CHAPTER I

INTRODUCTION

The Asian moon scallop *Amusium pleuronectes* (Linn.) is one among few species of economic bivalve mollusks, and is the only pectinid species which supports trawl fisheries in the Thai waters. Although no direct record in the Thai fisheries statistics on the annual harvest of this species prior to 1986 is available, direct observations and personal inquiries from various scallop's landing places suggested that this species has become an economically important species for over ten years. According to the 1986 Fisheries Record of Thailand (Department of Fisheries, 1988), the annual catch and value of the scallop were reported to be about 244 metric tons and 5,124,000 baht respectively. The whole production reported were from otter board trawls, and all of those 244 tons were obtained from the Gulf of Thailand. This reported quantity seemed to be too low comparing to the actual harvest. There were numerous minor landings of the species including from Andaman coast as well, which might be of substantial quantity.

In the Gulf of Thailand, the scallop *Amusium pleuronectes* is harvested throughout the year with seasonal peak of abundance during the months of May to November (Chungyampin, 1983; Thubthimsang, 1984). Scallops are harvested not only for human consumption purpose, but also for their shells which now can be used as a raw material for the shellcraft industry and lime manufacture. Scallop, although being mostly obtained scallops from the western part of the Gulf of Thailand as reported by Chungyampin (1983), ranged from 200-300 kg to sometimes as large as 2-3 tons per day. A smaller wholesaler of seafood market in Bangkok had an average sold amount of 100-200 kg per day. In another report (Thubthimsang, 1984), a daily amount of scallop entering cool-storage companies or seafood exporters located near the Marine Fisheries Division, Bangkok, which mostly got scallops harvested from the eastern part of the Gulf of Thailand, was about 20 tons per day. The wholesale price of fresh-on-shell scallop ranged between 10 to 30 baht per kg, but the production was seasonal and limited within only 6 months a year, May to October.

At present, scallop fisheries in Thailand is totally dependent on the existing natural stock, as there is no culture technology developed for this species yet. Thus, the need for conservation and management in harvesting of this species would result in making decisions to regulate catches of a stock which usually based on yield predictions (Heald and Caputi, 1981). Therefore, information on growth, mortality, and also recruitment of the stock is very vital for such decisions.

Studies on scallop in Thailand are still very limited. Moreover, none of those pertained to the study of growth, mortality and recruitment of the exploited populations. This study, therefore, aims to provide the basic informations hopefully to be useful for further stock assessment of the scallop, *A. pleuronectes*, population in Thai waters, as well as to provoke more investigations on the feasibility of the cultivation in the future.

recorded as the smallest in quantity of annual production, attained highest price (per kg.) comparing to other bivalve mollusks in Thailand (Table 1). Most of the scallops in Thailand are sold to the cool-storage companies through which they will be processed to shucked scallop and then sold to large restaurants or exported as frozen or chilled scallop with a sale revenue of several millions baht per annum.

Table 1 Record of the total catch and value of economic mollusks of Thailand in 1986.

Type	Quantity (tons)	Value (1,000 baht)	Average Price/kg (baht)
Bloody cockle	13,595	44,593	3.28
Green mussel	28,110	50,507	1.80
Oysters	1,439	14,425	10.02
Horse mussel	8,406	9,152	1.09
Short necked clam	101,232	291,690	2.88
Scallop	244	5,124	21.00
Other shellfishes	7,665	32,815	4.28
Total	160,691	448,306	2.79

(Source : Department of Fisheries, 1988)

The example of scallop production during seasonal harvesting months, May to November, of one seafood cool-storage company which

Objectives

1. To study the growth of the Asian moon scallop, *Amusium pleuronectes* (Linn.), in the Eastern Gulf of Thailand by estimating the population growth parameters: L_{∞} and K, of the von Bertalanffy growth formula, as well as to determine the relationship among shell dimensions, and size and weight relationship of the scallop.

2. To determine the mortality and recruitment pattern of *A. pleuronectes* population in the study area.

3. To study the reproductive cycle and gonadal development as well as the size at maturity of the scallop in the study area.

4. To study the occurrence of the pea crab *Pinnotheres* sp. associated with the scallop, as well as the effect of association.

