch landing of the benthos, the squids, the cuttlefish and some demersal fishes varied at same trend. Normally, although in modeling the fish catch landing, we should construct the model by the kinds of fishes. In this model, I treated the fish resources collectively to avoid the complexity of the model. The fish resources in the Rayong coastal area increases due to birth, and decreases due to natural mortality, predation, otherwise fishing and contaminant poisoning by the industrial waste. The inflow of the fish resources occurred through the two phases which are the fingerings and the juveniles because the hatchlings don't become soon the object of fishery, and need to take three years until it is fully grown. In this growth period, the population of the fingerings and the juveniles is decreased by natural mortality, predation, and contaminant poisoning. Therefore the fish resource is defined as follows;

Fish resources (t)

= Fish resources (t-dt) + Fish recruitment (dt) – Natural mortality/ Predation (dt) – Contaminant poisoning (dt) – Fish catch (dt) (11)

Fish recruitment (dt)

= Birth (dt) – Natural mortality& Predation of the fingerlings – Contaminant poisoning of the fingerlings (dt) – Natural mortality & Predation of the juveniles – Contaminant poisoning of the juveniles (dt) (12)

The fish catch landing depends on the fish resources and the fishing effort. And the fishing effort depends on the previous fish resources and the population of the fishing households. Additionally the fisheries products are shipped to near restaurants in this area. Therefore it is expected that the demands of the fisheries products is increased by the growth of the tourists. Therefore the fish catch landing and the fishing effort are defined as follows;

Fish catch landing (dt)

= Fish resources (t) * Fishing effort (dt) (13)

Fishing effort (dt)

= (Basic fishing effort *(const.)* + Demands of tourism (dt)) * Population of the fishing households / Fish resources (14)

The total fishery income is calculated to multiply the fish catch landing by the average price. The average price is affected generally by the fish catch landing and the popularity & the demand of the fisheries products. Additionally this model considered the effect of the contaminants on the fish price. Therefore the total fishery income and the average price are defined as follows;

Total fishery income (dt)

= Fish catch landing (dt) * Average price (dt) (15)

Average price (dt)

= Basic price ± Price shift from fish catch landings ± Popularity & Demand of fish – Price decline from contaminants (16)

4.2.5. Ocean pollution Section

The object of ocean pollution section is to posit the amount of the contaminants which have a impact on the fish resources and the condition of the coral reef. The indicators of ocean pollution are some kinds of heavy metals (Zn, Cu, Cd, Pb, & Mn), BOD, DO, pH, Nitrogen oxide and Sulfides. It is extremely hard work to measure these values accuracy. In addition, it is difficult to clarify these effects on the fish resources and the coral reef condition scientifically. Thereby in this model, the amount of the contaminants from the industrial waste is set subjectively. It was assumed that from 1990 to 1995 when the industrialization began to expand in this area, the amount of the contaminants was increasing and after 1995 that the rapid decline of the fish catch landing appeared, the increment of the contaminants gradually decreases, and the amount of the contaminants decreases by decrees because of the diffusion effect. The amount of the contaminants was defined as follows;

Amount of contaminants (t)

= Amount of contaminants (t-dt) + Inflow of contaminants from industrial waste (dt) – Amount of diffused contaminants (dt) (17)

4.2.6. Garbage Section

The objective of garbage section is forecast the amount of garbage on the beach in this area which has a impact on the variation of the number of visitors. The data of garbage was referred to "Study on Actual Situation of Drifted Garbage. Thunyawit Pongpo.2002. **[17]**". According to this report, the amount of drifted garbage in Thailand has two origins which are from Thailand and from foreign country, which ratio is 97 to 3. This ratio is very high compared with Japanese coastal area which the ratio of Japanese origin, foreign origin, and unknown is 13.8, 21.2, and 65.0. On gulf of Thailand, it is estimated the garbage originated from

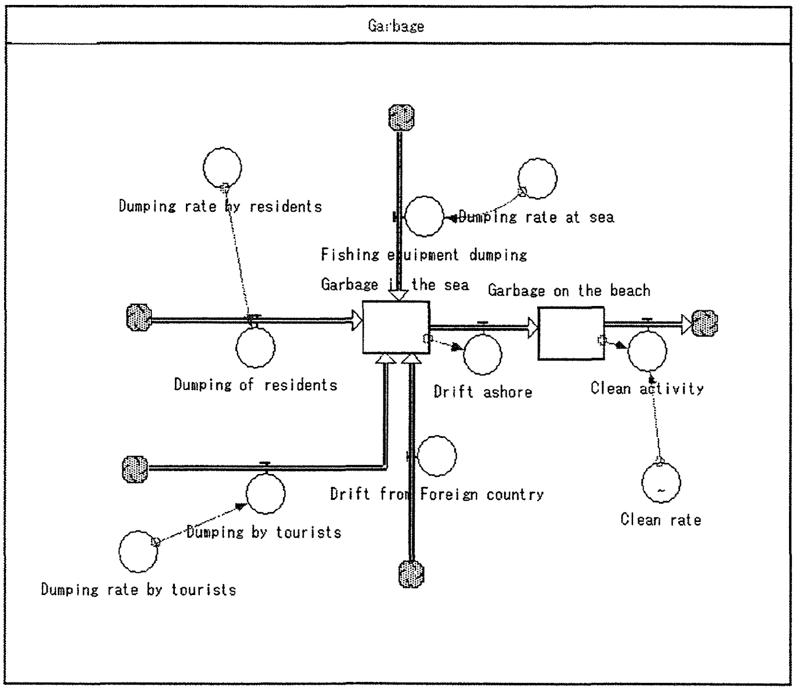

Fig 4-6. Garbage Section

Table 4-2. The kind and source of garbage Unit : %

	Fishing household	Regidents	Tourists	Total
Styrofoam	42	21	7	70
Bottle	0.2	1	0.8	2
Can	0.3	1.5	1.2	3
Plastic	5	10	10	25
Total	47.5	33.5	19	100

Thailand is large amount because the gulf is enclosed coastal sea and the ocean current flows into this gulf. Whereas this trend is also seen on the Andaman Sea side affected by the typhoon occurred on the Indian Ocean. From here onward, we can find the garbage dumped in Thailand is extremely large amount.

According to **[17]**, the amount of garbage in the Rayong coastal area (Mae Pim Cape Beach 100m & Suan Son Beach 200m) in 2000 is 2220. Additionally, the amount of garbage originated from foreign countries in this area is estimated 3, because the total amount on the gulf of Thailand is 15. The kinds of the garbage are made of bottle, can, plastic, and Styrofoam, the ratio of which is 2: 3: 25: 70. Most of the Styrofoam garbage which occupied most percentages is originated from the fishing equipments as a buoy. Furthermore, although this research aimed at the artificial objects, actually the natural objects (drifted wood and bamboo) were also very noticeable. Therefore it is expected the landscape by actual seeing is worse than by the data of model.

The origins of the garbage are thought as the residents, the fishing households, and the tourists. Moreover according to chapter 3, it is clarified that the large amount of garbage in the Rayong coastal area is originated from the residents.
In this model, given that the ratio of the garbage from the residents, the fishing households and the kinds and each amount of the garbage made of bottle, can, plastic, and Styrofoam, the ratio of the garbage from the residents, the fishing households was defined as 47.5 : 33.5 : 19 (Table 4-2). And each amount of garbage is affected by the number of origins.

The garbage dumped by the residents, the fishing households, and the tourists drift on the sea, and some amount of which is washed ashore. Most this garbage on the beach is collected and burned up by cleaner. The amount of garbage was defined as follows;

Amount of garbage in sea (t)

= Amount of garbage in sea (t-dt) + Garbage from residents (dt) + Garbage from fishing households (dt) + Garbage from tourists (dt) – Drifted garbage (dt) (18)

Amount of garbage on beach (t)

= Amount of garbage on beach (t-dt) + Drifted garbage (dt) – Collection of garbage (dt) (19)

4.2.7. Coral Reef Section

Coral reef is sensitive to the shift of the environmental condition, in these days in tropical area decline and destruction of the coral reef become a problematic. In the Rayong coastal area, the condition of the coral reef is also getting worse to worse according to observation research of the coral reef. The objective of the coral

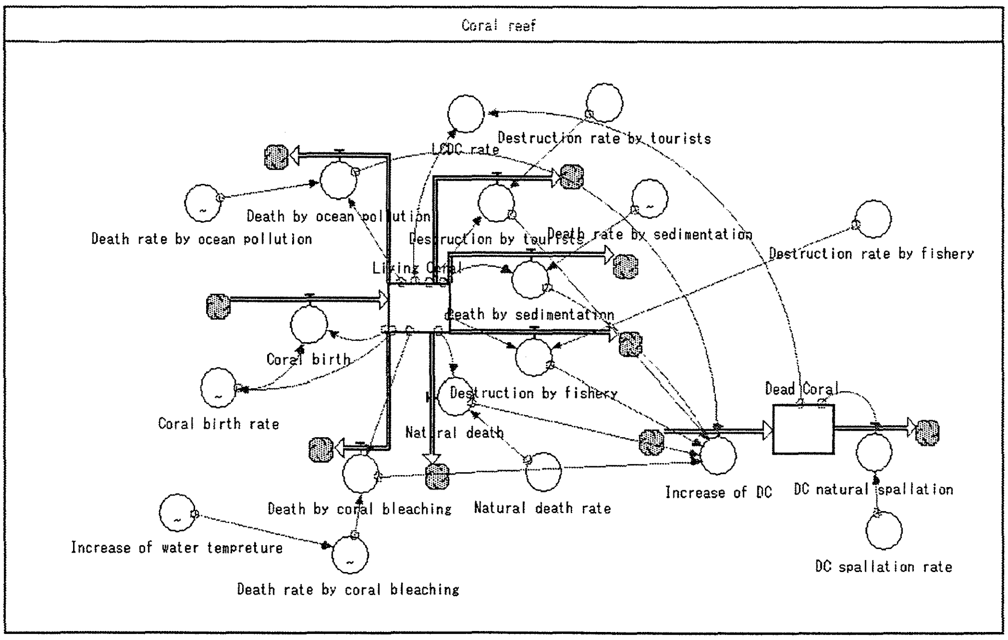

Fig 4-7. Coral Reef Section

reef section is to predict the condition of the coral reef inshore in the Rayong coastal area which has a impact on the number of tourists and the fish resources slightly. There are many tourists in the Rayong coastal area for the purpose of relaxation, nice climate, and marine sports. The destruction of coral reef and the sediments of the red soil mean the decreasing of the tourists, especially the divers.

Generally, the causes of the decline of the coral reef are the sediment of the soil, the predation by acanthaster, the bleaching coral by up of water temperature, the destruction by tourists and fishery. In Thailand, the most serious factor is the destruction by fishery, and which causes 50% of decline of the coral reef. Second serious factor is ocean environment shift by the sedimentation of the red soil and the industrial waste, which causes more than 40% of decline **[20]**. The runoff and the sedimentation of red soil are caused by tourism development, especially the construction of hotel, and some infrastructures. More than 90 % of the decline of the coral reef is caused by these two factors. Additionally, in the Rayong coastal area, few destructions by the tourists was reported **[20]**, and this factor will become more serious with the increment of the tourists in future. In 1999 the coral bleaching was reported. This phenomenon will also become more serious with global warming.

In this model, in order to represent the condition of the coral reef quantitatively, I defined new indicator of the coral reef by multiplying the length of the coral reef by the condition level of the coral reef. The condition of the coral reef was defined as follows;

Amount of coral reef (t)

= Amount of coral reef (t-dt) + Birth (dt) – Destruction by fishery (dt) – Death by sedimentation of red soil (dt) – Death by ocean pollution (dt) – Destruction by tourists (dt) – Death by bleaching (dt) (20)

The destruction of fishery, the death by sedimentation of red soil, the death by ocean pollution, and the destruction by the tourists depends on the population of the fishing households, the number of increment of hotel, the amount of the contaminants, and the number of the tourists, respectively. The coral bleaching is set to occur every 10 years after 1999.

Furthermore, this model employed the ratio of the living and the dead coral reef because for divers not only the area or length of the coral reef, but also the ratio of the living and the dead coral reef is important temptation to dive in the sea. Therefore it is considered that when the coral condition gets a impact on the tourism, the ratio of the living and the dead coral reef can be a indicator of impact on the tourism. The ratio of living and dead coral reef was defined as follows;

Ratio of living and dead coral reef (dt)

= Amount of living coral reef (t) / Amount of dead coral reef (t) (21)

Amount of dead coral reef (t)

= Amount of dead coral reef (t-dt) + Amount of death of coral reef (dt) – Break of coral reef (dt) (22)

Amount of death of coral reef (dt)

= Destruction by fishery (dt) + Death by sedimentation of red soil (dt) + Death by ocean pollution (dt) + Destruction by tourists (dt) + Death by bleaching (dt) (23)

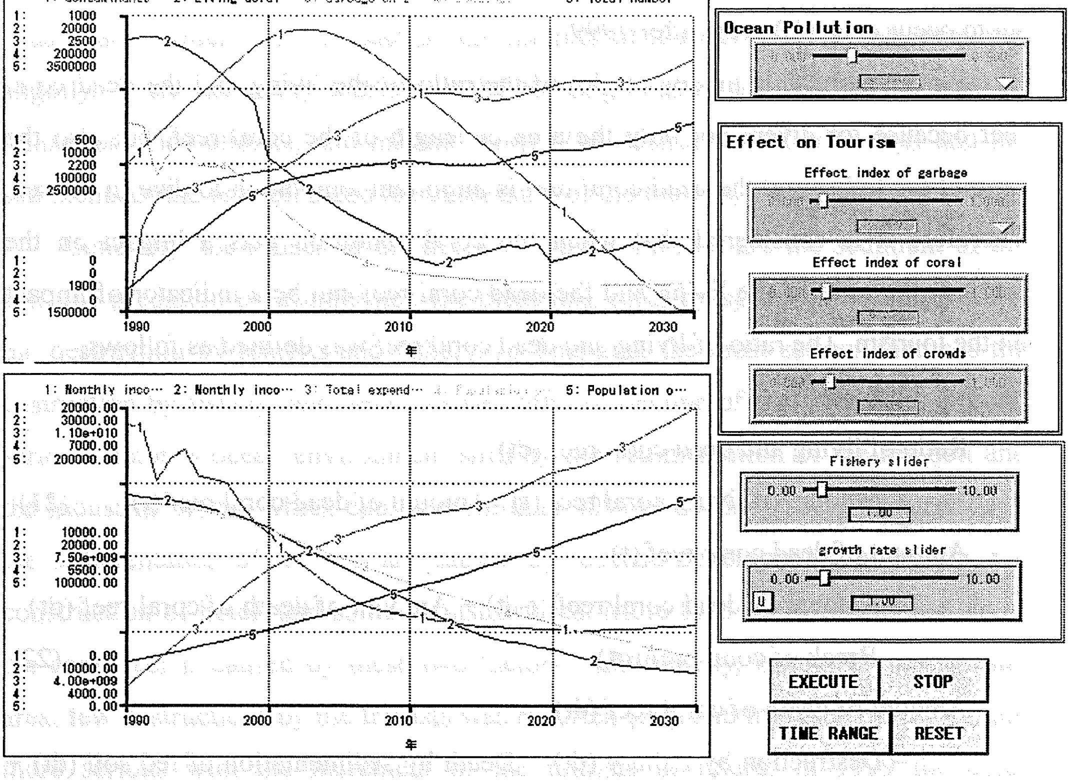

Fig 4-8. User Interface for simulation

4.3 Result and Discussion

The result of the modeling process was a friendly model for user because STELLA has a simply interface to simulate. The user can easily change the parameters and thereby simulate a broad range of scenarios. A parameter can be turned off or the equation can be turned on. Alternatively, a specific numerical value can be inserted by slide bar. Firstly, I evaluated this simulation model from the correlation coefficient between the values of the statistical data and this model. This calculated value of the correlation coefficient reflects the accuracy of this simulation model. Secondly, I simulated this model in the case the Rayong coastal area develops on present showing. On the basis of this result, I clarified the interlinkages between the components of this model. Thereby I discussed future condition of this area in this scenario, and indicated some problems and key factors for further development in future.

Table 4-3. Correlation coefficient

		Year											Correlation coefficient
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Fish catch landings	D	164547	146910	77354	112688	177915	166270	105483	94325	79482	77504	79943	0.828
	M	126379	124833	91263	108449	114773	99187	99218	101341	92520	85789	80611	
Number of visitors	D					1840874	2108460	1966230	2140941	2172223	2323964	2478375	0.925
	M	1711772	1794270	1877835	1960381	2042941	2125291	2206439	2283883	2357321	2428383	2484197	
Total expenditure of visitors	D					4725501021	6281570064	4434904418	6885922434	5883133030	6480449218	7138915363	0.697
	M	4714730000	5008770000	5314350000	5621040000	5933280000	6250350000	6569060000	6881160000	7185260000	7486300000	7741070000	
The population of the fishing household	D	6075	5977	5879	5782	5684	5586	5489	5391	5293	5196	5098	0.969
	M	6021	6021	6012	5994	5968	5935	5894	5847	5793	5734	5670	
The population of the worker of tourism industry	D					35344	42046	44897	35480	33611	51278	61435	0.661
	M	30093	32110	34183	36313	38501	40749	43057	45429	47861	50355	52910	
Number of hotel	D							167	192	198	205	186	0.541
	M	144	149	154	159	164	169	175	181	187	194	200	

D = data ; M = model

4.3.1 The evaluation of the simulation model

In predicting something in future by the simulation model, the accuracy of the model is the most important because the improper simulation model elicits the completely different results. Erroneous results give only the wrong regional management policy. Therefore, I evaluated this simulation model from the correlation coefficient between the values of the statistical data and this model (Table 4-3). Five items are evaluated; the fish catch , the number of visitors, the total expenditure of visitors, the population of the fishing households, the population of the worker of tourism industry, and the number of hotel, because these data are organized quantitatively and in chronological order in 1990s, which are quoted from the same statistical data as in Chapter 3. The correlation coefficient values of the fish catch , the number of visitors, the total expenditure of visitors, the population of the fishing households, the population of the worker of tourism industry, and the number of hotel are 0.828, 0.925, 0.697, 0.969, 0.661, 0.541, respectively. All correlation coefficient values are generally high, especially the number of visitor and the population of the fishing households. This implies this simulation model is appropriate to the regional management tool.

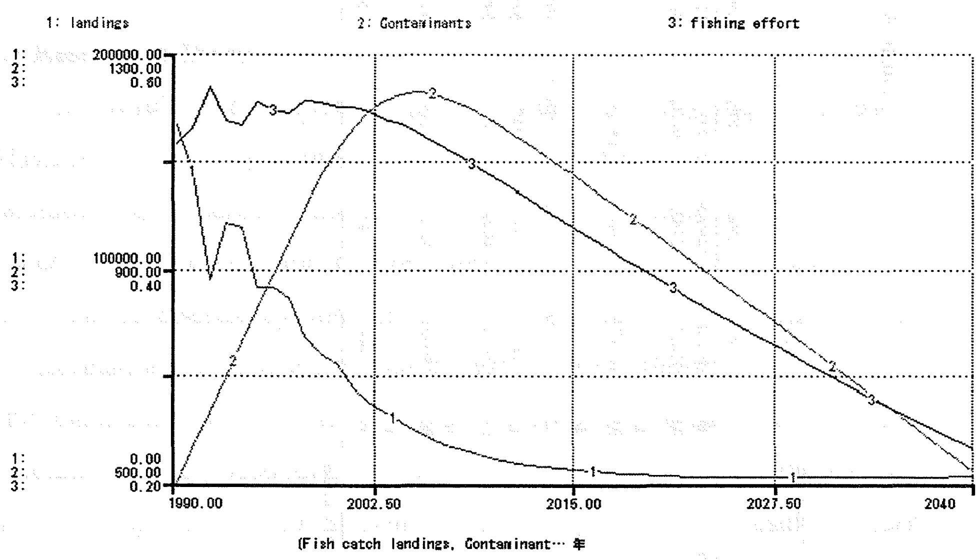

Fig 4-9. The linkages between the fish catch landings, the contaminants and the fishing effort.

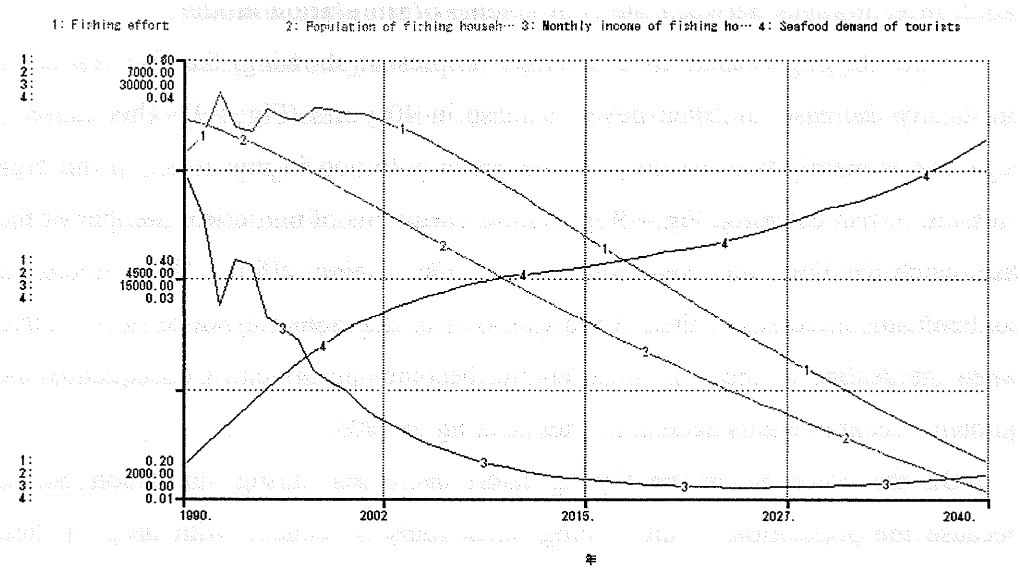

Fig 4-10. The linkages between the fishing effort, the population of the fishing household, the monthly income of the fishing households and the seafood demand

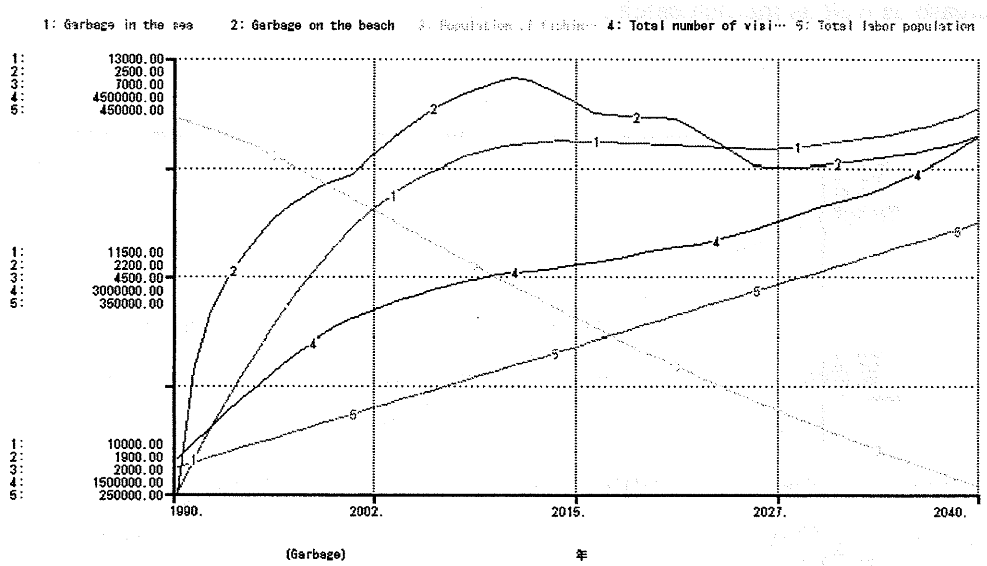

Fig 4-11. The transition of the amount of garbage & the linkage between the amount of garbage, the number of tourists, fishing households and residents

4.3.2. Interlinkages between the components of simulation model

If the Rayong coastal area develops on present showing, the fish resources drastically decrease and then never increase in 40 years (Fig 4-9). This cause is regarded as mainly two reasons, i.e. the ocean pollution in this area and the high pressure of fish catching. Fig 4-9 shows the transitions of numerical number of the fish catch landing, the contaminants and the fishing effort. The amount of contaminants increases at first. Almost inflows of the industrial waste stop in 2002 when the decline of the fish catch landing becomes prominent. Consequently the amount of contaminants decreases after peaking in 2003.

On the other hands the fishing effort decreases during simulation period because the population of the fishing households is reduced with drop in their income (Fig 4-10). In this result, the cause of depressed fish catch landing is estimated the effect of the contaminants on fish resources stays strongly for a while. After the contaminants almost diffuse the fish catch slightly increase. As to the total income of fishery, while the average price of the fish resources per one ton increases in inverse proportion to the fish catch , the total income of fishery decrease as well as the fish catch .

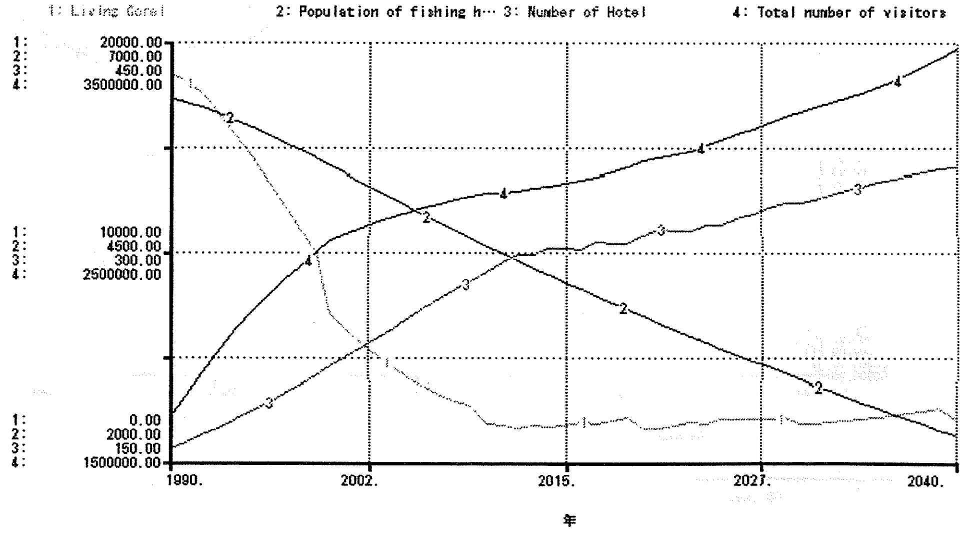

Fig 4-12. The transition of the coral condition & the linkage between the coral condition, the number of fishing households, hotels and tourists

From the questionnaire survey in chapter 3, it is emerged that the garbage can be the matter of tourism industry in the Rayong coastal area. According to the result of this simulation, the amount of the garbage is estimated to increase during the simulation period (Fig 4-11). This increment has third trends, one of which is drastically increment until 2011, and two is slightly decrement from 2011 to 2025 at second stage. And after this, the final trend is increment gradually. The first trend is mainly affected by dumping the fishing equipments. On the other hands, the final trend is caused by the increment of the number of visitors and residents, while ocean dumping falls into the decay because of the decrement of the fishing households. The second trend is not affected by two factors above, therefore at which the amount of garbage slightly decreases from the clean-up activities.

The living coral condition in the Rayong coastal area gets worse like the other areas (Fig. 4-12). In 1990s, the living coral condition drastically decreases because of the fishery and the coral bleaching in 1999. And from then onwards, the living coral condition remains on the verge of extinction because of the coral bleaching every 10 years, the destruction of the divers and the sedimentation from the construction of many hotels, but gets better only to a slight degree in last 10 years. The dead coral condition varied similarly with the living coral condition. The ratio of living-dead coral also decreases as the living coral condition in 1990s, and from 2000 to 2015 keeps same value which is about 0.4. In last 15 years, the value of this ratio begins to increase bit by bit, and which shows the sign of recovery of the coral condition.

As to the number of visitors, all of Thai tourists, Thai excursionists, Foreign tourists, and Foreign excursionists increase steadily, although each rate of their change is different (Fig 4-13). The increment trend of the number of visitors can be separated in two types. First has the steady increment because the number of visitors is seldom affected by the coral condition, crows of visitors, and garbage in this term which appears in 1990s. The increasing rate of Second trend which appears after 2000 is lower than first because of the deterioration of the coral condition. The number of visitors is limited by the capacity of hotel in this area, but never be affected because the numerical value of the capacity is far larger than the number of visitors. The crowds of visitors also scarcely influence them.

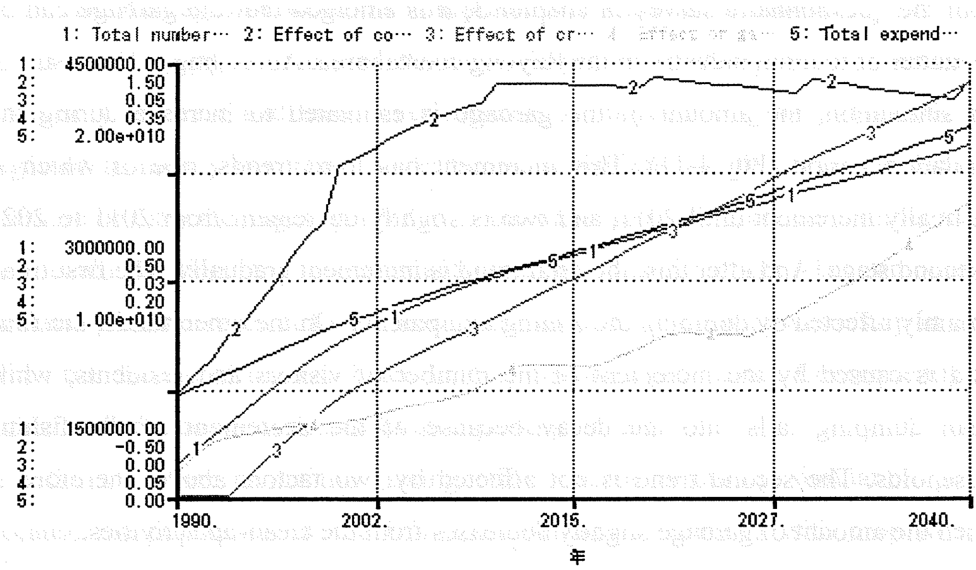

Fig 4-13. The transition of the number of visitors & the linkage between the number of visitors, the coral condition, the amount of garbage, crowds, and the expenditure of visitors

Consequently, the total expenditure of visitors has steady increasing trend as well as the number of visitors.

The monthly incomes of the fishing households and the worker of the tourism industry are calculated on the basis of dividing the total monthly income by the population, respectively (Fig 4-14 & 15). The monthly income of the fishing household varied with the fish catch landing, and thereby the amount of their monthly income drops off to about 3000 Baht in 2040, while the population of them decreases. 3000 Baht as the monthly income at net present value is very sever to make a living in the area. Therefore some fishing households may change their job or move out to the other place. As to the worker of the tourism industry, the monthly income increases with the growth of the total expenditure of visitors at first, but from that onwards decreases slightly because the increasing rate of the population of them is gradually larger than one of the total expenditure of visitors.

Fig 4-14. The transition of the incomes of the fishing household & the linkages between the monthly income, total revenue, and population

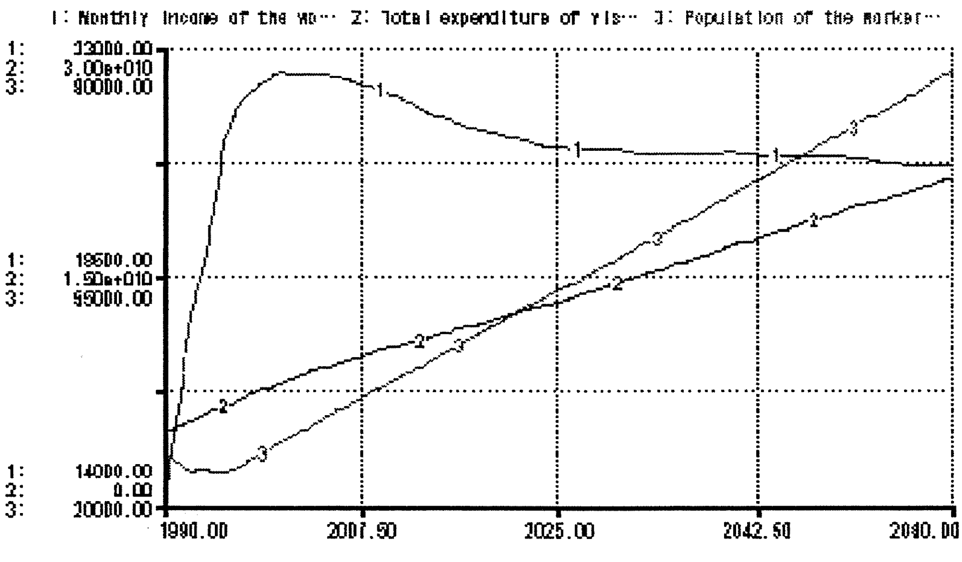

Fig 4-15. The transition of the worker of tourism industry & the linkages between the monthly income, the total revenue, and the population

This model is based on the assumption that the contaminants from industrial waste currently have a great impact on the ocean environment and the fish resources, which can be one of the subjects for a future discussion. Consequently the fish stocks drop off suddenly, the catch landing and the income of the fishing households also drastically decrease. The downturn of fishery in this area makes the fishing households change their jobs or move out to the other places some day. Meanwhile the sign of a slight recovery of the fish resources appears in last term of the simulation period when the effect of the contaminants and the decreasing trend of the fishing households begin to sink down at last. The condition of the fish resources and the economics of the fishing households, however, are almost certain to be very serious for a while. Therefore some of fishery, environment and economic policy are need to enforce in this area. Although the fishery which is the largest factors of the destruction of the coral reef and the plastic garbage on the beach fall in decay, the condition of the coral reef and the amount of the garbage could not improve absolutely because many construction of the hotels and a lot of the tourists, excursionists from the development of the tourism industry affect the condition of the coral reef and the amount of the garbage instead of the fishery. The degrees of the impact of the tourists on the coral reef and the garbage are not clarified scientifically, but it is assured of the existence of serious threats to the coral reef and the garbage.

The growth of the tourism industry gives the increment of income to the workers of the tourism industry. On the other hands, the extreme growth also brings the slight decrement of their income reversely. In addition, a lot of visitors have a great impact to this environment. Therefore this result implies the growth of the tourism industry is not necessarily better.

4.3.3 The problems for regional management in the Rayong coastal area

From the analysis partly of the interlinkages between the components of simulation model, some problems for the regional management appeared. First problem of the vast amount of garbage is emerged. The outflow of the garbage stock is only from clean-up activity. Actually, some cleaners clean and weep the beach in this area. In this model, the rate of the garbage collection is set at 70 to

80%, which increases one percent every year, and the maximal value is 80%. More 70% of the garbage stock is collected every year, but the amount of garbage never decreases because anytime during the simulation period there are a lot of litterbugs such as the fishermen, the residents, and the visitors. Therefore more clean-up activities need to be enforced, which have the higher rate of garbage collection.

Similar problem occurred on the future of the coral reef condition. The most serious factor of the decline of amount of the coral reef is the destruction of fishery. During the simulation periods, the fishing households decrease, while the total population of residents increase and the tourism development are promoted. Thus the coral condition is never recovered during the simulation periods. In other viewpoints, in future, it is certain that the tourism industry develops and the total population of the residents in the Rayong coastal area. Therefore the coral reef will always be affected by something, that is, the coral reef will not recovered so much. As well as the garbage problem, the coral reef needs to be enforced to educate the tourists and to improve the way to construct the hotel and buildings.

The most important problem in this area is considered there is no means to activate fishery in this area. On present showing, after the impact of the contaminants is very small, the fish resources recover little by little. But the natural recovery of the fish resources takes about 60 years. In reality, the fishing households can not wait a recovery of the fish resources because they can not make a living by fishery. Therefore, until the fish resources have recovered, some measures toward the coastal fishery and the fishing households are required quickly. For example it is better to give a chance to change alternative jobs to them.

As a further problem, for instance in 100 years, after the fish resources recover, it is occurred another problem that the growth of population of the fishing household from the increment of the fish catch landing gets more impact on the coral condition and the amount of garbage, thus which bring about the decline of the visitors (Fig 4-16). In this result, it is clarified that fishery has a great influence among the coral reef, the garbage and even tourism, although at the beginning first this effect is very small and in hiding. Thus, it still be important to treat the matter of the garbage and the coral reef.

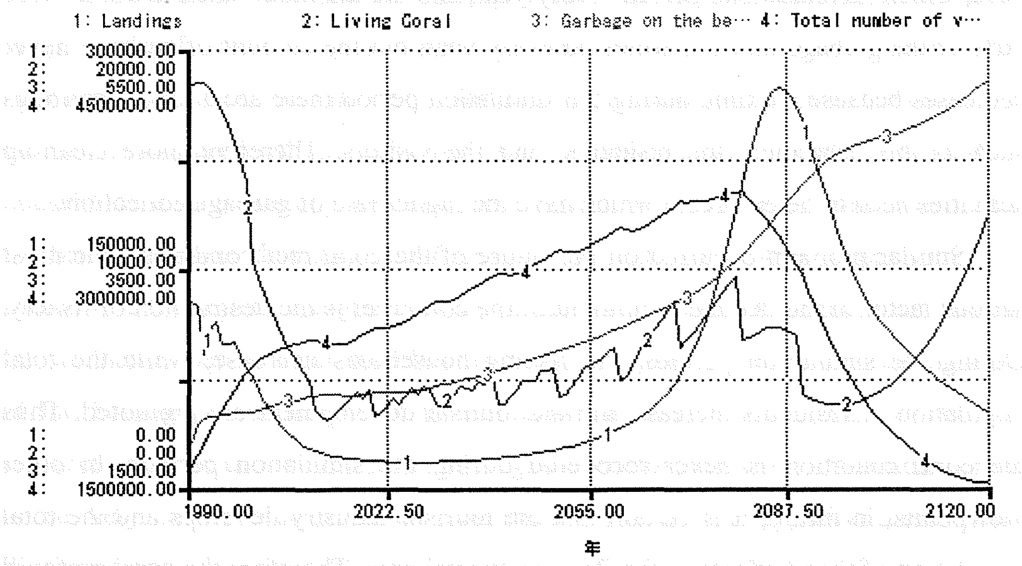

Fig 4-16. The transition of the fish catch landing, the living coral condition, the amount of garbage and the total number of the visitors in 130 years

After that, the fish catch landing and the number of visitors repeatedly increase and decrease one after the other. Therefore once the fish catch landing increase enough, it is observed that fishery and tourism industry in this area manage each condition. But it still be remains two matters. First matter is that the shift from increment to decrement of the fish catch landing and the number of visitors is unstable. Additionally, the cycle period of increment and decrement is so long. One period take 50 years. This means the living of the fishing households and the worker of tourism industry is not stabilized at constant level. Furthermore, on the period when the fishery hover at low level, the incomes of the fishing household and the worker of tourism industry are very low, and they can not make a living by own job only. Therefore development of this area on the present showing is not good for this area anyway.

In the terms of the incomes, it has already mentioned the fishing households will have low income because the fish catch landings will decrease. On the other hands, the income of the worker of tourism industry will also decrease gradually, because the increasing rate of the population of them is gradually larger than one of the total expenditure of visitors. Therefore even tourism needs some strategies to gather more tourists and excursionists for increment of the income per one household.

4.4 Conclusion

In this chapter, I constructed the simulation model represented the interlinkages between tourism, local community, and natural environment by system dynamics. From this modeling, it is clarified the interlinkage between the components is very complex, and each ripple effect of these components among the regional model has a great impact on other components. Therefore, this simulation model could bring some problems to the light which the general consideration could not clarify.

From the result of simulating this model, in the Rayong coastal area, the fishing household and fishery are very important keys to manage this area very much. Because the fishing households will keep the low incomes in developing on the present showing, and in case the fish catch landing increases, the effect of the fishery on the amount of garbage and the coral reef. Therefore the present fishery will have to change the ocean environment-friendly.

As a concrete matters, four problems are clarified. First is continuously increment of the garbage on the beach. Second is continuously declination of the condition of the coral reef. Third is the decrement of both incomes of the fishing households and the worker of tourism industry. Last is the heavy impact of the fishery on the ocean environment. These problems have a relationship each other as well as the components of this simulation model. Thus in only case that all of these problems are solved completely, the Rayong coastal area mange successfully. And these solutions are the best way of the regional management in the Rayong coastal area.

These results and considerations proved in practice that this simulation model by system dynamics is effective tool to analyze comprehensively the complex web of local community, and provides the great deal benefit for a regional management. By shifting the parameters in each section of this model, I can observe these variations of the components in the various scenarios. Additionally, on the basis of the results of many simulations in the various scenarios, I will be able to forecast the shift of the Rayong coastal area, and enforce the effective management policy toward all problems.

Chapter 5 Regional management policy

To implement the regional management policy successfully, the administrators and the official mangers have to look all over the management area, and consider not the individual phenomena, but also the valance of all kinds of phenomena comprehensively. Actually, however, it is quite difficult to consider all kinds of phenomena comprehensively, because various phenomena are overly complicated and construct the complex web between the phenomena in the regional area. This is why the forecast the future shift of the phenomena is very sever, because the shift of local community is accompanied with the unexpected variation in various points.

System Dynamics is one of the simulation methods, and developed for the purpose of the analysis of the complexity in social issues. System Dynamics realize to bring out the relationships between the phenomena and estimate the degree of the variation of the phenomena affected by others. In other viewpoints, when some shifts are given actively, all shifts caused by ripple effects from the active shift can be forecasted. Therefore this method is regarded as the effective solution for regional management policy.

In this study, I constructed the simulation model for regional management in the Rayong coastal area by System Dynamics. This model provided many problems of the present situation and the future problematic phenomena in this area. These results can be the indicator of the appropriate regional management policy in this area. And from this result, it is certain that this method can be applied to the other area.

As a mention about the concrete regional management policy in the Rayong coastal area on the basis of this simulation model, the regional managers have to consider to improve the fishery system and recover the fish resources at first because the fishery and the fishing households in this area are the indicators for regional management. In other words, the improvement of fishery and the economic condition of the fishing households have a effect on all phenomena by the ripple effect. Secondary, the treatment and education to the origins of the garbage problem and the decline of the coral reefs need to be enforced. As alternative regional management system, Introduction of ecotourism is effective to implement the management policy as mentioned above. In considering the application of ecotourism to the Rayong coastal area, Ecotourism planning should include the employment of the fishing households, and environmental education to the residents and the tourists for the prevention them from dumping the garbage and destruction of the coral reef. A future issue is to simulate the effect and the ripple effect of introducing ecotourism by System Dynamics, and to feed this result back to the simulation model for regional management.

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Southeast Asia Sea Turtle Associative Research

目次

Sea turtle conservation in India: existing laws and problems – A case study from Gulf of Mannar, Southeast coast of India

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ABSTRACT
Olive ridley, green, hawksbill, leatherback and loggerhead turtles have been found to occur along the Indian coast. The Gulf of Mannar, located along the Southeast coast of India is a marine biosphere reserve and is unique for coral, seaweed and sea grass ecosystems. Gulf of Mannar is also an important place wherein all the five species of sea turtles have been reported. The survey indicated that the turtles were abundant along Gulf of Mannar coast in 1960s and 1970s. This could be evidenced from the live turtle trade existed in this coast in 1960s with Sri Lanka with an annual landing of about 3000 to 4000 turtles between Rameswaram and Mimisal. Also, turtle poisoning have been reported along this coast. After the enactment of the Indian Wildlife (Protection) Act 1972, the exploitation has got much reduced. Though all the five species are legally protected under Schedule I of the Indian Wildlife (Protection) Act 1972, the exploitation is still continuing along the Tuticorin coast of the Gulf of Mannar. The turtle number has got reduced along this coast in recent years due to habitat disturbance and exploitation. Green turtle is the much exploited species for the meat and the fisher folk are offered lucrative price by the turtle meat traders. Four green turtles have been recently rescued from the traders and released back into the sea. Though the present law is enough to contain the exploitation, shortage of manpower and facilities for its effective implementation are considered as the major lacuna for the continuing turtle exploitation apart from the lack of awareness among the coastal people.

KEYWORDS: Sea turtle, Gulf of Mannar, Tamil Nadu, exploitation, conservation

INTRODUCTION

India is one among the twelve mega-diversity countries which together constitute about 60 to 70 % of the world's biological diversity. India has an exclusive economic zone of 2.1 million sq. km. Five species of sea turtles, olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta)* and leatherback (*Dermochelys coriacea)* are distributed along the Indian coast. Except the loggerhead, all other species have been reported to nest along the Indian coast. Among the five sea turtles, olive ridley is the most common and abundant in India and is unique for its mass nesting along the Orissa coast (Karthik R., 2000; Kar, 2001). Three olive ridley mass nesting beaches-Gahirmatha, Devi river mouth and Rushikulya-are located in the Orissa state. The olive ridleys are said to be migrating along the coasts of Tamil Nadu and Andhra Pradesh states towards the mass nesting beaches in Orissa.

