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Gonadal Development, Age and Growth of the Shortnecked Clam, *Ruditapes philippinarum* (Pelecypoda: Veneridae), on the Coast of Kimje, Korea

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=국문요약=

金堤沿岸에 棲息하는 바지락, *Ruditapes philippinarum* (Pelecypoda: Veneridae)**의 生殖巢發達과 年齡 및 成長**

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1993년 2월부터 1994년 1월까지 1년간에 걸쳐 西海岸의 全羅北道 金堤郡 심포 潮間帶에서 採集된 바지락 *Ruditapes philippinarum*을 대상으로 組織學的 方法에 의해 生殖巢發達 및 産卵期를 조사하였고, 이들 個體群의 年齡 및 成長을 조사하였다. 조사된 결과는 다음과 같다.

바지락은 雌雄異體이며, 生殖巢는 內臟囊의 肝中腸腺下部와 足部의 網狀結體組織 사이에 위치하고 있었다. 卵巢는 수많은 卵巢小囊으로 되어 있었고, 精巢도 수많은 精巢細管으로 구성되어 있었다. 産卵期는 6월 초순에서 10월 초순까지이었고, 主産卵은 수온이 23℃ 이상인 7월과 8월 사이에 일어났다.

成熟卵의 크기는 약 65~70 um였으며 生殖巢發達段階는 分裂增殖期 (2~3월), 成長期 (4~5월), 成熟期 (4~9월), 放出期 (6~10월), 退化 및 休止期 (7~3월)의 연속적인 5단계로 구분할 수 있었다.

바지락의 貝殼에 나타나는 輪紋은 年1回 형성되며 輪紋 形成時期는 3월로 조사되었다. 初輪 形成期間은 8個月 (0.67年)로 나타났다.

殼長 (SL: mm)과 體重 (TW: *g*)間의 관계는 $TW = 1.208 \times 10^{-4} SL^{3.158}$로 비선형의 멱함수 (power function)로 나타났으며, 殼長 (SL: mm)과 殼高(SH: mm)間의 관계는 $SH = 0.726\ SL - 0.483$, 殼長 (SL: mm)과 殼幅 (SW: mm)間의 관계는 $SW = 0.542\ SL - 1.803$의 직선으로 나타났다.

年齡 (t)에 대한 殼長 (SL_t)의 Bertalanffy 成長式은 $SL_t = 68.34\ (1 - e^{-0.221(t+0.418)})$ 年齡(t)에 대한 體重 (TW_t)의 Bertalanffy 成長式은 $TW_t = 75.16\ (1 - e^{-0.221(t+0.418)})^{3.158}$ 이었다.

INTRODUCTION

The shortnecked clam, *Ruditapes philippinarum* (Pelecypoda: Veneridae) is distributed in the coast of Korea, China, Japan, northwestern coast of America, *etc.* (Loosanoff and Davis, 1963; Anderson, 1982). Especially, this clam is found in silty sand in the intertidal zone in the southern and west coast of Korea (Yoo, 1976; Kwon *et al.*, 1993), and it is one of the important edible bivalves.

However, in connection with the recent sharp reduction in the standing stock by marine pollution, reclamation work, and reckless overcatching of this clam, it has been noted as a target organism that should be managed by the reasonable fishing regime. Regarding Korean and Japanese shortnecked clam, there have been many previous studies on the morphology including morphological variations of the larvae (Choe, 1965; Kim, 1973), on the physiological studies including mortality (Choe, 1966a, b), resistance (Ikematsu, 1956; Kurashige, 1942a, b), ciliary activity (Choi and Lee, 1961), on ecology including growth (Kurashige, 1943a; Choi, 1964a; Ikematsu, 1957a; Yamamoto and Iwata, 1956; Hur, 1994), distribution (Ikematsu, 1957b), drilling (Choi, 1962, 1964b), early life history of the larvae (Yoshida, 1935, 1953), population dynamics and secondary production (Ohba, 1965; Kim, 1986; Choi, 1987; Yoon, 1992), on reproduction including artificial discharge (Iwata, 1948 ; Sagara, 1958), the spawning season (Kinoshita, 1939; Korean Central Fisheries Experiments Station, 1939; Tanaka, 1954 ; Yasuda *et al.*, 1954; Momoyama and Iwamoto, 1979), histological note on the gonads (Ko, 1957), development (Miyazaki, 1936), on the aquaculture including cultivation (Hatanaka *et al.*, 1943; Yasuda and Takamori, 1952) and seed production (Won, 1994). There are still disagreements in our knowledge and little information is available on this subject.