Expectation

The data and result obtained from this study will eventually enable to :

1. provide the basic information on population growth, mortality and recruitment pattern, as well as on biological aspects, i.e. reproduction and association with other organism, of the Asian moon scallop *Amusium pleuronectes* (Linn.) in the eastern part of the Gulf of Thailand.

2. provoke interest in the assessment of the country's valuable fisheries resources which will lead to conservation planning and fisheries management, as well as to spur investigations into the feasibility of scallop cultivation in the very near future.

Review of Literatures

Bivalve mollusks of the Family Pectinidae all over the world, or widely known "scallop", have been identified to more than 300 different species. Most of the economic important ones were found disseminate in warm and temperate seas (Mottet, 1979). The majority of the world scallop production depends entirely on natural harvesting which has recently been declining considerably. Reports on annual world harvesting of scallop decrease from 834,186 tons in 1984 to 596,282 tons in 1985 (FAO, 1987). This decline is probably due to the over-exploitation and poor spatfall (Lovatelli, 1987). However, although the main production of scallop is from harvesting of the wild stock, a considerable portion of production now comes from active aquaculture which becomes more and more successful. As in 1984, Japan, the leader in scallop fisheries, produced 209,187 tons of *Patinopecten yessoensis* from natural harvesting and additional 73,948 tons from culture. At present, the production from aquaculture becomes to be more than 50% of the total production (Lovatelli, 1987).

Many species of scallop are harvested all over the world. The most important species in Japan is the giant ezo or Japanese scallop *Patinopecten yessoensis*. This scallop is a cold water species living in the northern areas of Honshu and Hokkaido Islands, which are the main culture areas. Other important species are the fan shell scallop *Pecten albicans*, and the queen scallop *Chlamys nobilis*. In the United States, the principal species of interest are the bay scallop *Argopecten irradians*, the calico scallop *A. gibbus*, and the purple-hinge rock scallop *Hinnites multirugosus*. In Canada, the giant scallop *Placopecten magellanicus* is the most important species in terms of harvested quantity. In European waters, valuable species are the king scallop *Pecten maximus,* and another queen scallop *Chlamys opercularis.* The species represented in the Victorian and Tasmanian catches are *Equichlamys bifrons, C. asperrimus,* and *P. fumata.* In Shark Bay, Western Australia, and in Central Eastern Queensland, the predominant catch is the saucer scallop *Amusium balloti.* Other commercially important species are the Pacific calico scallop *C. circularis* along the Mexican coast, *Argopecten purpuratus* in Chile, *C. patagonica* in Argentina, *C. islandica* in Iceland, *C. glabra* in Greece, *P. novaezealandiae* in New Zealand, and the Asian moon scallop *Amusium pleuronectes,* in Southeast Asia.

Several species of scallop have been induced into culture technology. With great successes of scallop aquaculture nowadays, many countries are now not only rely upon natural seeds, but also utilize artificially propagated or hatchery produced seeds.

General Characteristics of Scallop

Among over 300 species of pectinid bivalves, their characteristics are of great variations. The simple feature to differentiate the species are color of shell, shape and sculpture patterns. The most important taxonomic key features are the shape and dimension of the auricles, shape of the valves and type of radiating ribs.

Members in the genus *Amusium* found in Indo-Pacific region are classified by Habe (1964) to 2 species namely *Amusium pleuronectes* (Linn.) and *A. japonicum* (Gmelin). These two species are classified into 5 subspecies, i.e. *A. pleuronectes pleuronectes*, found in Ryukyu Island region (Japan), Formoza (Taiwan), China, Philippines, Thailand and Indonesia; *A. pleuronectes australiae*, found in New Guini and North Australia; *A. japonicum japonicum*, found in Honshu, Shikoku, Kyushu (Japan) and China; *A. japonicum formosum*, found in Ryukyu, Formoza and China; and *A. japonicum balloti* found in New Caledonia and Northern Australia.