The turtles migrating to Indian waters are on the decline in recent years owing to many threatening factors. The main detrimental factor is the incidental catch which is more on the east coast. The incidental catch is more along Tamil Nadu next to Gahirmatha coast in Orissa and the gill nets are accounted for the major killings (Rajagopalan *et al.*, 2002). They observed higher incidental catch during January to February in the year 1997 and 1998 and during that period, the mortality due to incidental catch was observed all through the year along Tamil Nadu (Rajagopalan *et al.*, 2002). Exploitation by humans, developmental activities on the beach including artificial illumination, predation by wild animals and beach erosion are the other factors affecting the sea turtles. All the five species of sea turtles are listed under Schedule I of the Indian Wildlife (Protection) Act 1972 and India is a signatory to the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Tamil Nadu state which is located along Southeast coast of India has a coast line of about 950 km. All 5 species of the sea turtles have been reported along Tamil Nadu coast and is considered the next dense nesting area for olive ridleys after Orissa. Sporadic nesting of olive ridley occurs along the northern coast of Tamil Nadu especially between Nagapattinam and Chennai coast. The coastal stretch between Tranquebar and Pazhayaru, Mamallapuram and Chennai, Point Calimere and Nagapattinam and Kanyakumari and Trichendur are the other turtle nesting areas in Tamil Nadu. In Gulf of Mannar and Palk Bay on the south, except the leatherback, the other four species were reported (Kar and Satish B., 1982). In the Kanyakumari to Trichendur stretch, the core nesting area has been identified as between Manapad and Periathalai (Bastian F., 1983). Turtle nesting has been reported during December to February and also during April to June (Murugan, 2003). The rich coral reef and sea grass areas in Gulf of Mannar form a good foraging ground for sea turtles

The sea turtle study in India is mainly focused towards olive ridleys, especially the mass nesting beaches in Orissa. But, there are other places wherein nesting of other sea turtle species has been reported and are also under threat. So, the objective of this paper is to address the sea turtle conservation issues in India through a case study in Gulf of Mannar. A survey was conducted during mid 2003 in the coastal villages and islands and the previous reports were also taken into account for comparison and assessment.

GULF OF MANNAR

The Gulf of Mannar Marine Biosphere Reserve, established in 1989, is located along Tamil Nadu State, Southeast coast of India between 8° 46' and 9° 14' N lat. and 78° 9' and 79° 14' E long. and covers an area of about 10,500 sq. km. The biosphere consists of 21 islands categorized under four groups - Tuticorin, Vembar, Kilakarai and Mandapam groups. Tuticorin group comprises Van, Kariachalli, Kasuwar and Velanguchalli Islands; that of Vembar group Upputanni, Puzhuvunnichalli and Nallatanni Islands; the Kilakarai group Anaipar, Valliamunai, Poovarasanpatti, Appa, Talairi, Valai and Mulli Island and that of Mandapam group Musal, Manoli, Manoliputti, Poomarichan, Pullivasal, Krusadai and Shingle Islands (Fig.1).

The biosphere harbours marine biodiversity of global significance and is considered as the richest coastal regions of India with about 3600 species of fauna and flora. Two coastal districts – Ramanathapuram and Tuticorin are located along the Gulf of Mannar. One of the islands, Krusadai is considered as biologist's paradise which is unique for the endemic living fossil Balanoglosus (*Ptychodera fluva)*. 11 species of sea grass belonging to 6 genera are reported to occur in Gulf of Mannar. The biosphere is characteristic for the occurrence of sea turtles and dugongs.

STATUS OF SEA TURTLES IN TUTICORIN AREA OF GULF OF MANNAR

The habit of sea turtle meat consumption exists in Tuticorin area for many decades. In 1960s, exclusive sea turtle fishing was carried out in Gulf of Mannar and Palk Bay region and live turtle trade existed with Sri Lanka. An estimated 3000 to 4000 turtles were landed annually between Rameswaram and Mimisal during that period and green turtle represented three fourth of the catch (Rajagobalan, 1984). Rameswaram, Kilakarai, Tuticorin, Tondi and Pamban were the assembling centers for the captured turtles. Special pens were erected in the sea to keep the live turtles. Special types of nets, 'Pachuvalai' and 'Kattuvalai' were used for turtle fishing. Pachuvalai' was a cast net and that of 'Kattuvalai' was a type of haul net. During1971-76, the green turtle constituted the major share of around 89% along Gulf of Mannar and Palk Bay (Agatheesapillai and Thiyagarajan, 1979). Turtles are also got trapped in the bottom net for skates and rays, 'Thirukkai valai' in Gulf of Mannar area. Turtle poisoning related death or injury has been reported along Tuticorin coast (Silas and Bastian Fernando, 1984). The local names for the sea turtles in this area are 'Peramai' for green turtle, 'Sithamai' for olive ridley, 'Azhungamai' for hawksbill, 'Yezhuvarai or Thoniamai' for leatherback and 'Perunthalaiamai' for loggerhead.

A survey in 1977 mentioned about turtle nesting in Puluvinichalli, Nallathani, Anaipar, Valiamunai, Appa, Valai, Mulli, Hare, Manoli, Manoli-Putti and Pullivasal Islands (CMFRI, 1977). The report indicated large scale nesting in Nallathanni Island during that period. But the recent survey in the Nallathani Island by the author indicated the lapse of prominent turtle nesting. Also, the survey among the fishermen indicated the drastic reduction or absence of turtle nesting activity in the islands.

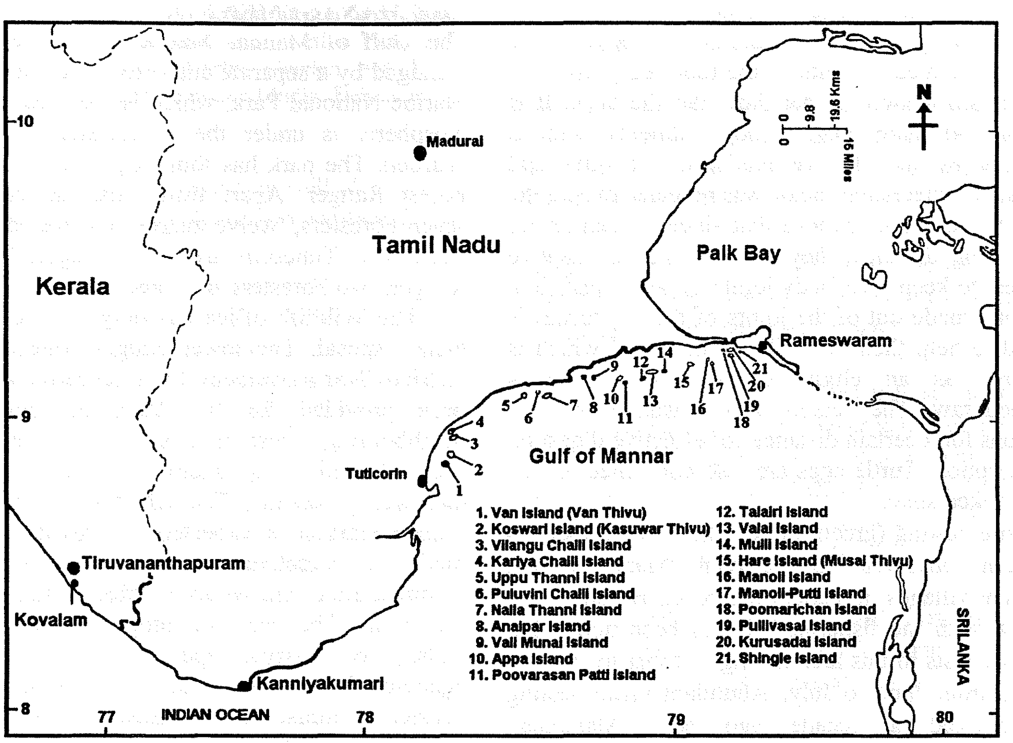

Fig.1. Map showing the Gulf of Mannar and Palk Bay.

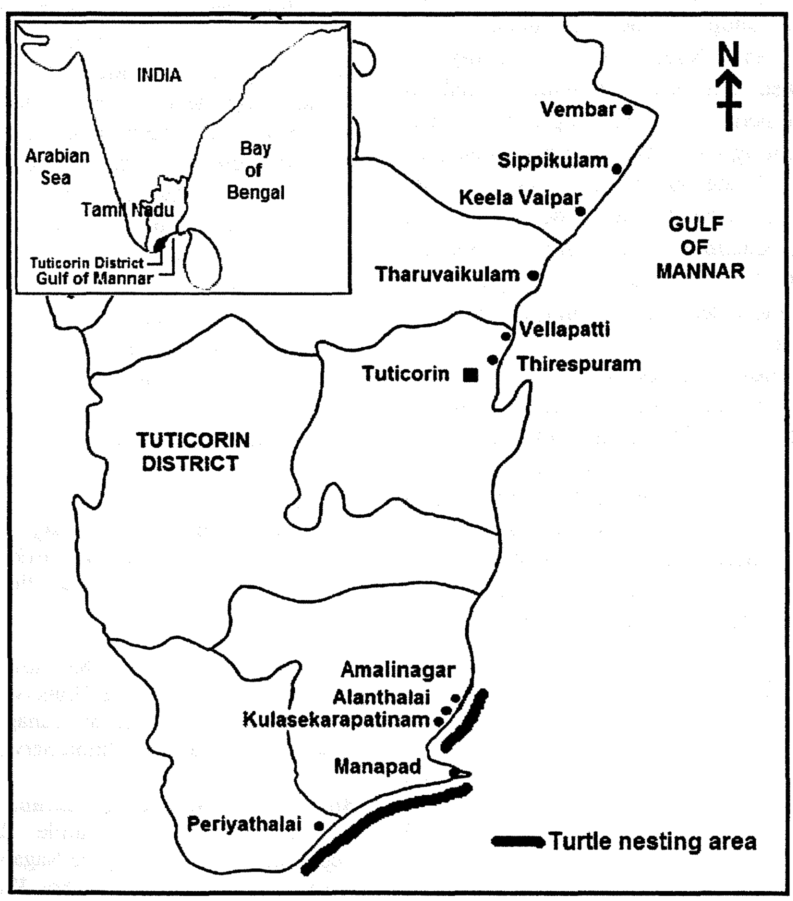

Fig.2. Map showing Tuticorin district

A survey was conducted in the coastal villages of Tuticorin during mid 2003 to assess why these people like the turtle meat in spite of the reported poisoning. The common answer is that they like the taste. It is also said to cure many body ailments and is considered as an effective medicine for piles and diarrhea. An interesting factor was revealed during the survey. Some people believe that since the sea turtles travel a long distance, they possess special adaptive characters to keep their body joints in good condition. So, a soup made out of the joints of the sea turtles is believed to help them too. The turtle blood which is considered as an elixir (Rajagopalan, 1984) is consumed raw. The person who consumes the raw blood runs for a certain distance for effective digestion and absorption. Turtle eggs are also consumed as raw and in cooked state.

Turtle nesting (green, olive ridley and hawksbill) has been observed in between Manapad and Periathalai villages in Tuticorin district. Based on the interview with the fishermen, it has been noted that the turtles nests in this area during October to January and also from June to July. Abundant turtle nesting was observed a decade ago near Alanthalai, Kulasekarapattinam and Amalinagar (Fig.2). But, the continuous poaching for eggs and meat trade have reduced the nesting intensity and only sporadic nesting is observed (Bhupathy and Saravanan, 2002).

In northern Tamil Nadu coast especially in Nagapattinam coast, gill nets are widely used. In contrast to the southern coast, the people in this area have no habit of eating the turtle meat and hence, the fishermen chop off the head or flippers of the entangled turtles in order to save their nets from damage. But, egg poaching is quite high in this area like southern part. A recent study by Bhupathy and Saravanan (2003) indicated the poaching of 69 out of 72 nests by humans.

Four green turtles were rescued from the traders on 23 July 2003 by the Gulf of Mannar Marine National Park officers at Tuticorin with the help of police and were released back safely with the help of Suganthi Devadason Marine Research Institute on 24 July 2003. Before the release, the measurements were recorded for each turtle (Table 1). Obviously, after 1979, this record gives some sort of information on the green turtles distributed in Gulf of Mannar.

Table 1. Data of rescued green turtles

St. No.	Sex	CCL (cm)	CCW (cm)	Wt. (kg)
1	♀	61	59	26
2	♀	76	71	51.5
3	♀	92.5	78	70
4	♂	98	79	83.5

THE MANAGEMENT OF GULF OF MANNAR

The Gulf of Mannar Marine Biosphere Reserve is managed by a separate authority. The Gulf of Mannar Marine National Park, which is the core sector of the biosphere, is under the supervision of a Wildlife Warden. The park has four ranges, each headed by a Forest Ranger. Apart from this, the authority has seven Foresters, twelve guards and five administrative staff. The Tuticorin area is managed by a Forest Ranger, two Foresters and three Guards.

The Wildlife office has only two petrol boats at their disposal. The lower budget allocation for fuel restricts their movement. Only recently, a vehicle has been provided for the Tuticorin unit from the neighbouring forest division. But the ceiling on the fuel utilization is again a hurdle in effective monitoring process. The UNDP-GEF project under implementation is expected to provide the required facilities. Effective coordination between district administration and wildlife office is also the need of the hour. The lack of proper awareness on the endangered marine species among the various agencies like Coast Guard, Customs, Police and district administration aggravates the problem of management. After the rescue of the green turtles on 23 July 2003, additional check posts have been established along Tuticorin coast.

The infrastructure for the effective management of the Gulf of Mannar Marine Biosphere Reserve is to be strengthened under the UNDP-GEF project. Considering the vast area of the biosphere reserve, the man-power and the number of petrol boats have to be suitably increased. Though the legal protection for the management of the biosphere reserve is adequate, its effective enforcement is the need of the hour. Also, the legal proceeding against defaulters is a protracted process which has to be speeded up or a fast-track court may be established to deal with such cases. The creation of awareness among the people and involving them in conservation issues are very important for successful management of the sea turtle resources along Gulf of Mannar.

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Reconstruction of three-dimensional moving paths of green turtles by means of magneto resistive data loggers

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ABSTRACT
We reconstructed the spatial and temporal diving behavior of a green turtle using cutting edge data loggers. The reconstruction of three-dimensional moving paths of the green turtle has been one of important themes in SEASTAR2000 project.
To reconstruct the three-dimensional moving paths of green turtles, we developed the magneto-resistive acceleration data logger (MR logger) to record magnetic field and acceleration. Field experiments were conducted in Huyong Island, Thailand. The MR logger and Speed/Depth/Temperature data logger (PDT logger) were attached on a carapace of a female green turtle nested on the beach. Sampling frequencies of the data loggers were 10 Hz for the MR logger and 1 Hz for the PDT logger. The 3-D moving paths of the green turtle were reconstructed by her horizontal body directions, vertical tilt angles and swimming speeds. The horizontal body directions of the green turtle were calculated from the surging and swaying magnetic field. The vertical tilt angles of the green turtle were calculated from the surging acceleration.

KEYWORDS: green turtle, diving behavior, three-dimension, data logger

INTRODUCTION

The green turtle (*Chelonia mydas*), listed as an endangered species on the IUCN red list, and has been recognized as species for conservation in many countries. Traditionally, to conserve the turtles, many studies were focused on the investigation on the beach. The biotelemetry contributed to these studies undoubtedly. For example, long or short distance migrations between reproductive sites and feeding sites were found using satellite telemetry in their habitats (Hays *et al.*, 2001; Hatase *et al.*, 2002). In the studies using data loggers, Eckert *et al.* (1989) reported that leather back turtle (*Dermochelys coreacea*) has dived to more than 1,000 m. Recently, Minamikawa *et al.* (2000) reported that the lung air was used to achieve neutral buoyancy in loggerhead turtles (*Caretta caretta*). Although spatial-temporal analysis of the behavior of the sea turtles is very important for better understanding of the species, a three-dimensional diving path for the sea turtles is still unknown. Major reason is that the measurement technique, which can record spatiotemporal data, has not been developed. Sea turtle researchers who used data loggers depended on time-depth series data logger (Eckert *et al.*, 1989; Minamikawa *et al.*, 2000). But, time-depth-series data alone cannot give a real moving track of aquatic animal. In this paper, we introduce the new data logger to record the magnetic field and acceleration. We tried to calculate body direction and tilt angle of the green turtles through this data logger and to illustrate a three-dimensional diving path of the turtle.

MATERIALS AND METHODS

Data loggers

To measure a three-dimensional diving path of green turtles, we developed two types of data loggers (Fig. 1). Magneto-Resistive (MR) logger has two types of sensors, MR sensor and acceleration sensor. The MR sensor is to record a surging and a swaying magnetic field, whereas an acceleration sensor records a surging acceleration and a swaying acceleration (Fig. 2). The MR logger has a memory of 64 MB (5,760,000 data) and is programmed to record the data at an interval ranging from 5 ms to 1 min. The range of measurement and resolution were ± 2 Gauss and ± 1 % FS (magnetic field) and ± 98 m/s^{-2} and ± 0.2 % FS (acceleration), respectively. The instrument was 40.8 mm in diameter, 300 mm in length, and weighed 320 g in water.

CCD logger has a color CMOS sensor to record 28,000 pixels photograph. The sampling interval is four photographs per 1 hour. The logger has a memory of 1 MB (80 photographs). A light sensor equipped with the CCD logger helped in taking photos in the daytime because the logger does not have a flash unit. The instrument was 92 mm in length, 40 mm in width, less than 28 mm in height, and weighed 155 g in water. Swimming speed and depth were monitored using speed-depth-temperature (PDT) logger (UWE-200PDT; 13 g in water, 20 mm in diameter, 90 mm in length, Little Leonardo Co., Ltd), simultaneously.

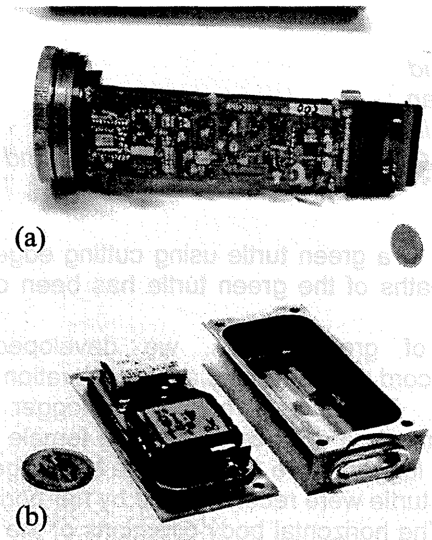

Fig.1. Photos of a MR logger and a CCD logger. The photo (a) is MR logger and the photo (b) is CCD logger.

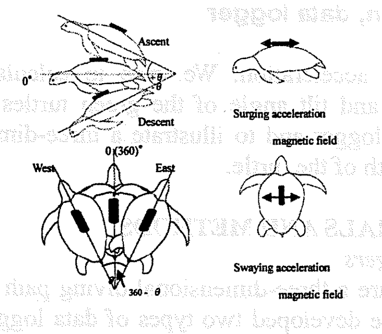

Fig.2. Schematic diagram showing the direction of surging and swaying geomagnetic and acceleration recorded by a data logger on the carapace of a green turtle (black bar). Data for surging acceleration were converted to tilt angles. Data for surging and swaying geomagnetic were converted to body directions.

Field experiments

Experiments were conducted on the nesting beach at the Huyong Island of Similan Islands (8.28°N, 97.38 °E) in the Andaman Sea from May 15 to May 31, 2003. The Huyong Island is a desert island. But it has a primal nesting beach of green turtles in the Similan Islands. The length of the nesting beach is approximately 800 m and the beach is protected by the Royal Thai Navy. All nesting turtles landed on the beach are identified by microchips inserted to their roots of both flippers and inconel tags. Generally, green turtles lay eggs several times on the same beach at approximately 2-week intervals during one breeding season. Therefore, if we attach the data loggers to a turtle at first or second nesting, we can recover the data loggers from the turtle at next nesting.

Night patrol was conducted from 8:00 PM to 4:00 AM to find female green turtles landed on the beach for nesting. The data loggers were attached on the carapace of the nesting female green turtle (Curved carapace length 100.0 cm) after the turtle laid eggs. First we attached two wooden pedestals on the carapace of the turtle using epoxy resin. We used the pedestals to attach the MR logger parallel to body axis of the turtle, and the pedestals played a role as float. Second, the MR logger (sampling frequency 10 Hz) was attached on the pedestals using cable ties. The PDT logger (sampling frequency 1 Hz) was attached beside the MR logger using epoxy resin. The CCD logger was attached on the front of carapace of the turtle using epoxy resin. We retrieved the data loggers from the turtle when the turtle subsequently returned to the beach.

Body direction

Figure 3 shows normalized outputs of the MR sensor. The normalized outputs were ranging from −100 to 100. When the sensor was held horizontally and was rotated clockwise from the north direction, responses of the surging and swaying magnetic field recorded by the MR sensor showed the cosine (surging) and sine (swaying) functions. We calculated the horizontal body direction (θ_l) using this relationship between surging magnetic field (x) and swaying magnetic field (y) by following Equation 1.

$$\theta_l = \begin{cases} 90 & (x = 0, y > 0) \\ 270 & (x = 0, y < 0) \\ 180 + \mathrm{atan}(y / x) * 180 / \pi & (x < 0) \\ \mathrm{atan}(y / x) * 180 / \pi & (x > 0, y > 0) \\ 360 + \mathrm{atan}(y / x) * 180 / \pi & (x > 0, y < 0) \end{cases} \qquad (1)$$

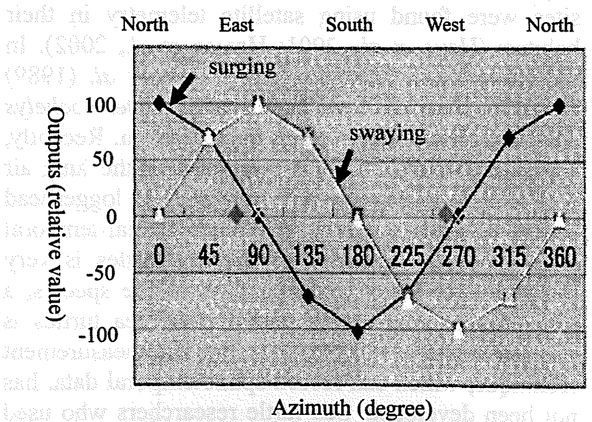

Fig.3. Normalized outputs of MR logger when the logger was held horizontally and rotated clockwise from the north.

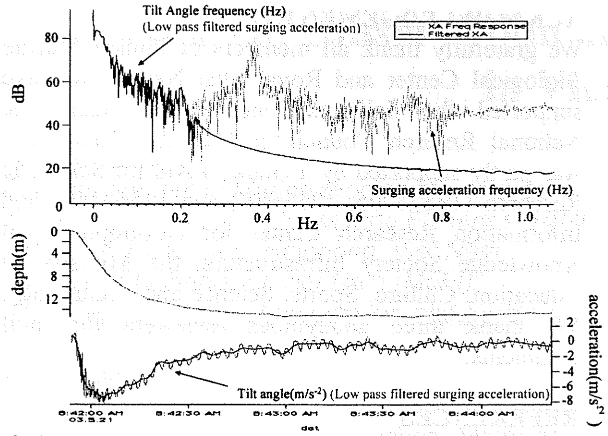

Fig.4. Frequency response and expanded time-series of surging accelerations of the turtle for a typical diving. The Upper graph shows frequency response of surging acceleration and lowpass filtered surging acceleration. The lower graph shows expanded time-series of depth, surging acceleration and lowpass filtered surging acceleration, which showed tilt angle of the turtle.

Tilt angle

The acceleration sensor along the body axis of an animal is affected by both forward movement s of an animal and gravity (Yoda *et al.*, 2001; Tanaka *et al.*, 2001). We found the peak at 0.36 Hz. This peak may indicate a flipper movement frequency of the turtle. Moreover, high frequency variations ranging from 0.2 Hz to 0.4 Hz recorded in the surging acceleration may indicate to be caused by the flipper movement for the turtle. These frequencies were filtered out using a 0.2 Hz low-pass filter (IFDL Version 3.1; WaveMatrics, Inc., USA; Tanaka *et al.*, 2001) to get the tilt angle (Fig. 4). When the animal is still or moving at constant speed, the gravity vector (g = 9.8 m/s^2) will change in response to the tilt angle (Tanaka *et al.*, 2001). Therefore, we have calculated tilt angle (θ_2) of the turtle using low-pass filtered surging acceleration (A) as the following Equation 2

$$\theta_2 = \operatorname{asin}(A/g) \qquad (2)$$

We tried to attach the MR logger parallel to body axis of the turtle using the two wooden pedestals. However, it was difficult to put the MR logger exactly parallel to the body axis of the turtle. Therefore, it was necessary to correct an initial error of the tilt angle calculated from the surging accelerations. As described by Sato *et al.* (2003), initial error of the tilt angle can be corrected by the comparison between a dive profile measured by depth sensor and calculated dive profile by several adjustment tilt angle. Therefore, we corrected the initial error of the tilt angle by this method.

Horizontal moving paths

Horizontal moving paths of the turtle, which are longitudinal moving distance (d_1) and latitudinal moving distance (d_2), was calculated from the body direction (θ_1), tilt angle (θ_2) and swimming speed (v) by Equation 3 (longitudinal movement) and Equation 4 (latitudinal movement).

$$d_1 = v * \cos(\theta_2) * \cos(\theta_1) \qquad (3)$$
$$d_2 = v * \cos(\theta_2) * \sin(\theta_1) \qquad (4)$$

RESULTS AND DISCUSSION

We analyzed the data from May 21 to May 23, 2003. The turtle carried on with a continuous dive. The mean maximum depth of dives was 13.88 m. The mean duration of dives was 18.17 min. The mean rate of bottom time (bottom time per dive duration) was 0.35 % (n = 95).

The data presented in Figure 5 describe a typical dive of the turtle. Dive duration was 710 seconds. Maximum dive depth was 15.20 m. Mean swimming speed was 0.81 m per second. Figure 6 shows horizontal moving path and relationship between swimming direction and diving depth. The turtle descended northwestward and ascended southwestward during this dive. The turtle has maintained its direction relatively constant during this dive. Therefore, we illustrated the three-dimensional diving path of the turtle by direction and swimming speed data (Fig. 7). However, the illustrated moving path of the turtle may be affected by ocean current because the PDT logger measured a swimming speed using a propeller. Therefore, an estimated error that could affect the accuracy of the calculation of the turtle was accumulated in the moving path. Davis *et al.* (2001) and Mitani *et al.* (2003) adjusted the accumulation of the errors of the three-dimensional diving path of seals using "dead reckoning" methods. However, we cannot apply this method to adjust the accumulation of errors because a start position of dive of sea turtles differs from a goal position of the dive. To adjust the accumulation of errors of the diving track, it is very important to get positional information of diving turtle. Now we are developing the Argos transmitter equipped with GPS sensor for sea turtle study. So we will adjust the accumulation error of diving path of the turtle using GPS position in the near future.

Three-dimensional analysis by the MR logger will gratefully contribute to the studies on behavior of sea turtles. For example, we know that a sea turtle lay eggs on the beach and migrate between the fixed feeding area and fixed nesting area. However, the ability to find the nesting beach and feeding area is still unknown. A body direction of the turtle measured by the MR logger will contribute to elucidate this ability.

Traditionally, migration paths of sea turtles were studied using satellite telemetry (Hays *et al.*, 2001; Hays *et al.*, 2002; Hatase *et al.*, 2002). However, when detailed aspects of satellite tracking data are considered, such as speed of travel and small-scale movements of sea turtles, then location accuracy is likely to become an important issue (Hays *et al.*, 2001). In sea turtle study, a high proportion of locations may be of low quality because a signal from a transmitter uplinks to the satellite only when a turtle swim at sea surface. The MR logger tracking will become a solution for this problem. MR logger can track a migration path of the turtle continuously. The recording time of the MR loggers, however, are limited due to their battery. Therefore, our future plan is to track more detailed migration paths of turtles all through the inter-nesting intervals.

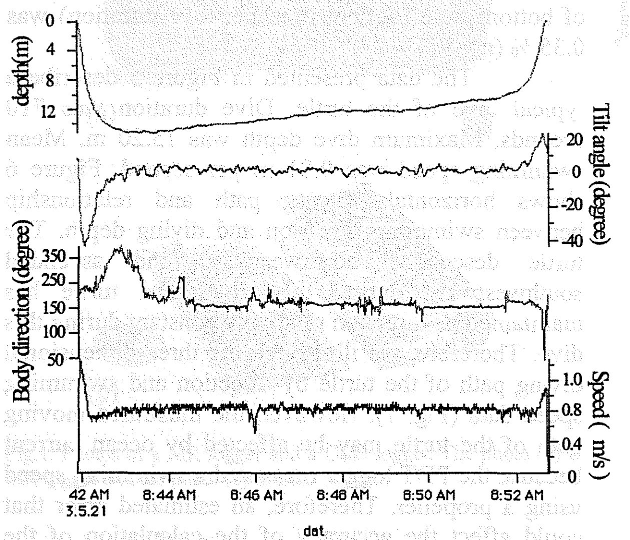

Fig.5. Expanded time-series of depth, tilt angle, body direction and swimming speed for typical 1 dive of the turtle.

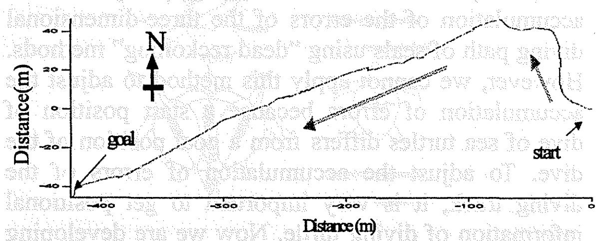

Fig.6. Horizontal moving path for typical 1 dive of the turtle.

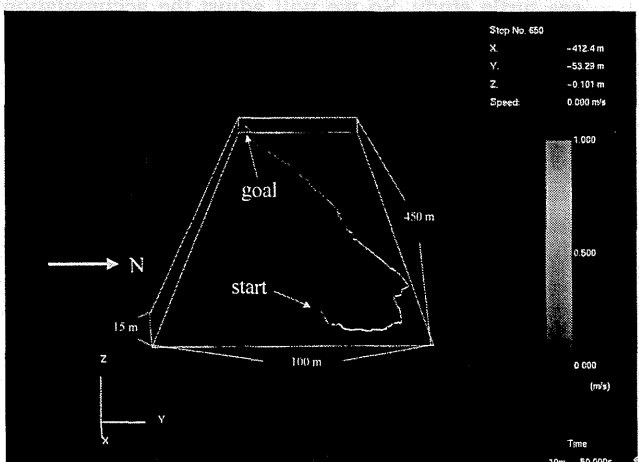

Fig .7. Three dimensional moving paths for typical 1 dive of the turtle.

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We gratefully thank all members of Phuket Marine Biological Center and Royal Thai Navy who have supported the field experiments. We thank the National Reserch Council in Thailand. This study was partly supported by a Grant-in-Aid for Scientific Research (13375005, 12556032 and 14560149) and Information Research Center for Development of Knowledge Society Infrastructure, the Ministry of Education, Culture, Sports, Science and Technology. We thank three anonymous reviewers for their comments.

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The research, conservation and management of sea turtles in Viet Nam

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ABSTRACT
It is recognized that there are five species of sea turtle to reside in Viet Nam. However, there are only three species often nest on beaches. Major nesting beaches are concentrated on offshore-islands in the Tonkin Gulf, Central Coasts and Islands in the Southern part of Viet Nam. Our results showed that locals have harvested nesting turtles and approximately amount of 50% of eggs for each species during nesting season, with the exception of Tho Chu Island, Con Dao National Park and Nui Chua Natural Reserve Area. Continuation of those threats will lead to the extinction of sea turtles in Viet Nam in the forthcoming decades. The current threats for marine turtles are including: (i) the incidental and opportunistic capture by fishermen and locals; (ii) the direct take of nesting females and their eggs at beaches; (iii) the urbanization, illegal trade issues, sand mining, tourism development and marine debris... The largest risk for marine turtles are bottom trawlers, especially in "Cao bay" trawling with big mesh-size net, gillnet operation, long-line net with several hook operators and diving activities. In general, most green, hawksbill and olive ridley turtles are captured by those methods. The immediately taken action to preserve sea turtles and other wildlife, based upon the collaboration between Local, National Sectors and Regional Organizations are the best choice.

KEYWORDS: loggerhead, olive ridley, leatherback, green and hawksbill turtle, Tonkin Gulf, National Park, Reserve Area.

INTRODUCTION

The seawaters and remote islands of Viet Nam are recognized as a critical habitat for sea turtles of the world. Research, conservation and management activities on sea turtles have been conducted in coastal provinces of country as well as in other countries of ASEAN/SEAFDEC members. There are 5 species, which had been found in Vietnam Seawater and they have been threatening species (Hamann Mark, 2002).

Since early 1998, the Ministry of Fisheries has appointed the Research Institute for Marine Fisheries (RIMF) as National Institution taking responsibility for research activities and proposing the general framework in managing and protecting sea turtles in Viet Nam.

OBJECTIVES

Our program objectives on the sea turtle conservation are:

- To facilitate in regarding to the research, conservation and management for sea turtles between ASEAN/SEAFDEC Countries and Viet Nam,
- To enhance the common awareness in term of protecting the sea turtles and their habitats,
- To introduce some advanced technologies in monitoring, controlling and surveying for sea turtle resource with integrated coastal zone management approaches,
- To primarily set-up the National Database as well as National Action Plan for Sea Turtle Conservation and Management beyond 2010.

RESULTS AND DISCUSSION

The distribution of sea turtles

Nesting season and hatch rate

Annually, hundred of sea turtles went to shoreline for nesting on sand beaches. Nesting season for sea turtles differs among different species. In general, nesting season lasts from March to November. Con Dao (Ba Ria-Vung Tau), Tho Chu (Kien Giang) and Nui Chua (Ninh Thuan) Reserve Park are the main nesting sites and so on.

Nesting behaviour of sea turtles showed that turtles nest at nighttimes. Hatch rate of sea turtles depends on the interaction of numbers of factors, such as salinity, humidity, temperature, gas flow, rainfall, tidal inundation, erosion, and predation. The hatch rate ranged with average of 67,93% during the period of 1994 till 2003 (Table 2; Figure 2).

Table 1: Nursing grounds of sea turtles found in Vietnam

No	Nursing ground	Sea turtle species
1	Con Dao Archipelago (including 14 places)	*Chelonia mydas, Eretmochelys imbricata, Caretta caretta*
2	Nui Chua Natural Reserve Area (Ninh Thuan)	*Chelonia mydas, Eretmochelys imbricata, Lepidochelys olivacea*
3	Quang Ninh (including Vinh Thuc Island and Minh Chau beach)	*Chelonia mydas*
4	Bach Long Vi Island (Hai Phong)	*Chelonia mydas*
5	Spratly Archipelago	*Chelonia mydas, Eretmochelys imbricata*
6	Phu Quy Island	*Chelonia mydas, Eretmochelys imbricata*
7	Phu Quoc Island	*Chelonia mydas, Eretmochelys imbricata*
8	Tho Chu Archipelago	*Chelonia mydas, Eretmochelys imbricata*

Source: Hamann Mark 2002; Le Xuan Ai *et.al.*, 2002.

Table 2: The hatch rate of Sea turtles in 1994 –2003.

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Hatch rate (%)	19.92	35.32	74.37	75.29	78.32	80.31	81.15	84.38	73.23	76. 99

Source: (RIMF_MoFI, WWF and IUCN, 2003).

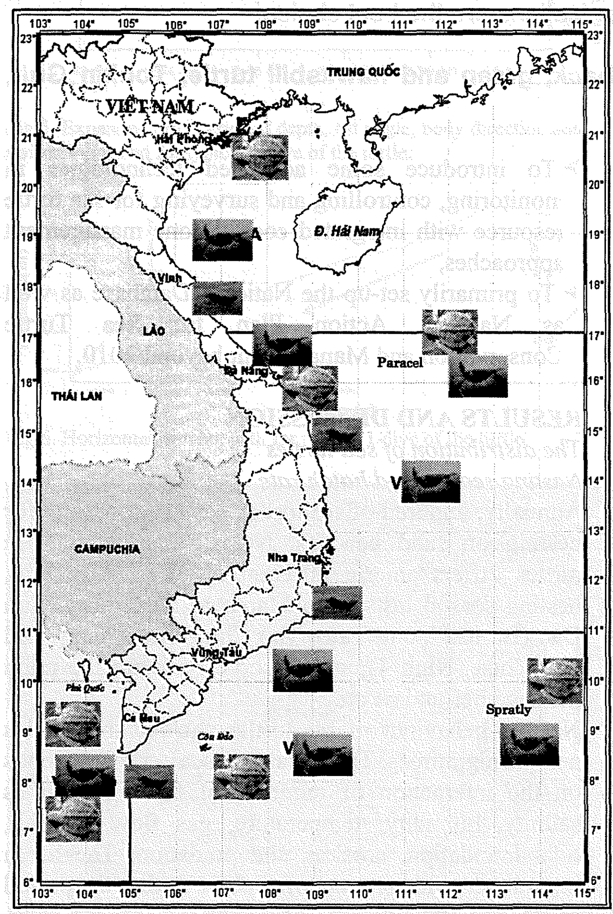

Fig. 1. The Map of distribution for Sea Turtles in Viet Nam Seawater

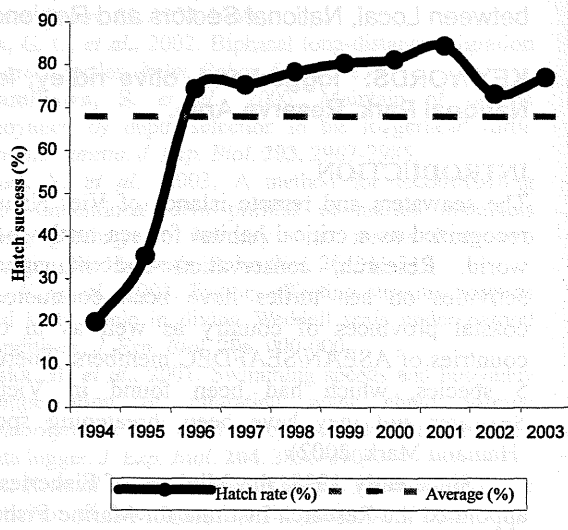

Fig. 2. Hatch rate of the Sea Turtle in Viet Nam

Threats to marine turtles in Viet Nam:
At all stages of their life cycle marine turtles are subject to various impacts that may combine their survival and capacity to breed successfully. These impacts have the potential to decrease population sizes and threaten the species with endangerment. Listed below are summarised threats that have been identified by the previous and recent researches and surveys, which of these threats is presented below (Table 3).

Table 3. Potential human-related impacts/threats associated with species marine turtle in Viet Nam. Although they do not nest in Viet Nam, reside in Viet Nam's waters these are threats to a distant nesting population(s).

Human-related impacts	Green (southern)	Green (northern)	Green (Gulf of Thailand)	Green (Spratly)	Hawksbill	Hawksbill (Spratly)	Olive ridley	Leatherback	Loggerhead
Defence activities	✗	✗	?	✓	✗	✓	✗	✗	✗
Diseases	✗	✗	✗	✗	✗	✗	✗	✗	✗
Sand mining	✗	✓	✗	✗	✗	✗	✓	✗	✗
Tourism Developement	✓	✓	?	✗	?	✗	✓	✗	✗
Illegal egg collecting	✓	✓	✓	?	✓	?	✓	✓	✗
Incidental catch – lines	✓	✓	✓	?	✓	?	✗	✗	✓
Incidental catch – gill nets	✓	✓	✓	?	✓	?	✓	✓	✓
Incidental catch – Longlines	✓	?	?	?	✓	?	✗		✓
Incidental catch - trawl nets	✓	✓	✓	?	✓	?	✓	✓	✓
Ingestion of, or Entanglement in, marine debris	?	?	?	?	?	?	?	?	?
Illegal direct take – in Viet Nam	✓	✓	✓	?	✓	?	✗	✗	✗
Direct take – overseas	?	?	?	?	?	?	?	?	✗

Source: National Action Plan for sea turtle conservation and management of Viet Nam beyond 2010.
Notes: "✓ = threat present, ✗ = threat absent or not recorded, ? = the impacts are suspected but have not been documented."

Table 4: The number of released hatchlings during the period of 1994-2003.

Year	1994	1995	1997	2001	2002	2003	Total	Average per year
Hatchling (individual)	6,000	28,500	70,000	90,000	140,450	161,210	496,160	82,693

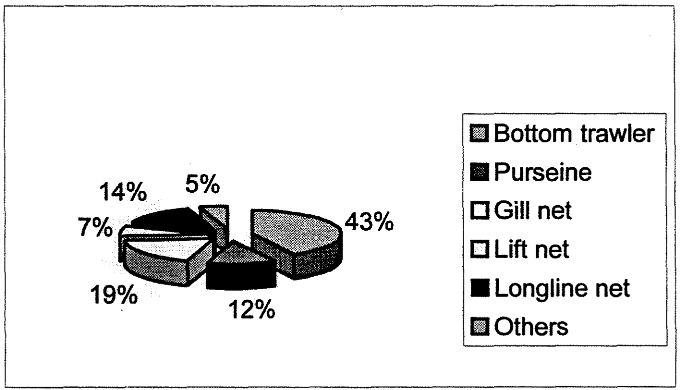

Fig. 3. Percentage of fishing gear in fisheries sector of Viet Nam

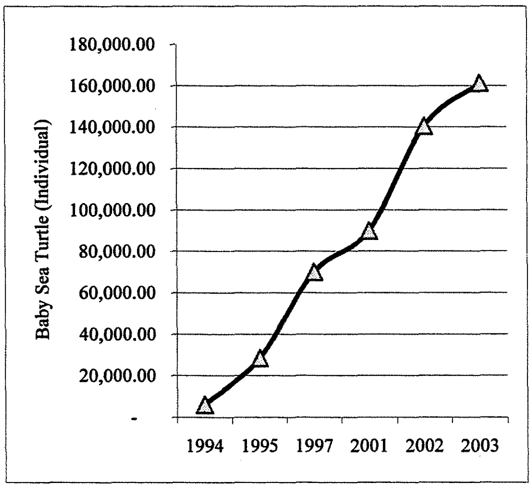

Fig. 4. Amount of baby sea turtle released into Seawater

Direct and indirect take of nesting and foraging turtles and eggs

Interview-based studies were carried out in 1998-2002 by RIMF and 2002 by IUCN_VN, in Thanh Hoa (Tonkin Gulf), Quang Nam, Da Nang and Khanh Hoa provinces (Central of Vietnam), Phu Quy, Con Dao, Tho Chu and Phu Quoc Islands (Southern part and Gulf of Thailand). The results showed that almost marine turtles were incidentally caught by various types of fishing gears especially by bottom trawls, gillnets, long-line and sometime by purse seine. However, number of marine turtles incidentally caught by fishing gears as by-catch in Viet Nam was estimated to be less or more than 30 individuals per year (Mark Hamann et al., 2002).

Direct harvest

The direct take of turtles and eggs from the nesting beaches is a principal factor underlying the decline in nesting numbers of all marine turtle species in Viet Nam. However, data from a joint (IUCN, RIMF and MoFI, 2002) survey indicate that most of the eggs harvested in the non-protected locations. It is clear that Vietnamese nesting populations cannot sustain this practice. In addition, fishing techniques such as longline fishing and gill nets, have been adapted or used to. Hence most of the foraging turtles are caught accidentally in fishing gear. However, the opportunistic capture of both green and hawksbill turtles by fishermen want diving for other economically important marine products such as molluscs and crustaceans poses a significant threat to these species. This take could involve hundreds of turtles from each species, and needs to be eliminated in the near future if Viet Nam's foraging populations of these species are to survive. The fishing sector in Vietnam has grown considerably over the last more 10 year. By 2002, while the number of artisan vessels has remained similar, the number of registered vessels had increased to 79,000. Most of these (69,000) work in the coastal zone. Of these registered vessels (Source: Research Institute for Marine Fisheries_RIMF):

- 42.3% are registered as bottom trawlers
- 12.3% are registered as purse-seining vessels
- 19.2% are registered as gill net vessels
- 7.0% are registered as lift netting
- 14.2% are registered as long lining vessels
- 5.0% are registered as other.

Fishers using SCUBA, Hookah or free divers, dive around the coral/rocky reef areas, usually around islands. In some locations these divers attempt to catch fish using cyanide, however, most are diving to collect commercially valuable species of finfish, mollusc and crustacean such as lobster and abalone.

Incidental take

The incidental capture of marine turtles is a large and widespread problem, with a large percentage of these either drowning in fishing gear or being killed for food when accidentally caught in nets and brought on boat alive. The fishing methods of most concern are, (1) bottom trawling, (2) drift and gill nets, and (3) longlines.

RIMF (2002) reported that between 1993 and 2001 there was an average of 69,000 registered vessels operating within the waters of total 23 coastal provinces in Viet Nam. Of the registered vessels operating, nearly 42.3% are bottom trawlers and 19.2% are gillnetting vessels. Survey data compiled by MoFI, RIMF and IUCN indicate that turtles are caught as bottom trawl or gill net bycatch in 15 of targeted provinces, with catch rates varying from one turtle per province per year up to 10 of turtles per year (Pham Thuoc et al., 2002).

Trade issues

Several green turtles and hawksbill turtles are illegally sold for the production of stuffed turtles or shell products (Thomson, 2002). This trade has been reported on by several authors (Baird, 1993; Duc and Broad 1995), and although it is difficult to ascertain actual numbers of turtles that are killed each year, or the rate in which products turn over in stores, the number of products for sale with significant numbers of turtle shell products being sold to international and domestic tourists. While most olive ridley, leatherback and loggerhead turtles that are killed, indirectly or directly, are eaten by fishers or sold for food (Baird, 1993).

Impacts on foraging habitat and food sources

The number of fishing and tourist boats along the Viet Nam coastline has increased significantly in the last two decades. Associated with this has been an increase in marine noise and pollution levels e.g. oil/fuel residue, rubbish (including plastics, discarded net and other foreign material). These factors have negatively affected marine turtle populations in other areas of the world through ingestion, entanglement, injury, and obstruction or by degrading the foraging or nesting habitats, and it is likely that they have contributed in some way to the demise of marine turtles in Viet Nam. In fact, these factors are to constitute the largest non-by-catch or consumptive threat for marine turtles in Viet Nam. Marine debris does not only impact marine turtles but also threatens the health of the marine ecosystem and dependent industries such as tourism and fishing. Unless this problem is addressed in the short term, Viet Nam's valuable coastal and marine ecosystems will be under serious threat of becoming irreparably damaged.

