CHAPTER I

INTRODUCTION

Mud crab (*Scylla serrata* Forskäl) is one of the economically important species in mangrove areas, and occurs throughout tropical and warm temperate regions. Because of its good flavor, attain large size, and can be kept for several days without special treatment made mud crabs in high demand in the market. In Thailand, during the years 1977 - 1984, the production of mud crabs cost about 119 million baht, and a large amount of mud crabs were caught at on the average of 4,525 tons each year (Marine Fisheries Statistics,1986). This portunid crab supports substantial artisanal fisheries associated with mangrove forests. The total catches of *Scylla serrata* at Bangla mangrove area Phuket province, approximately 600 hectares, in 1986 were 2,675 kg as revealed by Poovachiranon (1987). The production was about 5 kg per hectare. During January to June, monthly production were ranged 250 - 380 kg and decline in the landings were 110 - 180 kg during July to December. Mud crab fishing were related to tidal cycle. In Satul province, Onkong et at (1987) surveyed on the annual mud crab production amounted to 454 tons. The highest catches were recorded during May to August and lowest in January to April. Mud crabs are one of the most important fishery resources harvested commercially from the Ranong mangroves. This crab fishery supports about 70 full - time fishermen in four villages in Klong Ngao area

Mud crab, ***S. serrata***, occupies a wide range of habitats from the intertidal and the subtidal zone. Generally, they prefer to live in the mangrove of estuarine area (Fielder, 1978). Each stages of ***S. serrata***, especially the juvenile stage, seek shelter in the mangrove areas such as in small creeks and channels, under stones, in sea grass beds and even in between roots or pneumatophores of the mangrove trees (Hill et.al., 1982). Smaller ***S. serrata*** specimens stayed far up the creeks within the mangrove and large ones are found near to the sea or at the mangrove edge (Macnae, 1968). This showed that the mangrove is a very important area for these ***S. serrata*** to spend their live and activities there.

Mangrove forests which play the vital role as mud crabs habitat have been destroyed and decreased rapidly in recent year as shown in Table 1. There are several causes contributing to mangrove destruction in Thailand such as over - exploitation of wood resources, mining, urbanization, construction of harbors and channels, industrial expansion, and conversion of mangrove areas to aquaculture and salt pond (Paphavasit, 1985; Aksornkoae, 1987; and Aksornkoae, 1990). During the last four years from 1986 to 1989, the conversion of mangrove areas to shrimp farming was the major cause of mangrove destruction of an estimated area of 80,000 hectares (Chantadisai,1990). In addition, heavily exploitation of mud crab as well as a large number of young and gravid female were caught without any control and management. These activities further diminished the mud crab natural population.

Table 1: Status of mangrove area in Thailand during 1961 - 1989. (Adapted from Aksornkoae, 1987, Kongsangchai, 1989 and Aksornkoae, 1990)

Years	Mangrove areas (Hectare)	Decreased Areas (Hectare)	Per cent of Decreased Areas (%)	Decreasing Rates (Hectare/year)
1961	367,900			
		55,200	15.00	3,943
1975	312,700			
		25,344	8.10	6,336
1979	287,356			
		18,662	6.50	3,110
1985	268,694			
		88,135	32.80	22,034
1989	180,559			
1961-1989		187,341	51.00	6,691

Mud crabs culture, however, have been promoted by Fisheries Department. Special focus on mud crabs culture such as, rearing of crab larvae, culturing of small mud crabs to a large - attainable size, and some aspect of their ecology have been widely investigated (Vaikul,et al 1972; Chayarat et al, 1976; Songtawontawee et al, 1979; Darooncho, 1988 and Chayarat, 1988). The stock assessment of this species in natural habitat, on the other hand, such as growth, recruitment pattern, and mortality rates; the reproductive biology such as the female size at first sexual maturity, and the peak of spawning season data are limited. These information are required in order to manage the mud crab resources with high efficiency in the future.

Ranong is one of the six provinces situated on the Andaman coast line of Thailand. The province lies between latitude 9° 21' to 10° 42' north and longitude 98° 24' to 98° 56' east. The mangrove forests in Ranong have been estimated to cover an areas of about 22,592 hectare. Klong Ngao mangrove forest is one of the mangrove areas located in Ranong province to be selected for studying the aspect of growth, recruitment, mortality and reproductive biology of mud crab (*Scylla serrata* Forskäl). Therefore the study on fishery biology of this species would benefit the management of mud crab natural population in this area as well as in others.