Amusium pleuronectes, the Asian moon scallop (Figure 1), is described as having shell medium in size, attaining about 8-10 cm in length. The shell is thin, rather flat, circular shape with small auricles which are almost equal on each side of the umbo. The outer surface of shells is smooth and polished but with different colors. The left valve is reddish purple while the right one is white. The inner surface of both valves, light rosy white in color on the left and white on the right, has fine internal ribs radiate to the margin and obsolete to the umbonal areas, with 22-34 in number on the right valve. The number of internal ribs is a key feature to distinguish *A. pleuronectes* from *A. japonicum*, as the latter species has larger number of 42-54 ribs.

Scallops also differ with regard to the environmental niches they occupy. The niches are not determined by food preferences as with many other filter feeders, but by the bottom composition and depth (Lovatelli, 1987).

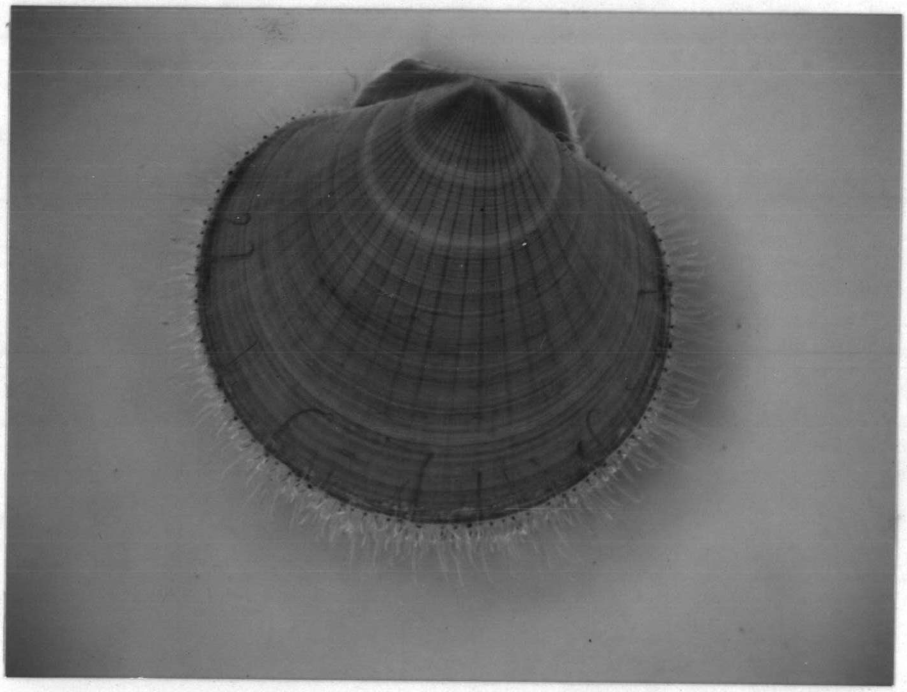

Figure 1 The Asian moon scallop, *Amusium pleuronectes* (Linn.).

Distribution and Abundance of Scallop in Thai Waters

Scallops or pectinid bivalves found in the Gulf of Thailand have been reported to be of 6 genera, 11 species (Thubthimsang, 1984). Among those, only *A. pleuronectes* is most abundant and important for Thai economics. This scallop can be found in both the Gulf of Thailand and the Andaman sea, in the habitat of 10-40 meters depth, with sea floor composed of sandy mud, muddy sand or sand. It is found most abundant in muddy sand or sandy bottom surroundings with 20-30 meters of water depth. Thubthimsang (1984) reported that *A. pleuronectes* was widely found and densely distributed in the areas from Sattaheep; Chonburi Province, to Samed Island; Rayong Province on the eastern coast, and from Samroiyod to Tabsakae; Prachuap Khiri Khan Province on the western coast of the Gulf of Thailand. The most abundance season of scallop harvesting was in May-October for the eastern coast and in October-November for the western coast of the Gulf of Thailand.

The Chang Islands, as being the selected area for this study, is also one of the main fishing grounds of scallop in Thai waters. Catching rate reported from fishery investigation conducted by the Governmental Marine Fisheries Division in 1980, by using an otter board trawler in one trawling station, between Koh Mak and Koh Kood, had reached as high as 19 kg per hour (Thubthimsang, 1984).