Coral reefs in Viet Nam have long suffered from explosive and cyanide fishing, and sea grass and mangrove habitats have experienced decades of clearing, harvesting, sedimentation and other anthropogenic impacts. Considerable efforts have been made in recent years by various Government and Non-Government Organisations to stop these destructive fishing operations, to promote the suitable use of marine resources and coastal habitat protection (RIMF).

Impacts to nesting turtle habitat

Sand mining

It is unknown whether current sand-mine operations have impacted upon nesting distributions in Minh Chau and Quan Lan Island, however, if the mining area is extended to the beaches where nesting currently occurs (Son Hoa) threats to the stability of the nesting beaches are inevitable. Along the mainland coast sand mining exists in numerous areas, however it is unknown whether any conflicts with marine turtle nesting beaches exist. Continued marine turtle surveys in Phu Yen and Khanh Hoa provinces will be required to determine if any negative impacts are likely along those beaches.

Urbanization and Tourism

The beaches on which turtles are still occasionally seen nesting are mostly undeveloped and mainly located on offshore islands, or away from tourist developments. However, the beaches on Son Tra peninsula (Da Nang City) and several beaches in Quan Lan and Minh Chau are earmarked for tourist development. If these beaches are developed, marine turtle nesting rookeries may be threatened by a variety of factors such as beach removal or alteration, physical obstruction to the dunes, lighting, noise, and increased beach use by people.

Marine debris

Once thrown in the water, whether the original receptacle is a gutter, drain, creek, river or ocean, rubbish has to end up somewhere. Many mainland beaches in Viet Nam have extremely high levels of marine debris. Much of this debris consists of glass, plastics and polystyrenes, and other items associated specifically with fishing such as floats, nets, and light bulbs. This is a problem for marine turtle nesting because it may impede movement and nest digging, lead to injury and infections, and in some cases may cause turtles to be trapped.

Management activities

National and NGO programs

In 1995, the Programme " Salvation of Sea Turtles in Vietnam " has been launched and supported by WWF-Indochina. Observations on nesting behaviour of marine turtles have been conducted during reproduction period in Con Dao Island. Nesting on nesting sites in Con Dao are recorded and marked, and those being threatened be washed away by wave should be removed to safe sites. Nearly, emerged hatchlings are rearing in tanks for period of time then is released to sea. However the baby turtle in 1996, 1998, 1999 and 2000 are not yet statistically completed and missed. Present research has being conducted in relation to sea turtles in Viet Nam. The topic titled " Study on marine turtles resources, to determine measures to protect and develop their resources in seawaters of Viet Nam since 1998 only and with very limited budget granted by Ministry of Fisheries of Viet Nam. The main objectives of the study are as follows:

- To estimate the abundance and distribution of sea turtles.
- To study on tagging, nesting behaviour and biology.
- To study on affect of fishing gears on sea turtles.
- To establish sanctuaries

On the other hand, activities on conservation of sea turtles in Con Dao have been carrying out since 1995 with assistance of IUCN_VN and WWF_Indochina in both technical and financial terms.

Turtles, Dugong, Sharks and Fish rays are not wanted in prawn trawl nets. Turtle Excluder Devices (TEDs), which reduce those target in term of the termin 'bycatch', but improve the value of the prawn catch. TEDs are metal grids placed inside the trawl net, which block the entry of larger sea-life and allow prawns to pass through. However, TED implementation has not applied yet in Viet Nam.

With the help of governmental agencies, RIMF coordinated with SEAFDEC/TD developed the Juvenile Trash Excluder Device (JTED). It now requires that JTED be encouraged for using on Swallowed Fishery Operating in order to minimize juvenile mortality. During the period of 9-15th May 2001, JTEDs introduced into Viet Nam in collaboration between SEAFDEC/TD and RIMF. The experiment and demonstration were carried out at Cat Ba bay at Hai Phong City. The result had been less or more successful. Fishing boats, which installed with a JTED with 3 distances of bars, included of 20, 30 and 40 cm interval (see more detailed in SEAFDEC/RIMF report concerned). Those results also showed that 28 trial hauls with 3 different bar distances has not been found the best distance of bar. It maybe caused by too small targets as well as is not enough haul of trial. ***However, those rigid sorting grids JTEDs have higher separating performance than rectangular and semi-curve ones for release juvenile and trash fishes.*** The highlight issues are still thinking about how much the survived rate of Juveniles after escaping of JTEDs that is not known (Nguyen Phi Toan et al., 2001).

Based upon the previous results, RIMP staffs had carried out another JTED trial operations in the

South of Viet Nam. This trial last 2 Month from September till October, 2003 in the outermost of buffering Zone at Con Dao National Park to reassess the survived rate of Juveniles. Generally, the result showed that the percentage of the rate of Juveniles escaped is 20% higher than it was trials in 2001 (Nguyen Phi Toan personal information unpublished). Tagging activities have been also initially conducted since 1998 especially on Green Turtle, Hawksbill in some coastal areas at Viet Nam, especially at Con Dao National Park in the collaborative program among SEAFDEC member countries as well as WWF_Indochina project for the sea turtle conservation (Nguyen Duy Thuong, 1999).

Satellite telemetry of marine turtles has proven to be a valuable tool for initiating conservation awareness programs in local communities and communicating that management of marine turtles is the responsibility of numerous user groups from a variety of agencies and locations. A project using modern satellite telemetry is initiated by WWF_Indochina, NOAA at Con Dao National Park to increase the awareness and understanding about marine turtle migration. This primary allowed Con Dao NP staffs to access information and follow the track of the turtle as she migrates back to her foraging area.

However, the difficult problems being faced in research and conservation of marine turtles in Viet Nam are shortage of financial support, lack of training opportunities, insufficient knowledge to technology and it's applications, etc.

Some Conservation Activities at Con Dao National Park:

* 1994-2003: It is recognized that On 5 Island (rookeries), there are 2082 Sea Turtles for nesting, which included 4 Hawksbill.

* 8/1998 till 2003: there are 1230 turtles had been tagged by SEAFDEC tags as well as several tags had been made by Con Dao National Park.

* 1995-2003, 376.680 hatchling of 6252 egg clutched had been released into sea.

* Two green turtles had been used in terms of Satellite tracking studies to determine their pathway and foraging ground at southern part of VN Seawater. Unfortunately, a green turtle lost PTT with its ID: TE 19590 (USA) at Hon Cai Lon Island. Another one attached PTT on 3rd July 2001. It surfaced during 8 day and moved to nearby Vung Tau. It travelled total period of 30 day and nesting on Phu Quy Island, which is far from the started point of 342 km (Con Dao report, 2003).

RECOMMENDATION

There is strongly urged to provide the resources necessary to enforce for the prevention of trade in sea turtle products. It maybe building on experience and knowledge gained by other ASEAN/SEAFDEC nations and continue researching and evaluating in terms of useful TED's and JTED's in the Vietnamese trawl fisheries.

There is strongly urged to collect baseline biological data on foraging area populations. If implemented, this would be the first systematic foraging ground study as well as to conduct baseline surveys of sea turtle distribution, abundance, status and threats in our region.

There is strongly urged to continue supporting the extremely valuable nesting beach tagging studies and uses modern satellite telemetry techniques to increase the awareness and understanding of local Vietnamese community about sea turtle migration at Con Dao National Park, Nui Chua (Ninh Thuan) Reserve Area and Tho Chu Island (Kien Giang). There is a need of enhance awareness and develop the suitable Eco-Tourism Activities as well as ban the illegal market of Sea Turtle businesses. In addition, the coordination with the Regional and International Organization in order to protect the Sea Turtles and other wildlife is very necessary.

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No genetic divergence between green turtle *Chelonia mydas* nesting populations from the Andaman Sea and the Gulf of Thailand

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INTRODUCTION

Thailand faces two seas *i.e.* the Gulf of Thailand and the Andaman Sea. The two seas are separated by the southern part of Thailand through Malaysian peninsular and further semi-separated by Indonesia (Fig. 1). These geological barriers act effectively to limit geneflow among conspecific populations from the two seas as revealed in several marine organisms *e.g.* banana prawn *Peneaus monodon* (Supungul *et al.*, 2000; Klinbunga *et al.*, 2001), giant clams *Tridacna squamosa*, *Tridacna maxima* (Kittiwattanawong, 1999; Kittiwattanawong *et al.*, 2001), starfish (Benzie, 1999), rock oysters *Crassostria spp.* (Bussarawit, 2003). Additionally, separation at community level was detected (coral reef fish communities, Satapoomin, 2002). At the larger scale, this geological barrier may serve as a wall to separate marine organisms between Indian and Pacific oceans.

A green turtle *Chelonia mydas* is another organism distributes in both the Gulf of Thailand and the Andaman Sea (Phasuk, 1992). This allows a possibility to test the effectiveness of this geological barrier. In our previous study (Kittiwattanawong *et al.*, In press), satellite transmitted tracking of the nesting green turtle populations from the Andaman Sea and the Gulf of Thailand suggested contemporary allopathic life cycles (Fig. 1). However, such a finding only reflects the present scenario. An improved understanding of life history may be obtained by research on population genetic structure. Several kinds of genetic materials vary from proteins to nucleic acids can be employed to reveal population genetic structure (Avise, 1994). Since, genetic materials are inherited from one generation to another, information obtained from genetic materials reflect the summary of natural history from the past till present (Futuyma, 1986; Page and Holmes, 1998).

This study was an analysis of nucleotide sequence from mitochondrial DNA (mtDNA) at control region or D-loop which is recognized as highly polymorphic site (Norman *et al.*, 1994). Within the d-loop, the mutation rate is approximately five to ten times that of the rest of the mitochondrial genome, (Aquedro and Greenberg, 1983). The paper describes the genetic diversities and divergence of the two green turtle nesting sites *i.e.* Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea (Fig. 1).

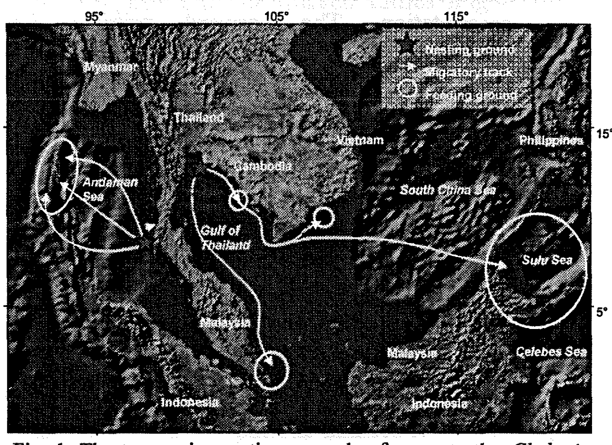

Fig. 1. The two major nesting grounds of green turtles *Chelonia mydas* in Thailand (Khram Island in the Gulf of Thailand and Huyong Island in the Andaman Sea) with the satellite transmitted results showing the simplified migratory routes and their feeding grounds.

MATERIALS AND METHODS

The tissues

The samples were collected with supports from the Royal Thai Navy during 2001-2002. Usually, the staffs patrolled the beaches at night during high tide. After a turtle had laid eggs, the staffs scanned for a microchip tag at the both flippers, and a new one would be inserted subcutaneously to the left flipper when it was not found. Thereafter, a small piece of skin tissue (approximately 0.3x0.3 cm^2) at the inner flipper was cut with a sterile surgery knife and put into a 2-ml microcentrifuge tube filled with sodium chloride saturated DMSO or TNES (a mixture of 150 mM NaCl, 10 mM Tris-HCl pH 7.5-8.0, 25 mM EDTA, and 0.5% SDS) solutions and stored at room temperature. The antibiotic medicines such as Gentian Violet, Povidoiodine, or tetracycline oilment were put on the wounds before the release of the green turtles. Twenty-seven samples were collected from Khram Island in the Gulf of Thailand and nineteen samples were from Huyong Island in the Andaman Sea. All samples were exported and analyzed at Graduate School of Agriculture, Kyoto University, Japan under the permission of the CITES.

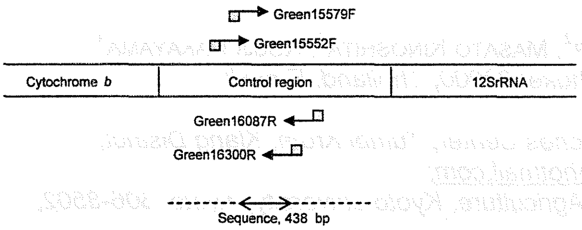

Fig. 2. Location of the primers employed in the study overlaid to a none-scale mtDNA of *Chelonia mydas*. Arrows indicate the nucleotide synthesis directions. The line with both ends arrows indicates proximal length of nucleotide sequence (438 bp).

DNA analysis protocol

The tissues were digested with Proteinase K. The DNA solutions were obtained by a standard phenol/chloroform extraction (Sambrook *et al.,* 2001) and precipitation. The forward primers *i.e.* Green15552F (FGTGT C CACA CAAAC TAACT ACCT), Green15579F (CTGCC GTGCC CAACA GAACA) and reward primers *i.e.* Green16300R (GTCTC GGATT TAGGG GTTTG GCG), Green16087R (CCAGT TTCAC TGAAT CGGCA) were used to obtain the specific nucleotide sequences in the control region mtDNA (Fig. 2). Afterward, the selected sequences were amplified with a PCR machine. The PCR products then were run on the Argarose gels to identify the successful of PCR amplification. Finally, the PCR products were sequenced with an automated sequencer to obtain direct reading of the nucleotide sequences.

Data analysis

The nucleotide sequences were aligned and cut using the computer program CLUSTAL W 1.7 multiple sequence alignment (Thompson *et al.,* 1994). Haplotypes were determined by examining the aligned sequences. Haplotypes were assigned when one or more base changes differed from the consensus or conserved sequence. Haplotype (h) and nucleotide (π) diversities were calculated according to the method described by Nei 1987. Divergences between the two populations were calculated as Gst (based on haplotype frequencies, Hudson *et al.,* 1992), Nst (based on nucleotide sequences, Lynch and Crease, 1990), and Tamura-Nei's genetic distance (D_{TN}, Tamura and Nei, 1993). Nst is similar to Fixation indices (Fst) described in Weir and Cockerham (1984), but uses the Jukes and Cantor (1969) correction. Additionally, the differences in haplotype frequency among populations and the nucleotide divergence among haplotypes are also taken into account in the calculation of Nst (Ramey II, 1995). Gst and Nst values range from 0 to 1, which indicate from non existence of population subdivision to well defined sub population. A chi-square test (Hudson *et al.,* 1992) based on pair-wise comparisons of haplotype frequency data was also conducted to detect genetic differentiation between populations. Gene flow (Nm) between the two populations was estimated from Nst and Gst values by the formula Nm=0.5(1/Nst or Gst–1) (Wright, 1951). Nm can be interpreted as the absolute number of individuals exchanged between populations per generation (Avise, 1994). All calculations were performed by the program DnaSP version 3.99.5 (Rozas and Rozas, 1999) and MEGA version 2.1 (Phylogenetic and molecular evolutionary analyses, Kumar *et al.,* 2001). The nucleotide sites with gaps or missing data were completely excluded from the analysis. All sampling errors were reported as standard error (SE) calculated by the mentioned programs with 1,000 bootstrap replicates (Nei and Kumar, 2000). A chi-square test was conducted to test for a significant genetic divergence between the two populations (Nei, 1987; Hudson *et al.,* 1992).

RESULTS

Diversity

The aligned sequences contained 438 base pairs (bp) with 254 polymorphic sites. There were 8 haplotypes assigned from the 49 green turtles sampled from the Andaman Sea and the Gulf of Thailand (Table 1). The two most dominant haplotypes (B1 and A1) were observed in common in the both waters. The number of haplotypes was higher in the samples from the Gulf of Thailand (7 haplotypes *i.e.* A1, A2, A3, B1, B3, B4, B5, and B6) than the Andaman Sea (3 haplotypes *i.e.* A1, B1, and B3). The haplotype A2, A3, B4, B5, and B6 were detected only from the Gulf of Thailand, while B3 was edemic to the Andaman Sea.

Overall haplotype diversity (Andaman Sea and Gulf of Thailand combined) for the green turtle nesting populations of Thailand was high (h=0.640; Table 2). However, haplotype and nucleotide diversities in all cases might be slightly less than the actual value since the calculations excluded gaps in the aligned sequences. The Gulf of Thailand had a slightly higher degree of haplotype diversity than the Andaman Sea. On the contrary, nucleotide diversity was higher in the population from the Andaman Sea than the Gulf of Thailand.

Table 1. Distribution of the mtDNA control region haplotypes between the nesting populations of the Andaman Sea and the Gulf of Thailand.

Haplotype	Andaman	Gulf	Total
A1	8	8	16
A2	-	1	1
A3	-	1	1
B1	10	15	25
B3	1	-	1
B4	-	1	1
B5	-	1	1
B6	-	3	3
Total	19	30	49

Divergence and geneflow

Low genetic divergence between the nesting green turtle populations of the Gulf of Thailand and the Andaman Sea was detected in both haplotypic (Gst=0.00311) and nucleotide levels (Nst=0.02838) as well as genetic distance (D_{TN}=0.016±0.003). The estimated female mediated gene flows (Nm) from haplotype and nucleotide data were 161 and 17. This finding implies a lack of population subdivision between the nesting populations of the Andaman Sea and the Gulf of Thailand, and a sufficient degree of gene flow to prevent genetic differentiation between the two populations. The chi-square tests of genetic divergence of both Gst and Nst, revealed no significant differentiation (P>0.05) between the nesting populations of the Gulf of Thailand and the Andaman Sea.

DISCUSSION

Our results indicate that the two nesting green turtle populations from the Gulf of Thailand and the Andaman Sea are well mixed. The present geological boundary (the part of the Southern continent from Thailand to Malaysia peninsula down to Indonesia) seems not to effectively prevent the geneflow between the two populations as observed in invertebrate species (Kittiwattanawong, 1999; Supungul *et al.,* 2000; Kittiwattanawong *et al.,* 2001; Klinbunga *et al.,* 2001 Benzie, 1999; Bussarawit, 2003). However, this finding is not accord with the previous results of satellite tracking that the two nesting populations possessed separated feeding grounds and hence, they may be separated populations (Kittiwattanawong *et al.,* 2003). This contradiction leads us to discuss which of the two findings is the better understanding of the population structure.

First, genetic information may not echo the real time structure due to the high genome conservation, while tracking results reveal a present distribution of green turtle nesting populations. Extremely low genetic divergence rate in sea turtles has been reported in various genetic material levels such as protein (hybridization test, Karl *et al.,* 1995), chromosome (banding pattern, Bickham, 1981), Single-copy nuclear DNAs (Karl *et al.,* 1992), and microsatellite loci (Fitzsimmons *et al.,* 1995). In addition, mtDNA evolution in turtles proceeds at a several-fold lower rate than "conventional" vertebrate pace (Avise *et al.,* 1992; Bowen *et al.,* 1996). Such evidences suggest that a large part of genetic information has been remaining the same since the founding of the two populations from a common ancestor.

A limitation of our study is, however, the small sample size of the tracking. Only 11(Khram Island) and 9 (Huyong Island) turtles were tracked although we believe the sample size was appropriate considering the nesting population size at Khram Island (<100 nesters per year, Monanunsap and Charuchinda, 1994) and Huyong Island (12 individuals per year). In addition, the period of tracking period may be too short (9-126 days, Kittiwattanawong *et al.,* 2003) compared to the life span of the sea turtles (60 years, Seminoff, 2002). This suggests that the tracked turtles might do not stay at the same feeding ground, but wander to the wider range than we expect. Incorporate of this factor with a long range migratory ability may break down the barrier and hence leading to a mixing of the populations. Lastly, the sea level fluctuation may support the genetic-based finding. Geneflow between the two populations can occur by migration across seaways (via stepping stone mechanisms along nesting and feeding grounds or directly via long migratory pattern) in-betweens Malaysia peninsula-Sumatra, Sumatra-Java. These seaways have been closed and widen up over the time scale due to sea level fluctuation (Geyh *et al.,* 1979). Figure 3a shows that there were two periods that sea level were higher than the present during the past 140,000 years (Potts, 1983). High sea level would widen the Strait of Malacca, seaways in between Sumatra-Java, and consequently allowed higher geneflow of these two populations (Fig. 3c). In contrast, lower sea level would narrow the seaways or even closed them (Fig. 3b).

The present high sea level which started about 4,000 years ago may maximize the geneflow and cause a low genetic divergence (Fig. 2b, c, and d). This rise and fall of sea level may make two populations one non-differentiated population.

Table 2. Haplotype diversity (h), Nucleotide diversity (π), number of polymorphic nucleotide, and average number of nucleotide difference for the green turtle nesting populations from the Andaman Sea and the Gulf of Thailand. Diversity indices were calculated by DnaSp ver.3.99.5 (Rozas and Rozas 1999) and MEGA ver 2.1 (Kumar et al. 2001).

	Andaman	Gulf	Overall
Haplotypes diversity (h)	0.573±0.014	0.687±0.016	0.640±0.011
Nucleotide diversity (π)	0.294±0.068	0.264±0.008	0.272±0.005
No of polymorphic nucleotide	251	254	254
Average No of nucleotide difference	129	116	119

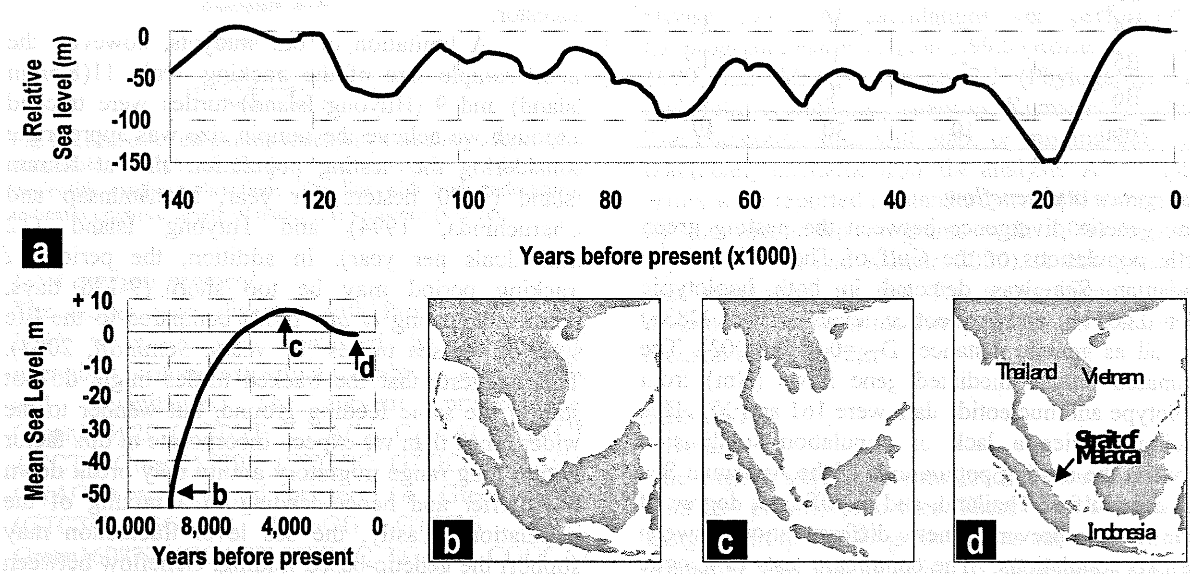

Fig. 3. a) Sea level fluctuation over the past 140,000 years ago (Potts 1983). b), c) and d) Sea levels and topographies of SPouth East Asia during 8000, 4000 years ago and at present, respectively (modified from Lekagul and McNeely 1977; Geyh *et al.* 1979).

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Satellite tracking of female green turtles *Chelonia Mydas* at Ma'Daerah Turtle Sanctuary, Malaysia

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ABSTRACT
Two kiwiSAT 101 satellite transmitters were deployed in July 2003 on female green turtle (*Chelonia mydas*) for the purpose of understanding their inter-nesting migration. The study was conducted at Ma' Daerah Turtle sanctuary in Kertih, Terengganu, Malaysia. The data received were analysed and plotted on to a digital map to estimate the travel points and distance travelled. The turtles roamed the water in the vicinity of nesting site and rarely travelled far during the nesting season. The furthest distant travelled to the sea (East) is approximately 42.4 km, to the South 44.4 km and to the north 7.8 km. Percentage of GPS location near (5-12 nm) nesting shore was 83.3% and far (>12 nm) was 16.7%. From this study, it is suggested that the strict/compulsory conservation boundary within the selected nesting site should be between 0-12 nm and additional 45 km for the outer boundary.

Keywords: KiwiSAT, female green turtle, Terengganu

INTRODUCTION

The decline of sea turtles population is still a result achieved from a long term struggle to conserve it (Mortimer, 1990). Breeding adults were killed in incidental catch by fisherman or hit by speeding boats Mortimer (1990). Tisen and Bali (2000) found out that the inter-nesting resting areas lies within a kilometre from mainland where illegal trawling took place resulting in multiple incidental catch of turtles.

Studies on turtle migration has been done by numerous researchers for example Shiba *et al.* (2002) and Ibrahim *et al.* (2002). PTT transmitter was used as the main turtle locator and deployed on several female and male turtles to get the location of each and every turtles released. Arai and Ono (2000) stated the positive and negative side of using these platform terminal transmitters (PTT) as the data produced relied on several uplinks from the PTT before a good positioning of the turtle can be achieved. Previous studies showed that from all the data received from ARGOS, the satellite operators more than 50% were with minimum uplink i.e. one uplink giving no location of the turtle. However for the time being, this is the best method for collecting location data from released sea turtles.

A study was carried out by TUMEC (Turtle and Marine Ecosystem Centre, Malaysia) using PTT transmitter to determined the pre and post nesting of green turtle at Ma' Daerah turtle Sanctuary, Terengganu Malaysia. This study was in conjuction with an education program run by TUMEC for an A level Matriculation students of Yayasan Satu Matriculation College. As a show of support to the turtle conservation activity the college students help raised some fund to purchase a PTT and satellite transmission services. The sum of money raised was RM 15,000.00. The PTT was then attached to a female green turtle and released by the deputy minister of education who officiate the opening of the program.

Recent study by Ibrahim *et al.* (2000) showed that the maximum radial distance from the nesting site travelled by a turtle during interesting period was 14.3 km. The speed of swimming was between 0.05 km/hour to 11.70 km/hour. The turtle were observed to stay offshore of her nesting site before completing her nesting activities. Bali *et al.* (2000) reported that it took 45 days post-nesting for a female turtle to swim a distance of 1506 km with average speed of 35 km/day.

Determination of nesting and inter-nesting area was also carried out using normal tagging fin data to see the degree of site fidelity. Tagging data of different nesting site along the coast of Terengganu were collected and compared. Proper fin tagging will last to as long as more than ten years and improper tagging and data recording will expedite the tag loss. In Malaysia now, the main and most reliable tagging was using fin clip tag. Tagging activities in Terengganu were done by the Department of fisheries staff. Turtles observed during nesting activities were tag and recorded.

Observation on leatherback turtles showed that nesting site changes from one to different site following tidal current. In 2003 during leatherback nesting season a turtle was observed to nest at three different sites which were separated by at least 20 km (Pers. comm., fisheries assistant). The distance between nesting sites and the degree of site fidelity of a female green turtle has to be determined as this may affect the nesting protection zone and protection activities. For the purpose of understanding the behaviour of sea turtle during nesting and inter-nesting, a study was carried out using PTT satellite tracking and analysis of fin tags. The result can then be converted into actions for example proper monitoring, surveillance and protection.

Objective of this study

1. determine pre, post nesting position, the site fidelity and other possible nesting site using tag record and PTT data.of green turtle from Ma' Daerah.
2. determine problems from using PTT and fin tagging for sea turtle study.

MATERIALS AND METHODS

Platform transmitter terminal (PTT)

Two PTT with serial number 38619 and 38620 were used to tag two female green turtles at Ma' Daerah, Terengganu. The PTT 38619 was tag to a female with fin tag number MY1615/MY1660 on the 6th of July 2003 and laid her eggs for the last time on the 20th July 2003. The second PTT tag (38620) was attached to a female green turtle with fin tag number MY 1005/1016.

The data from ARGOS were relayed from Dr Nobuaki ARAI from the Kyoto University, Japan through e-mail transmission. Data from 38619 were received starting 29th June 2003 until the 12th September 2003. The data transmission for 38620 were received between 7th August and 8th August 2003 for only two days.

The data received than transferred to Excell program for analysis and sorting. This then transferred to SURFER 6 program for plotting. The data were separated into three categories; a) all seaward data, b) LC's 1, 2 and 3 and c) all LC's 3 data. For plotting purposes also, all close up data and overlapping data were erased from the map.

A base map was created by scanning a section from British Admiralty chart 3543. The map was than overlaid with the position map using SURFER 6 program.

Tag data

Tag data from two different sites were compared to see the nesting site fidelity of the green turtle. The tag data was collected from Ma'Daerah and Cherating.

RESULTS

PTT Tagging

Data from PTT tagging were received from ARGOS via Kyoto University (Dr Nobuaki Arai) since 29 June 2003. After processing the data and using only the data with Location Class of 1, 2 and 3 a total of 34 data were used for 38619 turtle and 10 for 38620 turtle. All the data used were from August PTT transmission.

Positions which were on the mainland during the testing of the PTT were erased and selected positions plotted (Fig. 1).

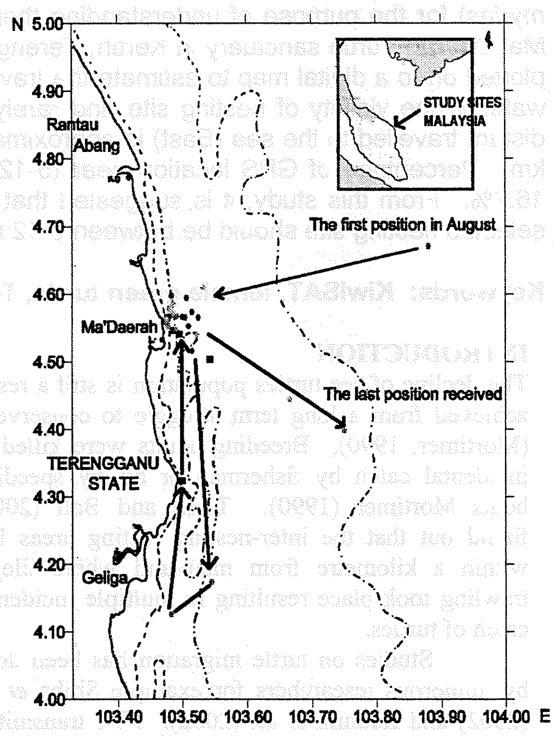

Fig. 1 Travel positions of the PTT38619 green turtle tag at Ma'Daerah Turtle Sanctuary

The LC3 data for PTT 38619 plotted showing the movement of the turtles (Fig. 2).

Data plotted for PTT 38620 showing the movement of the second female turtles (Fig. 3). Movement from the lowest position to the second position took 3 hours, 2 to 3 took 12 hours, 3 to 4 took 2 hours and 4-5 took 20 minutes

Location class percentages for PTT 38619 from 155 data were as Table 1.

Table 1: a) Percentages of Location class for PTT 38619, 38620

38619		
LC categories	No	%
LC3	57	36.8
LC2	16	10.3
LC1	15	9.7
Not good	67	43.2
Total	155	100
38620		
LC categories	No	%
LC2	1	8.33
LC1	2	16.67
LC0	2	16.67
LCA	4	33.33
LCB	3	25.00
Total	12	100

Fin Tag

Fin tag data for the year 2003 were collected from 2 sites, Ma' Daerah and Cherating Pahang. The data were analysed for number of nesting and major nesting site for each turtle base on the number of nesting recorded. From the tag data observed on females nesting at the study sites, both female with PTT tag did not land to nest at neither Ma' Daerah nor at Cherating. PTT location nearest to shore may indicate the female roaming the area but not landing to nest.

DISCUSSION

Tagging system

Observation in July and August showed that the data from PTT-ARGOS satellite system on turtle tracking was unreliable. After two months of deployment, most of the data received were within low quality location class. More than 155 dataset were received from the ARGOS satellite transmission but after selecting data set with proper positioning, a total of 155 dataset were used in this study which were from 1st to 31st August 2003.

The best location class LC3 were 57 data set (36.8%), LC2 16 data set (10.3%) and LC1 15 (9.7%). The rest 43.2% were of LC0,LCA, LCB and LCZ. Overall approximately only 30% of the data were usable. When reflecting to the cost spent, this tagging system should be improved to increase the cost effectiveness of the money utilized.

The problem with this type of PTT were experienced during mounting and starting of the PTT. The PTT used did not responded, as it should in the manuals. It did not blink ten times during starting and the transmission detector did not give out the transmission beep at the same time. Due to this problem, the transmitter were dismount and remount twice for PTT 38619 and unluckily most of the LC3 data received were during the dismounting of the PTT in most the days in July 2003. The PTT 38620 was deployed and started but did not transmit properly giving only 8 good LC in August and was never heard since.

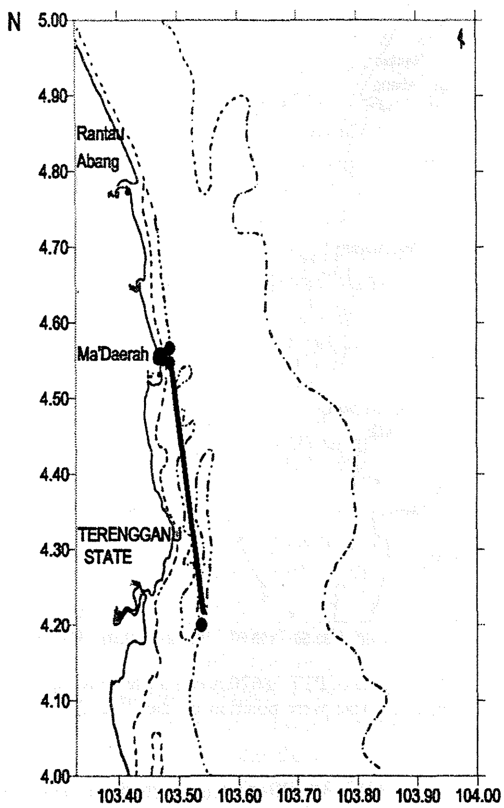

Fig. 2 The LC3 for the PTT38619 green turtle and the last position was approximately 40 km south from the nesting site at Ma'Daerah

Comparing the data from the PTT and inconel tag recorded from female turtle nesting no PTT attached females came up to the beach to nest in August at Ma' Daerah turtle sanctuary. Although most of the PTT's position were near the nesting site the turtle might probably just roaming the area before departing. From the inconel tag data, during the nesting season of Ma' Daerah from 31/3 to 28/9/2003, the PTT 38619 turtle had nested for seven times whereas the PTT 38620 turtle had nested only 3 times. But both did not come up to nest in August 2003.

PTT 38619 turtle started to nest on the 20th of May, 2nd June, 12th June, 21st June, 1st July, 11th July and 20th July. She laid her eggs seven to ten days apart from each nesting days. The last recorded nesting activity was on the 20th of July

2003. Due to problems in the starting of PTT the tag was not on any turtle until the 6th of July. When the location for this turtle was plotted, she was about to leave the nesting ground to the south (Fig. 1). This might indicate the probability of the southern part of peninsular was its grazing area.

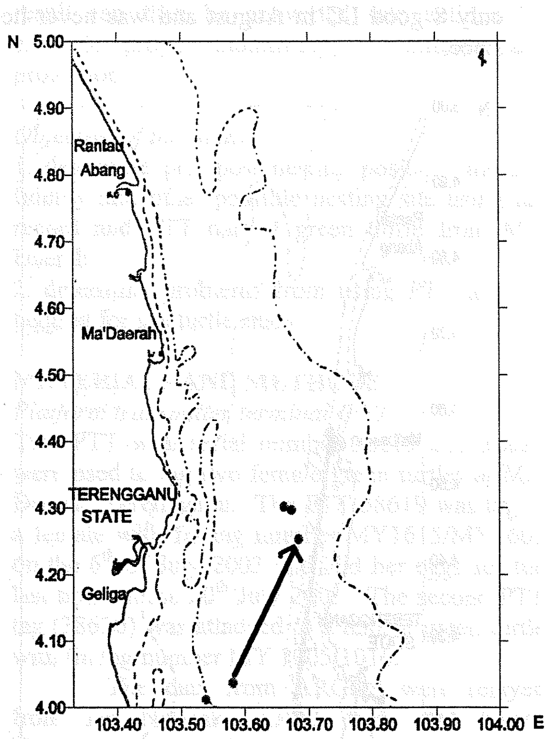

Fig. 3 Positions of PTT 38620 green turtle showing northward movement. These were position on the 7th and 8th of August 2003

PTT 38620 turtle started to nest on the 6th July, 17th July and 28th July. She only laid her eggs in July and the duration between her nesting days were eleven days. Unfortunately there were only twelve data received from this turtle. When the data were plotted, all locations indicated that the turtle was going northward from most probably Cherating, in the state of Pahang (Fig. 3). But landing was not recorded either in Cherating area or somewhere else in Pahang. These position showed that the turtles swam a far distance after nesting activities for an unknown reasons.

Nesting versus PTT observation

PTT positions were useful in detecting the movement of sea turtles but fin tag data was needed for confirmation of the turtle activities. Although the turtle were located near the nesting beach, it was confirmed that no nesting activities happened. The study also showed that there were no typical pre and post nesting activities for some of the turtles. Some might still be around the nesting sites for a duration of time before swimming away and some might swim away after a few nesting activities and the distance covered was quite far. The inconel fin tag on sea turtle was accepted by many as the tagging method of sea turtle but in some instances these tag did not last long as observation showed that there was three tag replacement for a single turtle occur at Ma' Daerah. Human errors might be one of the factors as improper tagging resulted in tag lost. Snagging, fish bite and severed limb can also cause the turtle to loose its tag.

Summary/Suggestion

1.Development of new system of tracking system which can give better and reliable position should be developed.
2.System developed must also be cost effective.
3.Standardization of tagging method should be carried out.
4.Tag loss condition should be thoroughly examined.

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Satellite tracking of immature loggerhead turtles in the Northwestern Pacific

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ABSTRACT
Five subadult loggerhead turtles (*Caretta caretta*) captured in the northwestern Pacific in 2002 and 2003 were tracked by satellite telemetry. Two juvenile loggerheads in age of 1+ and 2+ hatched and kept in an Aquarium were also tracked by satellite telemetry in the northwestern Pacific. Five subadult turtles moved at the average speeds of 1.1 to 2.1 km/h with the total distance ranged from approximately 2,200 to 8,800 km during total tracking of 132 to 186 days. The average speeds of 2 juvenile turtles were 2.1 and 1.0 km/h with the total distance of approximately 4,300 and 3,800 km during total tracking of 85 and 156 days, respectively. All subadult turtles moved rapidly the long distance along the Kuroshio Current and its extension and stayed in warm water mass for a long time. The warm water mass might be important feeding grounds of subadult loggerhead turtles. On the other hand, juvenile turtles migrated to higher latitudes than subadult turtles. The difference between subadult and juvenile turtles might result from the difference of feeding grounds by growth stage, body size, ability to swim, or individual career history of turtles.

KEYWORDS: loggerhead sea turtle, satellite tracking, migration, subadult, immature

INTRODUCTION
Sea turtles are widely distributed in tropical and subtropical waters in the world. Recently, incidental take of sea turtles by longline fisheries was noticed (Brogan, 2002). The Fisheries Research Agency of Japan attempts to develop mitigation measures for incidental take of sea turtles in tuna longline fisheries through research activities. In addition to management of incidental take of sea turtles, we have also worked on conservation of sea turtles on the nesting beach and studied ecology, nesting behavior, oceanic distribution and feeding ecology, of sea turtles, particularly loggerhead turtles (*Caretta caretta*). It is very important to make clear the oceanic distribution and migration route of loggerhead turtles for the conservation and management. Although many studies have been conducted on the movements of post-nesting female loggerheads (Japan Fisheries Resource Conservation Association, 1999; Hatase et al., 2002), there is little information on the movements of immature turtles in the ocean. In this study, subadult loggerhead turtles captured in the northwestern Pacific and juvenile loggerheads hatched and kept in an aquarium were tracked by satellite telemetry.

MATERIALS AND METHODS
Two subadult loggerhead turtles (SCL: 62 and 65 cm) captured in the northwestern Pacific on May to June in 2002 and 3 subadult turtles (SCL: 64, 64 and 70 cm) in the same period and same area in 2003 were captured through longline operations by research vessels, Taikei-maru No. 2 and Kurosaki. These turtles were tracked by satellite telemetry in the northwestern Pacific. Two juvenile loggerheads in age of 1+ and 2+ (SCL: 40 and 53 cm) hatched and kept in the Port of Nagoya Public Aquarium were also tracked by satellite telemetry in the northwestern Pacific to compare with the behavior of subadult turtles. The satellite transmitters, Teronics model ST-6, ST-18 or Wildlife model SDR-T16, were attached to all turtles. Total distances, average daily distances and average speeds of all turtles were estimated by their movements between the average daily positions. The relationship between movements of turtles and two measures of oceanic conditions, oceanic flow and sea surface temperature which are data from the Japan Meteorological Agency and the Naval Research Laboratory, US Navy were examined. The frequency distribution of time spent in depth classes recorded by transmitters of 2 subadult and 1 juvenile loggerheads in 2002 were also examined.

RESULTS AND DISCUSSION
The results of satellite tracking of 5 subadult and 2 juvenile turtles are shown in Table1. The results of 2 subadults are May to the end of October 2003, but we keep tracking them at the time of writing. During total tracking of 132 to 186 days, 5 subadult turtles moved at average speeds of 1.1 to 2.1 km/h (Table 1). The total distance ranged from approximately 2,200 to 8,800 km (Table 1). On the other hand, the average speeds of 2 juvenile turtles were 2.1 and 1.0 km/h with the total distance of approximately 4,300 and 3,800 km during total

tracking of 85 and 156 days, respectively (Table 1). Therefore, average daily speeds of juvenile turtles were similar to that of subadults.

The movements of 5 subadult turtles released in 2002 and 2003 are shown in Figures 1 and 2. These turtles stayed in small areas for a long time and moved rapidly a long distance to the north or east (Figs. 1, 2). On the other hand, the movements of 2 juveniles hatched and kept in the aquarium are shown in Figure 3. These juvenile turtles moved to the east and north and rarely stayed in a small area for a long time (Fig. 3). In the northwestern Pacific, the Kuroshio Current and its extension flow to the east and in some areas, there are warm water mass associated with the Kuroshio extension. Our results suggest that the 5 subadult turtles moved rapidly over long distances along the oceanic flow and stayed in the warm water mass for a long time (Fig. 4). Turtles remained in waters between about 17 to 23 degrees of sea surface temperature. Two juvenile turtles moved to the east and north as the sea surface temperature increased. This suggests that the movements of juvenile turtles were related to sea surface temperature rather than the flow of sea water. Juvenile turtles moved at lower temperature than subadults.

Subadult turtles stayed on warm water mass for a long time and moved to east around 35 °N, while juvenile turtles migrated at higher latitudes, around 38 and 42 °N, than subadult turtles (Figs. 2 and 3). The frequency distributions of depth recorded by transmitters in 2002 are shown in Figure 5 for 2 subadults and 1 juvenile. Although subadult turtles dived frequently over 26 m, juvenile stayed near the sea surface (Fig. 5). These results suggest that behavior of juvenile turtles was affected by sea surface temperature and there were differences in feeding habits between subadult and juvenile turtles.

CONCLUSION

The subadult turtles moved eastward along the flow of the Kuroshio extension and remained on warm water masses for a long time, and dived deep. In contrast, juvenile turtles moved to north and east depending on sea surface temperature and stayed at the sea surface. Our results suggest that the warm water mass which is an area of high productivity is a feeding ground for subadult loggerhead turtles. The difference between subadult and juvenile turtles might result from the difference of feeding grounds by growth stage, body size, ability to swim, or individual career history (wild or captive).

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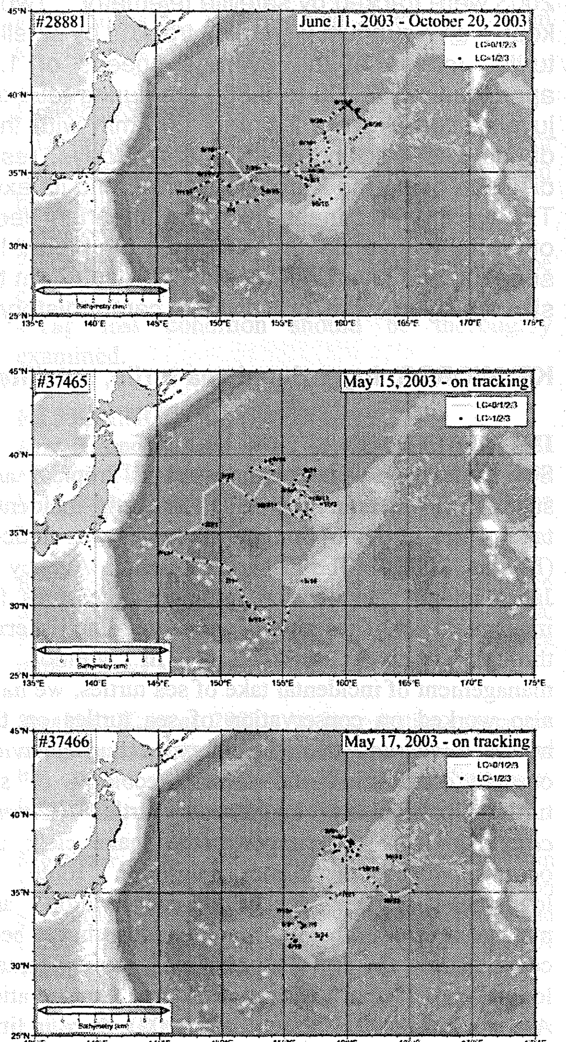


Fig. 1. Satellite tracking of 3 subadult loggerhead turtles (ID: 28881, 37465 and 37466) in 2003 (Estimated accuracy in latitude and longitude; Line: > 1 km, Dot: < 1 km).