Objectives

The main objectives of this study are as follows:

1. To determine the growth of mud crab by using their length-

frequency data and the correlation between carapace width and weight of the species.

2. To determine the recruitment pattern and mortality rates in the population.

3. To describe the detailed histological changes of gonadal development of the female crabs.

4. To study sex - ratio between male and female crabs in the population.

5. To study the female size at their first sexual maturity in Klong Ngao estuarine area.

<u>Expected Result</u>

To obtain the baseline fishery biology data of the mud crab to:

1. Estimate the catchable size of mud crab from growth, recruitment and mortality analyses in order to control the stability of their population in Klong Ngao Mangrove Forest.

2. Estimate the possibility of mud crab spawning season around Klong Ngao Mangrove Forest from Gonado - somatic Index and sex - ratio

data. This will be beneficial for the establishment of the mud crab fishing time.

Literatures Reviewed

Systematic Classification

The systematic classification of mud crab is as follow;

Phylum	Arthropoda
Class	Crustacea
Subclass	Malacostraca
Superorder	Eucarida
Section	Macrura
Superfamily	Scyllaridea
Family	Syllara
Genus	Scylla
Species	serrata
Scientific name	***Scylla serrata*** Forskäl

(Branes, 1974).

<u>Natural Habitats</u>

The mud crab (*Scylla serrata* Forskäl) is the large Portunid crab, and occurs throughout tropical and warm temperate regions from the East coast of Africa to Okinawa, Australia, and in several groups of Pacific islands (Macnae, 1968; Motoh, 1977; Heasman, 1980). In Thailand, mud crabs are found along the coast both in the Gulf of Thailand and the Andaman sea, where they occur in estuary and mangrove areas.

It has been indicated that the mud crab occupies a wide range of habitats from the intertidal and the subtidal zone. They prefer to live in mud or sandy mud of the mangrove of estuarine area(Fielder, 1978). Each stage of the mud crab, especially the juvenile stage, seeks shelter areas such as in small creeks and channels, under stones, in sea-grass beds and between roots and pneumatophores of the mangrove trees(Hill et al.,1982). Smaller specimens are captured far up the creeks within the mangrove and large ones are found near to the sea or at the mangrove edge (Macnae, 1968). A study on the distribution of each stage of the mud crab on tidal flat in Australia showed that juvenile crabs of 20 - 90 mm. carapace width stayed in the mangrove zone, and remained there during low tide. Subadult crabs (100 - 149 mm.) migrate into the intertidal zone of to feed at high tide and retreat to subtidal zone at low tide. Small number of adult crabs (150 mm.- larger sizes) migrated into the intertidal zone of the mangrove, while most stayed mainly to subtidal zone(Hill et al., 1982)

Since the mud crab is a predator of a slow moving and sessile benthic invertebrates (Hill, 1976), migration into the intertidal zone would reduce intraspecific competition and also considerably extend the feeding area available to the population.

The burrows of the mud crabs are usually associated with mangrove and tidal creeks. They become less common inland and are seldom found beyond the landward limit of the mangrove. Most burrows extend into the ground almost exactly 30 degree to the horizontal to a depth at least 0.8 meter below the surface, and extend under the lowtide water level, and always contain some water. Such water is usually more saline and cooler than adjacent creek water, and nearly devoid of dissolved oxygen. Burrow appear to be a permanent structures which are used by successive generation of mud crabs and also protect them during molting and mating periods when they are vulnerable (Fielder, 1978).

Feeding Habits

Mud crabs are both scavengers and cannibalism (Ariola, 1940). They emerged from the burrow during an hour after sunset and buried again shortly before or within 30 min. after sunrise. They are thus obviously nocturnal animals. Analysis of the content of the foregut has been made in South Africa and Australia (Hill, 1976). It was shown that subadult and adult mud crabs fed mainly on mollusks and crustacean. Fish remains were found in the gut of a small number of specimens. However, in mud crabs trapped from fish ponds there were no fish remains, but the shrimp *Leander pacificus* was found (Hiatt, 1944).

Plant material is uncommon in mud crab foregut.Only in small specimens of 15 mm., the foregut were full of plant material. Gut of small crabs (less than 30 mm.) also contained mollusks and crustacean remains. It was therefore possible that plant material may form part of the diet of the juvenile crabs (Hill, 1976).