Growth of Scallop

Growth of shellfish is often described in the form of growth rates over a certain time period. The mean length or weight of two consecutive samples are recorded. This form of growth assessment implies that the recorded means are representative of the general growth of the entire population. This assumption is most probably applicable whenever the measured materials have a normal distribution. However, in case where the variable is distributed with more than one modal class, the arithmetic mean of the sample becomes increasingly unsuitable to be used in growth analysis (Tuaycharoen, Vakily, Saelow and McCoy, 1988). Thus, the use of the parameters of the "von Bertalanffy Growth Function" has been employed to describe the growth performance.

Growth of fish, or aquatic invertebrates, may be defined as the change over time of the body mass, or body weight (Pauly, 1984), conceived as the difference between two processes with opposite tendencies, one building up body substances or "anabolism" and the other breaking these substances down or "catabolism". Both processes are proportional to some power (d, m) of body weight (w), as :

$$dw/dt = Hw^d - kw^m \quad \text{.........................(1)}$$

where : dw/dt = the change in body weight per unit time

H = the coefficient of anabolism

k = the coefficient of catabolism

Base on this relationship, the von Bertalanffy Growth Function (VBGF) was derived by assumming $d = 2/3$ and $m = 1$. As the anabolism is proportional to metabolic rate when catabolism is proportional to weight itself and metabolism is proportional to 2/3 of the weight, according to von Bertalanffy's "2/3 Law of Metabolism" (Pauly, 1982).

The VBGF is expressed in the form :

$$L_t \quad = L_\infty(1 - e^{-K(t-t_o)}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

for growth in length, and :

$$W_t \quad = W_\infty(1 - e^{-K(t-t_o)}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

for growth in weight, where L_∞ and W_∞ are asymptotic sizes or the mean sizes the fish would reach if they were to grow indefinitely, K is a growth constant, and t_o is the age the fish would have at length or weight zero if they had always grown according to the equation, L_t and W_t are the predicted sizes at age t.

The VBGF, as being considered the most commonly used model in fishery biology, is widely accepted to express the growth of fish or other aquatic invertebrates included bivalve mollusks (William and Dredge, 1981; Heald and Caputi, 1981; del Norte, 1986; Llana, 1988, etc.). Jones (1981) stated that this model can fit most of the observed data of fish growth and it can be incorporated readily into stock assessment models. Pope and Mason (1980, quoted in del Norte, 1986) reported comparison of the von Bertalanffy and Gompertz equation [$Y_t = Y_\infty \exp(-b_e - K_t)$] to be used for studying the growth in *Pecten maximus* and *Chlamys opercularis.* They found that although the Gompertz curve also gave a good description, the von Bertalanffy curve was undoubtedly the better for the latter part of the scallops' growth curve, which is a more important part from the population dynamics point if view.

Growth of fish or aquatic invertebrates is known to be affected by environmental condition. The growth of fish oscillates seasonally, especially in sub-tropical and temperate waters. Therefore, Pauly and Gaschutz (1979) had presented the modified VBGF as seasonalized version to express the seasonally oscillating growth of fish. This seasonalized VBGF is :

$$L_t = L_\infty \{1 - e^{-[K(t-t_o) + (CK/2\pi)\sin(2\pi(t-t_s))]}\} \quad ....(4)$$

while C expresses the amplitude of the growth oscillations, and t_s is the start of the sinusoid growth oscillations with respect to $t = 0$; $t_s + 0.5$ = winter point (WP) or the time of the year when growth is slowest (Pauly, 1984).

Several methods have been used to determine the growth performance of scallops. Many studies dealt with interpretation of growth rings on the valves of, and which restricted to, the temperate species, e.g. *Pecten maximus* (Mason, 1957; Baird, 1966), *Chlamys varia* (Conan and Shafee, 1978), and several other species (Heald and Caputi, 1981). Besides studying growth ring on shells, the growth checks in resilium of scallop was also analyzed in *Placopecten magellanicus* (Merril, Posgay and Nichy, 1966, quoted in Heald and Caputi, 1981). From several works, the annual nature of the growth rings was verified. The first growth ring in *Chlamys opercularis* was reported to occur when the scallop is a little more than 1 year old (Taylor and Venn, 1978).