Table 1. Movements of subadult and juvenile loggerhead turtles by satellite telemetry.

ID No.	Growth Stage	SCL (cm)	Body Weight (kg)	Tracking Date	Tracking Period (day)	Total Distance (km)	Ave. Daily Distance (mean±S.D. km)	Ave. Speed (mean±S.D. km/h)
ID 07829	Subadult (Wild)	62	43	29 May 2002 - 30 Nov.	186	6536.3	35.3 ± 25.9	1.5 ± 1.1
ID 07811	Subadult (Wild)	65	41	14 Jun. 2002 - 8 Dec.	178	8790.6	49.7 ± 30.1	2.1 ± 1.3
ID 28881	Subadult (Wild)	70	57.5	11 Jun. 2003 - 20 Oct.	132	4920.7	37.6 ± 25.6	1.6 ± 1.1
ID 37465	Subadult (Wild)	64	46.5	16 May 2003 - 31 Oct. (continue)	169	2752.5	32.8 ± 20.8	1.4 ± 0.9
ID 37466	Subadult (Wild)	64	43.5	18 May 2003 - 31 Oct. (continue)	167	2177.0	26.2 ± 18.5	1.1 ± 0.8
ID 07800	Juvenile(1+) (Captive)	39.7	8.7	29 May 2002 - 21 Aug.	85	4275.3	50.9 ± 36.8	2.1 ± 1.5
ID 27975	Juvenile(2+) (Captive)	53	19.8	8 Jun. 2002 - 10 Nov.	156	3830.9	24.7 ± 22.6	1.0 ± 0.9

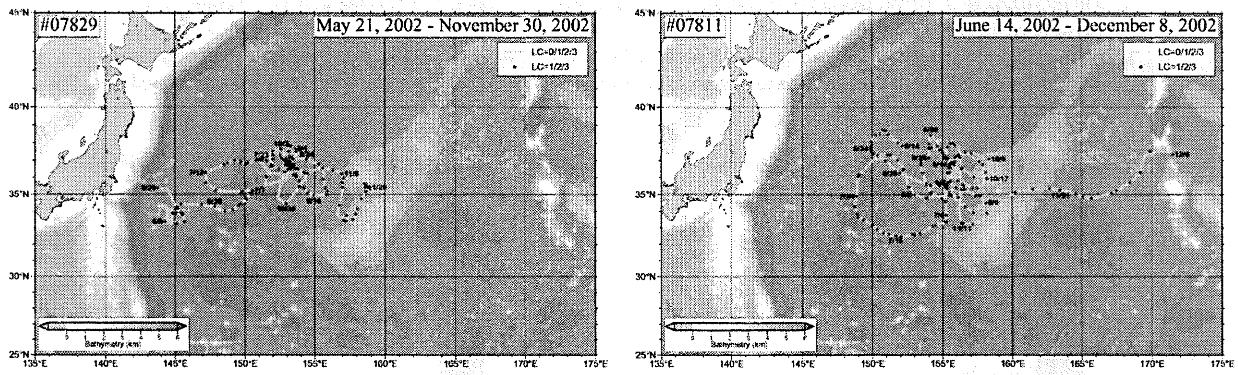


Fig. 2. Satellite tracking of 2 subadult loggerhead turtles (ID: 07829 and 07811) in 2002 (Estimated accuracy in latitude and longitude; Line: > 1 km, Dot: < 1 km).

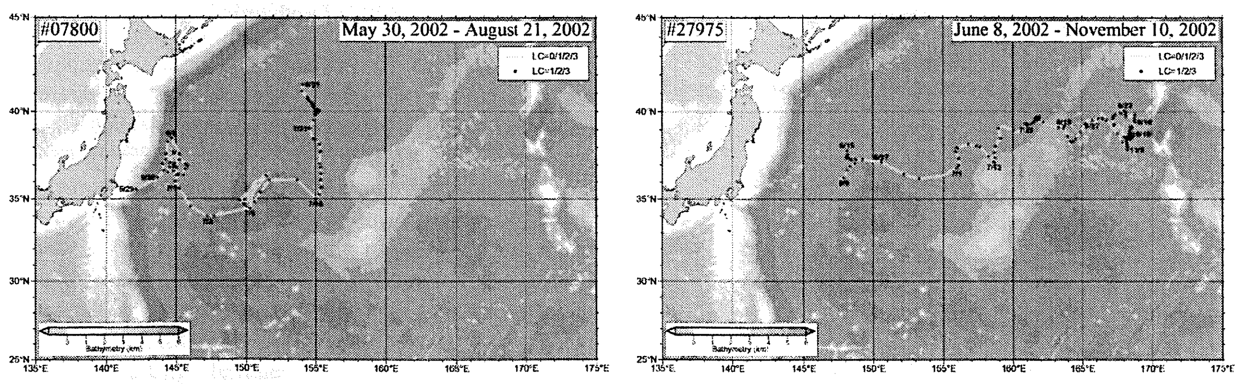


Fig. 3. Satellite tracking of 2 juvenile loggerhead turtles (ID: 07800 and 27975) in 2002 (Estimated accuracy in latitude and longitude; Line: > 1 km, Dot: < 1 km).

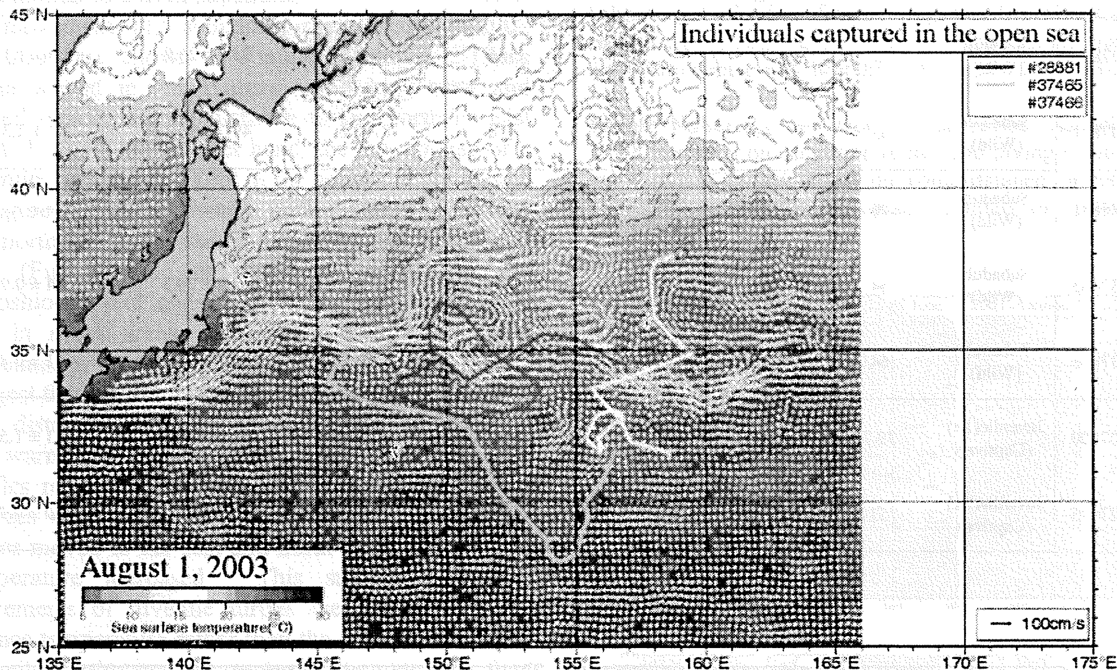
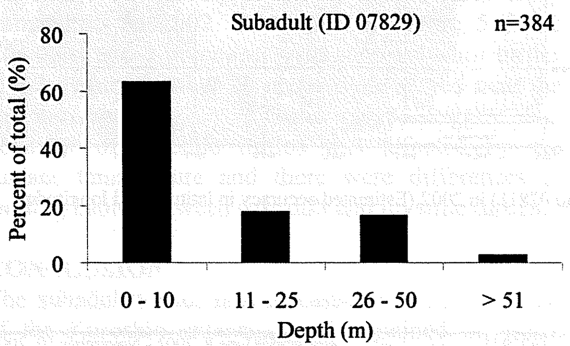
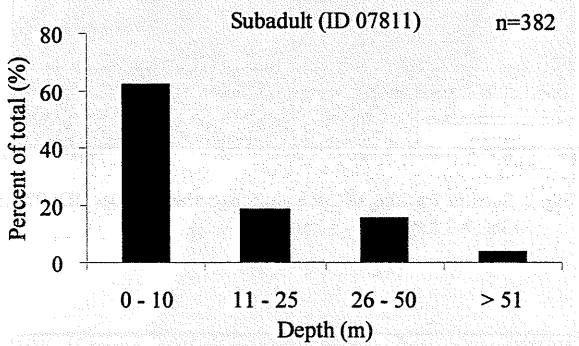


Fig. 4. Relationship between movements of 3 subadult turtles (ID: 28881, 37465 and 37466) and two measures of oceanic conditions, oceanic flow and sea surface temperature on August 1, 2003. Data of oceanic conditions were presented from the Japan Meteorological Agency.





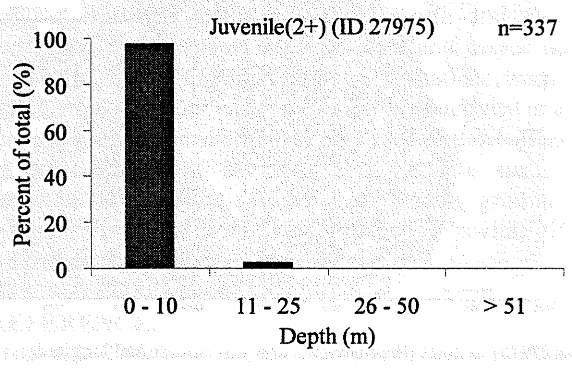


Fig. 5. Frequency distributions of depth for 2 subadult (ID: 07829 and 07811) and 1 juvenile (ID: 27975) loggerhead turtles in 2002.

Oceanic migration of post-nesting loggerhead sea turtles (*Caretta caretta*) in the northwestern North Pacific tracked by satellite telemetry

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ABSTRACT
Two post-nesting loggerhead turtles which nested at Omaezaki beach, Japan were tracked during 2002 and 2003 in the northwestern North Pacific by satellite telemetry. The first loggerhead was tracked for 265 days from 29 July 2002 to 19 April 2003 with total distance of approximately 9,800 km. The turtle traveled eastward from the Pacific coast of Honshu to offshore after staying near its nesting site for a week. Then it remained in the offshore area around 36-37 °N and 155-158 °E from the end of September to the middle of November. In late November, the turtle moved eastward again, and turned to the south when it reached 170 °E in the middle of December. Finally, it turned westward in February. Tracking of the second loggerhead tagged in 2003 is still in progress, although this loggerhead was released in a subsequent year, its tracks were similar to the first turtle. The relationship between movements of the turtles and oceanographic conditions (sea surface temperature and sea surface currents) were examined. Movement tracks of these turtles correlated with the Kuroshio Extension Current and seasonal changes of temperature in the Transition Region. The Transition Region is known as a highly productive area and may provide an important feeding ground for post-nesting loggerhead turtles.

KEYWORDS: post-nesting loggerhead turtle, satellite telemetry, oceanographic conditions

INTRODUCTION

Loggerhead sea turtles (*Caretta caretta*) are believed to travel great distances during their lives. In the North Pacific, nesting beaches of the loggerhead turtle are located almost exclusively along the middle and southern coast of Japan. Hatchling loggerheads disperse from beaches into the ocean. These juveniles grow to subadults in the eastern North Pacific has been confirmed using genetic analyses (Bowen *et al.*, 1995). Upon reaching adulthood, loggerheads migrate from the oceanic feeding area to nesting beaches in Japan. A portion of the post-nesting loggerhead population migrates for feeding to the East China Sea as documented by tagging-recapture methods (Kamezaki *et al.*, 1997). However, distribution patterns and migration routes of post-nesting loggerhead sea turtles are not well known. The study of migration routes for loggerhead sea turtles is important to demonstrate the seasonal changes in their distribution and feeding grounds. In the present study, we investigated oceanic migration of post-nesting females by satellite tracking. In addition, we examined the correlation between their migration routes and oceanographic conditions, sea surface temperature and sea surface currents.

MATERIALS AND METHODS

On 29 July 2002 and 18 July 2003, satellite transmitter (ST-6 and 18, Telonics Inc.) was deployed on two loggerhead turtles at Omaezaki beach, Shizuoka Prefecture, Japan referred to below as No. 1

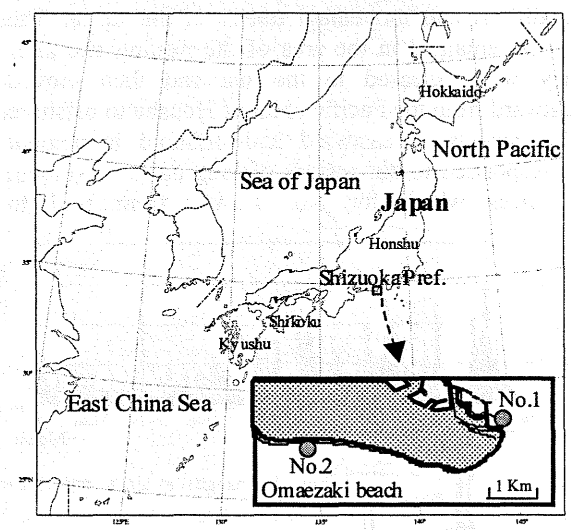

Fig. 1 Location of Omaezaki beach, Shizuoka Pref., Japan. Circles show the location of released points of turtles to the sea.

and No. 2, respectively (Fig. 1). Satellite transmitters were attached with epoxy resin to the carapace of each individual after they nested, and then released to the sea. Their straight carapace length (SCL) was measured with calipers to the nearest 1 cm, and their SCL were 75 and 82 cm, respectively. Tracking of No. 1 finished on 19 April 2003. Tracking of No. 2 is still in progress, and here we use the data through October 2003 (Table 1). The loggerhead turtles were tracked using the Argos system, and locations with classes 3, 2, 1, 0, A and B accuracy were used to track. The daily travel distance was defined as the minimum straight line distance between daily mean positions on the sea surface. We used data from the Japan Meteorological Agency for examining the relationship between migration routes of turtles and oceanographic conditions, sea surface temperature and sea surface currents.

Table 1 Information on two loggerheads tracked by transmitter

Name	Strait Carapace length	Number of eggs	Deployment date	Date of last transmission	Duration of tracking days
No.1	75 cm	118	29 July 2002	19 April 2003	265
No.2	82 cm	100	18 July 2003	Continuing	75

RESULTS

Total travel distances of No. 1 and No. 2 were 9,787 and 4,535 km, and daily mean travel distances were 36.9 and 42.0 km, respectively. Maximum daily movement was approximately 200 km. Daily travel distance of each turtle consisted of repeated intervals of long and short distances (Fig. 2). From summer through autumn, both turtles displayed this pattern but after autumn, the movement distances of No. 1 gradually shortened. Although they were released in different years, their tracks were very similar (Fig. 3). We examined the relationship between oceanographic conditions and movement tracks of the turtle. The turtles remained in the area of the nesting site after they were released to the sea and then moved eastward from the Pacific coast of Honshu to offshore. The periods of eastward and offshore movement corresponded to the periods of long daily movement distances which for No. 1 was from mid to late-August, and for No. 2 was from mid-August to early-September (Fig. 2). At that time, the tracks of both turtles followed the Kuroshio Extension Current (Fig. 4). Afterward No. 2 remained in the area around 35-36 °N and 152-154 °E north of the Kuroshio Extension Current where the sea surface temperature was approximately 23 (Fig. 5). Subsequently they moved eastward again, and No. 1 turned to south in the Transition Region around the 170 °E (Fig. 6). Finally, it turned westward in the area of the North Equatorial Current with westward direction and weak flow (Fig. 7). Both turtles always remained within the southern part of the Transition Region where the temperature was from 17 to 23 ℃ approximately rather than in the Subarctic and Subtropic Regions.

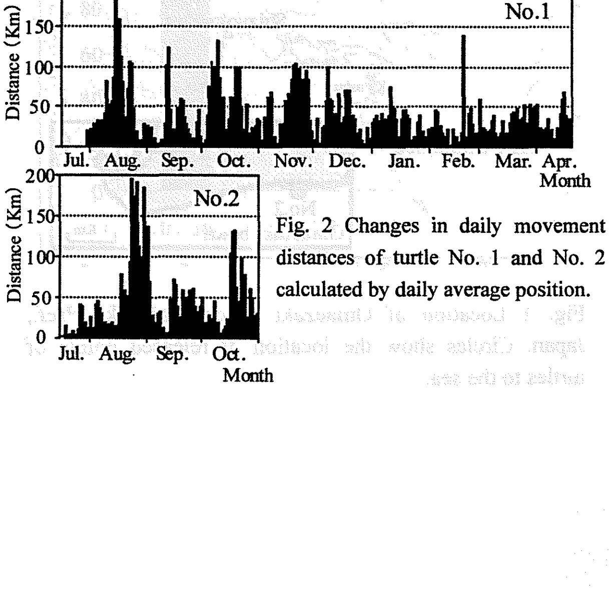

Fig. 2 Changes in daily movement distances of turtle No. 1 and No. 2 calculated by daily average position.

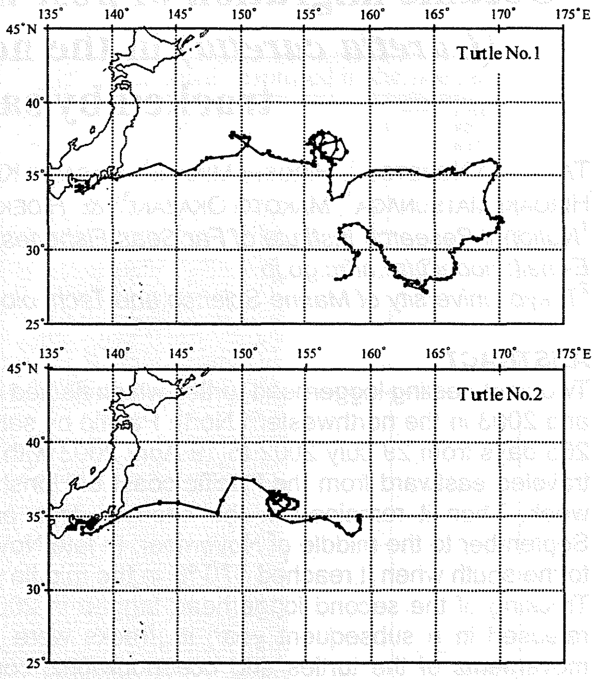

Fig. 3 Complete track lines of two post-nesting loggerhead turtles. The plot shows the daily position of each turtle.

DISCUSSION

The loggerhead turtles released in Omaezaki migrated toward the northwestern North Pacific, and they remained for some time in this region. This indicates that after nesting on beaches in Japan, some post-nesting loggerheads migrate to the northwestern North Pacific, not to the East China Sea. Hatase *et al.* (2002) has shown using stable isotope analyses and satellite telemetry that larger females come from the East China Sea to the nesting beaches in Japan, and smaller females come from the North Pacific. However, it is not clear whether the turtles we tagged (75 and 82 cm SCL) would be considered large or small according to Hatase *et al.* (2002). Therefore, it is necessary to investigate the migration routes of post-nesting females of various sizes using the satellite telemetry.

In the present study, turtle's daily movement distances were repeatedly long and short. These movement patterns probably related to the speed of flow in the Kuroshio Extension Current and North Equatorial Current. When No. 1 moved southward from autumn to winter, it probably reflected a change in the location of the southward of Transition Region associated with a decline in sea surface temperature. It is suggested that oceanic movements of post-nesting females were affected by the currents and seasonal changes in sea surface temperature in the southern part of the Transition Region. The Transition Region is known as a highly productive area, and is used by many pelagic fishes and squids as a feeding ground. Our findings suggest that this region may also provide important habitat for post-nesting loggerhead sea turtles.

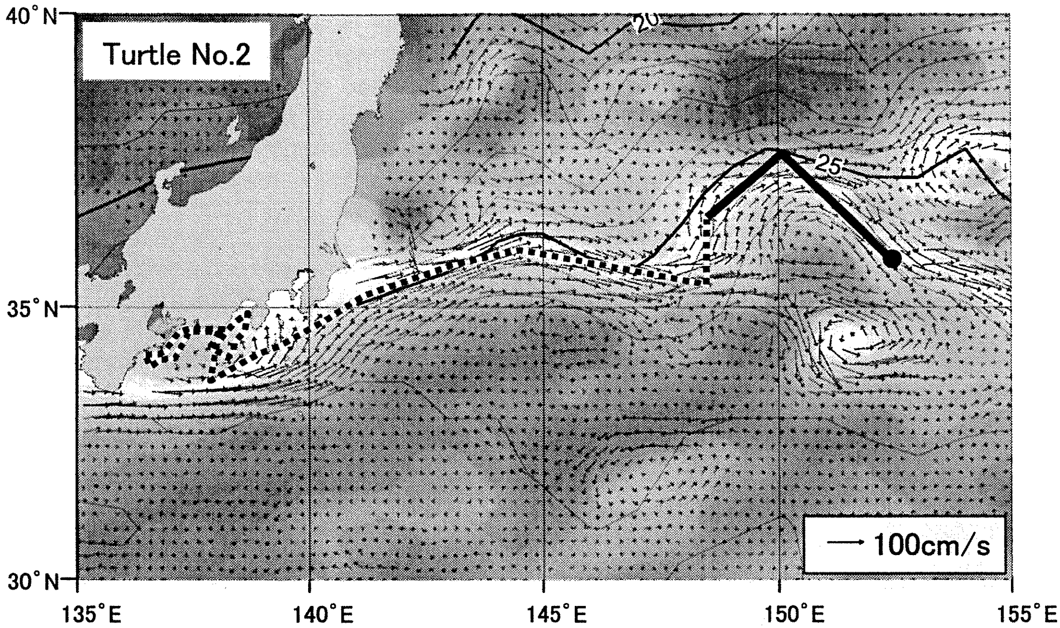

Fig. 4 Relationship between movement track of turtle No. 2 (solid line) and oceanographic conditions (sea surface temperature and sea surface current) from 29 August to 2 September 2003. The dashed line shows the track from 18 July to 28 August 2003.

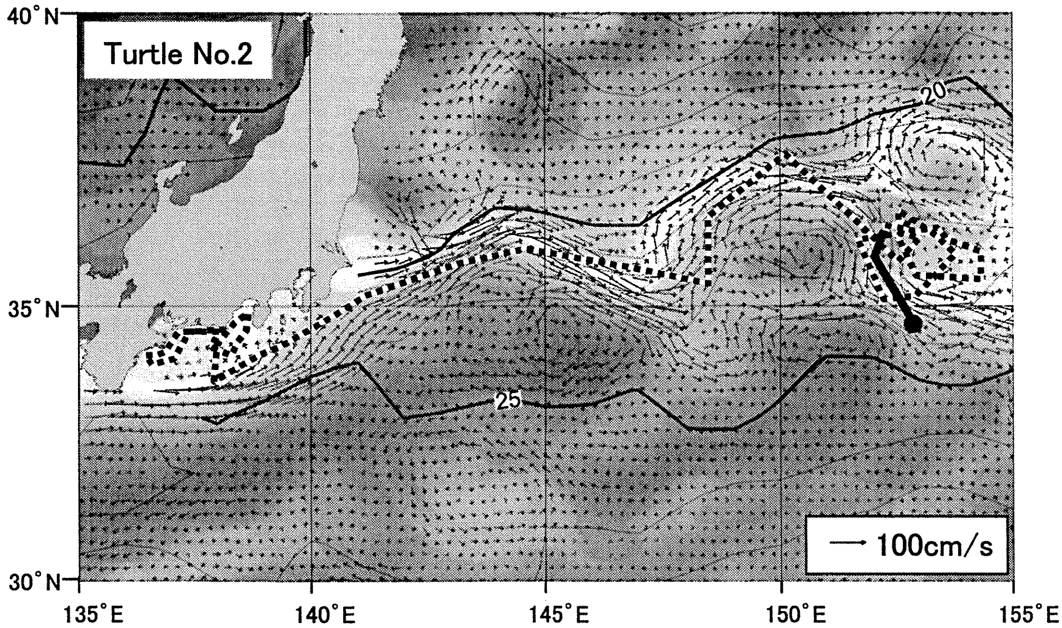

Fig. 5 Relationship between movement track of turtle No. 2 (solid line) and oceanographic conditions (sea surface temperature and sea surface current) from 13 to 17 October 2003. The dashed line shows the track from 18 July to 12 October 2003.

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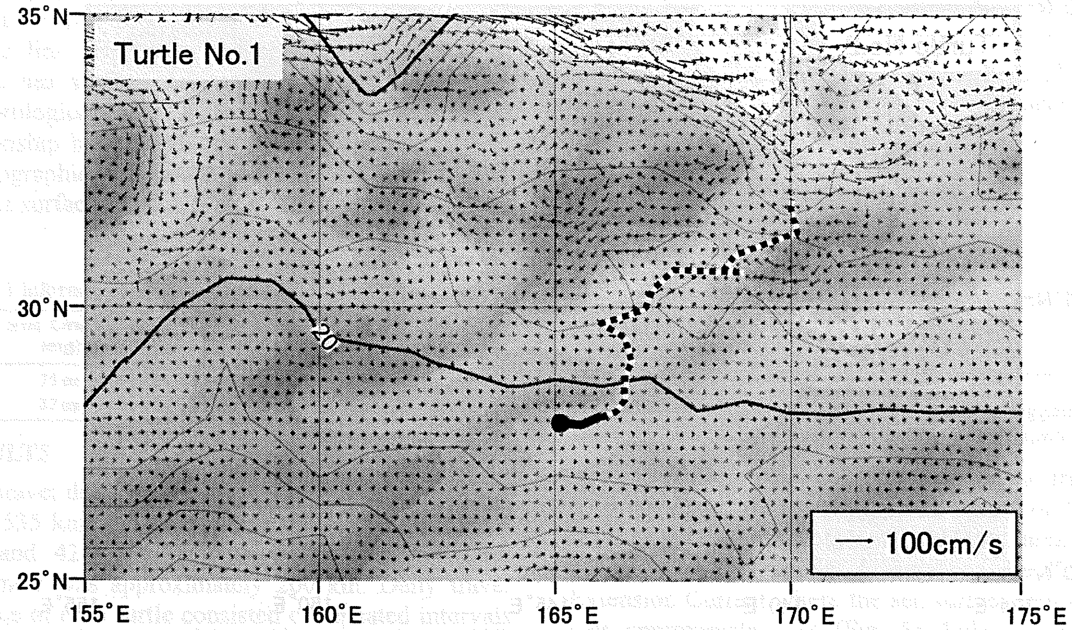

Fig. 6 Relationship between movement track of turtle No.1 (solid line) and oceanographic conditions (sea surface temperature and sea surface current) from 31 January to 4 February 2003. Dashed line shows the track from 1 to 30 January 2003.

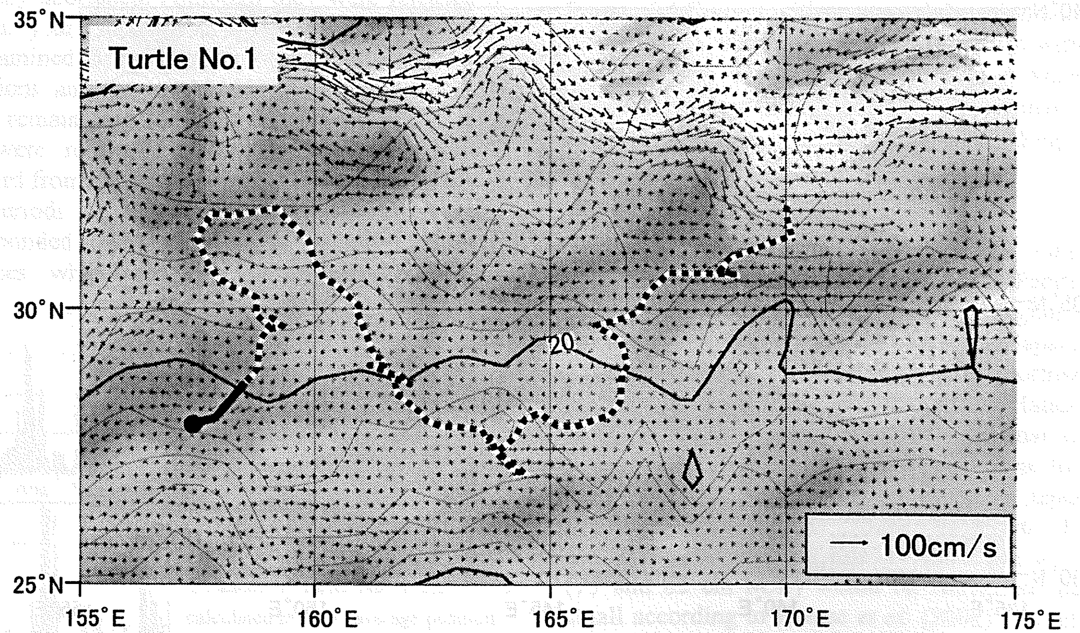

Fig. 7 Relationship between movement track of turtle No. 1 (solid line) and oceanographic conditions (sea surface temperature and sea surface current) from 16 to 20 April 2003. Dashed line shows the track from 1 January to 15 April 2003.

The conservation and management activities for sea turtles in Japan

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ABSTRACT
Loggerhead, green, and hawksbill turtles nest in Japan, and leatherback and olive ridley turtles are distributed around it. Conservation of these sea turtles has been focused on in recent years. The conservation activities by NGOs became popular from the late 1980s. The government of Japan also involved in the conservation and management of sea turtles. In the nesting site, there are many conservation activities mainly conducted by NGOs. Those are monitoring for the number of nesting female and eggs laid at each beach, and protection of eggs and sea turtles on the beaches. Some research activities, including tag and release and satellite tracking, are conducted by research institutes, universities and NGOs. At sea, monitoring by-catches by tuna longline fishery and experiment to mitigate sea turtle by-catch are conducted by the Fisheries Agency and the National Research Institute of Far Seas Fisheries (NRIFSF) including comparative experiment of circle and conventional tuna hook for sea turtles. Research activities to track loggerhead turtles by satellite are also conducted by NRIFSF. Fishery Agency and NRIFSF jointly promote educational activities on the conservation of sea turtles. Under this activity, the Species ID Sheet and the Release Manual for sea turtle were distributed to the fishermen.

KEYWORDS: conservation, management, Japan

INTRODUCTION

Sea turtles are very familiar to the Japanese through legends and old tales from ancient times. Egg and meat of sea turtles were utilized in the local areas of Japan. However, many fishermen traditionally release sea turtles caught by fishery with sprinkling liquor as welcome ceremony to the god of happiness.

Tortoiseshell of hawksbill turtles has been utilized from Edo-era, about 300 years ago, and traditional high-grade skill of carving has been established. Conservation of sea turtles has been focused on in more recent years. The conservation activities by NGOs for sea turtles increased and became popular from the late 1980s. They are conducting assessment of nesting sea turtles and protection of eggs. The government of Japan also involved in the conservation and management of sea turtles and has been promoting several activities on it.

1) Distribution of sea turtles around Japan

Loggerhead, green, and hawksbill turtles nest in Japan. Hawksbill turtles inhabit only southern islands of Japan. Green turtles breed eggs southern islands and Ogasawara Islands of Japan. Loggerhead turtles are distributed in more northern part of Japan. They breed from southern islands to the central part of Honshu. Although no leatherback and olive ridley turtles breed in Japan but they are distributed around it.

Assessments of loggerhead turtles at major beaches have been conducted since mid-1980s in Japan. From more than 60 beaches, the data on nesting were reported (Kamezaki et al. 2002). The number of nesting increased in the early period of research then decreased around 1990 and at the bottom in mid-1990s and it increased since then (Shiode 2002). Early increase of nesting female might be due to the increase of research effort.

Green turtle was abundant in the Ogasawara Islands. It has been harvested since the late 19th century. The number of green sea turtles harvested decreased from around 1,500 in 1880-1900 to around 100 in 1980-1990 (Suganuma 1994). At present, green turtle in the Ogasawara Islands is protected and still continuously harvested under severe control. Tokyo metropolitan government conducts conservation activity of green turtle in the Ogasawara Islands and authorizes this fishery is sustainable one.

Hawksbill turtles are distributed around Okinawa Islands in Japan and are historically harvested. The number of harvest ranged about 50-120 during 1989-1993 (Kamezaki 1994).

2) Review of threats (mortality) on sea turtles

Causes of sea turtle mortality, disturbance for breeders and unsuccessful nesting in Japan are summarized in Table 1. Factors are classified into biotic, abiotic and human activities for both at nesting site and sea. At nesting site, biotic factors are consisted with Predation, Diseases and parasites, other nesting turtles, and Vegetation. Affect of other nesting turtles is not considered as cause, because the number and density of nesting sea turtles are not large in Japan.

Abiotic factors include Erosion and Accretion, Tidal inundation, Heavy rains and Typhoon, and Thermal stress. Erosion and Accretion are also raised by human activities mentioned below. Especially, erosion of beach becomes a serious problem recently. That the construction of a barrier to control soil erosion at river stops the sand supply from the river become a cause of beach erosion.

Regarding human activities affecting sea turtles reproductions are Transplantation of egg, Beach development, Dredging, Direct harvest, Beach lighting, Pollution, Disturbance (beach vehicles and etc.), and Collisions with boat near nesting beach. Among those, stopping sand supply from the river and constructions on beach for protecting beaches (tetra pod and protecting bank) are the most important ones.

Factors affecting sea turtle mortality at sea include Predation, Diseases and Parasites as a biotic factor. It is question what kind of abiotic factor exists at sea. Regarding human activities, coastal fisheries include direct fishery for sea turtles at the Ogasawara for green and Okinawa Islands for hawksbill turtles, Coastal set net and small gill net fisheries. For offshore fisheries, Tuna longline, Drift gillnet operating inside 200 miles, and Trawl fishery have some interaction with sea turtles. Collision with boat also happened at offshore.

3) Legal status

Sea turtles are protected and managed by Fisheries Resources Protection Act, Natural Monument Protection Act, and several legislations of local governments. Tokyo metropolitan government authorizes the green turtle fishery in the Ogasawara Islands as sustainable one. Hawksbill fishery in Okinawa Islands is managed by local government.

4) Participating organizations

Among the government agencies, the Ministry of Environment, the Ministry of Land, Infrastructure and Transport, the Fishery Agency and Local Governments involved in the conservation and management of sea turtles. For example, the Ministry of Environment promotes and encourages the activity of many NGOs. The Ministry of Land, Infrastructure and Transport starts to promote to create a gentle slope shores protection rather than use of tetra pods, for the protection of nesting sea turtles. Fisheries Agency monitors fishery by-catches and promote development of the methods to mitigate sea turtle by-catches by tuna longline fishery.

The research activities have been conducted by the Fishery Research Agency (FRA), Universities, Aquariums and NGOs.

5) Activities at the nesting sites

There are many conservation activities for sea turtles mainly conducted by NGOs on nesting beach in Japan. Those are monitoring for the number of nesting female and eggs laid at each beach, and protection of eggs and sea turtles on the beaches. Transplantation of eggs is sometimes conducted for the conservation. Japanese Society of Sea Turtle gathers data on the number of nesting females in each beach to estimate annual total number of nesting female in Japan. Some research activities, including biological measurement for nesting females, tag and release and tracking by satellite, are conducted by research institutes, universities and NGOs.

The Ministry of Land, Infrastructure and Transport promote the creation of sand beach instead of the protection by tetra pod for the nesting sea turtles. Some experiments to change light bulbs of streetlight along the nesting beach to weak light for avoiding disturbing nesting females have been conducted.

6) Activities at sea

Monitoring by-catches by tuna longline fishery and experiment to mitigate sea turtle by-catch are conducted by the Fisheries Agency and the National Research Institute of Far Seas Fisheries (NRIFSF) which belongs to FRA, including comparative experiment of circle and conventional tuna hook for sea turtles indoor and fields. Research activities to track loggerhead turtles by satellite tag, and tag and release using conventional external and internal tag are also conducted by NRIFSF. Experiment for the modification of set net to release sea turtles from the gear is conducted by the Ishigaki branch of Seikai National Fisheries Research Institute, which is one of the Institutes of FRA.

7) Other activities

Protection of nesting beach for leatherback turtles and satellite tracking of leatherback turtles are being conducted in the Papua (Indonesia) by joint force of NGO and NRIFSF. The experiments for sea turtle aquaculture are conducted in the Ishigaki Island by National Center for Stock Enhancement which belongs to FRA.

8) Education

Fishery Agency and NRIFSF jointly promote educational activities on the conservation of sea turtles. Under this activity, the Species ID Sheet for improving the accuracy of the logbook report and the Release Manual for sea turtle caught by tuna longline fishery to increase survivorship of sea turtles were distributed to the fishermen. The educational sessions for the fishermen on the conservation of sea turtles were held in several places of Japan in collaboration with Government, NGO (Global Guardian Trust) and

NRIFSF.

9) International cooperation

Joint research program "SEASTAR2000" is conducted with several Southeast Asian countries and Kyoto University. The project was mainly focused on the research of behavior and conservation of adult female green turtle during post nesting periods around the Gulf of Thailand and the Andaman Sea.

World Tuna Longline Fishery Conference (WTLFC) was held in Tokyo 26-27 August, 2003. Representatives of major tuna longline fishing organizations in the world including Japan, Chinese Taipei, Korea, Philippines, Indonesia and China and the relevant fisheries authorities met and reviewed the current situation surrounding the tuna longline fishing activities including the issue related to the incidental catch. After the serious discussion, the participants of the WTLFC conference agreed to appeal internationally their legal fishing activities and to take actions to promote responsible fishing, jointly and cooperatively. The WTLFC adopted the joint declaration.

FAO Inter-governmental Consultation for the conservation of sea turtles is going to be held in Thailand in 2004 by the Japanese Trust fund.

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Table 1. Causes of mortality, disturbance and unsuccessful nesting of sea turtles in Japan.

Life stage	Eggs	Hatchling	Juveniles	Adults	Breeders
Nesting site					
Biotic factor					
Predation	Yes	Yes	-	-	No
Diseases and parasites	?	?	-	-	No
Other nesting turtles	No	No	-	-	No
Vegetation	?	Yes	-	-	No
Abiotic factor					
Erosion, Accretion	Yes	No	-	-	Yes
Tidal inundation	Yes	No	-	-	No
Heavy Rains, Typhoon	Yes	No	-	-	No
Thermal Stress	Yes	Yes	-	-	No
Human activity					
Transplantation	Yes/No	?	-	-	-
Beach Development	Yes	Yes	-	-	Yes
Dredging	Yes	Yes	-	-	Yes
Direct harvest	Yes	No	-	Yes	Previously
Beach lighting	No	Yes	-	-	Yes
Pollution	?	?	-	?	?
Disturbance	No	Yes	-	-	Yes
Collisions with boat	No	No	-	Yes	Yes
Garbage	No	Yes	-	-	Yes
At Sea					
Biotic factor					
Predation	-	Yes	Yes	Yes	Yes
Diseases and parasites	-	Yes	Yes	Yes	Yes
Abiotic factor					
?					
Human activity					
Artificial debris	-	Yes	Yes	Yes	Yes
Direct fishery	-	-	Yes	Yes	Yes
Coastal set net	-	Yes	Yes	Yes	Yes
Coastal gill net	-	-	Yes	Yes	Yes
Purse seine	-	-	Yes	Yes	Yes
Tuna longline	-	-	Yes	Yes	Yes
Drift gillnet	-	-	Yes	Yes	Yes
Trawl fishery	-	-	Yes	Yes	Yes
Collisions with boat	-	-	Yes	Yes	Yes

SEAGRASS MEADOW and GREEN TURTLE IN CAMBODIA

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ABSTRACT

Green turtle (*Chelonia mydas*) have been reported as an abundant species among five species of sea turtles in Cambodia's sea. Green Turtle have been known as plant eaters. Mainly a few species of seagrass In Cambodia, four large Seagrass meadows have been selected as demonstration sites in two provinces and one municipality. KKSG1 and KKSG2 were selected in Koh Kong province, KAMPSG1 in Kampot Province, and KEPSG1 in Kep Municipality. So far, there is no confident information have been mentioned about seagrass species and specific seagrass species which are the most favored species for green turtle even some survey had been conducted. Due to the process of the survey did not continue, feeding ground zoning for Sea Turtles have not set up yet. To address this issue, survey on seagrass species conducted in 2002 in KAMPSG1 and KEPSG1 by using three methods are 1. to interview with local people who are living around seagrass area, 2. seagrass net, and 3. mapping seagrass areas, in order to find out seagrass species and feeding ground for green turtle. As a result, eight species of seagrass found in the area, in which two of them are dominated species, are *Enhalus acoroides* and *Thalassia hemprichii.* Whereas from interview indicated that green turtle mostly found in Kep municipality and Kampot province, particularly in areas that is reach of *T. hemprichii.* Although, there is no quantities information on feeding ground and specific seagrass species for green turtle are strongly aware yet. However, future plan is under planning to conduct more survey in other zones in order to get fully satisfied information on favored seagrass species and their location for green turtle. It is expected that, clear result from the future activities will be useful to set up feeding ground for Sea Turtle, particularly green turtle. Therefore, many activities need to be done in the coming future for the sack of protecting and conserving Sea Turtle population as well as their feeding ground in Cambodia Water and also in the Southeast Asia. But fund for activities is seeking from concerned agencies and NGOs.

KEYWORDS*:* Seagrass meadow, green turtle,

I. INTRODUCTION

The Kingdom of Cambodia has 435 Km coastline, locates in the Gulf of Thailand, and extends between the Thai's border in the West and the Vietnam's border in the South. The Exclusive Economic Zone (EEZ) of the country is the area from the shore 200 nautical miles off shore covering 55,660 Km^2 (Smith. J, 2001).

Along the coastline, there are many natural resources such as beaches, mangrove forest, coral reef and seagrass beds which served as feeding grounds, spawning ground and habitats for marine lives.

Among these, seagrass beds is one of the main sources that play very important role in ensuring sustainability coastal resources and other endangered marine animals, particularly Sea Turtle population, moreover, also provides feeding ground and nutrient-rich habitat for divers and range of fauna and flora (Mckenzie, L. J. & Campbell, S. J. 2002).

According to Try (2002), have reported that there are five species of marine turtle in Cambodian sea, in which green turtle is the abundant species mostly encountered in seagrass areas and often accidentally caught fishermen by stingray hook line, Surrounding net, Trawling net and Scomberomorus gill net (Try *et al.*, 2002).

However, there has no the report that significantly indicated about information on relating to preferred /dominant of seagrass species in specific areas as a major feeding ground for Sea Turtles, particularly Green turtle. But, based on the report of research of DoF (2002), indicated that there are four sites of seagrass beds, namely KKSG1, KKSG2, KAMPSG1 and KEPSG1 are the biggest meadow in Cambodia Waters, in which first two sites (KKSG1 and KKSG2) in Koh Kong province, second site (KAMPSG1) in Kampot province and third site in Kep Municipality.

In term of preserving, knowing the crucial potentials of these existing seagrass bed as well as managing and conserving program in Cambodia on endangered species, especially Sea Turtles, two of four seagrass sites (KAMPSG1 and KEPSG1) selected to conduct a survey and research in 2002.

Respectively, more clear data and information relating to specific feeding ground or preferred species of seagrass of green turtle and other potentials of seagrass will be completely done in more two sites in Koh Kong province, if any financial support funded to DoF with good joint collaboration from outsider.

II. SURVEY ON FEEDING GROUND OF GREEN TURTLE

The initiative concept on sea turtle research and conservation just restarted in the past few years after civil war in the country. To date, there hasn't been any quantitative information on specific feeding ground of green turtle a long the coastline of Cambodia. Fishermen living along the coastal area, in particular in Kampot province and Kep Municipality mentioned that sea turtles basically have been seen in different habitats based on locations where they were accidentally caught. Of which, green turtle mainly caught in Kep City and Kampot province.

Therefore, in order to get advantages during the research program on seagrass meadow of Coral-Seagrass Component, the Sea Turtle Team requested Coral-Seagrass Team to conduct the survey and research together. Then this suggestion was agreed by the Director of the Department of Fisheries and Coral-Seagrass team. This cooperative group was separated into two groups, in which one group is inland survey and an other group is underwater research. Clearly, all activities and result mentioned in following procedures.

III. METHOD

Three methods were used to conduct the survey/research are

1. Use questionnaires and note taking to interview with local people who are resident living around the seagrass sites by using questionnaire and note taking,
2. Use GPS to record position to zoning and mapping.
3. Use Seagrass net method to determine species composition and percentage cover of seagrass by species.

IV. RESULT OF SURVEY RESEARCH

4.1. Area found speciecs for Green Turtle

(*Thalassia hemprichii*)

Based on the survey/research on land and underwater about seagrass composition and specific feeding ground and preferred species for green turtle in Kampot province and Kep Municipality, there are six seagrass areas, namely in Preak Tnaot, Preak Ampil, Preak Kdat, Preak Koh Touch, Roluos and Phnom Dong in KAMPSG1 and there are two seagrass areas, namely Koh Tonsay and Koh Tbal in KEPSG1.

Eight seagrass species found in those areas such as *Enhalus acoroides, Cymodocea rotundata, Halodule pinifolia, Halodule uninervis, Halophila deciens, Halophila ovalis, Syringodium isoetifolium and Thalassia hemprichii*, in which *Enhalus acoroides* and *Thalassia hemprichii* are dominant species.