Reproduction

Mating Behavior

Internal fertilization occurs in mudcrabs (Ariola, 1940). Sex organ of 1.5 - 2.5 years crabs are highly developed ready for copulation. The female mud crab will release the pheromone into the water to attract the male crabs. After that, they begin to form pairs.

Mating takes place within the period of about 48 hour after the female mud crab molted. Spermatophore are transferred, via the male pleopods, and viable for many months. Copulation may takes more than 8 hours , after which the female right herself but remain beneath the male for another few days until the her exoskeleton is substantially harden. In natural habitats, it is possible that some of this mating behavior occurs in the burrow (Fielder, 1978).

Gonadal Development

Ovaries of the female mud crabs begin to enlarge and change color when they attain sexual maturity. It has been noted that immature ovaries are often translucent. When they become sexually mature, the ovaries initially become white and then tan. The immature oocyte of these ovaries are reticulated cytoplasm with little yolk present. As oocyte enlarge and mature, yolk globule form in cytoplasm and the ovaries become yellow, orange or reddish orange with the latter being the most common color (Quinn and Kojis, 1987). Apparently, there is no relationship between crab size and ovary color (Heasman, 1985).

Poovachiranon (1987) studied the relationship between abdominal width of female *S. serrata* and the development of each stages of ovary at Bangla, Phuket province. The development of ovary is divided into 4 stages by the change of ovary color, as follows:

Stage 1: A long narrow translucent strip of ovary is above the digestive gland.

Stage 2: The ovary begin to change color to creamy or pale yellow above the digestive gland.

Stage 3: The ovary becomes yellow, and covers 1/3 - 3/4 part of digestive gland.

Stage 4: The ovary covers most part of the digestive gland, and become orange or redish orange.

Poovachiranon also found that there were relationship between FMI (Female Maturity Index) and the development of each stage of ovary. When FMI values recorded at 0.88, the crab ovaries were at 2^{nd} - 4^{th} stages. The female gonads were developing when FMI values were at least 0.88 or the size of 11 cm. carapace width. He then proposed that 11 cm. should be legal size of mud crabs in the catches in order to protect this fishery resource.

Spawning & Larval Development

It is obvious that egg - berried female mud crabs migrate into the sea to spawn (Ariola, 1940; Hill,1983; Heaseman, 1985). They move out approximately 30 - 50 kilometers off shore, and extrude about 2 million eggs at a time. Female mud crabs can extrude repeat batches of egg without further copulation, but the second and third spawning are characterized by reduction in the number of eggs produced (Ong, 1966). The eggs take 12 -13 day to hatch into zoea larva, and stay where they feed, grows, and molts for around three weeks passing through four zoeal stages in the process. The fourth zoeal stage molt into the different larval stage called a megalopa which is about 4.5 mm. long. At this stage, the larvae have migrated close to the inshore water, probably by the current. Finally, the megalopa stage molts into a small crab instar, and moved into mangrove areas which are nursery ground to spend their lives in there (Chayarat et al.,1976; Songtawontawe et al., 1979; Hill, 1983).

Poovachiranon (in press) conducted biological studies of the crab, ***Scylla serrata***, in the mangrove ecosystem on Andaman Sea. He found that reproduction occurred throughout the year with the dominant peak from October to December. It was predicted that the spawning migration of mature female crabs mostly occurred during October to February. Poovachiranon (personal communication) also observed the spawning route off the Andaman coastline could be as far as 80 kilometers.

Aspect of Growth, Recruitment, and Mortality

Growth and Age Parameters

Growth describes the relationship between size (length, or weight) and age of an organisms (unit of week to years). In decapod, growth is accomplished almost entirely by molting. Life - spans in these decapods usually range from $<$ 1 to 1.5 year (many penaeids) to more than 50 year (*Homarus* spp.). Age can be determined indirectly from size frequency data after the construction of some sort of age - size key based on data from modal analysis or tagging experiments. This is clearly not an ideal situation. Tagging experiments in decapods are not the easy tasks due to hard parts used for aging are lost each time a decapod molts. Because size increase occur almost entirely at the time of molt, the measured of growth rate is made up of two components, size increase at molt and the time interval between molts. Thus estimation of decapod growth rate is difficult due to the discontinuous nature of size increase and lack of appropriate methodology for age determination. The data used to estimates growth rates generally are of three types;

- Length - frequency data, often from the commercial catch.
- Size increase during time at large from marking to recapture.
- A combination of separate estimates of molt increment and molt interval.