Tagging is another method used in growth analysis of scallops. The method has been applied with various techniques, e.g. with Petersen discs, celluloid discs, and plastic strips stuck on to scallop shell. Heald (1978) reported the successful method of marking *A. balloti* by using plastic tag and alpha-cyanoacrylate adhesive, compared to other tagging techniques. The tagging-recapture method has been used effectively to assess the growth of many commercially-exploited species of scallops with reasonable success.

Size frequency analysis is another method for growth determination. The use of size frequency distribution to determine the growth of scallop is stated to be the more readily used and is a practical method to apply in the tropics (del Norte, 1986). Heald and Caputi (1981) reported that attempts to age *Amusium* valves have proved unsuccessful to date because growth checks are not obvious on the valves. Fortunately, *Amusium* is well-suited to the use of height-frequency data to determine size at age, because it is short-lived and has few age classes. If overlap occurs, the distributions can be reliably separated. They also stated that the analysis of height-frequency data may be satisfactory for short-lived species with distinct year classes, but in medium to long-lived species, this group of methods are rarely sufficient for reliable assessment due to its subjectivity.

The methods conventionally used for the analysis of length-frequency data, originally introduced by Petersen since 1891 (Pauly, 1982, 1987), can be distinguished to two basic techniques :

- The "Petersen method", that is the attribution of relative ages to the peaks of length-frequency sample.

- The "modal class progression analysis" (George and Banerji, 1964, quoted in Pauly, 1982), that is the linking up of the peaks of length-frequency samples sequentially arranged in time by means of growth segments.

With the Petersen method, the problem consists of identifying those peaks representing broods spawned at known or assumed time intervals, thus generating questionable results. The modal class progression analysis has its major problems in the identification of those peaks which should be connected with each other by growth line. This method sometimes leads to erroneous results due to the effects of long and repeated spawning seasons on length-frequency distributions (Pauly, 1980b, 1982).

To improve the reliability of growth estimates base on the analysis of length-frequency data, a combination of those two earlier methods into one called "integrated method" was suggested (Pauly, 1978, 1980b). With this new method, the "ELEFAN" (**E**lectronic **LE**ngth **F**requency **AN**alysis) microcomputer program has been developed (Pauly and David, 1981).

Del Norte (1986) studied the growth of scallop *A. pleuronectes* in the Lingayen Gulf, Philippines, by estimating the VBGF growth parameters from length-frequency data, with length refered to shell height, using ELEFAN microcomputer program. The result showed that growth parameters estimates for L_∞ was 10.6 cm and K was 0.92 per year. Llana (1988) also reported the growth estimates for the same species in Visayan Sea, Philippines, by using ELEFAN program led to the growth parameters, L_∞ = 10.0 cm and K = 0.94 per year.

Mortality

The number of individuals in a population cohort decreases by death from all causes. A basic equation used in fishery biology for expressing the mortality of fish is :

$$N_t = N_o e^{-Zt} \qquad \text{.................................(5)}$$

where N_o and N_t are fish numbers at time zero and t, respectively, and Z is the total mortality affecting the stock (Pauly, 1982).

Total mortality (Z) is the sum of natural mortality (M) and fishing mortality (F), that is :

$$Z = F + M \qquad \text{..................................(6)}$$

Natural mortality involves all ages and sizes of scallop and affects both exploited and unexploited stocks. Fishing mortality includes the shucking of scallops for market (direct fishing mortality) and other killings that take place incidental to capture (indirect fishing mortality). Fishing mortality occurs only in exploited stocks but may involve animals of all sizes and affect recruitment.

Natural mortality (M) can be estimated by computing an averaged M/K ratio from bivalve literature and subsequently comparing this value to the K value derived from the length-frequency data for particular species in question (Dr. D. Pauly, personal communication, April, 1988). By this method, del Norte (1986) estimated the M of *Amusium pleuronectes* to be 1.4 resulting from data in Table 2.

Total mortality (Z) can be computed by using the ELEFAN II, in the Compleat ELEFAN microcomputer program (Gayanilo, Soriano and Pauly, 1988). The program converts length-frequency data to catch curves given inputs of K and L_∞. The right-hand slope of the catch curve, with the sign changed, gives an estimate of total mortality, i.e. the sum of the natural and fishing mortalities. Substracting the estimate of natural mortality (M) from Z gives the value for the fishing mortality. According to Munro (1983), this is an excellent method of deriving estimates of total mortality and related information.