Generally, seagrass meadows are mainly growing inshore in sediment on the sea floor with clear shallow water. These meadows may be monospecific or may consist of multi-species communities, and the other species were found in small amounts. At Preak Thnoat, Km12, Phnom Dong village in Kampot Province, around Koh Tonsay in Kep Municipality. Information on seagrass composition and seagrass abundance species within the two areas are still not reliable. According to this survey/research, many green turtles have been caught and found in these two zones.

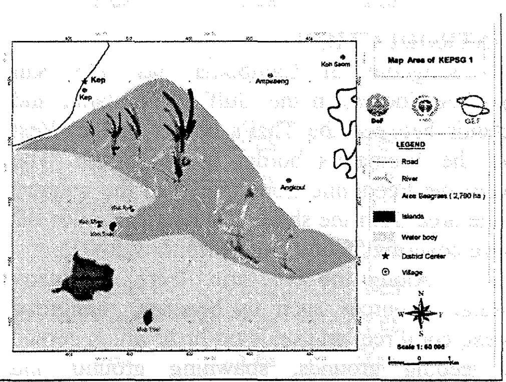

Figure 1. Seagrass area in Kep Municipality

4.2. AREA RICH IN *Thalassia hemprichii* and *Enhalus acoroides*

According to data and information obtained from the underwater research shown that the areas where cover by *T.hemprichii* are Phnom Dong, Kilodabpi and Rolous in Kampot province, and group of Koh Tonsay islands at earthen part of KohTonsay and Koh Tbal in Kep Municipality.

4.3. AREA FOUND GREEN TURTLES *(Chelonia mydas)*

Referred to the on-land interview with residents around selected site indicated that Green turtle is

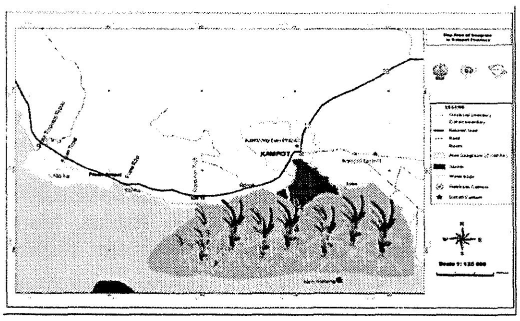

Figure 2. Seagrass area in Kanpot province

a well-known species can be found year round in their area, further green turtle have been considered as abundant species in the sea. On the other hand, Green turtles have been found broad expanses of shallow, sandy flats covered with seagrass or near seagrass beds in Phnom Dong, Rolous and Angkoul area, which is reported that the largest area among all of areas have been conducted an underwater research. However, information related to specific feeding ground and specific species of seagrass for green turtle still not completely obtained yet due to local people have not known clearly about individual name of those seagrass even in Khmer. Clearly, many kind species of seagrasses were called the same name in Khmer as Smao Samut.

Even thought, at least two more areas (Preak Ampil and Preak Kdat) were reported that mostly encountered green turtle as well.

4. 3. IMPACT TO SEAGRASS BED AND GREEEN TURTLE

From the survey resulted that there are several factors may be causing negative impacts on seagrass beds by anthropogenic influences such as mangrove deforestation, stingray hook line, and fishing practices, in which only engine-pushed net and trawling fishing are the most dangered activities on seagrass destruction. In addition, this illegal is not only caused degradation of diversity in the seagrass area, also reduced sea turtle population, particularly green turtle during their migration for feeding ground. Fishermen added that before here found many green turtles but now its number was decreased after trawling fishing have been operating these seagrass areas.

V. DISCUSSION

According to the survey/research in KAMPSG1 and KEPSG1 on percentage cover of seagrass composition and its relation to green turtle, even study randomly conducted in accordance with real situation at the survey/research sites, the result shown that eight species of seagrass beds have been found, of which two species are dominant species and many green turtle have been generally occurred in these two sites, especially in Phnom Dong, Preak Ampil and Preak Kdat areas.

Furthermore, it is expected that there are more than ten species of seagrasses have been presenting along the coastal area in Cambodia Water if other two (KKSG1 and KKSG2) in Koh Kong province will be completely conducted survey/research in the future. Clearly, based on Nelson (1999), mentioned that there are nine species of seagrass have been found along coastline.

With this regards, it is also hope that more number of feeding ground and preferred species of seagrass for green turtle as well as other sea turtles will be found in Koh Kong water.

Thus, we hope that some of seagrass areas in this research site and others resulting from future research will be proposed to be protecting site, in order to ensure sustainability of marine fisheries resources, as specific feeding ground for sea turtles, particularly green turtle.

VI. CONCLUSION

The research on seagrass beds in Cambodia might be able to say that this is a good initiative to set up any plan for future to prevent these seagrass beds from such crucial destruction trough more closed collaboration with local communities and other government agencies even some cooperation have been done.

With this regards, such idea will also distribute indirectly to manage and conserve green turtle as well as other turtle species, because of seagrass beds are the main habitat for marine animals and other endangered sepecies, particularly feeding ground for green turtle. So, if these activities still continuously operation in the seagrass sites, green turtle will be declined its number from Cambodia Water.

Hopefully, this information from this seagrass beds survey/research will be useful for local or regional management and conservation program on sea turtles, other seegrass medow and marine endangered species as well.

VII. RECOMMENDATION and SUGGESTION

To ensure sustainability of our sea turtles, other marine natural resources as well as their natural habitat and feeding ground, emergent co-management and cooperation need to implement with friendly thinking in order to solve this matter, especially cooperatively eliminate any illegal action that may be caused danger seagrass beds and green turtle. Furthermore, public awareness campaigns and extension programs on the importance of our existing resources should be immediately disseminated to all levels.

In this connection, more research is needed on feeding ground or areas could be suitable for setting up to be protected zones for protecting and conserving sea turtles and their habitat in the future.

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Sea Turtles in Ishigaki Island, Okinawa

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ABSTRACT

The current status of the nesting activity of sea turtles in Ishigaki Island, Okinawa, was investigated. It was revealed that the dominant nesting species was changing from loggerhead turtle, *Caretta caretta*, to green turtle, *Chelonia mydas* in the most southern part of Japan. The nesting populations were evaluated to be 10-20 females of *C. mydas* and 3-8 females of *C. caretta,* annually. On the average, *C. mydas* re-migrate to nest every 3.7years, suggesting that the females of *C.mydas* which nest in Ishiagki was about 100.

KEYWORDS: *Chelonia mydas, Caretta caretta,* nesting activity, nesting population, Okinawa

INTRODUCTION

Three species of sea turtles, *Caretta caretta, Chelonia mydas* and *Eretmochelys imbricata*, nest in the coast of Japan (Uchida & Nishiwaki, 1982). Ryukyu Islands, including Ishigaki Island, are utilized as a nesting site by all three species (Kamezaki, 1989, 1991). To make up conservation and management plans for sea turtles, it is important to evaluate the population size and the current status of the local breeding populations. This study introduces the evaluation of nesting populations of sea turtles in Ishigaki, the most southern part of Japan.

MATERIALS AND METHODS

All major sandy beaches in Ishigaki Island were surveyed for sea turtle nests in the daytime during the nesting season of sea turtles from 1995 through 2003. Species of the nest was identified using the morphology of nesting females, hatchlings, or adequately developed embryo in dead eggs.

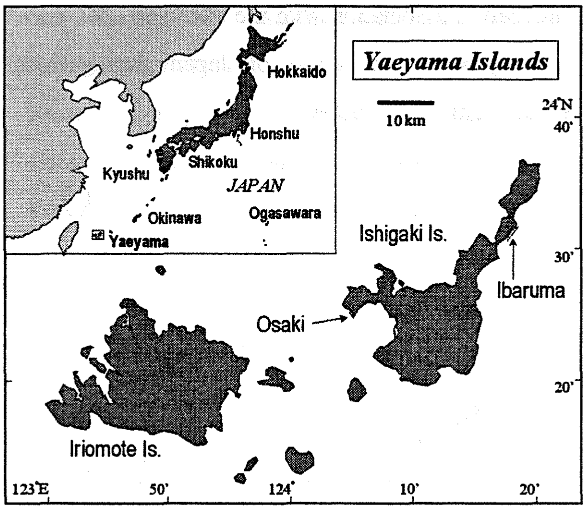

Fig. 1. Study site, Ishigaki Island, Okinawa.

Ibaruma beach (3km in length) in the eastern coast of the island is the biggest nesting site in Ishigaki,

(Fig. 1). Night patrols were done on Ibaruma from April through August for tagging nesting sea turtles. Plastic jumbo tags and inconel tags were used. Since 2001, passive integrated transponder (PIT; Trovan, Ltd.) tags were used concomitantly with the external tags. We also used the patterns, figures, and designs on the scutes of the carapace to identify nesting individuals.

RESULTS AND DISCUSSION

1. Nesting activity of sea turtles in Ishigaki

Fig. 2 shows the nesting activity of sea turtles in Ishigaki from 1995 through 2003. *C. mydas* occupied the 76% of the nests found in Ishigaki. The nest of *C. caretta* and *E. imbricata* was 17% and 5%, respectively. The remaining 2% of the nest was not able to identify species because of inadequate development of the embryos. In 1980's, the dominant nesting species of sea turtles was *C. caretta* in Ishigaki (Kamezaki, 1991). However, our result shows that the dominant nesting species in this island is changed to *C. mydas* from *C. caretta* during late 1990's and early 2000's. This transition may be induced in association with the decrease of *C. caretta* nesting along the coast of Japan during 1990's (Kamezaki *et al.*, 2003).

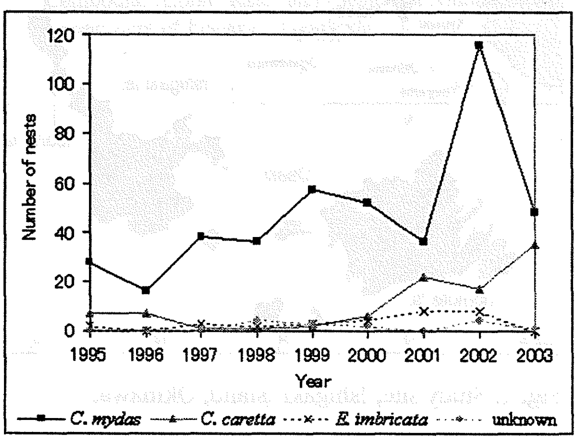

Fig. 2. Nesting activities of sea turtles in Ishigaki.

2. Nesting activities of sea turtles in Ibaruma

Ibaruma beach was nightly patrolled for tagging nesting turtles. The nesting season of *C. caretta* was from April through July, and that of *C. mydas* was from May through August, sometimes continuing until December (Abe, *et al.*, 1998). We have 15 to 38 nests of *C. mydas* and 0 to 8 nests of *C. caretta* in Ibaruma annually during 1995-2003 seasons. The average number of nests is 28.0 and 2.4 for *C. mydas* and *C. caretta*, respectively. The nesting of *E. imbricata* is rare; only two nests were recorded during the study. We identified nesting females of 3 to 8 *C. mydas* and 0 to 2 *C. caretta* in Ibaruma every year.

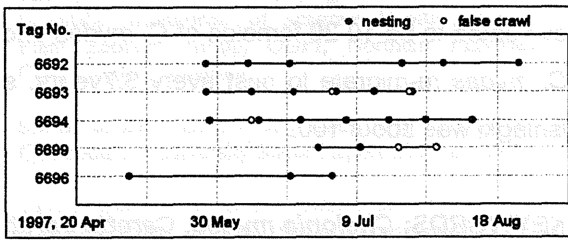

Fig. 3. Examples of re-migration of nesting *C. mydas* on Ibaruma in 1997.

Fig. 3 shows an example of the inter-nesting intervals of *C. mydas* in Ibaruma in a single nesting season. The upper 4 turtles in Fig.3 nested very regularly, with inter-nesting intervals of 11 or 12 days. Especially, No.6694 showed high nest site fidelity; her nests were not apart from each other by 50 m. On the contrary, No.6696 showed low nest site fidelity. At first she appeared in Osaki (Fig. 1), the western coast of Ishigaki 50 km far from Ibaruma. She was found nesting in Ibaruma in the eastern coast 46 days later. And 12 days later, she went back 50 km to Osaki. This result suggests that there are two types of nesting females. One type has high nest site fidelity and regularity. Another type is relatively migratory with low nest site fidelity.

3. Remigration between nesting seasons

In Ibaruma, 94% of re-migrants of *C. mydas* came back to nest 3 or 4 years after the former nesting season. On the average, they nested every 3.7 years. There was no female returned to nest more than 6 years after she was tagged. Therefore, we analyzed re-migrants identified before 1999, which were expected to come back until 2003.

The *C. mydas* identified before 1999 has been re-migrated to Ibaruma to nest by 69%. Other 31% appeared once and has never been found in Ibaruma until the end of 2003. Within the re-migrants, 33% came back once, 44% twice, and 22% came back to nest three times.

4. Nesting populations in Ishigaki

On the average, *C. mydas* and *C. caretta* nested 4.9 and 3.1 times in a single nesting season in Ibaruma, respectively. Applying this clutch number per female, we evaluate that the annual numbers of nesting females in all over Ishigaki were 10-20 *C. mydas* and 3-8 *C. caretta.* We estimated that the total number of the matured females of *C. mydas* population in Ishigaki was about 75, using the results of Ibaruma that nesting *C. mydas* re-migrated to nest every 3.7 years. In addition to this, certain numbers of females with low nest site fidelity may visit to nest Ishigaki. In total, the number of the nesting females in Ishigaki was assumed to be 100.

ACKNOWLEDGEMENTS

The members of Ishigaki-jima Sea Turtle Research Group (Mr. S. Yasumura, Mr H. Yanagida, Mr H. Yamagada, Ms. T. Suzuki, Ms A. Shinozaki) have done daytime patrol with the authors. Japan Sea Turtle Association provides plastic jumbo tags and inconel tags. The Resource and Environment Research Division, Fisheries Agency of Japan partly supported this study.

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Study on Population and Distribution of Two Common Sea Turtles, Green Turtle and Hawskbil Turtle in Indonesia

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ABSTRACT
The green turtle and hawksbill turtle are the most common of six sea turtle species existing in Indonesian waters. These two populations seem to be declined after observation of the decreases of nested sea turtles from year to year in some place where the turtles had been nesting frequently. This is caused by the habitat degradation and the un-stopped mortality due to the incidental capture and hunting by fishermen.

KEYWORDS: population, distribution, nesting, green turtle, hawksbill turtle

INTRODUCTION

Sea turtles are long-lived species that mature late in life and move great distances during their lifetimes. As trans-boundary species, sea turtles are excellent navigators, frequently migrating hundreds or even thousands of kilometres between foraging and nesting grounds, crossing international boundaries. They spend their lives at sea but return to land to produce. Adult females nest in multiyear cycles, coming ashore several times to lay hundreds of eggs during nesting season. After about 50 to 60 days of incubation, the hatchlings emerge and head for the ocean to begin life as pelagic drifters. While maturing over the course of several decades, they move in and out of a variety of ocean and coastal habitats.

Indonesia is an archipelago country of approximately 17,500 islands and 81.000 km of total coastlines, each with different geographically and topographically. This nature benefits turtles in their wide range of choice of habitats. Of seven species of marine turtles in the world, there are 6 (six) species, which have been identified to live and spread in Indonesian marine waters such as leatherback turtle (*Dermochelys coriacea*), olive ridley turtle (*Lepidochelys olivacea*), hawksbill turtle (*Eretmochelys imbricata*), loggerhead turtle *(Caretta caretta*), flatback turtle (*Natator depressus*), and green turtle *(Chelonia mydas*). Whereas *Lepidochelys kempi* is not found in Indonesian waters as this species only live in Atlantic Ocean around Mexico and American beaches. Consecutively, the most abundant species in Indonesia are the green turtle and hawksbill. The green turtles are suffered to the capture by fishermen, which bring them to the specific area (Bali) for the purpose of religious and culture. However, their population status and distribution are little known. This condition stimulated us to develop a study on this topic, for that this paper presented for the first step.

MATERIALS AND METHODS

Data presented in this paper were summarized from technical reports of some research activities that were conducted in some areas (Fig. 1), such as: Pangumbahan Beach (West Java), Alas Purwo National Park and Meru Betiri (East Java), Berau District (East Kalimantan), and Jamursba Medi Beach (Papua). The data that was analyzed from 1980 to 2000 included nesting sites, nesting season, and mortality.

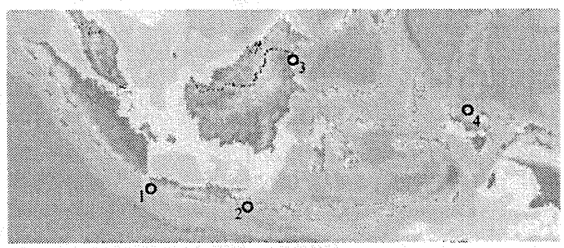

Fig. 1. Map showing the study sites: 1- Pangumbahan ; 2-Alas Purwo NP and Meru Betiri; 3-Berau District; 4- Jamursba Medi Beach.

RESULTS AND DISCUSSION

<u>*Green turtle*</u>

The green turtle with local name Penyu Hijau, Penyu Daging and Penyu Laut has traditional been utilized by coastal communities for centuries, particularly as a part of the Balinese culture. This turtle is commonly found and widely distributed throughout the Indonesian archipelagos and can be found to nest in a quite vast amount such as in Berau district of East Kalimantan province; and in small and remote islands throughout Indonesia. In Berau district, this population has been long contributed economically both to the local community and the government. There are about 8 (eight) nesting sites for green turtle species throughout Berau district such as in Derawan, Sangalaki, Semana, Mataha, Belambangan, Bilang-bilangan, Balikukup and Sambit islands (Table 1). Sometimes Kakaban island which is located in southern part of Sangalaki island has also been used by the green turtle populations for laying their eggs even though the nests often have become inundated or covered by the high tide so that the embryos down inside the nests. Since January 2002, the local government of Berau District has stopped the concession activity and declared the Sangalaki Island and Derawan Island as protected important nesting site.

Table 1. Number of nests on the five concession Islands in Berau District between 1998 and 2000 (Turtle, Foundation, WWF and KEHATI 2002).

Islands	Number of Nests		
	1998	1999	2000
Sangalaki	6985	10346	5065
Belambangan	2602	3819	2314
Sambit	482	1050	430
BilangBilangan	4483	7847	3935
Mataha	2746	4058	2334
Total	17298	27120	14078

Pangumbahan in West Java is also one of the major green turtle nesting beach in Indonesia and the only remaining nesting beach of any importance on Java. However, many largest rookeries have decreased in the last 50 years, due to over-harvest (Schulz 1984, Salm, 1984; Kitchener, 1996). As showed in the Figure 2, the green turtles nested in Pangumbahan with different peaks from year to year. There was a significant decrease of eggs laid from 1997 to 1998. This is due to the habitat degradation and indicates the decrease of green turtle populations. Green turtles were captured in several waters of Indonesia. Green turtles were captured as by catch of fish net in Arafura Sea with values reaching 95 individual in 1999. Almost no turtles captured after utilization of Turtle Excluder Device (TED) since 2001. Although this species has been protected based on the Governmental Law No. 7/1999, the captures of sea turtles were happened illegally in some areas by using drift gillnet. There are no significant data available to estimate the number of population of the green turtle existing in Indonesian waters.

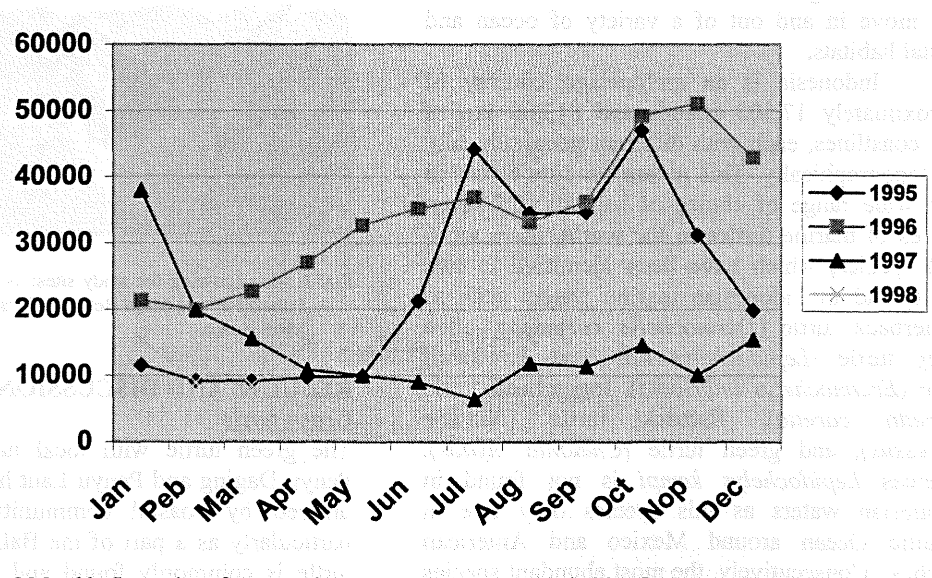

Fig. 2 Monthly fluctuation of green turtle eggs at Pangumbahan beach, West Java.

Hawksbill

There are several local names for hawksbill: Penyu Sisik, Fonu Koloa, Penyu Genteng, Penyu Kembang, Penyu Katungkera and Wau. This species has been protected based on Ministrial of Forestry decree no. 882/Kpts-II/1992 that is more strongly based on the Governmental Law No. 7/1999. At present hawksbill can still be found throughout Indonesia in significant number as reported by Halim and Dermawan (1999). Important nesting areas are the many islands in the Anambas and Natuna-Riau; Lima Momperang, Pesemut-Belitung, Segamat Island-Lampung, South of Ujung Pandang, Birah-birahan, Derawan-East Kalimantan (Salm and Halim, 1984; Schulz, 1984; Soehartono, 1993; Halim and Dermawan, 1999). The hawksbill turtle is exceedingly difficult to monitor for long-term trend, for a number of reasons. First, all small number of animal's nest on wide variety of beaches across abroad geographic area. Secondly; hawksbill beaches tend to be remote, inaccessible and sometime so narrow that the turtle leaves no crawl trace. Finally, hawksbill also exhibits the large annual fluctuation in nesting counts characteristic of green turtles. The figure 3 shows the hawksbill nested in small quantity in three different locations such as, Alas Purwo National Park-East Java; Jamursba-Medi Beach-Papua; Sukamade beach, and Meru Betiri-East Java.

In some rookeries the nesting time of this species varied seasonally, for instance in Kepulauan Seribu NP it is on December-April, Segamat Island-Lampung on December-April, Belitung on January-June, Paloh-West Kalimantan on February-May and Tambelan, Riau on February-May.

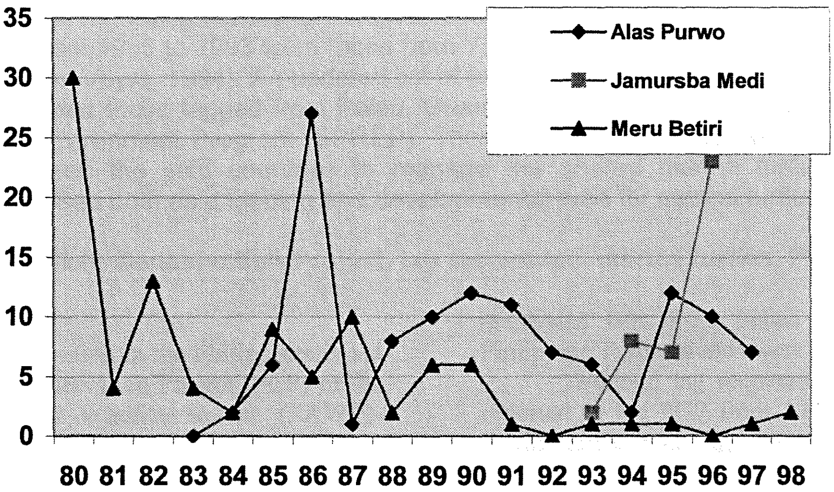

Fig. 3. Annual nesting trend of hawksbill turtles in 3 different places in Indonesia

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Marine turtles with foreign tags recaptured in the Philippines from 1993 to 2002

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ABSTRACT
The Pawikan Conservation Project (PCP) of the Protected Areas and Wildlife Bureau (PAWB) of the Department of Environment and Natural Resources (DENR) is the government agency of the Philippines tasked to conserve and manage the marine turtle populations in the country. In 1989, the PCP started its nationwide tagging program in cooperation and collaboration with the DENR Regional and Field Offices, non-government organizations, the academe, and private individuals. This nationwide tagging program is supplemented and complemented by the PCP's Information and Education Campaign regarding marine turtle conservation. Marine turtles with foreign tags recaptured in the Philippines from 1985 to 1993 were those from Yap, Micronesia; Yakushima Island, Japan; and Sabah, Malaysia (De Veyra, 1994). An updated list of foreign tag recoveries reported to the PCP from 1993 to 2002 included those tagged from Palau, Guam, Japan, Taiwan, Malaysia and by the South Pacific Regional Environment Program (SPREP). These further justify the need for an international collaboration between the said countries to manage the shared marine turtle resource and to recognize the Sulu Sea both as a feeding and developmental area for marine turtles.

KEYWORDS: Pawikan Conservation Project, tag recoveries, marine turtles, Philippines

INTRODUCTION

Marine turtle conservation in the Philippines is led by the Pawikan Conservation Project (PCP) of the Protected Areas and Wildlife Bureau (PAWB)-Department of Environment and Natural Resources (DENR). The PCP was created in 1979, which was then known as Task Force Pawikan (TFP). In 1989, the PCP started its nationwide tagging program in cooperation and collaboration with the DENR Regional and Field Offices, non-government organizations (NGO), the academe, and private individuals. Marine turtle tags were issued to the collaborators for this purpose. This nationwide tagging program is supplemented and complemented by the PCP's Information and Education Campaign regarding marine turtle conservation. Through these efforts, the PCP generated the much-needed public support in conserving marine turtles in the Philippines.

Through the Field Action Officers of the DENR, the PCP received reports of marine turtles captured with foreign tags. De Veyra (1994) originally reported marine turtles recaptured in the Philippines, which were tagged from Yap, Micronesia; Yakushima Island, Japan; and Sabah, Malaysia. Here, the list of foreign tag recoveries from the Philippines is updated from 1993 to 2002. Since the Philippine-Sabah Turtle Islands is inferred as a well-defined green turtle (*Chelonia mydas*) rookery (Trono, 1994), marine turtles with malaysian tags from Sabah encountered in the Philippine Turtle Islands were not included.

Foreign tag recoveries in the Philippines reported to the PCP from 1993 to 2002 included marine turtles with tags from Palau, Guam, Japan, Taiwan, Malaysia and by the South Pacific Regional Environment Program (SPREP).

A plotted map of movements of the said marine turtles is shown in Figure 01.

RESULTS AND DISCUSSION

In May 14, 1993, a hawksbill turtle (*Eretmochelys imbricata*) was released in the Sulu Sea near Negros Occidental. Its Curved Carapace Length (CCL) upon release was 41.3 cm and its Curved Carapace Width (CCW) was 37.5 cm. It was captured in the Sulu Sea near Negros Occidental on March 20, 1989. Upon capture, the tags attached to its left hindflipper read Palau Japan, MMDC No. 477. The hawksbill turtle came from the Micronesia Mariculture Demonstration Center (MMDC, which is now called Palau Mariculture Demonstration Center) turtle headstarting program which was supported by the Japan government (Theo Isamu, pers. comm., 2003). The program targeted hawksbill turtles (Sato and Madriasau, 2001) and the tag number represented the number of turtle released (Theo Isamu, pers. comm., 2003). RP6882 and RP6883 were applied to the right and left frontflipper, respectively prior to its release.

A hawksbill turtle with tag 738, Dalton Henley, England, Pat #894143, was recaptured in Sitio Puting Balas, Sugod, Tukuran, Zamboanga del Sur on August 28, 1991. The origin of the tag was not known (De Veyra, 1994). Further review of the original report revealed that the tag was a TWIN tag attached to the left hindflipper. The above inscription was from the bottom tag, the top tag read PALAU.JAPAN MMDC, TWIN Tag. The hawksbill turtle also came from the MMDC turtle headstarting program. The hawksbill turtle was released on the same area on January 16, 1992 but the captor removed the tag.

Green turtles originally tagged from Sandakan, Sabah, Malaysia were recaptured near the waters of Bacolod City, Palawan, Surigao City, Negros Occidental, and Antique. Communications with Sabah Parks of Malaysia were exchanged regarding these recaptures. Marine turtles with tags from the SPREP were recaptured in Southern Leyte (Visayas Region) and Oriental Mindoro (Luzon Region).

A green turtle with tags from Japan was recaptured near the waters of Brgy. Buenavista, Rapu-Rapu, Albay on February 28, 1998. The serial numbers of the tags were JPN7376 and JPN16132 in the right and left flipper, respectively. The green turtle was originally tagged in Yomitan, Okinawa, Japan on August 25, 1997 (Hideshi Teruya, pers. comm., 2002). The green turtle was released in Albay Gulf, Rapu-Rapu, Albay on March 05, 1998.

Another green turtle with tags from Japan was recaptured near the waters of Brgy. Bancao-Bancao, Puerto Princesa City, Palawan on September 27, 2002. JPN14638 was found in the right frontflipper and JPN25572 in the left hindflipper. Both tags were made from yellow plastic. The green turtle was originally tagged in Sakiyama, Iriomote Island, Okinawa, Japan on August 12, 1997 (Tatsuya Shima, pers. comm., 2003). The green turtle was released at the bay of Brgy. Bagong Silang, Puerto Princesa City, Palawan on September 27, 2002.

A green turtle with a tag from Taiwan was recaptured in Tapel, Gonzaga, Cagayan (Northern Philippines) on November 19, 1994. The tag read TW-010-011 PO Box 7-215 Keelong Taiwan 20224 ROC. RP726A and RP725A tags were applied on its right and left frontflipper, respectively. The turtle was released on November 26, 1994.

On January 02, 2002, a green turtle with a satellite transmitter from Guam was recaptured in Kulisi-an, Pangutaran, Sulu (Mindanao Area). DENR Region 9 informed the Guam Sea Turtle Project regarding the recapture of the green turtle in Philippine waters.

A record of all foreign recaptures given above is presented in Table 1.

The marine turtle recaptures and release shows the effectiveness of the PCP's marine turtle tagging and conservation program and further justify the need for an international collaboration between countries where the marine turtle resource is shared. Also, the records show the importance of the Sulu Sea both as a feeding and developmental area for the marine turtle populations of Malaysia, Japan, and Palau.

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Table 1. Marine turtles with foreign tags reported to the PCP from 1993 to 2002

Recovered tag(s)	Applied Phil. Tag(s)	Species	CCL and CCW	Recapture Area and Date of Recapture	Approximate Straight-line distance (km)
Palau **Japan**, MMDC No. 477 (LHF)	(RFF) RP6882 (LFF) RP6883	*E. imbricata*	CCL=41.3 cm CCW=37.5 cm	Sulu Sea; March 20, 1989 (near Negros Occidental); released on May 14, 1993	1352
(RFF) 37237 Sabah **Malaysia**	(RFF) RP9854 (LFF) RP9853	*C. mydas*	CCL=109 cm CCW=95 cm	So. Sibucao, Purok Rosas Pandan, Brgy. Banago, Bacolod City; December 20, 1993; 122°58'00" E 10°40'00" N	780
14213 RETURN TO TURTLE IS. ANOS NAT PARK BX 768 SANDAKAN SABAH **EAST MALAYSIA**				Brgy. Sabang III, Surigao City. Captured in 1993; 125°29'00" E 09°47'00" N	884
(LFF) 33863 Return to Turtle Island Park, Box 768, Sandakan, Sabah, E. **Malaysia**	(RFF) RP013B	*C. mydas*	CCL=110 cm CCW=97.5 cm	Green Island Bay, Roxas, Palawan; February 16, 1994; 119°23'00" E 10°16'00" N	520
33860 Turtle Island Park Box 768 Sandakan Sabah E. **Malaysia**			CCL=39 in CCW=30 in	Brgy. Babuyan, Puerto Princesa City, Palawan 1994 118°56'30" E 09°59'45" N	442
39098 Sabah **Malaysia**		*E. imbricata*	CCL=abt. 90 cm	near mouth of Babuyan River, Brgy. Babuyan, Puerto Princesa City, Palawan; October 28, 1994; 118°56'30" E 09°59'45" N	442
TW-010-011 PO Box 7-215 Keelong **Taiwan** 20224 ROC	(RFF) RP726A (LFF) RP725A	*C. mydas*	CCL=100 cm CCW=95 cm	Tapel, Gonzaga, Cagayan November 19, 1994; 122°00'00" E 18°16'00" N	832
(RFF) 47765 TURTLE ISLAND PARKS BOX 768 SANDAKAN SABAH **MALAYSIA**	(LFF) RP305B	*C. mydas*	CCL=100 cm CCW=89 cm	Brgy. Balaring, Silay City, Negros Occidental May 17, 1997; 122°58'35" E 10°48'00" N	676
(LFF) 48600 TURTLE ISLAND SANDAKAN SABAH **MALAYSIA**	(RFF) P13089 (LFF) P13090	*C. mydas*	CCL=102 cm CCW=98 cm	So. Tubog, Brgy. Lapaz, Hamtic, Antique February 10, 1998; 121°59'20" E 10°42'25" N	728
R-JPN7376 (metal) L-JPN16132 (plastic)	(RFF) RP8587 (LFF) RP8586	*C. mydas*	CCL=85 cm CCW=66 cm	Brgy. Buenavista, Rapu-Rapu, Albay February 28, 1998; 124°07'45" E 13°11'20" N	1486

Kushimoto Marine Park, Wakayama, **Japan**					
(RFF) 56490 (LFF) 56489 Sabah, **Malaysia**	(RFF) P14409 (LFF) P14408	*C. mydas*	CCL=99 cm CCW=92 cm	So. Meluang, Brgy. Lucbuan, Puerto Princesa City, Palawan; January 15, 2000; 118°54'30" E 09°59'30" N	442
5000 4999 Sarawak, **Malaysia**	(RFF) RP8412	*C. mydas*	CCL=123 cm CCW=75 cm	Brgy. Malinao, Narra, Palawan; May 19, 2000; 118°24'30" E 09°15'00" N	858
(RFF) 3464 Return SPC/SP REP BPDS NOUMEA CEDEX **NEW CALEDONIA** (and 3465)				Brgy. Ambao, Hinundayan, Southern Leyte July 4, 2000; 125°15'00" E 10°23'30" N	
(RFF) 90708 Box 768, 90708 Turtle Island Park, Sandakan, Sabah, **Malaysia**	(RFF) P16376 (LFF) P16377	*C. mydas*	CCL=94 cm CCW=92 cm	Brgy. Panacan, Narra, Palawan March 09, 2001; 118°24'25" E 09°15'10" N	364
MY(S)2539 MY(S)2540 Turtle Islands Park Box 768, Sandakan, Sabah, **Malaysia**		*C. mydas*		Brgy. Binduyan, Puerto Princesa City, Palawan; December 07, 2001	442
Satellite transmitter 439098 with inscription **"GUAM SEA TURTLE PROJECT PLEASE DON'T KILL ME"** Guam Sea Turtle Project, U.S.A. Return If Found (671)735-3987		*C. mydas*		Kulisi-an, Pangutaran, Sulu January 02, 2002; 10:00am 120°35'00" E 06°19'00" N	2804
JPN3484 **JAPAN**		*Unknown*		approx. 50m away from coastline east of Diogo Island on March 13, 2002	
4999 5000 Forest Development, Sarawak, **Malaysia**	(RFF) P16371 (LFF) P16372	*C. mydas*	CCL=50 cm CCW=46 cm	So. Borbon, Brgy. Panacan, Narra, Palawan; August 15, 2002; 11:00 am	858
(RFF) JPN14638 (LHF) JPN25572 (both yellow plastics) **JAPAN**	(RFF) P18761 (LFF)P18760	*C. mydas*	CCL=80.1 cm CCW=72 cm	Brgy. Bancao-Bancao, Puerto Princesa City, Palawan; September 27, 2002; 7:00 am	1768

(RFF) RMTP 649 SPC REP BPDS NOUMEA CEDEX **NEW CALEDONIA**	(LFF) P18875	*C. mydas*	CCL=107 cm CCW=94 cm	Dalahican, Roxas, Oriental Mindoro October 16, 2002; 121°32'00" E 12°36'30" N	

(RFF) right frontflipper
(LFF) left frontflipper
(LHF) left hindflipper

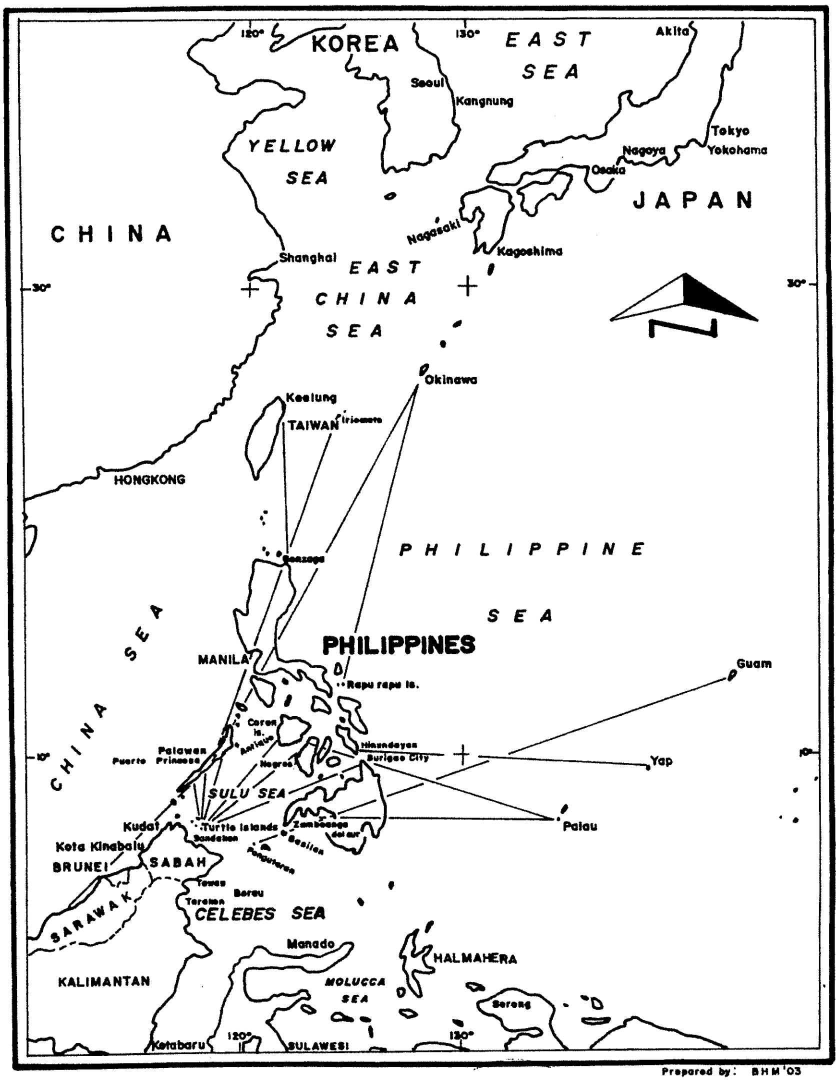

Figure 1. Plotted movements of marine turtles with foreign tags reported to the PCP from 1993 to 2002.

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COUNTRY REPORT

Emergence Success of Natural nests for Oliveridley on sandy beach, Kadonkalay Island in Myanmar.

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By

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Abstract

At the time of Maxwell's report (1911), the Kadongalay Island (15° 49' N , 95° 13' E) was existence. This island formed with deposited sand at the mouth of Bogalay River, Ayeyawaddy delta in gulf of Bengal, Kadongalay Island is (5) miles length and there quarters mile in breadlt turtles laying the eggs on this islanf from September to March (Seasonal time) yearly. Department of Fisheries was undertaking for sea turtle conservation and research started on Kadongalay Island in 1998. Kadongalay Island has found only oliveridley (Lepidochelys olivacea) attended to this island for nesting. About (120) nests could be found each year, along the sand beach in seasonal. All nests have beng preserved naturally. Nesting female turtles lay the egss on the sand bank (white siliceous sand), three different kind of places as lower slope, upper slope and dune. Data was recorded that nest location and date, and then watched until the time of hatching out. After the hatchlings were hatch out from clutches, and then examine and record the egg hatching rate and other parameters immediately. Data Collected for these clutches such as temperature, incubation period, emergence success and clutch sizes from three different areas. The results are showing that average temperature was 29.3°C, 51 days of incugsiton period and 96.17% of emergence success in dune. Average temperature was 28.53° C, 50 days of incubation period and 89.8% of emergence success in upper slope. Average temperature was 27.4°C, 49 days of incubation period and 95% of emergence success in lower slope. Digital thermometer and measuring tape were used for this research. All clutches size are not differ from each other, clutch neck depth was 7 to 8 inches, diameter of clutch bsase was 9 to 10 inches, an average total depth of clutches was 16 to 18 inches. Nesting turtles did not made the body pits in the above mentioned sand.

***KEYWORDS*; Kadonagalay Island.** Natural nests on pure sand bank (White sileceous sand), Oliveridley (Lepidochelys olivacea), temperature incubation period, emergence success, sand temperature of clutches, Digital thermometer and measuring tape.

INTRODUCTION

Myanmar coastline lies from north to south and has length of about 2831.84 Kilometes embracing many islands and sand banks.Sea turtles build their nests and lay their eggs on those islands and sand banks. Nesting of sea turtles are observed around Andaman sea in Mon State and Tanintharyi Division, Gulf of Bengal in Ayeyarwaddy Divsion and Bay of Bengal in Rakhine state. In Ayeyarrrwaddy delta, the beach of "Thameehla" island (Diamond island 15°51'N; 94°17' E), an island at the mouth of Pathein River, host the most nesting green and some olive ridley turtles, but Kadongalay island(15°49',94° 13' E),an island at the mouth of Bogalay River, rspectively host the nesting oliveridleys. At the time of Maxwell's report (1911), the Kadongalay island was existence. This island formed with deposited sand at the mouth of Boalay River in Ayeyarwaddy delta. Kadongalay island is (5) miles length and three quarters mile in breadth, turtles laid their eggs on this island from September to March yearly, Department of Fisheries was undertaken for sea turtle conservation and research started on Kadongalay Island since 1998. Only Oliveridley (Lepidochelys olivacea) has found on Kadongalay island they attend to this island for nesting. About (120) nests could be found each year, along the sand beach in seasonal.All the nests have being preserved naturally.

MATERIALS AND METHODS

Female turtlels made their nests to lay the eggs, on the sand bank of Kadongalay island.The sand bank is a white siliceous sand beach, rookery area is (5) miles length from east to northwest aspect cross bow shape and faced to the sea. There are three different kind of places using for experiment as lower slope, upper slope and dune on nesting area .Each nests were fixed pillars for date of laying eggs and Serial number to recognize. At the same time recorded in Data note book. Many datas and causes included in this book for preservative nests.The datas were recorded, such as Egg laying date and time, pillar serial number, sector number (for location of rookery) approximate hatched out date, Number of death hatchlings, Number of unhatched eggs, Number of undeveloped eggs, Number of total eggs, Number of predated eggs; etc: and then other events and causes were recorded as tagging and tag recovering and nest examination forms. Eleven clutches were used respectively to submit this paper, from different kind of places on the sand beach, such as lower slope, upper slope and dune.Above high tide level of the beach is known to be lower slope, dune is higher than the slope of beach and small sand hills, upper slope lies between lower slope and dune. The clutches of nest pillar selected as Number (32) (36), (42) (45) and (47) on the part of lower slope; nest pillar Number (1) (3) and (4) on the part of upper slope and Number (14) (23) and (31) on the part of dune, there were situated along the beach respectively.

When the mentioned clutcnes hatched, they were examined immediately, that of hatched egg shells, unhatched and undeveloped eggs were counted; the nest temperature was recorded, by digital thermometer; neck and toal depth of clutches were measured by flexible tape.The clutches of nest pillars from lower slope, upper slope and dune were reccorded for each clutches was listed in table(1).

The nest pillars from lower slope, Number: (32) (36) (42) (45) and (47); each nest temperature recorded as (27.6°C), (27.2°C), (24.4°C) (27.3°) & (27.8°C) respectively. Above mentioned clutches, that of total number of eggs (125) (121) (124) (120) and (128); hatchlings (123) (118) (116) (113) and (117);death hatchlings recorded (2) (1) (2) (3) and (4); Unhatched eggs listed as (Nil) (2) (6) (4) and (7); incubation period (53), (50), (50), (46) and (46) days.

As for the nest pillars from upper slope, Number : (1) (3) and (4) ; each nest temperature recorded as (28.3°C) (28.4°C) (28.9°C); total number of eggs such as (82) (121) and (113); hatchlings (78) (118) & (87); death hatchlings (1) (Nil) and (2); unhatched eggs (3) (3) and (24); incubation period, (50) (52) and (50) days respectively.

Nest pillar from dune areas, Number : (14), (23) and (31) each nest temperature recorded as (29.1°C) (29.3°C) (29.5°) and (29.5°C); as for total eggs were (134) (136) and (100); hatchlings. (128) (136) and (93); death hatchlings (1) (Nil) and (2); Unhatched eggs (5) (Nil) and (5); incubation period (51) (52) and (50).

RESULTS

The depth of each clutch is measured at the same time during the clutch inspection, the neck of each clutchs and total depth of clutches are measured and recorded. The depth of clutches collected from different locations does not differ to each other, according to their locations. The results of average total depths from different locations are shown in table(2).