Length frequency can be used most effectively in short - live species in which cohorts are identifiable, such as shrimp.In long - lived species such as a lobsters, variability in growth among individuals can resulted in a disappearance of clear peak marking cohorts. In environments with marked seasonal variation in temperature, this will result in plurimodal age classes if for some members of a cohort. The "temperature sum" needed to complete molting is not attained by the end of the warm - water season (Cobb and Caddy, 1989). Additional variability may be introduced by other factors such as breeding seasons, multiple spawning, temporal or spatial variation in food availability. In particular, migration of mature shrimps may occur at or around maturity, and be scheduled in relation to the molt cycle (Boddeke et. al., cited by Cobb and Caddy, 1989). Various method have been suggested for the analysis of length - frequency data especially of size modes equivalent to age classes. Several techniques are employed to divide samples with many peaks into component age classes such as Cassie's method and Bhattacharaya's method (Sparre, 1985; Cobb and Caddy, 1989), lead to the analysis of the modal progression of age classes over several years.

Mark and recapture methods are conceptually simple, but they are time consuming and expensive. Various tags are available for crustaceans. Some tags are retained through ecdysis if implant at the rear of the carapace where splitting occurs on molting.

An estimation of molt frequencies and increments can be combined to determine growth rate as applied to lobsters, shrimps and crabs (Cobb and Caddy, 1989). Data are often obtained from tagging, but the proportion of molting in a population can be estimated by morphological changes over the molt cycle. There are three models generally used to describe growth; the von Bertalanffy growth function, the Gompertz function, and the logistic method. All describe asymtotic curves. When comparisons are made among the models, the von Bertalanffy model generally fit the data best, especially for short - lived species. The von Bertalanffy model historically has been the choice of fishery biologist because parameter of this model are easily applied in the Beverton and Holt yield formation. But this justification is less relevant now that more flexible and realistic formulation can be easily handle by small computer (Cobb and Caddy, 1989).

The von Bertalanffy growth model developed from Pütter's continuity relationship;

$$\frac{dw}{dt}=Hw^{n}-kw^{m}\text{.........(1)}$$

Where

dw = the difference of weights.

dt = the difference of times.

H = rate of synthesis or anabolism coefficient.

k = rate of destruction or catabolism coefficient.

n and m = constant.

The relationship states that growth rates of fish or an animals may be conceived as the difference between two process with opposite tendencies, one building up body substances (anabolism), and the other breaking down substances (catabolism). Both processes being proportional to some power (n,m) of body weight (w).

From this relationship, the model most commonly used in fishery biology to expect the growth of fisheries, the von Bertanlanffy Growth formula is derived. It is, for growth in length, assuming n = 2/3 and m = 1, the form;

$$L_t - L_\infty(1-\exp^{-K(t-t_0)}) \ldots\ldots\ldots\ldots (2)$$

and

$$W_t - W_\infty(1-\exp^{-K(t-t_0)}) \ldots\ldots\ldots\ldots (3)$$

where

L_t = the predicted size at age t.

W_t = the predicted weight at age t.

L_∞ = asymptotic length or the mean lengths the individuals would reach.

W_∞ = asymptotic weight or the mean weights the individuals would reach.

t = the age of an organisms.

t_0 = the age of an organisms would have at length or weight zero.

K = growth constant or curvature parameter.

Several methods of determining K and L_∞ can divided into those methods which;

1) Require an assessment of the species or the separation of size frequency data into age classes.

2) Those which are based on tagging or,

3) Cage studies where growth can be measured directly.

Tagging studies in the tropics are generally under utilized. The analysis of size frequency data is the more readily used and practical application as compared to the study of skeletal parts. The reason for this is that it is generally easier to analyses length frequency data than to study skeletal parts. In addition less equipment is needed in comparison to tagging studies (Pauly, 1983).

The Petersen Methods (sensu stricto) and the Modal Class Progress Analysis are two earlier methods that fall under the category of length - frequency data analysis. The Modal Progression Analysis sometimes leads to erroneous results because of the effect of long and repeated spawning seasons on the length frequency distribution (Pauly and David, 1981). Realizing these failures, the computer program called ELEFAN (Electronic Length Frequency Analysis) is developed to interprets length - frequency data. This computer program allows an estimation of the growth parameters of the von Bertalanffy Growth Formula.