Table 2 Values of natural mortality (M) and growth coefficient (K) from different bivalves, used to compute M estimate for *Amusium pleuronectes*. (After del Norte, 1986)

SPECIES	M	K (per year)	M/K	REFERENCE
Tridacna maxima	0.21	0.074	2.84	Munro & Heslinga (1982)
T. maxima	0.15	0.132	1.14	McKoy (1980)
Tapes philippinarum	0.2005	0.9125	0.22	Yap (1977)
Amusium pleuronectes	1.29	0.92	1.4 (mean M/K)	del Norte (1986)

Recruitment

Recruitment, in fishery sciences, 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 individuals, or 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.

Interpretation of recruitment patterns may be base on spawning patterns on histological bases. Conan and Shafee (1978) stated that the biannual recruitment in *Chlamys varia* is due to a yearly "double spawning" pattern in spring and autumn.

Estimation of the rate of recruitment and determination of recruitment pattern were also viable through the analysis of length-frequency data by the ELEFAN II program.

The Compleat ELEFAN

The "ELEFAN" or **E**lectronic **LE**ngth **F**requency **AN**alysis is a system developed by Dr. Daniel Pauly and associates since 1980 to allow estimation of the fish population growth parameters based on the analysis of length-frequency data. The system consists of a number of programs, such as ELEFAN 0, I, II, etc. (Pauly, 1987; Gayanilo, et.al., 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 bivalves also have been studied by means of this program, including scallops *Amusium pleuronectes* (del Norte, 1986; Llana, 1988). The ELEFAN system has been improved until recently to the latest version called the Compleat ELEFAN to be used with IBM-compatible microcomputer (Gayanilo, et.al., 1988).

The VBGF considered in the ELEFAN program is the modified version (equation 4) to express seasonally oscillating growth of fish or aquatic invertebrates proposed by Pauly and Gaschutz (1979).

Size and Weight relationships

In fisheries research, measuring the length and weight are standard tasks and the data obtained are the backbone of many models used in fish (or aquatic animals) population dynamics (Vakily, Tuaycharoen and Nugranad, 1988). Such applications accomplish from growth estimates to the prediction of potential harvest.

Relationships among different dimensions of the shell

In the growth study carried out on many species of scallops, the correlation between linear dimensions of the shell have also been performed. Results obtained from study on *Pecten maximus* showed a high degree of correlation between length (dorso-ventral axis), breadth (anterio-posterior axis) and thickness of the scallop shell (Mason, 1957). According to that study, Mason further stated that the scallop grows proportionately in all dimensions and retains virtually the same shape throughout its life, with the exception of a concavity on the upper valve during the first year.

The relationships between different morphometric shell dimensions of scallop are expressed in the linear regression form :

$$Y = a + b X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where X usually refers to shell height (dorso-ventral axis), and Y can be any dimensions of the shell.

Conan and Shafee (1978) compared the allometric relationships between lengths and widths of the shell of the two groups, spring and autumn recruited individuals of *Chlamys varia*. They reported that there were no significant morphometric differences between the two groups of samples.

Length-Weight Relationship

The relationship between the length (L) and the weight (W) of fish, as well as scallop, can generally be expressed by the equation :

$$W = a\ L^{b} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where a is a proportionality constant and b is a power whose possible values lies between 2.5 and 3.5 (Carlander, 1969, cited by Pauly, 1982). When $b = 3$, weight growth is called isometric, meaning that it proceeds in the same dimension as the cube of length. When b is not equal to 3, weight growth is called allometric, meaning that it proceeds in a different dimension or differing from L^3, and can be either positive ($b > 3$) or negative ($b < 3$).

The equation (8) can be written in the linearized form :

$$\log W = \log a + b \log L \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

by which the value of a and b can be estimated by means of a linear regression.

Williams and Dredge (1981) studied *Amusium japonicum balloti* Habe, or *A. balloti* (Bernardi), from the Central Eastern Queensland and reported an allometric relationship between shell height and adductor muscle weight. Heald and Caputi (1981) determined the interrelationships of shell height, whole weight and meat yield for summer and winter samples of *A. balloti* from Shark Bay, Western Australia, and found slight seasonal differences in meat recovery.