Correlation between incubation period hatching success and temperature comparative datas are shown in graph.Due to the data collected from different location of Kadongalay island beach, which have being mentioned above, the presentation of the results are as follow;

(1) Average temperature of clutches
 (a) Lower slope - 27.4°C
 (b) Upper slope - 28.5°C
 (c) Dune - 29.3°C

(2) Average hatching period
 (a) Lower slope- 49 days
 (b) Upper slope -50.6 days
 (c) Dune -51 days

(3) Average percentage of hatching
 (a) Lower slope -95%
 (b) Upper slope -89.87%
 (c) Dune -96.17%

(4) Average undeveloped eggs
 (a) Lower slope -4 Nos
 (b) Upper slope -10 Nos
 (c) Dune -3 Nos

(5) Average death hatchlings
 (a) Lower slope - 2 Nos
 (b) Upper slope - 1Nos
 (c) Dune - 3 Nos

(6) Average total depth of cluthes
 (a) Lower slope - 13 inches
 (b) Upper slope - 15 inches
 (c) Dune - 18 inches

DISCUSSION

Due to the above mentionde materials and methods applied we have come across for discussion on the following subjects.

(1) Comparing average total depth of clutches

While examining the clutch depth from different locations, there were found a slight difference in average total depth at different locations. Naturally, female turtles attend to move on beach for laying their eggs, that the instinct of female turtles to choose the righ place of suitable moistures sand on beach for laying eggs. The average total depth of clutcches from different locations can be calculated (15.3) inches which is shown in table (2)

(2) Comparison in average temperature of Clutches.

The average temperature of cluthes in Lower slope is 27.4°C, as in upper slope is 28.53°C; and for dune area location the average temperature is 29.3°C. It can be conclude that the average temperatur in different zones are between 27.4°C and 29.3°C which is most suitable in hatching success. Since also the average temperatuere range is 27°C 29°C, the sex ratio of the hatchlings on Kadongalay island beach in nature confirmed to be equal (Reference to SDT 50, Limpus-et al 1983). SDT 50 = Sex determining temperature, 50% female

(3) Comparative Percentage of hatching rate from three differnt locations results (95%) in Lower Slope; (89.87%) in upper slope and (96.17%) in dune respectively. At Kdongalay island beach, the average percentage of the clutches hatching rate appears to be 93.68% and seem to be excellent condition. Thus, from the result findings, it can be conclude the average hatching percentage on Kadongalay island beach(ie; Silicious sand)is more than that of Thameehla island beach (ie, Calcareous sand). The meehla island situated at the mouth of Pathein River, where the incubation was done artificially and the average hatching percentage amount 70% to 80%, reportedly.Durig incubation period, with average temperature 28.6°C ± 0.5°C.Comparative results of the average hatching percentage in siliceous sand is 90.94% and 78.55% as in calcareous sand (Reference to speciesBIOLGY OF AUSTRALIASIAN FROG AND REPTILES, ed by Gordon Grigg, Richer Sline and Harry Ehmann, Royal zoological Society, New South Wales 1985 in pages 345-347)

Oliveridly (Lepidochelys olivacea), the only species appears to attend on Kadongalay island siliceos sand beach for nesting, and hatched naturally, scrutinizing sea turtlells Oliveridley's eggs hatching on siliceous sand in nature such as;

(1) Received satisfactory high percentage in hatching.

(2) Average hatched temperature equalized the sex ratio.

Therefore natural nest hatching of sea turtles on siliceous sand, it can be clearly summarize to be the most suitable condition for sea turtle conservation.

ACKNOWLEDGEMENTS

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TABLE(1)

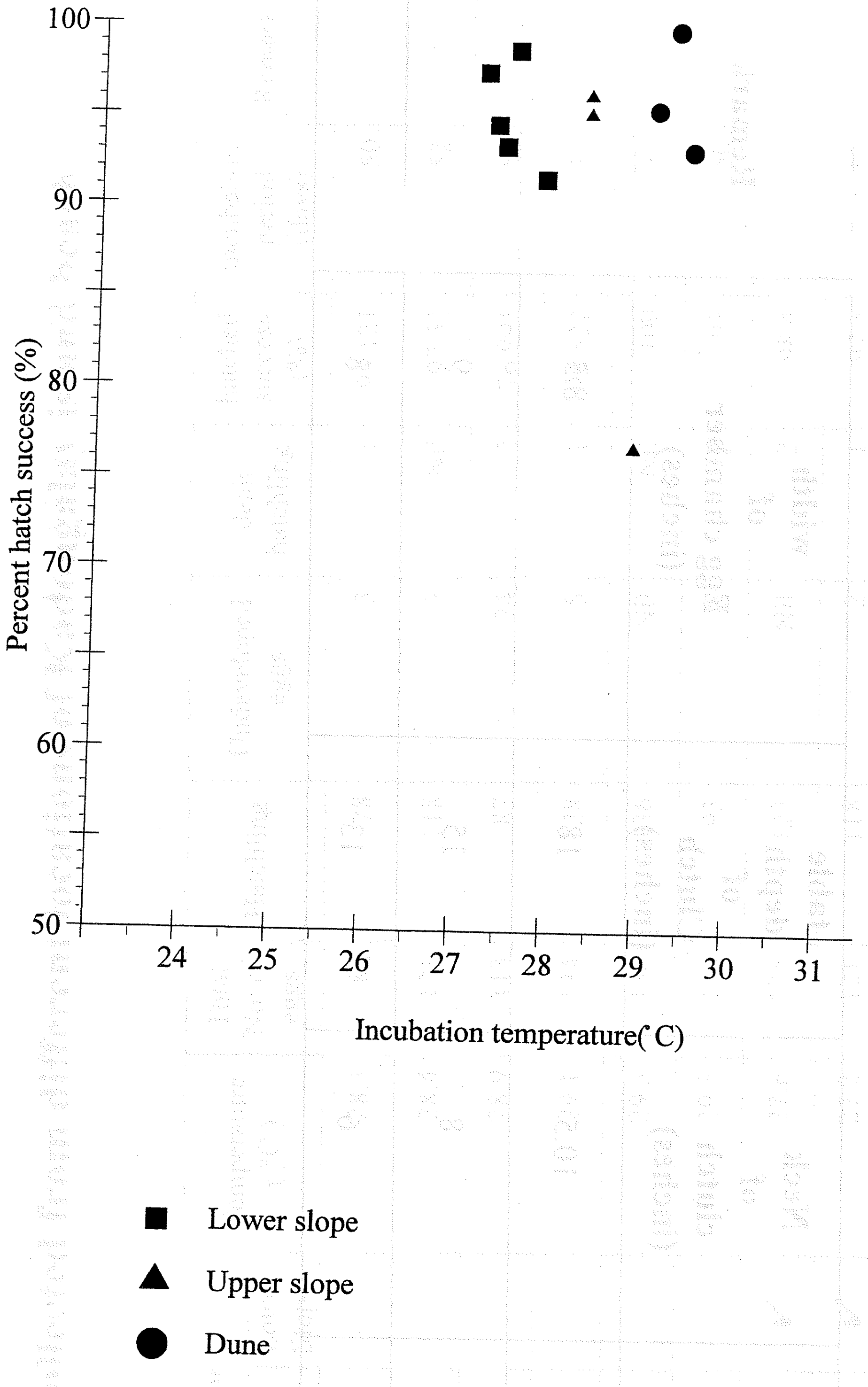
Hatching data collected from different locations of Kadongalay island beach

Sr: No:	Nest pillars No:	Date Laid	Location			Temperature (°C)	Total No: of eggs	Hatchling	Undeveloped eggs	dealt hatchling	hatched success (%)	incubation period (days)	Remark
			Dume	upper slope	Lower Slope								
1	1	31.12.02		✔		28.3	82	78	3	1	95.121	50	
2	3	3.1.03		✔		28.4	121	118	3	Nil	97.52	52	
3	4	3.1.03		✔		28.9	113	87	24	2	76.991	50	
4	14	1.2.03	✔			29.1	134	128	5	1	95.522	51	
5	23	16.2.03	✔			29.3	136	136	Nil	Nil	100	52	
6	31	25.2.03	✔			29.5	100	93	5	2	93	50	
7	32	25.2.03			✔	27.6	125	123	Nil	2	98.4	53	
8	36	28.2.03			✔	27.2	121	118	2	1	97.5	50	
9	42	5.3.03			✔	27.4	124	116	6	2	93.52	50	
10	45	13.3.03			✔	27.3	120	113	4	3	94.166	46	
11	47	14.3.03			✔	27.8	128	117	7	4	91.40	46	

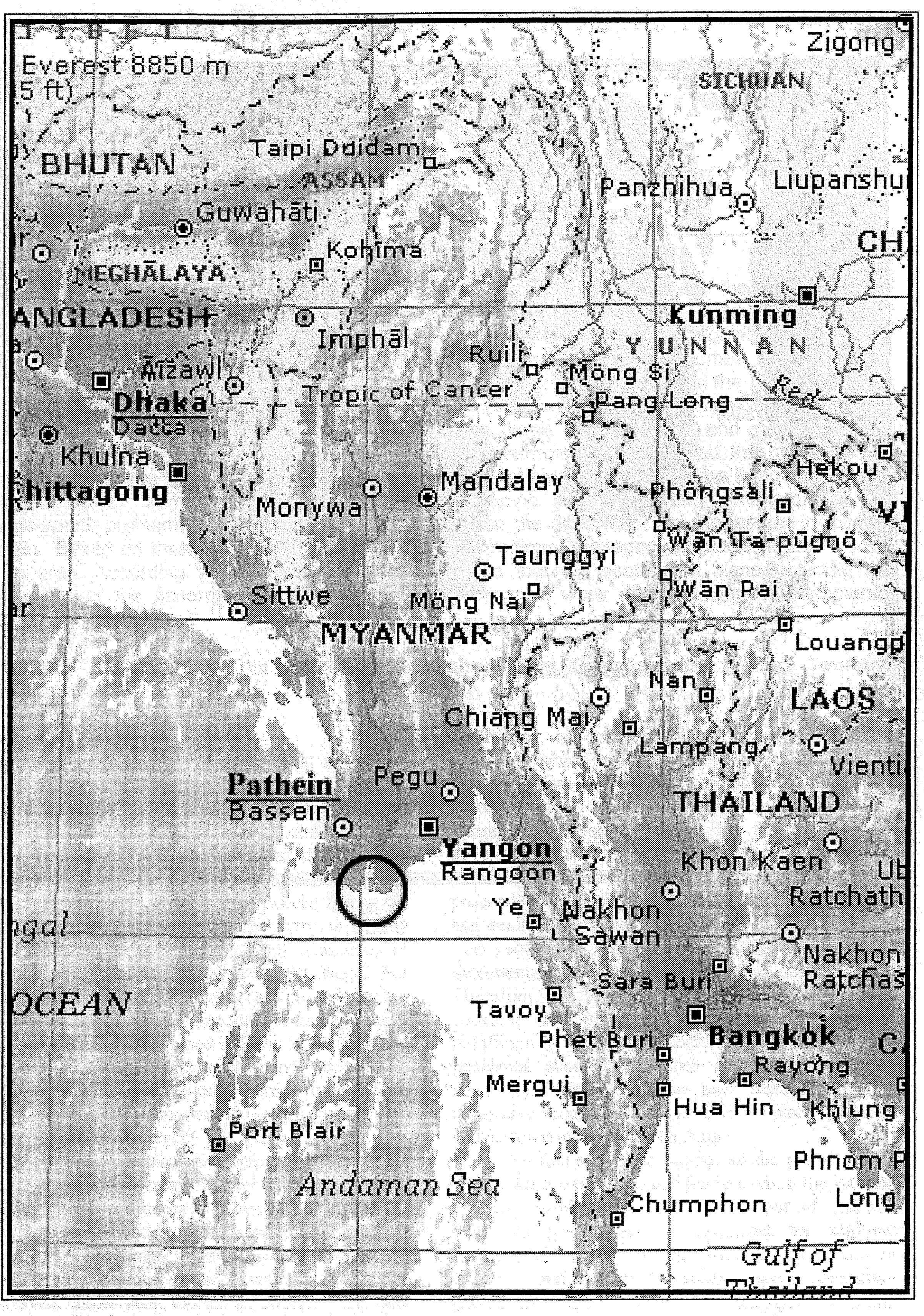
TABLE - (2)

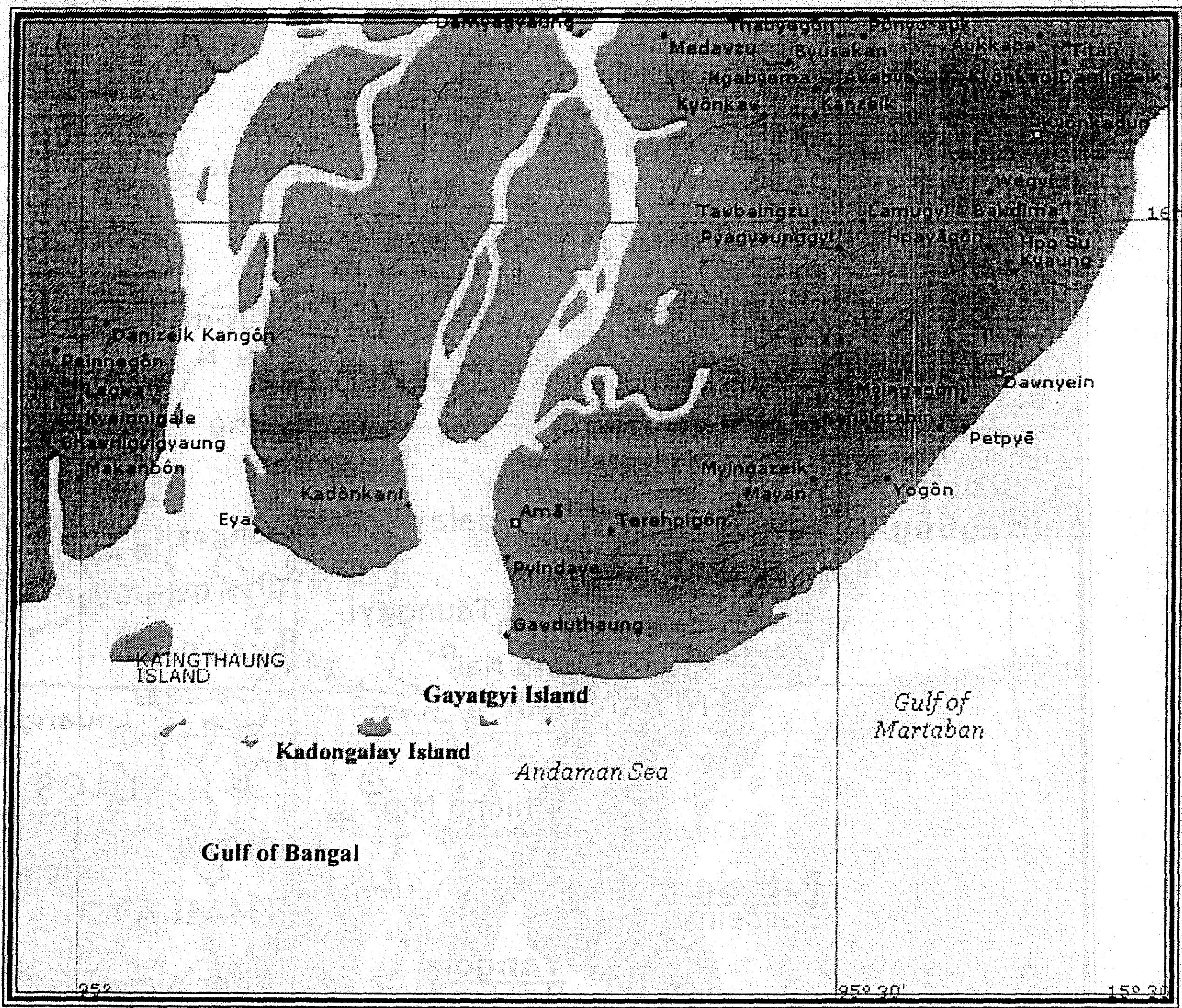
Average measurement of the clutches from different location or Kadongalay island beach

Sri No	Nest location	Neck of clutch (inches)	table depth of Clutch (inches)	width of Egg chamber (inches)	Remark
1	Dume	10.5	18	8.5	
2	Upper Slope	8	15	9	
3	Lower Slope	6	13	8	



Variation in hatching success of lepidochelys olivacea eggs relative to incubation temperature in sandy beach of natural nests for three different location. (See Table -1)


Everest 8850 m
Zigong
SICHUAN
BHUTAN
Taipi Ddidam
ASSAM
Panzhihua
Liupanshu
Guwahāti
Kohīma
MEGHĀLAYA
Kunming
YUNNAN
Imphāl
Ruili
Aizawl
Mōng Si
Dhaka
Dacca
Tropic of Cancer
Pang Long
Khulna
Hekou
Chittagong
Mandalay
Phôngsali
Monywa
Wān Ta-pūgnö
Taunggyi
Wān Pai
Sittwe
Mōng Nai
MYANMAR
Louangp
Nan
LAOS
Chiang Mai
Lampang
Vienti
Pathein
Bassein
Pegu
THAILAND
Yangon
Rangoon
Khon Kaen
Ye
Nakhon Sawan
Ratchath
Nakhon Ratchas
Sara Buri
OCEAN
Tavoy
Phet Buri
Bangkok
Rayong
Mergui
Hua Hin
Khlung
Port Blair
Phnom P
Andaman Sea
Chumphon
Long
Gulf of Thailand



Medawzu
Kyônkadun
Tawbaingzu
Lamugyi
Hpo Su
Kyaung
Danizeik Kangôn
Dawnyein
Petpyē
Kadônkani
Eya
Mayan
Yogôn
Terehpigôn
Pyindaye
Gawduthaung
KAINGTHAUNG
ISLAND
Gayatgyi Island
Kadongalay Island
Gulf of
Martaban
Andaman Sea
Gulf of Bangal
95°
95° 30'

The regional management model for ecotourism planning in the Rayong coastal area, Thailand

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ABSTRACT
In the coastal area with developing tourism, ecotourism is regarded as a means of the regional policy. To perform sustainable ecotourism needs to realize the management system on the basis of local's participation and willingness. In this study, the objective was to construct the regional management model on the basis of local's perception and awareness to assess some important ecological and economic interlinkages between tourism, coastal environment and local society in the Rayong coastal area, Thailand. In addition, we suggested the ecotourism planning and regional management from the result of modeling. For the modeling we gathered the available statistical data and materials about tourism, environment, fishery, and local community. Furthermore, we conducted the questionnaire survey for 188 groups of tourists visiting to the Rayong coastal area, and 172 families living in this area. From this survey, some important problems in developing local community emerged, i.e. the garbage-waste problem, the economic disparities between the fishermen and the worker in tourism business. Based on these problems, we constructed the regional management model in the Rayong coastal area. According to this model, it was concluded that the ecotourism plans including the employment of the fishermen and the trash-picking program were effective to good community development in this area.

KEYWORDS: Ecotourism, Area study, Coastal management, Questionnaire, Fishery, Tourism, Local community

INTRODUCTION

It's noted generally that natural environment are getting worse to worse with development of human society. In coastal area especially, we can see often the environmental deterioration because coastal zone is a point of contact between the land and the sea. In the various impacts on the coastal area, the tourism impact is rapidly increasing recently. Nature-based tourism is most popular among the tourists, in which marine tourism industry is rapidly growing. (Orams, 1999; Shackley, 1996). This trend of tourism development is expanding to the world. For developing countries, a rapid growing tourism industry has proved to be an increasingly important source of foreign exchange inflows. Nature-based tourism is an important tool for generating employment and income in underdeveloped, biodiversity-rich Third World regions because it requires comparatively small investments (Wunder, 2000). However, the tourism industry is increasingly having an ecological impact on the world's protected areas and the rising number of tourists presents both threats and opportunities (Goodwin, 1996).

Against this background, many regional managers and planners are beginning to seek the way to establish the regional management system which can realize environment conservation, tourism development, and local community development at all once. The good example of the regional management system is "Ecotourism". Ecotourism is compounded of many interrelated processes which influence the potential and success of ecotourism within a protected area and links between natural areas, the local people and tourism (Ross and Wall, 1999a). In the process of development of ecotourism, local perceptions will be an important factor influencing how its development proceeds (Campbell, 1999). Furthermore, if planning and decision-making do not involve local populations, then ecotourism will not succeed, and may even be detrimental to local communities (Ziffer, 1989). Therefore, the local perception is important key to consider the possibility of ecotourism success. Additionally, to date, although many studies have been performed about areas which are developing as an ecotourism spot, just a few have assessed how the sustainable ecotourism is realized in the place where the ecotourism is introduced in the future.

In this study, we conducted the questionnaire survey for the residents and the tourists in the Rayong coastal area which locates in the east part of Thailand. The objectives were to construct the regional management model on the basis of resident's & tourist's perception to assess some important ecological and economic linkages between environment, tourism, & local society in the Rayong coastal area. In addition, we suggested the ecotourism planning from the result of modeling.

STUDY AREA

Rayong province locates at the southeast, 210 km from Bangkok faces south onto the Gulf of Thailand. Many tourists visit this area to enjoy the marine sports and their relaxation. The number of tourists increases at approximately 4% per year in the past five years. In 2002, there were approximately 2.4 million tourists (Tourism Authority of Thailand, 2003).

Rayong province has another aspect of industrial area. In 1982, Thailand government has formulated projects for develop coastal area. Rayong province was determined to be an important stronghold for the heavy industrial development. The agricultural areas were replaced by heavy and continuing industries. And more than 6,500 rai (2,535 acres) of marine areas have reclaimed. In 1991 when Rayong province was also developing as the tourist spot, marine areas were utilized as the reservoir of waste sink for heavy industries. This industrial development caused environmental poor outcome in the air, the rivers and the sea (Sawasdee Foundation 2001). Although the scientific basis is not enough, this development is able to affect the ecological balance of the sea area. The area affected mostly was coastal area, in which the resident's economic living by fishery was gotten collapse. The total quality of marine fish landing was 166,270 tons at peak year in 1994, and then was decreasing at 79,943 tons in 1999 (Department of Fisheries, Thailand, 2002).

METHODS

The questionnaire survey was conducted in the Rayong coastal area from 20 February to 10 March 2003. The questionnaire was prepared in Thai and in English. The questionnaire survey for the residents was conducted in villages and towns along the coast. For the tourists, we conducted in 5 points; "Ban Phe", "Mae Pim Cape", "Samet Island", "Mannai Island", "Mannork Island" (Fig. 1). We interviewed 172 residential households and 188 tourist groups, of which 171 and 186 were valid respectively. The contents of the questionnaire were the personal evaluation about natural environment, economic condition and social infrastructure in the 10 years ago, at present, and in 10 years respectively, and about the environmental problem in the Rayong coastal area. Furthermore, we asked for respondent's opinion about these contents by open question. For the residents in fishing villages, we interviewed extraordinary about recent fishery. The valid respondents of this questionnaire were 24 households. In the case each question was not filled out or possible to be inadequate, we excluded these responses from consideration.

RESULT AND DISCUSSION

The current situation of local community form the perspective of the residents

We asked the residents for the personal evaluation about natural environment, economic condition and social infrastructure in the 10 years ago, at present, and in 10 years respectively. The number of valid responses was 170 respectively. Figure 2 shows the result of resident's evaluation about natural environment and economic condition.

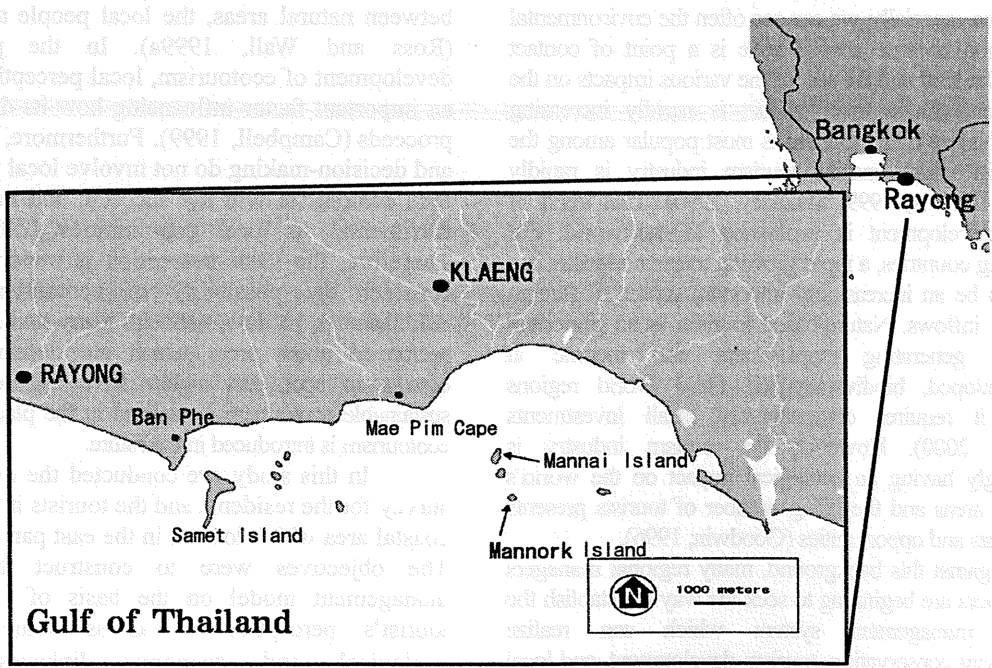

Fig. 1. The Rayong coastal area. This area locates at the southeast 210 km from Bangkok

As to natural environment, many residents felt the past condition had been bad, and the current condition was better than the past. The perceptions of the future condition tended to vary with each respondent. As concerns of economic condition, the perceptions of the past and the current condition were similar trend to the ones about natural environment. In point of future, residents tended to have optimistic feeling, although the responses varied to some extent. As for social infrastructure, many residents felt that the past condition had been bad, and the current condition was better than the past, moreover the future condition would be better than the current. According to these results it was considered that the perception about natural environment and economic condition varied with the individuals. Consequently we considered resident's evaluation additionally on the basis of resident's socio-demographic data.

The difference of the perception between the fishing households and the worker of tourism industry

As a result of the analysis the resident's perception on the basis of each socio- demographic data, it was emerged the difference of the perception between the fishing households and the worker of tourism industry. Most resident's jobs in this area were related to either fishery (n = 44) or tourism industry (n = 90). Many of the workers of the tourism industry tended to have optimistic feeling about natural environment and economic condition at present and in future respectively. On the other hand, many of the fishing households have pessimistic feeling. As for natural environment at present, the chi-square test was significant at 0.5 %, and as for natural environment in future and economic condition at present and in future the chi-square test was significant at 0.1 %. This difference of resident's perception is supported because the fishery was falling into the decline in this area (Department of Fisheries, Thailand, 2002), while the tourism industry was developing (Tourism Authority of Thailand, 2003).

There are many fishermen's opinions concerning the decreasing of the marine fish landing in the questionnaire. As to the current condition of fishery, 66 % (16 of 24 respondents) answered the fish catches were more decreasing than before. Only 1 respondent answered "Unchanged". The others unanswered. As to the fishery in future, 88 % (21 of 24 respondents) answered the fish catches will be decreasing. And the other answered "No idea". Additionally we asked 13 respondents who answered the fish catches will be decreasing about fishing in future. According to this result, 62 % (8 of 13 respondents) answered they would continue fishing here, from which we can see the fishermen persist in fishing in this area. As for the reason of the decreasing of fish catches, there is a opinion that vessel's trawling have possibility to decline the quality of the marine fish landing.

In the terms of resident's income, the average monthly income per household in Rayong province in 2000 is 14,739 Bahts (National Statistical Office, Thailand, 2002).

According to the questionnaire data, the average monthly income of fishing households (n = 22) was 12,850 Bahts, while the one of the worker of tourism industry was 18,458 Bahts. We can see the economic disparity between the fishing households and the worker of tourism industry. It was clarified that the fishing households had anxiety about their living and the fishing in future because of small income compared with the other, the decreasing of the fish catches, and the futureless of the fishing in this area.

The environmental condition form the perspective of the residents and the tourists

The environmental perception of residents had difference between the fishing households and the worker of tourism industry as we had mentioned above. This difference was the most in perception for future.

In addition, we interviewed the residents about the most important environmental problem in this area. The valid responses were 151 samples. In the whole, there are 40 % of the residents who answered "Garbage / Bad smell". The second and the third opinion were "Air pollution", "Decreasing of marine

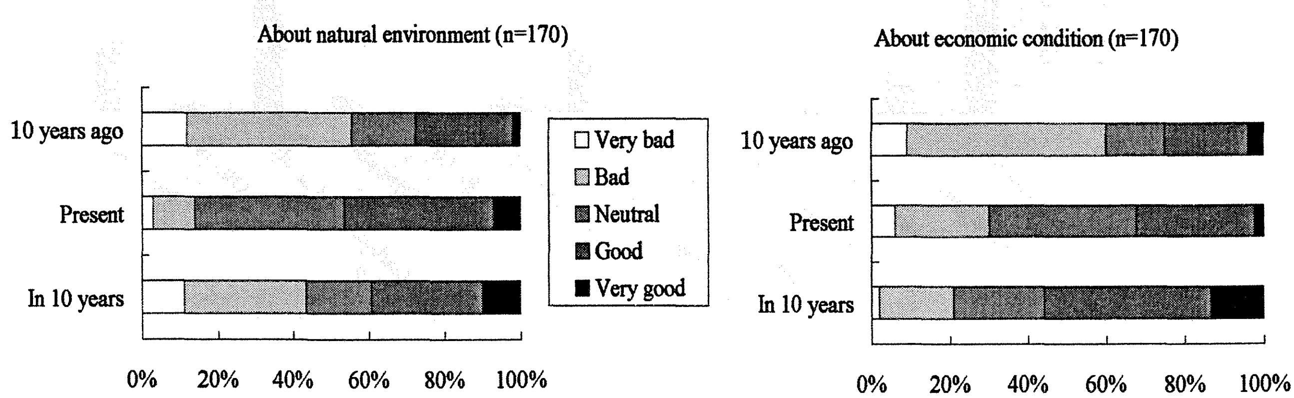

Fig. 2. Resident's evaluation about natural environment *(left)* and economic condition *(right)*

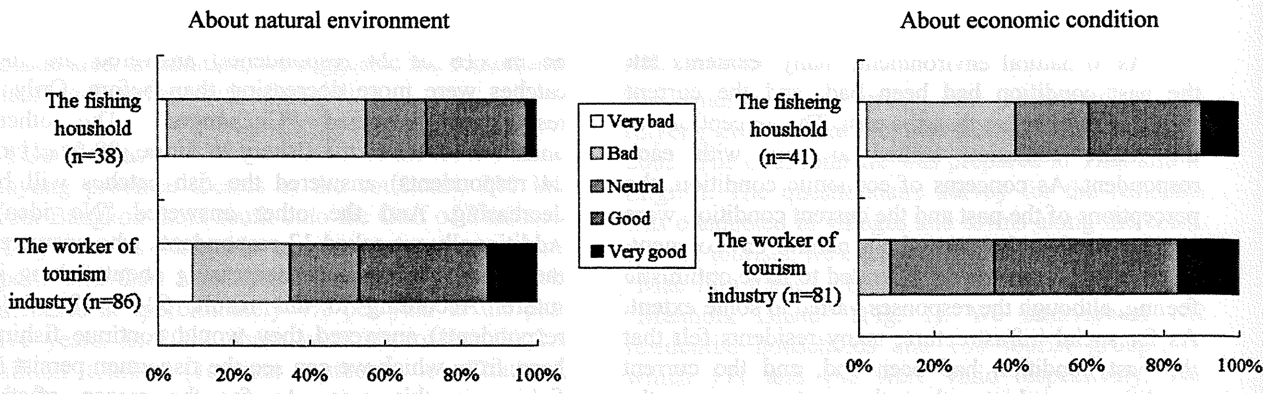

Fig. 3. The difference of the perception about natural environment *(left)* and economic condition *(right)* in 10 years between the fishing households and the worker of tourism industry (the chi-square tests were significant at 0.1% respectively)

species", the percentages of which were 21 % and 12 % respectively. The percentages of respondents answered "Nothing" were 12 %. These results show the residents in the Rayong coastal area have high level of awareness about the garbage problem.

For the purpose of the research about the tourist's evaluation of natural environment in the Rayong coastal area, we interviewed the tourists visiting to this area. The valid responses were 176 samples. Although the responses varied with the questionnaire spots, there are more unfavorable responses of "Very bad", "Bad" than "Very good", "Good" in each questionnaire spots except "Samet Island" which is designated as the ocean national park. In the next, we asked them about impression on the Rayong coastal area by open question. As for positive remark (n = 102), there were concerned to "Beach", "Clean Sea", "Nice climate", "Food", and "Good access". On the other hand, as for negative (n = 105), many responses were concerned with the garbage problem, the percentages of which were even 61 % of respondents who remarked negatively. In other responses, there were "Too many tourists", "High-priced". These results suggest that the environment in the Rayong coastal area was not good from the perspective of the tourists and the garbage was important problem for developing the tourism industry.

"Garbage" which mattered among the residents and the tourists is scattered along the street, on the beach, over the sea, and around the villages. Except the garbage over the sea, large part was thrown away by the residents. This garbage is much amount, to the extent which we cannot collect or clean up easily. Especially around the fishing villages there are a great deal of much amount of the garbage. Some of the fishing households live in the house built over the garbage. Furthermore, the garbage condition got worse and worse because stray dogs foraged for food.

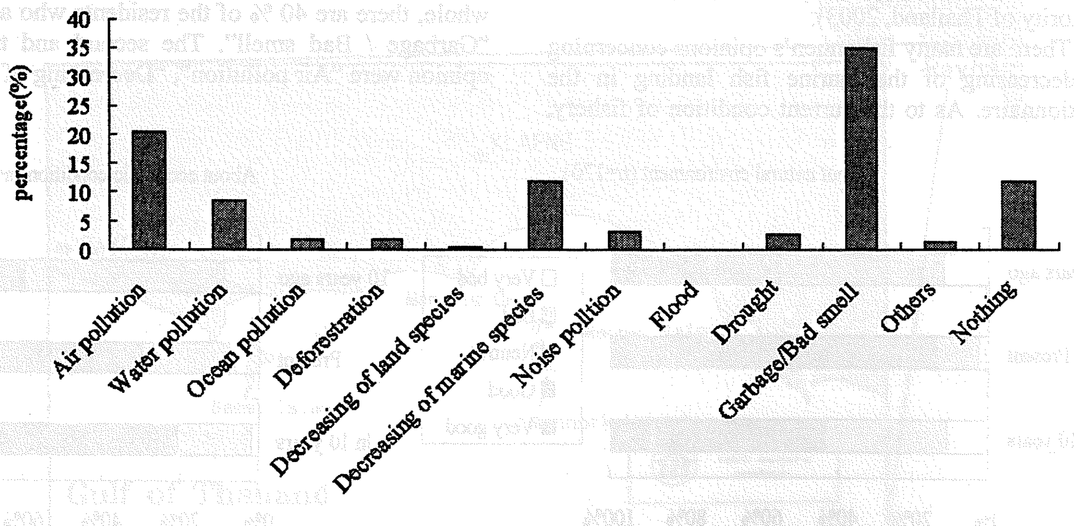

Fig. 4. The most important environmental problem in this area from the perspective of the residents: n=151

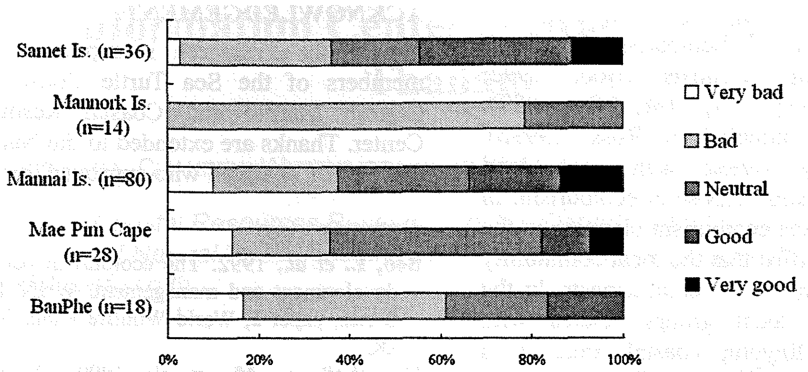

Fig. 5. The tourist's evaluation of natural environment in the Rayong coastal area (Samet Island, Mannork Island, Mannai Island, Mae Pim Cape, Ban Phe)

CONCLUSION

The regional management model in the Rayong coastal area

Based on these problems & some statistical data, we constructed the regional management model in the Rayong coastal area. This model's components are "Natural environment", "Residents", and "Tourists" (Fig. 6). As a subclass of "Natural environment", there are "Fishery resources", & "The amount of Garbage". And as a subclass of "Residents", there are "Fishing households", & "Worker of tourism industry". The interlinkages between all components show certain impact of one to the other, e.g. economical revenue, environmental destruction, and increment of tourists. Introduction of ecotourism creates new linkages in this model.

The current situation of tourism is very well and if the Rayong coastal area develops on present showing, it is expected that the tourism industry grows and with which the number of tourists is increasing for some time in the future.

Although it is not clear whether the ocean pollution gets better or worse, it is suspected that the decreasing of the fishing catches still remain for a while. Some measures toward the coastal fishery and the fishing households are required quickly.

A lot of tourists, especially foreign tourists, are displeased for the garbage. Recently the eastern coastal area in Thailand is being developed as a tour spot, for example Chanthaburi province and Trat province. The neglect of the garbage problem will cause the drain of the tourists to the other tour spots. The effect of the tourists on environmental doesn't come to the surface yet. But, the region managers or planners have to pay attention to the environmental pollution and the garbage problem caused by the tourists. Therefore, it is considered that the garbage problem was dealt with seriously from the resident level.

In terms of resident's income, the income of the worker of tourism will increase as tourism develops in this area. In the other hand, the income of the fishing households will decrease as fishery gets into a decline. This income gap is expected to widen more and more in future. From the result of the questionnaire, almost residents are original. Some emigrated to work from other area. Immigrant flow is getting to extend, and in future this trend will go on because the tourism industry will also develop. The important thing is to provide economic and social revenue to the residents accurately, not to the tourism companies. Additionally, it is important to give alternative income sources to the poor fishing households.

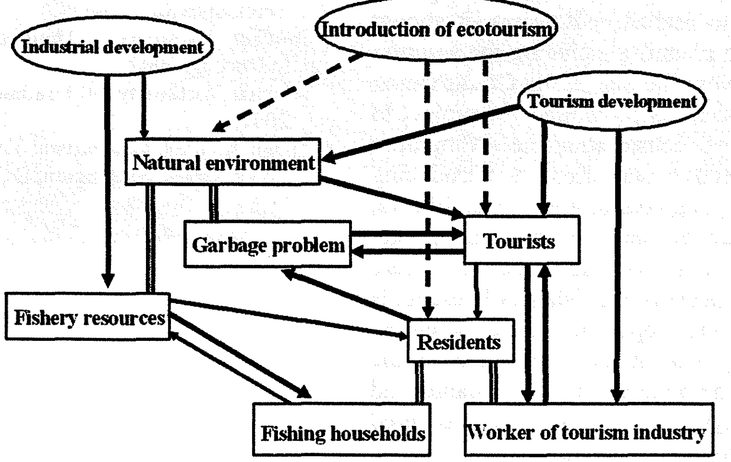

Fig. 6. The regional management model in the Rayong coastal area.

Ecotourism planning in the Rayong coastal area

To date, the definition of Ecotourism has been arranged by lots of scientists (Boo, 1992; Ceballos-Lascuráin, 1991; Cater, 1994; Ziffer, 1989), and the concept was modeled by Ross (1999b). However, the reality varied with each land characteristic and the main purpose of ecotourism. In this study, considering the ecotourism planning in the coastal area, it was clarified that the local community had some groups which had different aspects. In the case there are some local groups related with ecotourism like the Rayong coastal area, it is considered that the relationships between local groups or their occupations are very important. Additionally in case there are many low-income fishing households like this, even if they are related to ecotourism directly, their livings should not be oppressed with the development of ecotourism. By contrast, we have to make a ecotourism plan which can present new employment opportunities to them.

As Campbell (2002) said, local perceptions will be important factor in promoting to develop on the ecotourism. On the basis of this concept, the fact that the fisheries households feel good about the environmental and economic condition will fuel their motivation so much to participate in ecotourism. Meanwhile, although the local people tended to have further income, but not want any life-altering risk in this area (Okuyama *et al.*, 2003). Additionally, we can see the fishermen persist in fishing in this area. This implies that the difficulty in introducing ecotourism into the Rayong coastal area, because their hope for not altering the present life could motivate them to avoid new things. To make the fisheries households to be willing to develop ecotourism by themselves, ecotourism will have to be something appealing that they can benefit from. Therefore, when we will introduce ecotourism, whether we can make a program which gives another job that the fishing households want (for example, the short time job which we can employ many people) to them can be the key to the success of ecotourism.

To solve the garbage problem and the economic discrepancy is the best way to manage this regional area. In order that to realize ecotourism, it should make the ecotourism planning including the solution of these problems. Now the Sea Turtle Conservation Station in Mannai Island is promoting the project to gather the tourists (ex. constructing the information center). The prospective scenarios in introducing ecotourism in the Rayong coastal area are as follows; to increase the tourists because the tourists get another chance to visit to this area, to secure resident's income, especially the fisheries households, because the employment opportunities are increased. Concretely, the employment as a reception in the information center, the boatman to some Islands and the cleaner in the Rayong coastal area are considered as the appropriate ecotourism planning.

ACKNOWLEDGEMENT

The author's research is supported by all of the members of the Sea Turtle Conservation Station, Eastern Marine and Coastal Resource Research Center. Thanks are extended to the National Research Council of Thailand who approved this study.

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EMCOR Information Center at Mae Pim Beach, Rayong, Thailand

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ABSTRACT
An Information Center was constructed at Mae Pim beach in the province of Rayong, Thailand in order to address the lack of knowledge of the coastal communities within and adjacent Rayong province regarding the sustainable use of marine and coastal resources. The information Center was realized through the efforts of the Eastern Marine and Coastal Resources Research Center (EMCOR) in cooperation with the Sunthonphu district and Ford Motor Company. Information regarding the biology, ecology, and conservation of marine endangered species; marine ecology; and researches conducted by EMCOR can be found in the Information Center.

KEYWORDS: EMCOR, Information Center, Rayong province, East Coast of Thailand

INTRODUCTION

In the past centuries, Thailand's marine and coastal resources had been exploited haphazardly resulting in the decrease in mangrove forests and sea grass beds (which serve as nurseries for fishes), and destruction of coral reefs among others contributing to the decline of biodiversity as in figure 1. They are some cause of declining of marine animals such as sea turtle, dolphins, whales and dugong. More over some human activities such as fishing gears, environmental pollutions from industry and municipality discharge and boat travelling around shallow water are the cause of decreasing of dugong (Adulyanukosol, 2545; Intarasook, 2546) On October 2002, the Ministry of Natural Resources and Environment and the Department of Marine and Coastal Resources (DMCR) were created. The DMCR was mandated to develop relevant egulations regarding marine and coastal resource utilization with the objective to look after the action's marine and coastal resources through conservation, rehabilitation, and to ensure socio-economic integrity for future generations.

Activities in the management plan of the DMCR include mangrove reforestation and educating and inspiring the public c to participate in the activities of Department in promoting sustainable marine and coastal resource utilization.

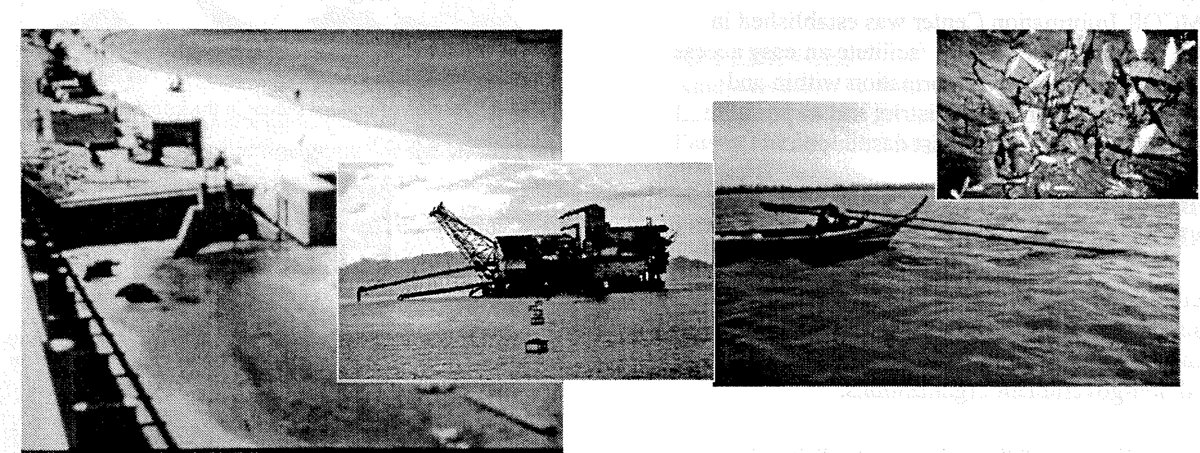

Fig. 1 Sample of haphazard exploitations

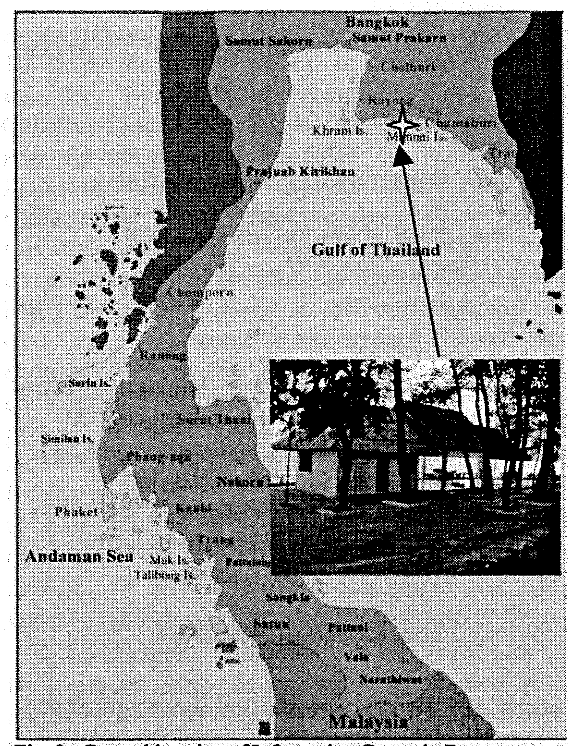

Fig. 2. General location of Information Center in Rayong province

EMCOR INFORMATION CENTER

In order to effect the education and information dissemination component, the Eastern Marine and Coastal Resource Research Center (EMCOR) of DMCR in cooperation with the municipality of Sunthonphu district and the Ford Motor Company established an information center in Mae Pim beach, Rayong province, east coast of Thailand. The EMCOR Information Center was established in Mae Pim beach in order to facilitate an easy access in communication and information within and adjacent the Sunthonphu district and to promote Rayong province as a tourist destination.