<u>Recruitment</u>

In Fisheries Sciences, recruitment is defined most commonly as the number of fish of a single year group entering the exploitable phase of a stock in a given period by growth of smaller individual (Royce, 1972). It is defined also as the number of fish from a single year group arriving in an area during a given period where fishing is in progress even though the fish may be so small that chance of capture is negligible.

To estimate the rate of relative recruitment from length - frequency data, the micro - computer program called ELEFAN II can be used (Pauly, et al., 1981)

<u>Mortality</u>

Total mortality (Z) is the sum of instantaneous rates of natural mortality (M) and the instantaneous rate of fishing mortality (F) (Beverton and Holt, 1965; Sparre, 1989). The mortality can then be defined as;

$$Z=F+M..........(4)$$

where

Z = Total mortality rate

F = Fishing mortality rate

M = Natural mortality rate

Estimation of total mortality is based on a 'catch curve' in conjunction with a length - frequency sample. The catch - curve method of estimating total mortality is generally applied to animals that have been aged, using the relationship;

$$\log_e N = a + bt \text{..........} (5)$$

where

N = the number of fully recruited and vulnerable animals of a given age t.

a = constant.

-b = Z, the exponential rate of total mortality.

When animals cannot be aged individually, one could conceive of replacing N in equation (5) by the number of animals in a given length class and replacing t by the relative age (t') of the animals at the mid - length of that class ($L_{t'}$), where t' is obtained by solving the von

Bertalanffy Growth Formula (Pauly, Ingles and Neal, 1985).

$$t = \frac{\log_e(1-(\frac{L_t}{L_\infty}))}{-K} \ldots\ldots\ldots\ldots (6)$$

The natural mortality in decapod or other aquatic animal is a parameters that is difficult to estimate directly, despite its importance. It is usually expressed annually, and ranges systematically with longevity from around 0.1 in long - lived lobsters and crabs to M = 1.5 or even 2.0 in short - lived penaeid shrimps (Cobb and Caddy, 1989). To estimates natural mortality when the growth of animals can be described by the von Bertalanffy Growth Formular (VBGF), and if it can be assumed that the oldest of an animals of a given stock reach approximately 95 % of their L_∞ value, then the von Bertalanffy Growth Formula can be solved such that;

$$t_{max} \approx \frac{3}{k} \ldots\ldots\ldots\ldots (7)$$

where

K = the growth coefficient of the VBGF.

t_{max} = the longevity.

The natural mortality is related to longevity, hence to K is thus obvious(Pauly, 1987; Pauly, Ingless and Neal, 1985). Similarly, animals with small L_∞ (*ie.* animals that stay small) should have more predators than large size animal. Small animals generally have, for constant K, a higher natural mortality than large animals. Mean environmental temperature has been demonstrated to have a direct relationship with natural mortality. These interrelationships can then be expressed in the term of a multiple regression as follows;

$$\log_{10}M=-0.0066-0.279\log_{10}L_\infty+0.6543\log_{10}K+0.4634\log_{10}T\ldots\ldots(8)$$

where

L_∞ = asymtotic length expressed in centimeter.

T = mean environmental temperature

K = the growth constant based on an annual basis.

Once total mortality (Z) has been estimated from a catch curve and natural mortality (M) from equation (8), preliminary estimates of fishing mortality (F) can be estimated by subtraction;

$$F=Z-M\ldots\ldots\ldots\ldots(9)$$

The Compleat ELEFAN

The ELEFAN (Electronic LEngth Frequency Analysis) is a system developed by Dr. Daniel Pauly and associates since 1980 to allow estimation of the von Bertalanffy growth parameters based on the analysis of length frequency data. The system consists of a number of programs, such as ELEFAN 0, I, II, III, etc. (Pauly, 1987; Gayanilo, Soriano and Pauly, 1988). The programs have been widely disseminated since 1980. Many papers and reports have been published which relied predominantly or at least partly on this program, employed to a wide range of animals, from cold temperate to tropical, and from invertebrates to teleost fishes (Pauly, 1987). Several crustacea and other invertebrates have been studied by means of the program. The ELEFAN system has been improved until recently to the latest version called the Compleat ELEFAN to be used with microcomputer(Gayanilo, et. al., 1988).

In this study, the application of the ELEFAN Program to the size frequency data in mud crab population might prove useful in the population study of this valuable fishery resources. The size frequency data in *Scylla serrata* population is based on the measurement of carapace width, and weight. These measurements are accurately and easily obtained from catch data and field sampling.