Regarding of the spawning seasons of the shortnecked clam, some researchers have reported that the spawning seasons are twice a year in spring and autumn in Sasebo Bay by histological investigation (Ko, 1957; Nishikawa *et al.*, 1967), and was twice a year in Aiti-ken, Tiba-ken, Kumamoto-ken, Japan by the measurement of fatness and morphometric data (Yasuda *et al.*, 1954), while they assumed that those are once a year in summer in Korea and Hokkaido, which is located in northern part of Kando district, Japan (Momoyama and Iwamoto, 1979). Therefore, in order to figure out the frequency and timing of their spawning, it should be confirmed correctly by histological study.

To maintain maximum sustainable yield through the reasonable fishing regime, it is necessary that ecological dynamic rules should be determined. Studies on the age determination (characters), and growth, reproduction of the clam in relation to numerical dynamics are first to be conducted in the population dynamics point of view to understand these rules (Zhang, 1991). Therefore, the main purpose of this study was to identify gonadal development, spawning, age characters (annual ring formation on the shell) and growth, using histological and morphometric procedures.

MATERIALS AND METHODS

Specimens of the shortnecked clam, *Ruditapes philippinarum* were collected monthly at the intertidal zone of Simpo, Kimje-gun, Korea from February 1993 to January 1994 (Fig. 1).

A total of 1,370 clams, ranging from 7.0 mm to 45.0 mm in shell length, were used for gonadal development by the histological study and growth study (Table 1). After the clams were transported alive to the laboratory, shell lengths and shell heights of the clams were measured by the Vernier caliper, and their

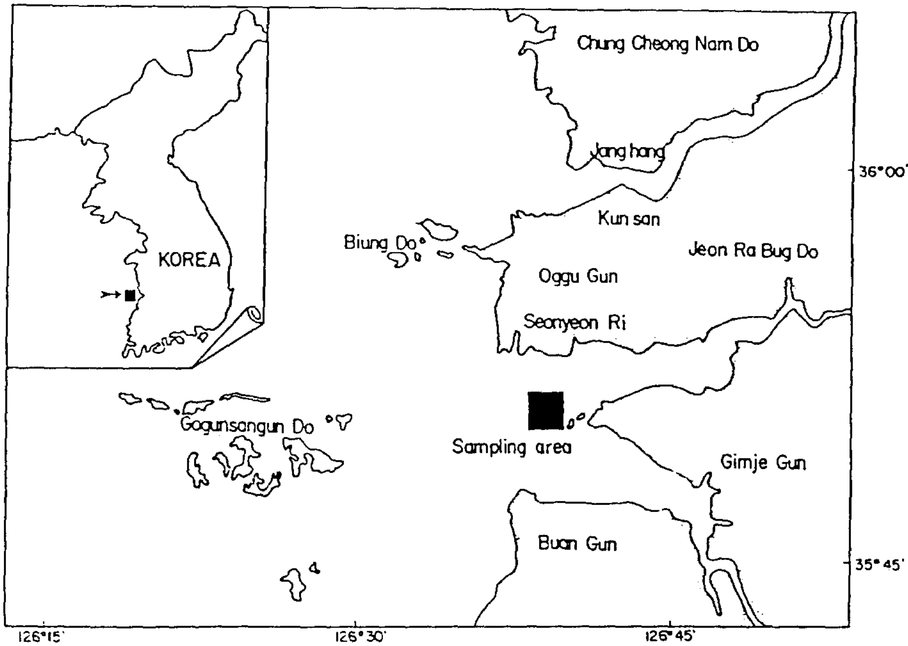

Fig. 1. Map showing the sampling area.