Reproduction

Studies on reproduction of scallops have been reported for many species, including *Amusium pleuronectes* (MacDuff, 1975; quoted in Dredge, 1981; Llana and Aprieto, 1980; del Norte, 1986). The scallop *A. pleuronectes* is a hermaphroditic species. Thus, according to Fretter and Graham (1964), it produces gametes of both male and female types either at the same time or else first of one sort and later of the other. The testicular and ovarian parts in the gonad of *A. pleuronectes* are separated from each other, as the former is proximal and lightly colored adjacent to the foot of the animal, while the latter is distal and darker colored (Llana and Aprieto, 1980).

In contrast with *A. pleuronectes*, the closely related species, *A. japonicum balloti* is reported to be normally a gonochoristic or dioecious (Dredge, 1981; Heald and Caputi, 1981), however, the incidence of bisexual or hermaphrodite also occurs in some specimens.

One method for reproductive studies is to determine extent of maturation via gonad color and condition changes observed macroscopically. In the gonad of *Pecten opercularis*, active ovaries are reported as having bright scarlet or rich vermilion color and ripe testes as creamy, spent or resting gonads are transparent and colorless (Amirthalingham, 1928). Sastry (1963), and Castagna and Duggan (1971) indicated the ripe stage gonadal colors as pink to deep orange to bright reddish-orange in *Aequipecten irradians*. Roe, Cummins and Bullis (1971) also pointed out that ripe ovaries of *Argopecten gibbus* were bright reddish-orange in color.

In many studies on the reproductive cycle of scallops, the cycle has been divided into a number of stages based on microscopic examination of histological sections of the gonads. In the work of Llana and Aprieto (1980), histological sections of some gonads at each stage were made to conform the gonadal stages determined macroscopically. They designated five developmental stages, I, II, III, IV, and V, according to particularly the color and condition of the gonad, and then later grouped into three, namely: Immature (Stages I & II), Mature (Stage III) and Spent (Stages IV & V). Dredge (1981) compared the microscopic and macroscopic classification of gonad stages of *Amusium japonicum balloti*, and stated that the macroscopic criteria led to some inaccuracies in describing gonad development, particularly for the earlier stages of development.

The extent of gonad development may also be determined through a quantitative measurement of gonad index [(gonad weight/body weight) x 100]. Sastry (1966, 1970) determined the gonad index for samples of *Argopecten* (*Aeguipecten*) *irradians* populations collected at intervals during the year and described the trend of events in the reproductive cycle. The gonad index for the population increased following the vegetative phase and reached the maximum just before spawning. The gonad index decreases during spawning and remains subsequently at a low level during the resting period.

Giese (1959, quoted in Dredge, 1981) suggested that the most suitable method for determining periodicity of reproductive activity in marine invertebrates is to make periodic histological examination of gonads.

Gametogenic cycles may occur among populations of a species on an annual, semi-annual, or continuous basis. The timing and duration of the gametogenic cycle and the number of cycles within the year may be a characteristic of specific population (Sastry, 1979). *Amusium pleuronectes* was reported to have a protracted or expanded spawning, that is, it is able to breed throughout the year (Llana and Aprieto, 1980). In *Argopecten irradians* (Sastry, 1966; 1970) and *P. magellanicus* (Naidu, 1970), the gametogenic cycle occurs on an annual basis. *Hinnites multirugosus*, the purple-hinge rock scallop in the San Diego area, was confirmed to reproduce semi-annually (spring to early summer and mid-fall to early winter) in Mission Bay area (spring and mid-fall) and Point Loma area (early summer and late fall) (Leighton and Phleger, 1981).

Association with Pea Crab

Llana (1979) reported the occurrence of the pea crab *Pinnotheres* sp. in mantle cavity of scallop *A. pleuronectes* in the Visayan Sea, Philippines, and stated that the occurrence was seasonal with most abundant in January. The gonads of infested scallops were somewhat deformed in outline and slightly smaller than gonads of uninfested individuals of the same size.