OBJECTIVE OF THE EMCOR INFORMATION CENTER

1. To provide a venue for public service in the field of marine and coastal resource management and to serve as focal point for the involved local stakeholders of Rayong, the government, academe, and non-government organizations.

2. To promote understanding and awareness of the threats and degradation in marine and coastal resources and to inspire public participation in marine and coastal resources and to inspire public participation in marine and coastal resource rehabilitation and conservation.

CONSTRUCTION OF THE EMCOR INFORMATION CENTER

The EMCOR Information Center is furnished with molded statues of marine endangered species that include sea turtles, dugongs, dolphins, and whales. Also, a computer and videos for film showings are furnished the Information Center as in figure 3 and figure 4. Information concerning the biology, ecology, and conservation of marine wildlife; marine ecology; sustainable use of coastal and marine resources; and studies conducted by EMCOR are offered in the Information Center. Also, tourist destinations in Rayong province are provided as in figure 5.

CONCLUSION

The EMCOR Information Center embodies the interests of the local government of Rayong, non-government organizations, and other concerned citizens to support the National Government in its cause to promote conservation and sustainable use of marine and coastal resources in the country.

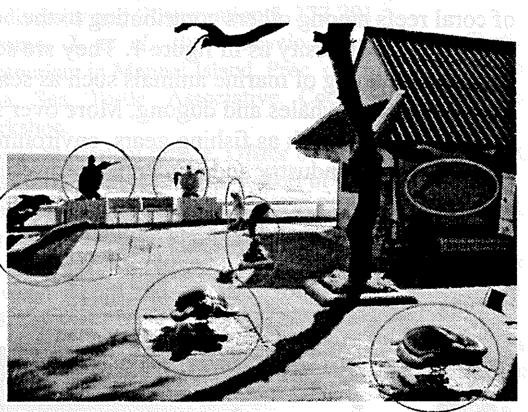

Fig. 3. Location of molded statues in the Information Center

Fig. 4. Location of computer and videos in the Information Center

Fig. 5 Position and style of Information charts in the Information Center

ACKNOWLEDGEMENTS

The authors acknowledges EMCOR-DMCR, the municipality of Sunthonphu district, the Ford Company, the graphic designers for the posters and computer information provided for the Information Center, and finally the sculptors of the marine wildlife statues.

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The primary assessment on the Dugong population in Viet Nam

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ABSTRACT
The biggest dugong reached to 3m in length and its weigh was more than 500 kilograms. Dugongs swim in the shallow coastal waters of southern part, which have protected them from large waves and storms. Dugongs float up only to breathe, and never come on to land. There is still lack of information on the population status of dugong. The Research Institute for Marine Fisheries (RIMF) and other institutions estimated that there are approximate 25 to 100 dugong individuals still living in the Southern part of Viet Nam. However, 5-6 dugongs were incidentally died each year in Phu Quoc, Con Dao and Tho Chu Islands as well as their adjacent, where are the most important seagrass meadows in Vietnam Seawaters. Dugongs are considered as a protected species listed in "Red Data Book" of Viet Nam as well as listed by CITES under the highest at-risk category. They only live in or in the vicinity of plentiful seaweed and seagrass, which is being destroyed by pollution, dredging and farm soil being washed into the sea. Dugongs have the dramatic decline in their numbers. Serious threats include the environmental degradation, serious typhoons (*Linda* hurricane for example), which destroy their favor habitats, and the accidental catch of dugongs in fishing operations, especially by trawling with big mesh-size and open-mouth net. The results of this study add important information about this species to the sparse information currently available, and recommend further research required particularly for Vietnam and neighbouring countries. Additionally, exchanging information, experiences and constructive discussions on proper actions and cooperation in terms of the scientific research, coastal management and the responsible fishing operation will be positive direction towards a better future for the dugong population in Vietnam.

KEYWORDS: Dugong (*sirenian*), family *Dugongidae,* calf, seagrass meadow, *Thalassia hemprichii* (Co bo bien), *Enhalus acoroides* (Co dua bien), *Halophyla ovalis* (co xoan), "cao bay" trawling net, Phu Quoc and Tho Chu (Kien Giang Province) and Con Dao National Park (Ba Ria-Vung Tau), Marine Protected Area (MPA).

INTRODUCTION

There are few scientific records available about the distribution, abundance and ecology of dugongs in Vietnam. Dugongs are referred as "Sea Cows", because they graze on seagrass. They are the only mammals eat large amounts of seagrass, leaving behind feeding trails of bare sand and uprooted seagrass. Primarily foods of dugong are sea grasses and sea algae (Koike, 1999). Dugong (Dugong dugon) has wide range of distribution, from longitude 30°E to 170°E and between the latitude of 30°N to 30°S. Dugongs are the only Indo-Pacific *sirenian* species alive today, occurring in limited numbers in various locations of Indonesia, Malaysia, Thailand, Myanmar, Papua-New Guinea, Philippines, Australia, Japan and Viet Nam (Nick Cox, 2002).

However, their population is thinly distributed in scattered groups within this range of seawaters. The dugong population is fast thinning in their range of distribution and is definitely an endangered species that are close to extinction.

The World Conservation Union (IUCN) has classified dugong as a vulnerable species for several years (Anonymous, 2000). Dugongs are a protected species also in Viet Nam. Dugongs only live where there is abundant seaweed and seagrass, which is being destroyed by dredging, farm soil and pollution being washed into the sea. They are also accidental victims of trawler net fishing (Cao bay) and gill net (Nguyen Long, 2003).

There is an increasing demand to use coastal zone for residential, recreational, and agricultural purposes. These activities will make the coastal zone more susceptible to the pollution, which cause the destruction and degradation of the seagrass beds. Pollution can also affect dugong physiologically through the bioaccumulation of toxic compounds. Dugong has been reported to accumulate mercury and chlorine compounds in the muscles (Anonymous, 2003).

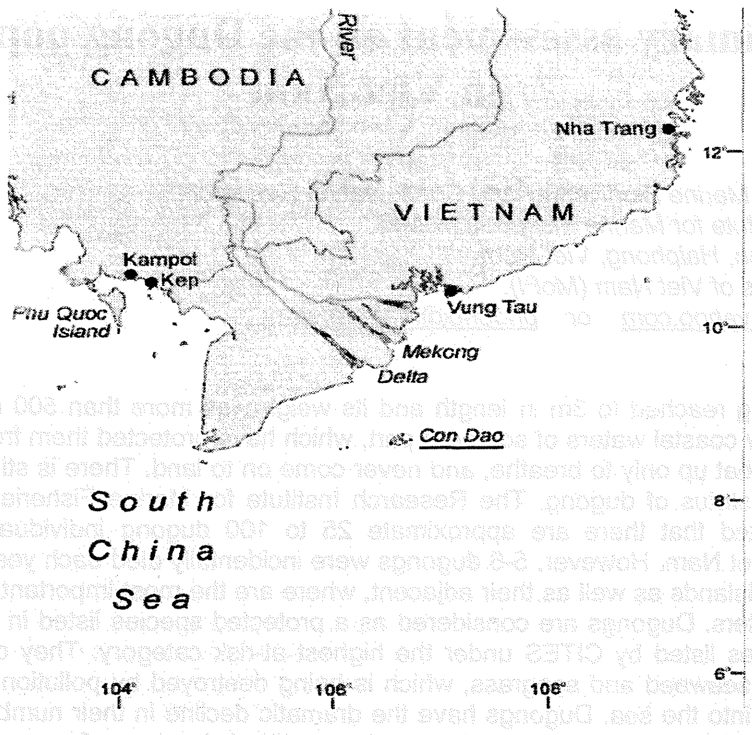

Fig. 1. Location map for Southern Vietnam and Cambodia (modified from Marsh *et. al.*, 1999)

The purpose of this study is to present a brief overview of the status of the dugong and its management in Viet Nam. We intended to provide comparative information that will enable to develop our national conservation plans for dugong and other listed species.

This paper contains little information of previous survey on dugong biology, distribution and abundance, threatening processes, legislation, and existing and suggested research and management proposals for Viet Nam.

The special objectives of this study are:

- ➢ To identify areas that still appearing significant numbers of dugongs;
- ➢ To consider how the negative impacts on dugongs can be minimized and their habitat protected;
- ➢ To identify the suitable areas for dugong conservation;
- ➢ To foresee and consider coordinative management plans for dugongs across neighboring water bodies if required.

MATERIALS AND METHODS

The range of dugong distribution is huge and scattered, making the data of the population dugong is quite difficult and costly. Aerial survey is the best method of assessing their population, but it is never used in Viet Nam due to its highly dependent on the weather conditions, the transparency of water and the available facilities. Therefore, within this research, the following way has been used to the primary collection of the related information:

- ✓ Field survey on the fisherman boats, assess the using fishing gear and their impacts,
- ✓ Gather and collect information from logbook of fishing boats,
- ✓ Collect information and news from Navy Force, Marine Investigator, Local Fishery Department,
- ✓ Interview and discussion by face-to-face, telephone, mobile phone, email in relation to dugong topic,
- ✓ Use questionnaires and analysis feedback,
- ✓ Take picture of specimen and habitats.

Phu Quoc and Tho Chu (Kien Giang Province) and Con Dao National Park (Ba Ria-Vung Tau), which situate in the Southern part of Viet Nam seawaters (see more in fig. 4), have been selected as the study areas for data collection from 1997 till 2003.

RESULTS AND DISCUSSIONS

Phu Quoc, Tho Chu and Con Dao archipelagoes in southern Vietnam, are locations in the country where dugongs are regularly seen. Recent seagrass surveys in the coastal waters of Con Dao, Tho Chu and Phu Quoc Island, recorded several apparent dugong feeding trails (Pham Ngoc Tuan, 2003), and evidence of the existence of dugongs around those areas are supported by reports of locally caught dugong meat being sold openly in local markets. Previous results from local fisher surveys conducted in Cambodia suggest the existence of a dugong population around Kep and Kampot, near to the Vietnamese border and Phu Quoc island (Beasley *et al.*, 2001).

Local fisher interviews conducted in 2003 in Phu Quoc-Tho Chu (Kien Giang province) and Con Dao (Ba ria-Vung Tau province) revealed that dugongs were seen much more regularly and in greater abundance 10-25 years ago than they are now. Whilst it appears that dugongs were often hunted specifically for meat and medicinal purposes, dugongs caught now, are done so accidentally, and mortality is presumably as a result of drowning in nets. More than thirty dugong carcasses were recorded in Phu Quoc, Tho Chu and Con Dao between 1997 and 2003.

SOME BIOLOGICAL CHARACTERISTICS

Dugong dugon belongs to the family *Dugongidae*. *Sirenians* are lonely, travel in pairs, or associate in groups of three to about six individuals. Generally slow and harmless, they spend all their life in the water (Lang Van Ken. 1997). They are vegetarians and feed on various aquatic plants (Kasuya *et al*., 2000).

Dugongs surface only to breathe, and never come on to land. Female Dugongs give birth underwater to a single baby. Birth takes place in shallow water and the baby dugong is able to swim to the top layer of the water for its first breath. Baby dugongs are about 100 to 120cm long and weigh 10 to 30 kg. The calf stays with its mother, drinking milk from her teats and following close by until 18-24 months of age (Aquino. 1998).

Based upon our staffs' observation in October and November, 2003 described that feeding dugong occurs primarily at night, when animals enter shallow waters to graze. Dugongs require about 25-30 kilograms of food per day (estimation based upon on their weight). In addition, when grazing, the dugong "walks" along the seabed with its flippers. The average swimming speed is about 2-7 km per hour, but if pressed this speed can be nearly doubled over short distances. Dives generally last 1-3 minutes, surfacing for very short periods per breath. Destructive behavior is very rare. Language, including whistling sounds and bleats, are generally only used when frightened. Breeding may occur throughout the year, although many births occur between July and September, annually (Nick Cox, 2002). Young animals hitch rides on their mother's backs, surfacing and submerging in enforced harmony. Although the drinking of milk continues for a year and a half, young dugongs begin sampling sea grasses at about three months of age. Dugongs feed strictly on submerged vegetation-leaves, roots, and rhizomes of sea-grasses and sometime seaweed. Babies of dugongs are breast-fed for about 18 months and after weaning will stay with the mother until new calves are born (Adulyanukosol *et al*., 1998).

With the low reproductive rate, long generation time and a large investment in each offspring, it is estimated that the maximum rate of increase is likely to be about 5 % per year (Anderson, 1981). As such, they are susceptible to over-exploitation. Their vulnerability increased by the dependence on a specialized environment, the sea grass habitat. In Vietnam, The Dugong reaches 3m in length and weighs more than 500 kilograms. Dugongs swim in the shallow coastal waters of southern part were they find protection from large waves and storms. Dugong males have ivory tusks used for fighting during male-male competition and caused of injure by themselves as well as for uprooting seagrasses (Nick Cox *et al*., 2003).

SEAGRASS ASSESSMENT

Seagrass play an important role in terms of adjustment and balance for coastal ecosystem; accretion and building up of sea substructure and as living habitats for dugongs. In addition, their functions have been recognized in the national strategies for sustainable fisheries development. There are 10 species of seagrasses had been found at those studied locations, namely: *Enhalus acoroides, Halophyla decipiens, H. minor, H. ovalis, Thalassia hemprichii, Cymodocea serrulata, C. rotundata, Halodule uninervis, H. pinifolia, Syringodium isoetifolium*. Total area of alone seagrass ecosystem is approximate 1930 ha in Phu Quoc, Con Dao and Tho Chu Islands as well as their adjacent seawaters (Nguyen Xuan Hoa, 2003 and Nguyen Van Tien, 2003).

Table 1: Area of seagrass at three studied sites

Index	Con Dao	Phu Quoc	Tho Chu	Others	Total seagrass of Viet Nam
Area (ha)	644	966	322	2668	4600
Percentage (%)	14	21	7	58	100

Table 2: The eyesighted dugong during period of 1997 till 2003

Index	1997	1998	1999	2000	2001	2002	2003	Average per year
Eyesighted dugong	77	82	34	56	71	63	49	61 ± 1

Due to the poor perception and together with many kinds of mismanaged operations, those resources, however, have being exploited and reduced, environment polluted, habitats of aquatic animal seriously decreased and degraded. The best ways to preserve seagrass is by leaving it undisturbed, mainly by preventing trawling, maintaining water quality by reducing nutrient and suspended solids loads and by using appropriate fishing gear.

The value of the products and ecological services provided by the seagrass systems of the South China Sea is estimated at US$ 22,400 per ha.year. The area of seagrass is not known precisely and improving estimates of the area and economic value of seagrass beds in the South China Sea is a key to improving their management (Fortes, 1993).

DUGONG IMPACTED BY HUMAN

The result survey conducted by Research Institute for Marine Fisheries (RIMF)'s researchers suggested that the predictable amount of 5-6 dugongs were killed each year in Phu Quoc, Tho Chu and Con Dao Islands and their neighboring, which are the most important dugong school in Viet Nam Seawaters. Although communities are not dependent upon the harvesting of dugongs, these animals are highly prized as food items. Since there is the weak enforcement of regulation to restrict the use of modern equipment, efficient hunting is possible. If the rate of died dugong population is greater than the renewable rate of dugong population of 10 % per year, then the dugong population is dropping.

Dugongs are slow moving and have little protection against predators. Being large animals, however, only large Sharks, Saltwater Crocodiles and Killer Whales are a danger to them, but main Predators are Humans. Threatened until recently by hunting for its meat (which is said to taste like beef), leather-like cover or fur-suit, oil (24-56 liters per adult), and bones and teeth, which are used to make healthy glues.

In previous year, the southern Viet Nam seawaters (including Phu Quoc, Tho Chu and Con Dao island) population dugong was counted that there had been attached approximately 42 individuals since 1990's (Nick Cox, 2002 and Pham Ngoc Tuan, 2003). The recorded data were collected in relation to dugong appearances during the period of 1997 till 2003, based upon the locally fisherman interviews, logbook on the fishing boats had been made by the concerning officers of those Provincial Department of Fisheries Protection that listed in table 2.

The major kind of fishing gear is the gill net and trawling net (which consist of 72% of total multigears) has reduced population off the coastal areas in southern Vietnam. The especial trawling with big mesh-size net "Cao bay" has significant reported to accidentally kill the dugongs (Nguyen Long, 2003).

Fishermen at Phu Quoc accidentally trapped an adult dugong on 10th December 2002. Other 9 of dugongs were attached during period of 2002 in the northern part of Phu Quoc Island (Ham Ninh seawater). Local fishermen trapped them and sold their meat with price of VND 25-35 thousands. Local informants always observe dugong and some of them think that they are only appearing in Ham Ninh seawater nearby a great seagrass meadows, which elongate approximately 20 km from Ham Ninh to Hon Son. This area maintain 3 species of sea grass, namely *Thalassia hemprichii* (Co bo bien), *halophyla ovalis* (co xoan) and *Enhalus acoroides* (Co dua bien) that is the most favor food of dugong (Fonseca, 1987).

During field survey, the informant also mentioned that dugong usual appear during July till November (Summer- Autumn). In addition, dugong is couple or group and one of them was caught, another turned around to look for missing one. That is a reason why dugongs have been trapped nearly entire group. According to the analyzed results from those studied areas, the distribution of dugong in Viet Nam are showed in table 3 and figure 2.

Table 3. Distribution of dugong in Vietnam Seawaters during period of 1997-2003

Location	1997	1998	1999	2000	2001	2002	2003	Locally average appearance per year
Con Dao	15	21	17	23	19	16	15	18 ± 1
Phu Quoc	35	31	11	19	28	26	32	26 ± 1
Tho Chu	27	35	6	14	24	31	2	19 ± 2
Total	77	87	34	56	71	73	49	63 ± 2

Table 4. Abundance of seagrass and frequency of dugong observation at three studied sites

index	Con Dao	Phu Quoc	Tho chu
Percentage of seagrass (%)	14	21	7
Frequency of dugong (%)	18	26	20

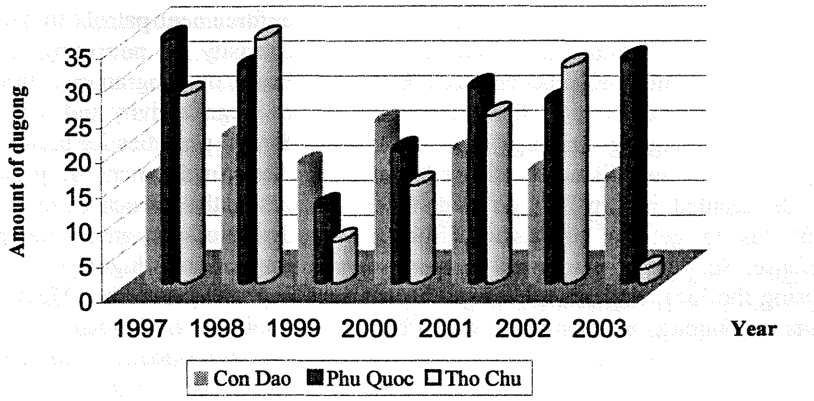

Fig. 2. Distribution of dugong in Vietnam Seawaters

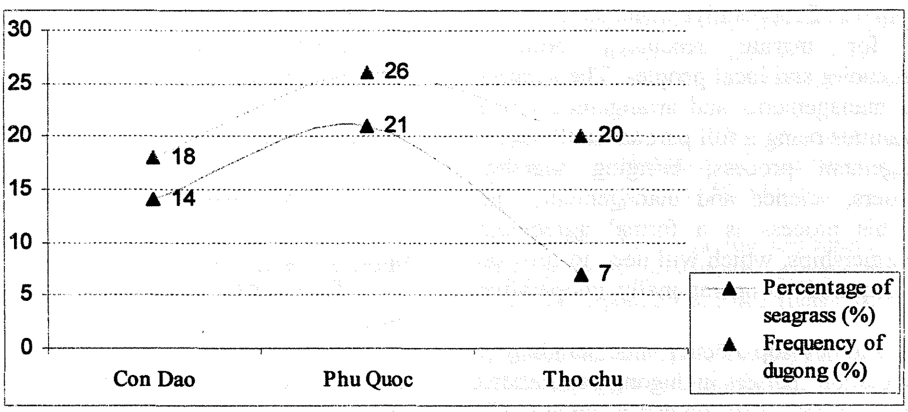

Fig. 3. Abundance of seagrass and frequency of dugong observation at three studied sites

According to our result, there is a close relationship between eyesighted dugong and seagrass abundance (see table 4 and figure 3 below).

From the figure 3 showed that there is a close relationship between the abudance of seagrass and frequency of dugong eyesight at the studied location.

MANAGEMENT APPROACHES

The dugong population is declining and they are in serious risk of extinction in Viet Nam due to limit of proper management in controlling of the fishing operation and nowhere to be found they are properly protected. Without conservation measures taken in Viet Nam such as prohibiting harvest and protection of its habitats. A questionnaire survey of dugong abundance in southern part of Kien Giang, Con Dao and Phu Quoc have been conducted by local authorities since 1998 due to the general concern about the local status of the dugong population. Additionally, those were followed by boat surveys that had been conducted since 2000.

Research

The research is to acquire information to assist in the recovery and maintenance of dugong populations. An integrated research project has been initiated since 1997, which reflect a wide range of priorities among managers, researchers and stakeholders with interests in dugongs. This project has been incorporated into the Dugong Research Strategy for Viet Nam in the forthcoming year. The categories include:

- ✓ Project designed to assess the effectiveness of the current dugong protection measures,
- ✓ Project likely to result in information, which will directly assist in maintaining dugong numbers,
- ✓ Project that will assist with the development and implementation of cooperative management arrangements,
- ✓ Project designed to minimize the impacts of management decisions on affected groups.

High priority should be given to monitoring dugong distribution and relative abundance using regular boat surveys and questionnaire circulation. Regular seagrass surveys are also required to assess temporal changes in seagrass meadows, and the impacts of events on dugong habitats in the Vietnam Seas. Research is also to study seasonal changes in seagrass growth rates and productivity with a view to developing a model of dugong grazing. Satellite tracking of dugongs in key areas is not available but those will provide detailed information on dugong habitat use, but has to get the permission from Ministry of Defense. Such information will be very useful for assessing the local impacts, for proposing the developments on dugongs and for other wildlife species.

Local Management

There is still a strong desire within the local communities to hunt dugongs as they are economic importance. All groups involving recognize the need for the development of cooperative managements and arrangements for marine resources between management agencies and local peoples. The success of cooperative managements and arrangements will involve communities being a full partner in all stages of the management process, bringing together customary owners, science and management. The next step in this process is a formal agreement between the partnerships, which will need to provide the resources required to operationally cooperative management.

In order to develop a better understanding of small scale population changes in dugong populations, community-based dugong preservation programs will have to be developed incorporating local expertise, provided personnel are available to coordinate such programs. This activity would contribute to developing appropriate mechanisms and tools for integrating local knowledge and scientific data.

Fishery Interactions

The effectiveness of the mesh netting restrictions and attendance in the Marine Protected Areas (MPAs) need to be monitored. It is important to note that a significant proportion of dugongs along the south coast of Viet Nam occur outside these Marine Protected Areas.

Therefore, management regimes for the dugong's area of possession but outside the MPAs need to be considered if the objective of management is to minimize human impacts on dugongs.

Regulation and enforcement

Viet Nam are supporting the following initiatives to maximize the effectiveness of fishing closures in the Marine Protected Areas (MPAs):

- ✓ Legislation of attendance at net rules under the Fisheries Resource Protection ordinance, which propagated in 1989;
- ✓ The enhancement of surveillance and enforcement patrols to focus on the MPAs. The intensity of patrolling and surveillance varies based on programmed priorities (i.e. knowledge of illegal activity and records of dugong deaths);
- ✓ Severe penalties for breaking netting regulations;
- ✓ The development of performance indicators to assess the impacts of the MPAs;
- ✓ The introduction of further measures to address impacts on dugongs other than mesh netting, especially in the MPAs (i.e. coastal runoff, habitat degradation);
- ✓ An independent socio-economic investigation of the operations of fishers with netting endorsements that are operating nearby the MPAs. The study will include an investigation on which fishers are using the current MPAs. A social impact assessment on resource used to (commercial and recreational fishing and tourism) in each of the MPAs to assess the implications of any further modifications to regulations in the MPAs;
- ✓ An investigation of how the current regulations in the Marine Protected Areas could be further modified to reduce adverse impacts on dugongs.

National framework Management

The effectiveness of the mesh netting closures and restrictions depends on there being no overall movement of dugongs from the one to other areas. To minimize the risks of this happening, it is particularly important to conserve dugong habitat, especially in the Marine Protected Areas.

The relevant management should collectively review the zoning of the relevant sections of the Marine Protected Areas and Fisheries Habitat Areas with a view to assessing their capacity to protect dugongs and their habitats. Key areas should be the focus. This initiative will provide resolve in the selection of seagrass and dugong habitat for inclusion in highly protected zones of the Marine Protected Areas.

The Marine Protected Areas will be zoned in consultation with user and interest groups, and will enhance the prospect of dugong survival in the area. Seagrasses and mangroves are given specific protection in Fisheries Habitat Areas, where all marine plants are protected, and can only be damaged or removed under permit.

CONCLUSION AND RECOMMENDATION

The Con Dao, Phu Quoc and Tho Chu National Park have been identified that still appearing significant numbers of dugongs. Those locations are the highest amount of dugong population, because of being distributed seagrass bed, the feeding habitats. The

National Park Authorities controlled the harvesting of dugong by the national regulation system. Dugong is now endangered and being strictly protected. A proposal recreation of aquarium is needed, for display and research purpose will be succeeded in taking care of these animals for few years. The long-term effectiveness of those areas will depend on community support and the maintenance of the dugong habitat by the marine protected area (MPA) establishment and management. It is important to have a high precision of population estimates for this vulnerable species. Precautionary management measures should be taken to minimize the continuing harvest and reduce the negative impacts on dugongs. It is recognized that it will be essential addressed for the socio-economic balancing adjustment to dugong conservation from governmental authorities. Finally, exchanging information, experiences and constructive discussions on proper actions and cooperation in terms of the scientific research, coastal management and the responsible fishing operation will be positive direction towards a better future for the dugong population in Vietnam and other countries in our region.

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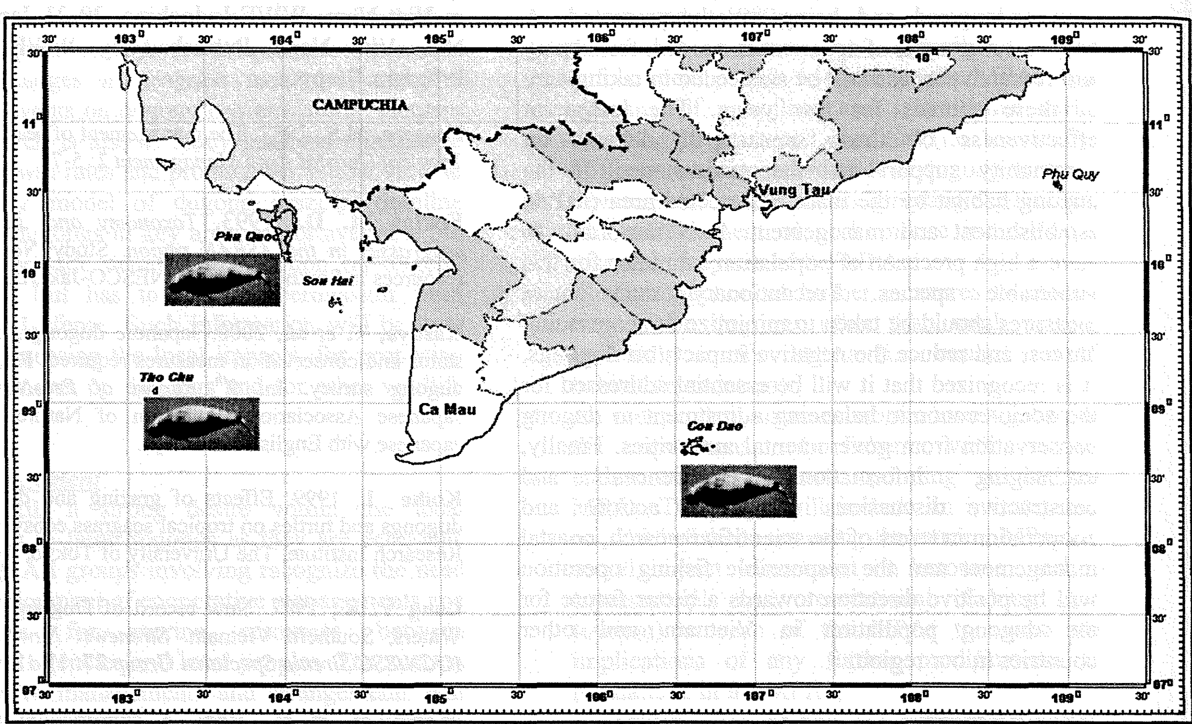

Fig. 4. Primary Map of Dugong distribution in Southern Part of Viet Nam

Fig. 5. Typical surfacing, and submerging sequence of dugong in Con Dao National Park

Acoustical Analyses on the calls of dugong

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ABSTRACT
Dugong, *Dugong dugon*, has become highly endangered species in the world. It is said that the decrease in the number of dugong population is mainly due to accidental catches by fishnets. A breakthrough to avoid the accidental catches, by-catches, is in urgent need. In this study, we described the technique to detect the direction of vocalizing dugong and the acoustical characteristics of dugong calls. This study can lead to a new observation method of wild animals. A number of dugong calls were recorded around Libong Island, Trang, Thailand, using two sets of dual channel stereo hydrophones on two research vessels. The center frequency of dugong calls ranged from 3-8 kHz, and the duration of the calls was classified roughly in two: 100-500 ms and over around 1000 ms. Vocalization intervals were classified in two patterns: 0 - 5 s and about over 20 s between each call. We applied the phase difference analysis to dugong calls recorded by a stereo hydrophone. The preliminary results suggested that the acoustical analyses on the dugong calls will be a powerful method to locate the vocalizing dugongs without any impact on them at all.

KEYWORDS: passive acoustical observation, acoustical characteristics, vocalization interval, direction analysis, arrival direction, arrival phase difference, sound pressure level

INTRODUCTION

Dugong, *Dugong dugon*, is one of the endangered species. They live in warm and shallow seawaters distributing throughout the world. The northern limit of their habitat is around the main island of Okinawa, Japan. The population of dugong in Okinawa, however, is said to be less than 50 (The mammalogical society of Japan), which is very small compared to other dugong habitats in many parts of the world. The decrease in the number of dugong population is mainly due to accidental catches by fish-nets and a death of an individual can cause a significant damage to the population. It is also of great interest to the fishermen in Okinawa, for, the area where the most sightings of dugong have been reported overlaps the main fishing area, which is off the north-east coast of the main island of Okinawa. Dugong protection and fishing restriction is the two conflicting matters to be solved. A powerful breakthrough to prevent dugong from these by-catches is in urgent need.

To protect the dugong population, we need to know their behavioral ecology such as moving paths and the usage of seagrass beds in the proposed area. The ecology of dugong, however, is not well-known, yet. Recently, passive biotelemetry techniques using underwater acoustics to locate or to observe presence of vocalizing marine mammals have been developed rapidly. Passive acoustic observation has been applied extensively for non-observable animals such as manatees (Phillips *et al.*, 2004). In the manatee case, collision with boats has been a major cause of deaths of manatees. To avoid the collisions, manatee calls are automatically detected out of the background noise in order to warn boaters of presence of manatee. We applied this technique to study the behavioral ecology of dugong. The passive acoustic observation uses arrival time difference at separated hydrophones to calculate arrival direction of a call. Its' main advantage is that it has no effect on behavior of the animal of study and it can be used to monitor vocal behavior of several individuals at once. To perform an effective monitoring, the animal of study must vocalize frequently and their calls must be easily separated from the background noise.

In this study, detection of arrival direction and acoustic characteristics of dugong call are described. These aspects are necessary in designing a new monitoring device to identify each individual and to warn fishermen of presence of dugong. This study will lead to an innovative monitoring method for dugong.

MATERIALS AND METHODSSTUDY SITE

For our survey, behavioral records and vocalization data are indispensable. Because the population of dugong in Okinawa is too small to perform a successive survey, we set our study site around Libong Island, Trang, Thailand (longitude N07°12'58.4" latitude E99°24'21.9"), where many sightings of dugong were reported beforehand. We set 5 study areas (#0 - #4) around the Libong Island (Fig. 1). The survey was conducted from 3rd of March to 6th of March. On the first day (3rd, March), recording was performed around #0, #1, and #2. But the background noise including pulse sounds was very loud and neither sightings of dugong nor the dugong vocalization was observed. On the second day (4th), we moved to the southern part of the Island (#3 and #4), where many sightings of dugong was reported during the proceeding survey that was conducted from 23rd to 29th of January, 2003. The background noise at station #3 was also too loud to record dugong call. Station #4 best suited the survey condition in the matter of recording and the number of dugongs sighted. So, for the rest of the survey (5th and 6th), the recordins were conducted in station #4.

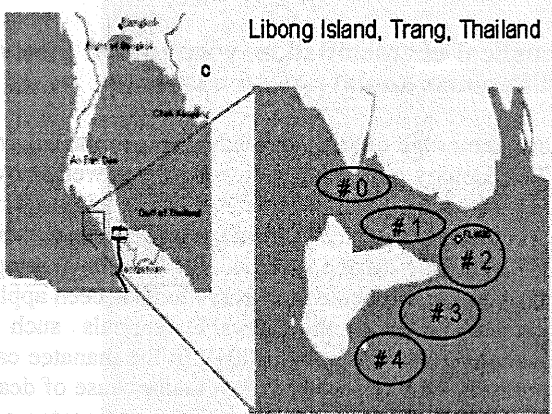
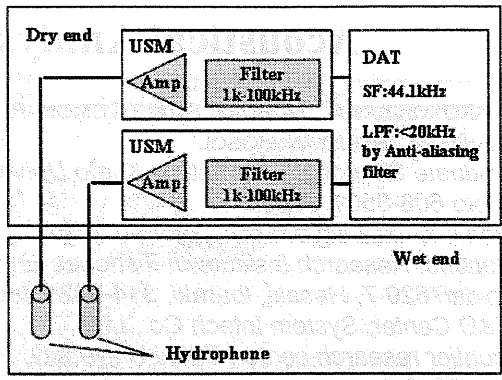


Fig. 1. Study site.

Equipments

Each of the two research vessels (vessel - A, B) were equipped with a set of two dual channel stereo-hydrophones (OKI ST1020), an amplifier (OKI SW1020), a digital audio tape recorder (SONY TCD-D8), GPS (Garmin GPS III), an echo sounder (HONDEX HE-5620), a compass and a distance meter. The array distances of the hydrophones were 5.2m (vessel - A) and 7.0m (vessel-B). (See Fig. 2 for the block diagram of the devices.)



* USM : Under water sound level meter

Fig. 2. Block diagram of the recording system.

Aerial survey

An aerial survey was performed simultaneously to support the visual observation from the research vessels. It is one of the most effective methods to observe the presence of marine mammals. Micro Lite flew at right angles to the shore repeatedly to perform an aerial survey at the same time as the recording of the underwater sound. The pilot of Micro Lite sat in front and the passenger in the back. Since the pilot had a good look out ahead and sideways, the pilot watched the front and the sides, and the passenger watched the both sides. When the observers on the Micro Lite found dugongs, the number of dugongs and their behavior were reported to the recording vessels using mobile phones. Micro Lite flew twice a day, in the morning and the afternoon. The flight duration varied depending on the number of the animals they found.

Recording

Recordings of underwater sound were started soon after the vessels reached the study site, using the DAT recorder, TCD-D8, with sampling rate of 44.1 kHz. The hydrophones were set at 1 m deep. The recording range was 120 dB, and 1 kHz high pass filter was applied. The vessels were anchored to keep the distance between each vessel in 100 - 300 m. The distance between the research vessels was measured with a distance meter. The direction from vessel - A to vessel - B was measured with a compass. When the observers in the vessels found dugongs, the distance and the direction to dugongs were measured. At the same time, the heading directions of the research vessels were recorded using a compass.

Wave pattern analyses

Wave pattern analyses were done using Cool Edit Pro 2 (CEP2 for short) and Ishmael 1.0 (ISH for short). CEP2 shows the sonar grams of dugong call, in which the horizontal axis is time and the vertical axis is frequency (Fig. 3). Center frequency, duration, and sound pressure level of a call were calculated using CEP2.

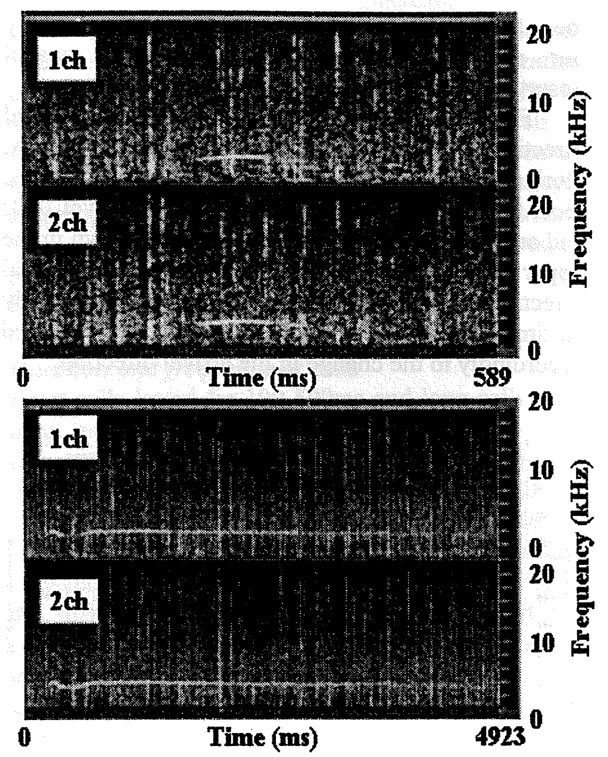
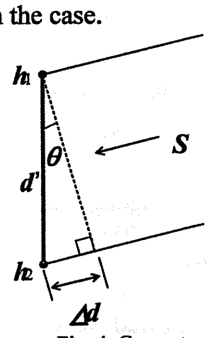


Fig. 3. Sonar grams of dugong call, which is shown in horizontal white lines. A typical example of short duration call with duration and frequency approximately of 1.9 s and 3.6 kHz respectively (upper) and long duration call with approximately of 4.6 s and 3.8 kHz (lower).

Then, phase difference between the two hydrophones in each vessel was calculated by cross-correlation using ISH to have the corresponding time difference. The arrival direction of a call at each vessel is calculated using trigonometric function as follows, where the two hydrophones are h_1 and h_2, and d' is distance between the hydrophones and $\Delta\tau$ is the arrival time difference and C is the underwater sound speed (1500 m/s). The calculation is done under assumption that the call is coming from S and the source of the sound is far enough to treat the sound wave as a plane wave (Fig. 4). There is one ambiguity in this calculation. It should be noted that the S can be on the other side of the hydrophone array, for the arrival direction θ would be exactly the same value in the case.



$$\sin\theta = \frac{\Delta d}{d'}$$

$$\Delta d = \Delta\tau \times C$$

Fig. 4. Geometry of calculating arrival direction θ.

RESULTS

Total of 1175 audible calls were recorded through the survey. There's a risk that CEP2 and ISH fail to distinguish between dugong calls and short pulse sounds from the background noise. To avoid this confusion, only the calls with frequency of over 1 kHz and duration of over 50 ms were selected for the analyses. The reason for the threshold is that a 1 kHz high pass filter was applied to the original recordings and the duration of typical pulse sounds was around 40 ms. The number of the calls became 774 after the selection. No available data was obtained from the recordings on 3rd of March.

Acoustical characteristics of Dugong call

Figure 5 and Table 1 show the acoustical characteristics of dugong call. The calls of dugong were categorized roughly in two in the matter of duration. One was a short call with duration of 100-500 ms and the other was a long call with over around 1000 ms. The center frequency of dugong calls ranged from 3 to 6 kHz. Only in the short calls, 8 kHz calls were observed.

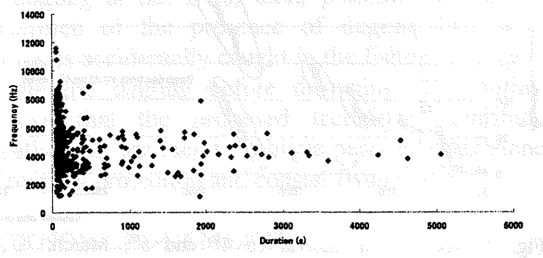


Fig. 5. Duration vs frequency of dugong call.

Table 1. Acoustical characteristics of dugong call

Duration	100-500ms	1000ms-
Number	704	74
Average of duration	126	1737
S.D of duration	87	1049
Average of frequency	4521	4152
S.D. of frequency	1615	1111

Figure 6 shows the distribution of vocalization intervals. Horizontal axis is time between each call in seconds. Vertical axis is number of call. Dugongs were most likely to vocalize once in 0 - 5 seconds.

Figure 7 shows the vocalization intervals on 4th and 5th of March. Horizontal axis is elapsed time from the start of recording. Vertical axis is accumulated number of vocalization. The steep parts of the slope mean that dugongs were vocalizing frequently. The steep parts on the 4th (2.0 s between each call) and the 5th (1.69 s, 1.74 s, 1.93 s, 1.71 s chronologically) of March had very similar slope. On the other hand, the value of the moderate parts ranged widely from 7 to 180 seconds between each call. Dugong had started vocalize very frequently at some points. It has been made clear that dugong had two patterns in vocalization interval

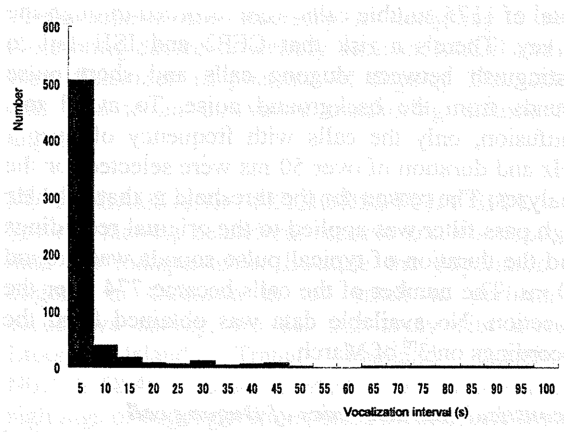


Fig. 6. Distribution of vocalization interval.

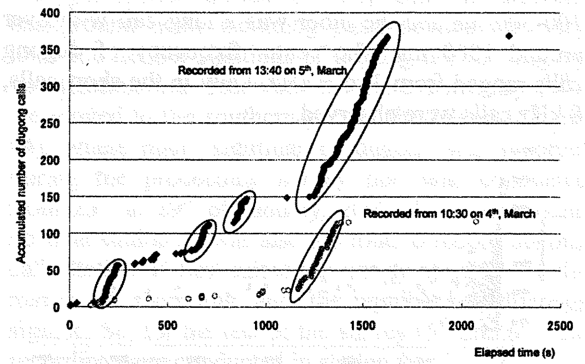


Fig. 7. Vocalization interval on 4th and 5th, March. ○, ◆ corresponds to the data recorded from 10:30 on 4th, 13:40 on 5th respectively.

Actually, according both to the visual observations from Micro Lite and from our research vessels and to overlapping calls in the sonar gram, there had been more than one dugong near the ships on 4th and 5th of March (Fig. 8).

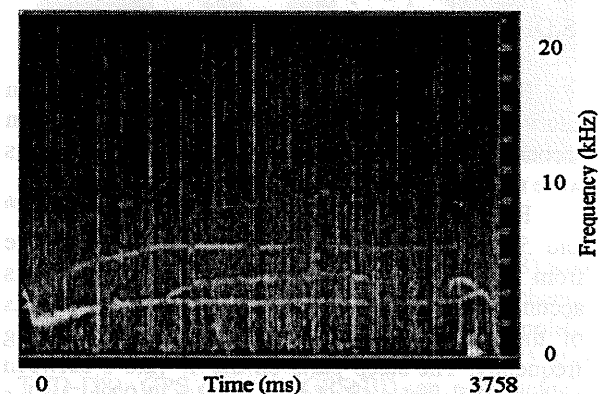


Fig.8. Overlapping calls. A long duration calls overlaps the first call in the middle. In the last moment, a short duration call overlaps the long calls.

Direction analyses

For the direction analyses, vocalization data recorded from 12:25 on the 6th of March were used. On 6th, there had been apparently only one individual nearby our research vessels according to the visual observations and no overlapping calls.

Figure 9 shows the change in the arrival direction and the sound pressure level at vessel-A. Horizontal axis is elapsed time from the start of the recording. Vertical axis is sound pressure level (dB) and arrival direction (degree), which are shown in the upper and lower graphs, respectively. The arrival direction of the dugong call is changing moderately as time goes by. The sound pressure level increased accordingly to the change in the arrival direction.

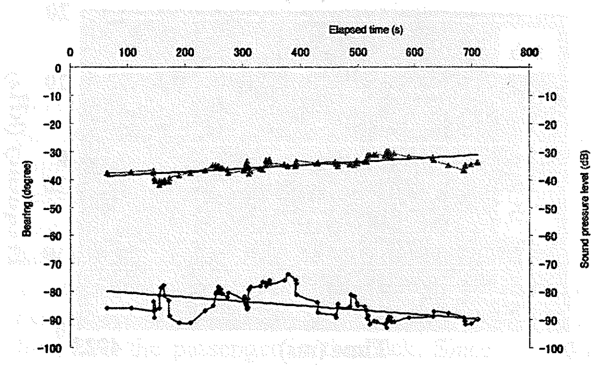


Fig. 9. Change in the sound pressure level (upper) and the arrival direction (lower).

Figure 10 shows the vocalization interval (upper) and the sound pressure level (lower). The frequency of vocalization is low at first, and is high for the next 2000 s and is low again at last. This alternation in the vocalization rate is due to the detectability of the recording devices. The farther the distance between dugong and the vessel, the less audible vocalizations are recorded. These preliminary results suggest that a dugong was coming closer at a steady angle to the research vessel.

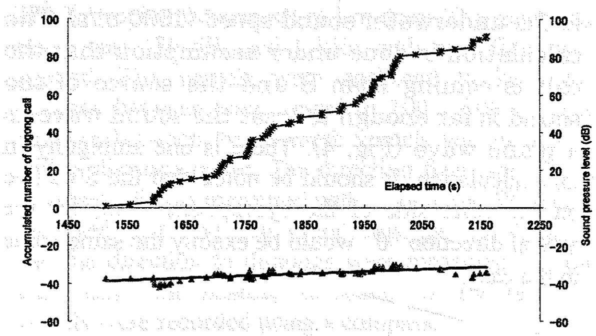


Fig. 10. Vocalization interval (upper) and the sound pressure level (lower).

DISCUSSION

The acoustical characteristics of dugong calls were described.

Vocalization interval

The values of short intervals showed very similar range: 0-5 s between each call. Periods of long interval, or almost non-vocalizing were also observed. There were sudden changes in the vocalization frequency on 4th and 5th of March, when a number of dugongs were observed near the research vessels. It was suggested that dugong had started to vocalize frequently on a certain occasion. Subjectively speaking, the occasion might have been an encounter with another individual. These preliminary results made the authors to think that dugong appear to be exchanging their calls with each other.

Duration and frequency of calls

Short calls lasted for 100-500ms and long calls were over around 1000ms. Frequency band was very narrow, ranging 3 to 6 kHz, and about 8 kHz just in the short calls. High frequency modulated call can easily be masked in the background noise. The length of the calls may be decided according to the distance between the vocalizing individual and the others. If the distance between individuals is far, short and successive calls are easier for the receiver individual to recognize the calls. In close distance to each other, the long calls may be vocalized.

Direction analyses

Movement of a dugong was described with the change in the arrival distance at vessel-A. With the results of the direction analyses from more than one research points, some intersection points of the directions for each call can be obtained, which can be supposed as a position of a dugong. Using a number of hydrophones eliminates the ambiguity that has been mentioned before.

The basic concept of the positioning of a vocalizing dugong is shown in figure 11, where the dugong calls are to be recorded by the sets of dual-channel hydrophones at each of A (0, d) and B (0, 0), and d is a distance between A and B. θ_1 and θ_2 are the arrival directions of a call at site A and B, and the position of the sound source is S (x, y).

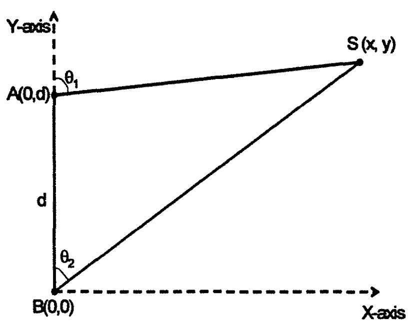


Fig. 11. Geometry of dugong positioning using trigonometry.

The unknown position S is estimated using trigonometric function as shown in Eq. (1.a), (1.b), (2.a) and (2.b).

$$\tan\theta_1 = \frac{x}{y-d} \quad (1.a)$$

$$\tan\theta_2 = \frac{x}{y} \quad (1.b)$$

These simultaneous equations are solved and then $\tan\theta$ is converted to result in Eq. (2.a) and (2.b).

$$x = \frac{\sin\theta_1 \cos\theta_2}{\sin(\theta_1 - \theta_2)} d \quad (2.a)$$

$$y = \frac{\sin\theta_1 \sin\theta_2}{\sin(\theta_1 - \theta_2)} d \quad (2.b)$$

Once the positions of vocalizing dugongs are obtained, by plotting the located positions in chronological order, the swimming path of dugong would be described. If the moving path is described, we would be able to study the behavior of dugong that is directly related to their vocal activity. This innovative tracking technique is completely new in monitoring dugong and does not affect the behavior of dugong at all. It is, then, possible to warn the fishermen of the presence of dugong before the animal is accidentally caught in the fishing net, and to rescue the dugong before drowning. The authors believe that the proposed technique contributes greatly as a first step to achieve peaceful coexistence of dugong protection and coastal fishing.

ACKNOWLEDGEMENTS

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Mekong giant catfish tracking project 2003 in the Mekong River

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ABSTRACT
Mekong giant catfish *Pangasianodon gigas* is one of the largest freshwater fish in the world. The fish is endemic to the Mekong basin and becomes high-degree endangered species listed in the IUCN Red List. Nevertheless little is known of the behavior. Ten Mekong giant catfish (TL: 76.5 to 88.5 cm, BW: 3.5 to 5.8 kg) were implanted with coded ultrasonic transmitters (Coded V16, Vemco Ltd.). Five monitoring receivers (VR1, Vemco Ltd.) were installed at Kong Chiam, Nakhon Phanom, Sri Chianmai, Sang Khong, and Chiang Khong along the Mekong River. The fish were released at Nakhon Phanom on 11 May, 2003. Three fish were recaptured by fishermen using set nets. One of the fish was recaptured at 100 km upward from the release point one week after release. This shows high performance of upward swimming of Mekong giant catfish in the Mekong River. Since 24 May, 2003, all fish are missing, unfortunately. Currently, the receivers are still waiting for the fish's coming.

KEYWORDS: Mekong giant catfish, biotelemetry, tracking, coded ultrasonic transmitter

INTRODUCTION

Mekong giant catfish *Pangasianodon gigas* is one of the largest freshwater fish in the world and grows up to 3 m in length and 300 kg in weight. The fish is endemic to the Mekong basin and becomes high-degree endangered species listed in the IUCN Red List. Nevertheless little is known of the behavior. Biotelemetry study on the Mekong giant catfish started with the background by the request of the Department of Fisheries, Ministry of Agriculture & Cooperatives of the Thai government in 2001. Ten Mekong giant catfish with coded ultrasonic transmitters were released in the Mekong River in 2002. Four fish were detected 6 to 9 days after the release by a receiver that was installed at the point 60 km upward of the release point. This shows high performance of upward swimming of Mekong giant catfish in the Mekong River. In 2003, another ten Mekong giant catfish were released. Preliminary results in 2003 were introduced in this paper.

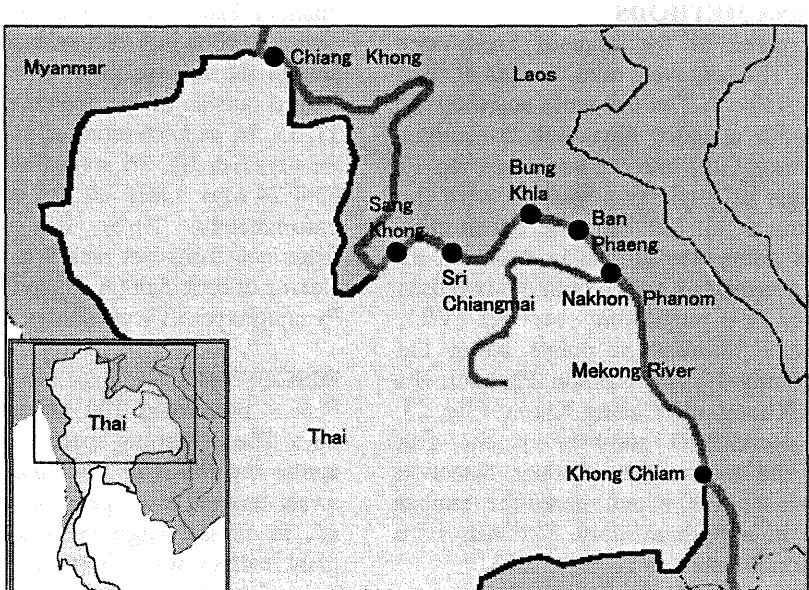

Fig. 1. Points of receiver, release and recapture,

Table 1. Details of the fish.

Fish ID	TL (cm)	BW (kg)	Recapture	Time	Point	Re-release	Time
31	81.0	4.3					
32	76.5	3.5					
33	83.0	4.6					
34	81.5	4.1					
35	88.5	5.8					
36	80.5	4.6					
37	81.0	4.4					
38	79.0	3.8					
39	81.0	4.5					
40	78.5	4.5					
A	75.0	3.5	18 May	10:00	Bung Khla	19 May	13:00
B	75.0	3.3	19 May	10:00	Bung Khla	19 May	13:00
C	75.0	3.3	20 May	8:30	Ban Phaeng	21 May	12:00

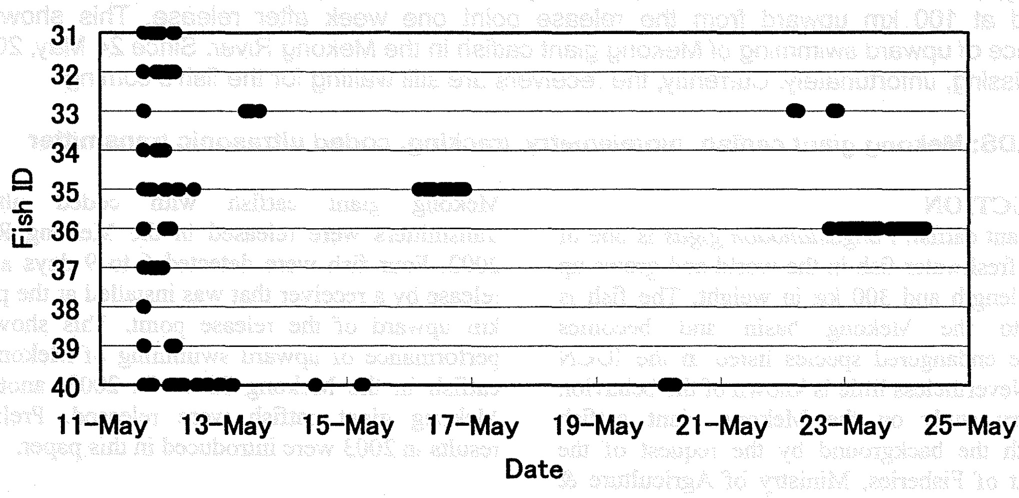

Fig. 2. Records of the receiver installed at Nakhon Phanom.

MATERIALS ANA METHODS

Artificial seed reared in the Karasin Freshwater Research Station, Thailand were used. Details of each fish are given in Table 1. The fish were anesthetized and implanted with a coded ultrasonic transmitter (Coded V16, Vemco Ltd.) into the body cave on 10 May 2003. Details of implanting method were the same as Mitamura et al. (2002a). The transmitters weighed 10 g in water, was 16 mm in diameter, 65 mm length. The transmitters emit a train of six pulses for identification. Five monitoring receivers (VR1, Vemco Ltd.) were installed at points along the Mekong River, Kong Chiam, Nakhon Phanom, Sri Chianmai, Sang Khong and Chiang Khong (Fig. 1). The receivers decode ID numbers of the fish implanted with the transmitters in their detection zone within a radius of 300 m and record the number and time stamp in a flash memory. The fish were released at Nakhon Phanom on 11 May, 2003.

RESULTS

The records were downloaded once in July. Figure 2 shows records by a receiver installed at Nakhon Phanom Fish ID: 33 and 38 moved outside of the detection zone just after release. The other fish stayed around the release point for 1 or 2 days and then moved outside of the detection zone. Some fish (ID: 33, 35, 36, and 40) returned to the release point again. Finally, fish ID: 36 stayed around the release point until 24 May. Later, all fish were missing until now, unfortunately. Three fish were recaptured by fishermen using set nets 7 to 10 days after release. Details of each fish (A, B, and C) are given in Table 1. Recapture points were shown in Figure 1.

DISCUSSION

Fish A performed 100 km upward swimming in 7 days. The swimming speed was about 14km/day. This agrees the result in 2002 that Mekong giant catfish swam upward at a speed of 10km/day (Mitamura *et al.*, in press). High swimming ability of Mekong giant catfish was observed again. Considering the size, fish A and B were fish ID: 38 and 32, respectively. In addition, these fish ware absent from the release point at the recapture time. Fish C was recaptured at 50 km downward from the re-release point of fish A and B. Considering the re-release and recapture time, Fish C was the same as the fish B. Fish B must be tired because of the capture. The fish might move downward after re-release and was recaptured again. Since 24 May, all fish were missing. Some fish might be captured by shy fishermen. Some fish might pass Laos side where is the outside of the detection zone of the receivers. Some fish might stay the point between 2 receivers. The transmitter will last until June, 2004. Currently, the receivers are still logging and waiting for the fish's coming. The missing fish will be detected sometime, somewhere.

ACKNOWLEDGEMENTS

The authors wish to thank staff of the Freshwater Research Stations for their all help in the experiment in Thailand. . The first author especially thanks Mr. Lhan, Mr. Sombat, Mr. Dong and Mr. Ohm. This study was supported by a Grant-in-Aid for Scientific Research (15780138), the Ministry of Education, Culture, Sports, Science and Technology.

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Pilot study on the movement of Mekong giant catfish in the reservoir

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ABSTRACT

Mekong giant catfish *Pangasianodon gigas* is endangered species. It is urgently necessary to learn more about the movement pattern of the catfish to conserve. We started the Mekong giant Catfish Tracking Project (MCTP) that is ecological research cooperatived with Thai government at 2001. In this paper, the first results of MCTP are introduced. Horizontal and vertical movements of Mekong giant catfish were determined using pressure-sensitive ultrasonic transmitters in the reservoir. We found the clear daily movement patterns of the catfish.The catfish appeared to favor relatively deep areas and had 2-3 km excursions at night. The catfish exhibited the ascent to the surface at dusk and the descent to the thermocline at dawn in the reservoir. These behaviors of the catfish might be related to the feeding behavior.

KEYWORDS: MCTP, Mekong giant catfish, endangered species, vertical and horizontal movement

INTRODUCTION

The Mekong giant catfish *Pangasianodon gigas* is endemic to the Mekong River and growing to colossal size. The catfish shows one of the fastest growth rates of any fish in the world, reaching 150 to 200 kg in 6 years (Walter *et al.*, 1996). The catfish is also one of the largest freshwater fish in the world, measuring up to 3 m in length and weighing in excess of 300 kg. The catfish is known to feed on algae and planktons, occasionally swallows algae-covered stones inadvertently. The catfish may also eat insect larvae and periphyton attached to the stones (Walter *et al.*, 1996). The catfish used to be distributed throughout the Mekong River basin from Yunnan Province, China to Vietnam. Currently, the catfish seems to be limited to the Mekong River and its tributaries in Thailand, Laos and Cambodia (Fig. 1).

Although, in Cambodia, Cambodian law forbids the capture, sale, and transport of the endangered species including Mekong giant catfish, the fishermen capture the catfish by incidental catch every year in Tonle Sap Lake and its tributaries (Zeb et al., 2001). To prevent the catfish from becoming extinct, the catfish was tagged in the hope that the catfish would be recaptured these days. In Thailand, Thai law allows the capture of the Mekong giant catfish. It is generally said that the spawning grounds of the catfish are located near Chiang Khong District, the northern part of Thailand. Now in Thailand, there is the only fishery cooperative of Chiang Khong District that is allowed to capture the wild catfish in the Mekong River. The fishermen in this cooperative use a gill net with a height of 3 m and mesh width of 40 cm to capture the catfish. The peak fishing season of the catfish starts from April to the end of May because the catfish migrates upstream to this district in this season to spawn. The river at this area is deeper and narrower, causing the current to flow swiftly. The fast current sweeps the catfish into the gill net and makes it difficult for the catfish to escape. In other districts, the catfish happens to be captured by incidental catch. The number of the wild catfish in the Mekong River has decreased due to the development of the Mekong River these days and so on. The behavior of the catfish, however, has been full of mystery.

As ecological researches are urgently necessary to conserve the catfish, the Mekong giant Catfish Tracking Project (MCTP) started at 2001, which is cooperatived with Thai government. We have conducted the telemetry experiments in two study sites, the Mekong River and the Mea peum reservoir that is located in Phayao province, a northern part of Thailand (Fig. 1). The Mea peum reservoir is the enclosed waters. Enclosed waters can be the suitable site for the behavioral ecology of the catfish because continuous tracking is possible. The objective of this paper is to introduce the first results of MCTP in the Mea peum reservoir.

MATERIALS AND METHODS

Study site

This experiment was conducted at the Mae Puem reservoir, where is located in Phayao province, a northern part of Thailand. This reservoir was constructed by damming up a river. The area of this reservoir was approximately 8.3 km^2. The maximum depth is approximately 15 m. We surveyed the bottom topography all over the reservoir using an echo sounder.

Table 1. Summary of treatment, body length, body weight, date tagged and date of track start.

ID	Total length (cm)	Body weight (kg)	Date tagged	Date of track start
42	108	13	18-May-03	20-May-03
43	103	13.5	18-May-03	20-May-03
44	116	14.8	18-May-03	20-May-03
45	116	17.6	18-May-03	20-May-03
46	120	18.8	18-May-03	20-May-03
47	113	16.2	18-May-03	20-May-03
49	110	17.2	18-May-03	20-May-03
50	111	14.2	18-May-03	20-May-03

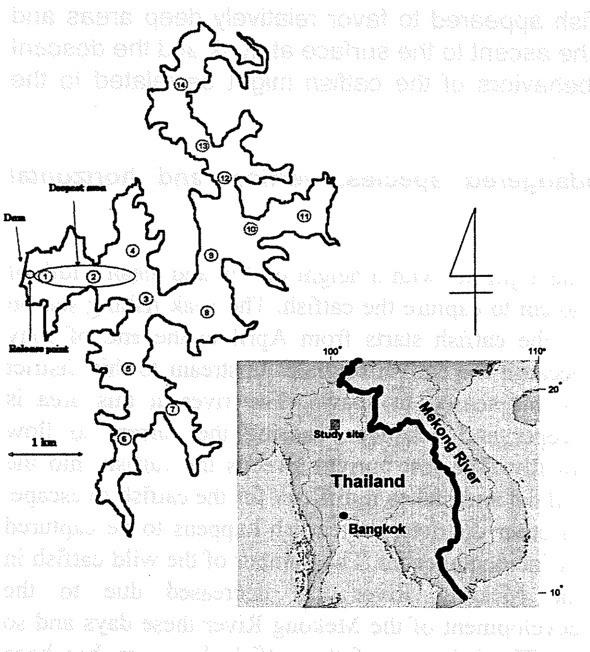

Fig. 1. Map of study site, Mea peum reservoir. This reservoir is located in Phayao province, a northern part of Thailand. This reservoir was constructed by damming up a river. The area of this reservoir was approximately 8.3 km^2 and maximum depth was about 15 m.

Tagging and coded ultrasonic transmitters

Recently the Mekong giant catfish has been bred in captivity by Thai government and widely introduced through Thailand. Because it is difficult to capture the wild one, all cultivated fish (Table 1) were used in this study. All the catfish (n = 8) were about 1 m of total length, 6 to 11 years old and immature.

We used ultrasonic coded transmitters that were 16 mm in diameter, 108 mm long and weighed 16 g in water (V16P, Vemco Co., Ltd.). The frequency of the transmitter was 69 kHz. The power of the acoustic signals was 159 dB. The interval of the transmission was about 40 seconds. The transmitter transmits complex codes consisting of eight pulses in a transmission. So the receiver can identify and record the ID number of a transmitter and the depth of the sample fish swimming. This allowed us to identify up to potentially 256 different fish using the same frequency (Vogeli *et al.*, 1998).

Transmitter Attachment

In May 2002 the experiment on the dummy transmitter was carried out to find the ideal attachment method, external or surgical internal attachment (Moore *et al.*, 1990). We attached the dummy transmitter to the pectoral fin of the 5 fish for external attachment. We inserted the dummy transmitter to the peritoneal cavity of each 5 fish for the internal attachment. Each group of the catfish was reared for the external and internal attachment in the fish pond. Five intact fish were also reared for the contrast experiment under the same condition. About a month after the attachment, we concluded that the surgical implantation was better than the external attachment because all the external tags were removed and the change of the body weight of internal fish was not significantly different from the intact fish.

For the release experiment, the transmitter was implanted surgically into the peritoneal cavity of the catfish under the anesthesia following our previous method (Mitamura et al., 2002). After the surgery, the fish were kept in a pool for about one day to allow them to recover. The catfish showed no observable effect of the surgery on their behavior. The release experiment was carried out on May 20 2003. The catfish were released one at a time at the surface of the reservoir at the dam side (Fig. 1).

Tracking system

We used 14 VR2 systems (Vemco Ltd., Nova Scotia, Canada) for tracking tagged fish. The VR2 systems logged data on the presence of fish tagged with coded transmitter. The dimension of the VR2 system is 60 mm in diameter with 205 mm length. The system has flush memories to record data and is powered by the lithium battery that lasts for up to 180 days. The receiver was installed at mid-water depth in a location in advance. The ID number, the date and time were recorded when the tagged fish passed within approximately 400 m of the receiver. We installed 14 VR2 systems in the Mea peum reservoir to cover all over the reservoir (Fig. 1). The areas around Sts. 1-4 and 9-12 were relatively deep, more than approximately 10 m. In contrast, other areas were shallow, up to 2 m deep. The data from VR2 systems were downloaded on 29-30 July 2003.

Water temperature

We measured the water temperature of the surface and the bottom of St. 1 in the reservoir during our experiment with two DT loggers (UME-190T, Little Leonard Co. Ltd.). This DT logger can record the ambient temperature and depth. Sampling intervals were 255 seconds. We also measured a vertical profile of the water temperature near St. 1 using another DT logger on 29 July 2003. In this measurement a sampling interval was 1 second.

RESULTS

Water temperature

Figure 2 shows water temperature of the surface and the bottom in the reservoir during our experiment. Average temperature of the surface and the bottom were 30.2 (±1.1 SD) °C and 23.6 (±0.6 deg. SD) °C respectively. Figure 3 shows the depth-temperature profile at the deepest area in the Mae peum reservoir nearby St. 1. Water temperature was stable from the surface layer to the depth of 6 m. However, it changed sharply at 6 m deep (Fig. 3).

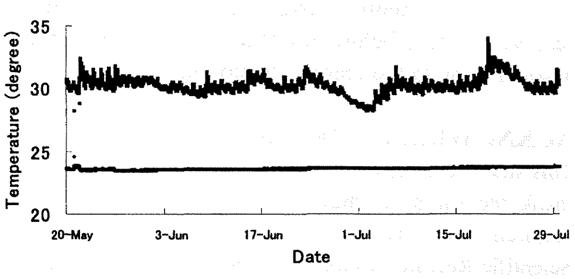

Fig. 2. Temperature of the surface and the bottom in the deepest area of the reservoir during approximately 70 days. Upper and lower lines indicated the temperature of the surface and the bottom, respectively.

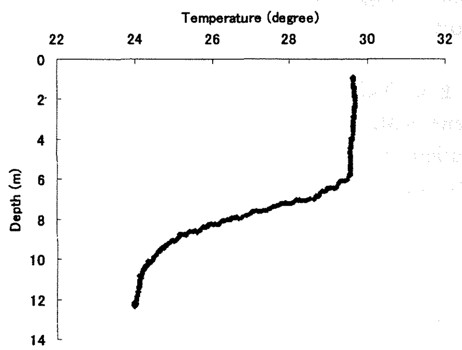

Fig. 3. Temperature profile in the deepest area of the reservoir.

Horizontal and vertical movement of Mekong giant catfish

All 14 receivers recorded the signals from the transmitters of tagged catfish when the data were downloaded approximately 70 days after the release.

The upper graph of Fig. 4 shows the horizontal movement of catfish 42 during our experiment. The catfish (ID 42) stayed mainly around Sts. 1-4 areas, where are the deepest in the reservoir. All tagged catfish appeared to favor relatively deep areas around Sts. 1-4 or Sts. 8-12 areas. The catfish (ID 42) generally favored deep areas, but the fish migrated all over the reservoir (Fig. 4). The lower graph of Fig. 4 shows horizontal movement of the catfish for a week after the release. The catfish migrated to other areas (Sts. 9-12) three times for a week although the catfish stayed mainly around Sts. 2-4. The fish conducted these 2-3 km excursions at night (Fig. 4). All catfish tended to have these short excursions at night although some excursions were made in the daytime.

Figure 5 shows the vertical movement of catfish 42 for a week after the release. There was clear vertical movement pattern during our experiment. The catfish swam upwards to the surface layer at dusk and remained below the surface at night. At dawn the catfish descended to depths around 6 m and remained there until the following dusk (Fig. 5). This catfish usually preferred deep areas where maximum depth is about 15 m (Fig. 4). However this catfish did not dive deeper than 6 m. The vertical profile of water temperature indicates that the mix layer was from surface layer to 6 m deep and that there was a sharp thermocline 6 m deep. This thermocline seems to be limitation to the vertical movements of this catfish. This catfish appeared to spend the majority of all the time above the thermocline (Fig. 5). All other fish also exhibited the remarkable pattern of the vertical movement similar to ID 42. The clear day-night vertical movement may be common characteristic for Mekong giant catfish in the Mae peum reservoir.

DISCUSSION

Our results indicate that the catfish favored relatively deep areas and exhibited the vertical movements above the thermocline in the reservoir.

The Mekong giant catfish is known to feed on algae, occasionally swallows algae-covered stones inadvertently. The catfish may also eat insect larvae and periphyton attached to the stones (Walter et al., 1996). In the Mae peum reservoir, some kinds of algae grow in the shallow areas and along the shore. Tagged catfish tended to migrate to other

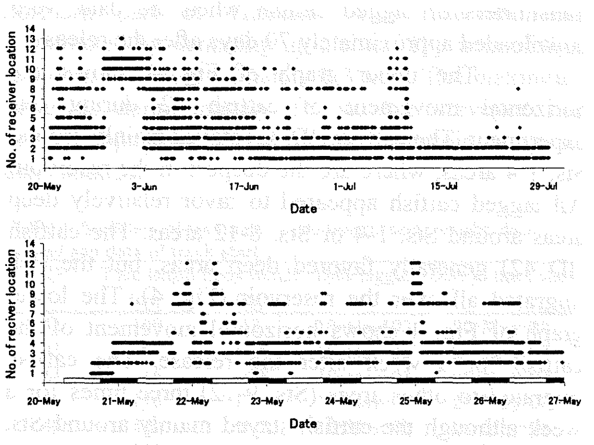

Fig. 4 Typical horizontal movement of the tagged catfish (ID 42). The dark horizontal bars indicate night time.

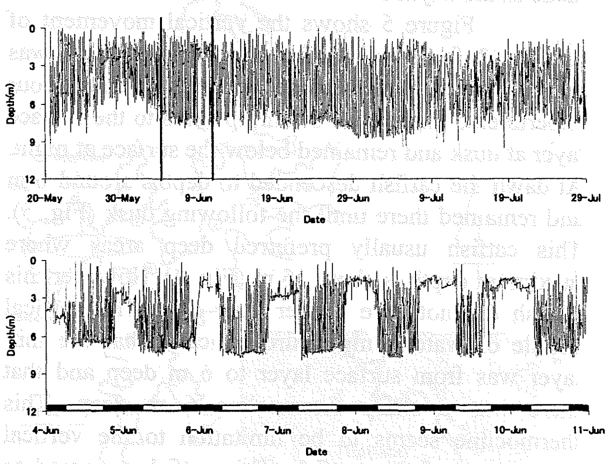

Fig. 5 Typical vertical movement of the tagged catfish (ID42). The dark horizontal bars indicate night time.

shallow areas from the main habitat or ascended to the surface at dusk. This movement to the shallow layer may be the movement to the shore from the deeper layer. In other words, the catfish may remain at the depth of 6-8 m above the thermocline in the daytime and move to the shore to feed on algae at night.

The Mekong giant catfish is also reported to feed on planktons (Walter et al., 1996). Some of zoo plankton generally remains at the deep layer in the daytime and remains at the surface layer in the night time in both the sea and the lake (Hattorori, 1989, Gliwicz, 1986, Bollenz et al., 1989). The Mekong giant catfish might vertically migrate to forage the zoo plankton in accordance with the movement of the zoo plankton. In order to learn more about the movement of the Mekong giant catfish it would be necessary to analyze stomach contents of the catfish. Additional experiments are needed to understand what and nowthe Mekong giant catfish feed on in the reservoir.

Horizontal and vertical movements of some fishes, for example Yellowfin tuna *Thunnus albacares* and bigeye tuna *Thunnus obesus,* were studied using ultrasonic transmitters and archival data loggers (Block et al., 1997, Brill et al., 1999, Dagorn et al., 2000, Musyl et al., 2003). These tunas exhibit clear vertical movement similar to the Mekong giant catfish. These tunas descend below the thermocline to forage and then return to the mixed layer in the daytime although they remain at the mixed layer at night. The thermocline limits the vertical movement of the tuna because tuna could not maintain body temperature for a long time below the thermocline. Therefore, these tunas spend major time above the thermocline. In the Mae peum reservoir, the change of temperature of thermocline is approximately 5-6 degree (Fig. 3). This change might limit the movement of the catfish.

In this study, we found that the catfish favored relatively deep areas and exhibited the vertical movements above the thermocline in the reservoir. These behaviors of tagged catfish might be associated with the feeding behavior.

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A study plan of development of a new device for recapturing free swimming fish

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ABSTRACT

Mekong giant catfish is one of the largest freshwater catfish in the world. It is endemic to the Mekong basin, and is endangered species. We have studied the Mekong giant catfish to conserve and enhance its resource by biotelemetry since 2001. In the Mae peum Reservoir in 2003, we found that the catfish vertically moved down only above the thermo cline in the daytime and up to the surface layer in the nighttime daily. This diel vertical movement appears to be related to the foraging behavior. However, the foraging behavior and prey items of the catfish are still unknown. One of the methods to clarify the foraging behavior and the prey items is to examine the stomach contents of the catfish in the daytime and the nighttime respectively. In order to examine the stomach contents transition hourly, we must be able to recapture the catfish at any time. Therefore, we made a plan to develop the new device named an Automatic Fish Recapture System (AFR System) to recapture the free swimming fish at the set time. And we will apply this device to the catfish and examine the stomach contents of the catfish and simultaneously study the migration of the catfish by incorporating with the biotelemetry system. Consequently, we will clarify the foraging behavior and the prey items of the catfish. In this paper, the outline of the AFR System and study plan of the catfish using this system is introduced.

KEYWORDS: Mekong giant catfish, diel vertical movement, Automatic Fish Recapture System (AFR System), stomach contents

INTRODUCTION

Mekong giant catfish (Pla Buk in Thailand), *Pangasianodon gigas* (Chevey, 1930), is endemic to the Mekong basin. The catfish is one of the largest fresh water fish in the world and the biggest record is 293 kg with the total length 3 m. It is said that this catfish feeds on plankton and algae (Walter et al., 1996), but it is not known many details. The catfish is delicious and is also valuable animal protein resources for the residents in the north of Thailand. However, due to the watershed development of the Mekong River these days and due to the incidental catch and so on, the number of the wild catfish in the Mekong River has decreased year by year (Niklas S. Mattson et al., 2000). Therefore, the catfish is listed on IUCN Red List for Critically Endangered and is included in CITES Appendix for most endangered species. So the import and export is strictly regulated. Also, in Thailand the catches of the catfish is strictly restricted, for example, only fishery cooperative of Chaing Khong District, the north of Thailand is allowed to capture the wild catfish only from April to June when the water level rises. In order to conserve and enhance the catfish resource, Thai government has put above mentioned fishing restrictions on and conducted artificial hatching study to increase the catfish resource since 1970s. In 2001, they succeed in producing second filial generation (F2) from first filial generation (F1) of the catfish. But behavior of the wild catfish, particularly habitat of young fish, is still unknown. Additionally when they release artificial hatching fish, we can't grasp his migration after releasing.

As researches are urgently necessary to conserve the catfish, the Mekong giant Catfish Tracking Project (MCTP) started at 2001 which is cooperated with Thai government. The first research was conducted in the Mekong River in 2002. It was revealed that the catfish widely migrated in the Mekong River (Mitamura et al., 2002; Mitsunaga et al., 2003). In 2003, the second research was conducted in Mae peum Reservoir where is located in Phayao province, the north of Thailand (Fig. 1). We found the following diel vertical movements of the catfish by biotelemetry. First, the catfish actively migrated during the nighttime. Second, main habitat of the catfish was deep area. Third, the catfish descended to the deep layer at dawn and ascended to the surface layer at dusk (Mitamura et al., 2003). These movements may be related to the foraging behavior and the prey items. The distribution and the movement of the prey items have a great impact on the catfish's movement because the catfish traces the prey items to eat. However, the foraging behavior and the prey items of the catfish are still unknown. If the foraging behavior and the prey items of the catfish are clarified in natural environment, we could definitely take measures to conserve the catfish, for example, to protect the area where main plants are distributed.

In order to clarify the foraging behavior of the catfish, it is necessary that the stomach contents every daytime and nighttime are examined. Therefore, 1) we will develop the new device for recapturing free swimming fish at any time. 2) We will apply this device to the catfish. 3) We will study the migration of the catfish by using biotelemetry system which we have already had. So, the objectives of this study are to clarify the foraging behavior and the prey items of the catfish.

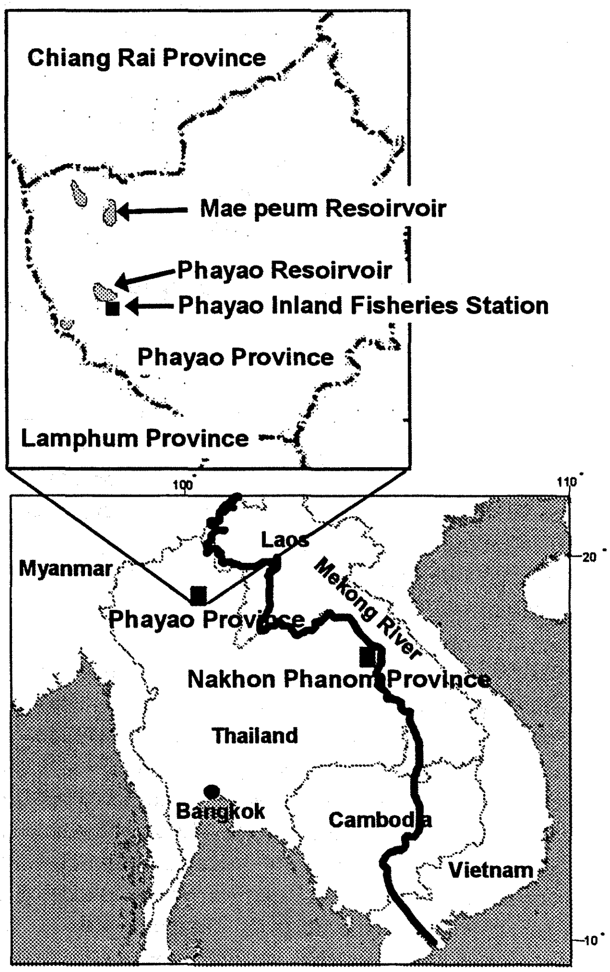

Fig. 1 Map of study site, at Phayao Inland Fisheries Station and Mae peum Reservoir in Phayao Province, the north of Thailand, and at Nakhon Phanom inland Fisheries Station in Nakhon Phanom Province.

MATERIALS AND METHODS

1. *Development of Automatic Fish Recapture System (AFR System)*

1-1 *Overview of AFR System*

We will develop a new device to recapture the free-swimming fish at any time. This device is named Automatic Fish Recapture System, for short, AFR System. Materials for development of the AFR System are an inflatable life jacket, a carbon dioxide (CO_2) cylinder and an ignition device with a timer. Mechanism of the AFR System is the followings. (1) We set the timer at the time when we want to recapture the catfish. (2) We attach the AFR System to the catfish. (3) We release the catfish into the reservoir. (4) When it comes at the set time, the ignition device will break the cover of the CO_2 cylinder. (5)Consequently, CO_2 is injected into the life jacket inside from the cylinder and the life jacket is inflated. (6) As a result, the catfish will be taken to the surface and be recaptured.

In order to develop the AFR System, as a matter of first priority, it is necessary to know minimum buoyancy to take the catfish to the surface, because buoyancy, weight and size of the AFR System interfere with the swimming of the catfish. Therefore, the trade-off between buoyancy, weight and size AFR System arises. So it is necessary to calculate minimum buoyancy required for the AFR System which is found by specific gravity of the catfish.

1-2 *Specific Gravity Measurement*

On 16th December 2003 at Phayao Inland Fisheries Station in Phayao Province, the north of Thailand, we conducted specific gravity measurement of the catfish (Fig. 1). Sample fish are 9 catfish, total length 60.0-81.5 cm, stocked at Phayao Inland Fisheries Station. Measured items are fork length, total length, body weight (on the ground) and volume (Table 1).

Table 1 Result of measurement. FL: Fork Length, TL: Total Length, BW: Body Weight, V: Volume, SG: Specific Gravity, SD: Standard Deviation

Fish No.	FL(cm)	TL(cm)	BW(g)	V(cm^3)	SG(g/cm^3)
1	57.0	64.0	2500	2772	0.9019
2	56.0	65.0	2300	2376	0.9680
3	70.0	79.0	4200	4356	0.9642
4	64.0	73.0	3500	3168	1.1048
5	69.5	78.0	3900	3960	0.9848
6	53.0	60.0	2100	1980	1.0606
7	66.0	73.0	3500	3564	0.9820
8	67.0	74.0	3800	3168	1.1995
9	73.0	81.5	5100	4752	1.0732
				Average of SG	1.0266
				SD of SG	0.0908

1-3 *Preliminary Test of AFR System*

In June 2004, the first operation check of the AFR

System will be conducted at the pool attached Kyoto University gymnasium center. The pool is a rectangle 25 m by 12 m with a depth of 1.6m. We will check whether the AFR System operates accurately underwater or not, and whether the object is taken to the surface by the AFR System or not. The AFR System will be attached to a sandbag of weight about 5-10 kg.

In August 2004, we will conduct the second operation check of the AFR System at the pond of Phayao Inland Fisheries Station in order to check whether the AFR System is not omitted from the catfish while it swims and whether the AFR system can actually take the catfish to the surface. And the AFR System attached to the catfish is possible to interfere with the migration of the catfish. To evaluate the effects of attached the AFR System, we will compare the growth rates of the catfish from the catfish with the AFR System from the control catfish without the AFR System. We use 12 catfish stocked at Phayao Inland Fisheries Station as sample fish. Three catfish are attached the AFR System, and the other 10 control catfish aren't. The catfish are attached the AFR System which is set up the timer to the back of the catfish and are released at the pond of Phayao Inland Fisheries Station. We stock these sample fish for 1 month.

1-4 *Field Test of AFR System*

In October 2004, at the Mae peum Reservoir in Phayao province of north Thailand (Figs. 1 and 2), field test of the AFR System will be conducted. The reservoir is constructed by damming up a river. As above mentioned, we attach the AFR System to 2 catfish stocked at Phayao Inland Fisheries Station. After we check the sample fish for any errors, we set one timer at 8:00 1 week later and another timer at 20:00 1week later. Then we release the catfish at the reservoir. At the set time, we will be able to recapture the sample fish taken to the surface.

2. Stomach Contents Research

2-1 *Plankton Research over the Whole of Mae peum Reservoir*

The catfish feed on plankton and algae. In habitat of the catfish (in the Mae peum reservoir in this study), it is very important to know the species, the habitat and the time zone of plankton. Plankton are closely related to the reservoir environment such as dissolved oxygen, water temperature, transparency. If we research the above, temporally distribution of plankton is maybe clarified. On the basis of this temporally distribution of plankton and the stomach contents research of the catfish mentioned in next chapter, 2-2, we can know whether the catfish selectively feeds on plankton and algae or not. Also, we can know when, where and what plankton the catfish feeds on. Thus, we can clarify whether the foraging behavior of the catfish causes the diel vertical movement of the catfish or not.

In June, August, October and December 2004, we will conduct the plankton sampling twice a day (daytime and nighttime) for 1 week. We draw the line east-west and north-south to map of the reservoir and the cross-points are the points obtaining plankton (Fig. 2). We obtain them by a plankton net in both surface layer and bottom layer of each point. The plankton obtained are fixed with lugol's solution and identified by the microscope.

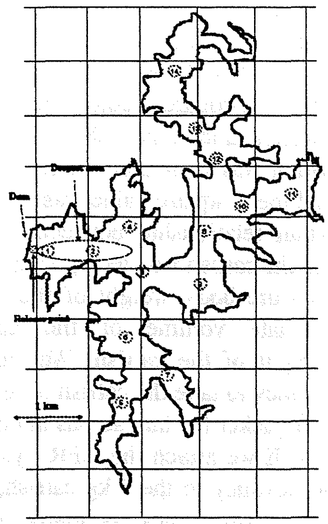

Fig. 2 Map of study site, at Mae peum Reservoir located in Phayao Province, the north of Thailand (Fig. 1). The numbers 1 through 14 suggest receivers (VR2) to log data of the transmitters.

2-2 *Stomach Contents Research (1-4: at the Field Test)*

We will obtain the stomach contents from the sample fish which are recaptured at the field test (1-4) and clarify the prey items of the catfish. At the first stomach contents research, in order to know all stomach contents, we cut the stomach and intestine and obtain the stomach contents. We attempt to obtain the stomach contents by using a syringe from next research, because we may be able to keep the catfish alive after we obtain stomach contents. The obtained stomach contents are fixed with lugol's solution and specified by using an optical microscope.

3. *Biotelemetry Study (1-4: at the Field Test)*

At the field test in the Mae peum Reservoir, in order to record the horizontal and vertical movement, we will also conduct the biotelemetry study. We use the coded ultrasonic transmitter which transmits transmitter's ID number and the swimming depth of the sample fish. The transmitters are attached to the AFR System when we attach the AFR System to the catfish at the field test (1-4). Also, we will use 14 receivers (VR2) to log data of the transmitters. We install the VR2 in the Mae peum Reservoir to cover all over the reservoir (Fig. 2). The VR2 continuously record automatically during 2 weeks. After we recapture the sample fish, we download the data of the VR2. We will analyze the horizontal and vertical movement of the catfish and clarify the behavior of the catfish in the reservoir.

RESULTS AND DISCUSSION

1 *Results of Specific Gravity Measurement*

1-2 *Specific Gravity Measurement*

The average of specific gravity of all 9 sample fish was 1.0266 g/cm^3 and the standard deviation of the 9 sample fish was 0.0908 (Table 1). Figure 5 shows the linearization by least-square method, in which y-axis shows body weight and x-axis shows volume. The factor of x which was equivalent to specific gravity was 1.0267 and the R square value was 0.91. In these results, a certain relationship between volume and body weight of the catfish was recognized. Therefore, if we only measure body weight of the catfish, we can also estimate volume of the catfish and underwater weight of the catfish. We can estimate sufficient buoyancy to take the catfish to the surface.

A life jacket for human has about 7 kg and 10kg buoyancy. If we attach the AFR System which causes 10 kg buoyancy to the 5 kg catfish, buoyancy of the catfish is two times as many as its own buoyancy. Therefore the catfish can not maybe swim to the bottom. We will conduct preliminary test and estimate minimum buoyancy to take the catfish to the surface in the future.

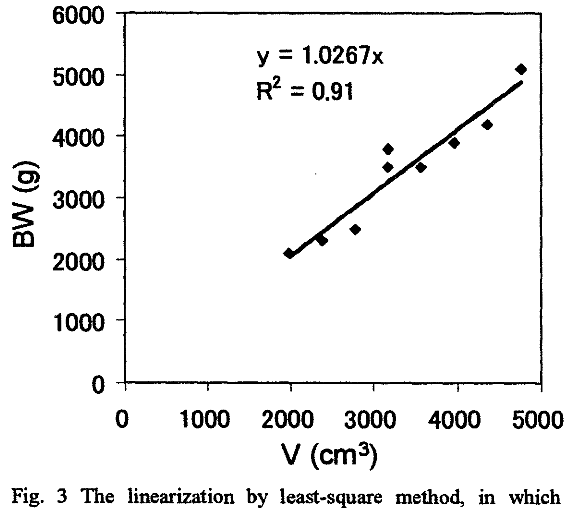

Fig. 3 The linearization by least-square method, in which y-axis is BW: Body Weight and x-axis is V: Volume.

2 *Expected Result*

We have already found that the catfish widely migrated along the Mekong River and the catfish diurnally migrated between the deep area and shallow area vertically (Mitamura et al., 2003 and 2004). However, the diel vertical movement of the catfish which may be related to the foraging behavior and the prey items is full of mystery. We can recapture the free swimming fish at any time by using the AFR System presented in this paper. Therefore we can research the stomach contents of the catfish every daytime and nighttime and the detailed prey items will be clarified. Results of both above mention and the biotelemetry experiments will indicate whether the catfish migrate to feed between deep area and shallow area. And these results will contribute to aquaculture of the catfish at lakes in Thailand. Furthermore, applying the results of this study to Mekong River, we will also contribute to conservation of the wild catfish.

We can't eradicate the effects of the attached the AFR System. However, further modification of this AFR System with a smaller lifejacket and smaller microelectronic devices should decrease its size. And the attached AFR System doesn't have large effects on the catfish. This method allows one to conduct the studies on different fish and diving animals.

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