Table 1. Sampling data and number of specimens of *Ruditapes philippinarum*

Sampling date	No. of specimens
Feb. 27, 1993	125
Mar. 26, 1993	87
Apr. 26, 1993	130
May 29. 1993	120
June 30, 1993	119
July 30, 1993	125
Aug. 25, 1993	89
Sep. 25, 1993	151
Oct. 30, 1993	142
Nov. 30, 1993	102
Dec. 24, 1993	101
Jan. 30, 1994	79
Total	1,370

total weight were weighted using a chemical balance.

Analysis of the gonadal phases was made by light microscopical examination of histological preparations. The tissues were subjected to standard histological procedures (dehydrated in alcohol and embedded in paraffin). Embedded tissues were thin-sectioned (5~7 um) on a rotary microtome. Sections were mounted on the glass slides, stained with Hansen's hematoxylin-0.5% eosin, Mallory's triple stain and PAS stain, and examined using a light microscope.

The relationship between shell length (SL) and total weight (TW) was analysed by multiplicative equation. And, the relationships between shell length and shell width (SW) and between shell length and shell height (SH) were analysed by the liner regression equation.

The model for the marginal index (MI') was adopted in this study whether the periodic rings on the shell observed by a light projec-

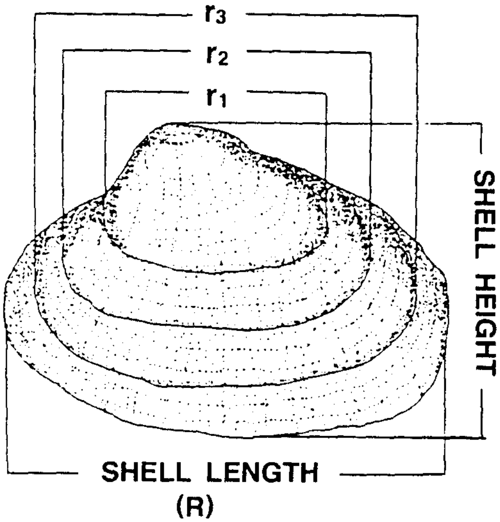

Fig. 2. Illustration of the measurement of annulus on the shell of *Ruditapes philippinarum.*

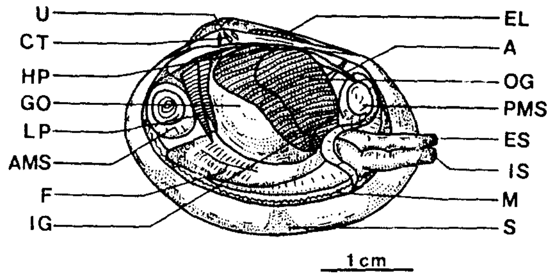

Fig. 3. Anatomy of *Ruditapes philippinarum.* Abbreviations; A: anus, AMS: anterior adductor muscle scar, CT: cardinal tooth, EL: external ligament, ES: excurrent siphon, F: foot, GO: gonad, H: hepato-pancreas, IG: inner gill, IS: incurrent siphon, LP: labial palp, M: mantle, OG: outer gill, PMS: posterior adductor muscle scar. U: umbo.

tor are suitable as the age characters of the clam employed. To confirm the relationship between shell length and ring radius, period of the ring formation and periodicity were investigated. Ages of the clams were determined by counting ring marks on the shell.

To investigate monthly changes in marginal growth on the shell, monthly marginal index (MI') were calculated in this study (Fig. 2). The formula is as follows:

$$MI' = (R - r_n)/(\overline{r_{n+1}} - \overline{r_n})$$

where, R: shell length, r_n: the rn ring radius, $\overline{r_{n+1}}$: mean length of the r_{n+1} ring, $\overline{r_n}$: mean length of the r_n ring.

To measure shell length and total weight during the period of the ring formation, total weight during the period of the ring formation was calculated by the mean shell length, and growth curves for shell length and total weight fitted to the von Bertalanffy's equation were expressed as:

$$SL_t = SL_\infty \ (1\text{-}e^{-k(t-t0)})$$

$$TW_t = TW_\infty (1\text{-}e^{-k(t-t0)})^3$$

where, SL_t=shell length (mm) at age t, SL_∞= theoretical maximum shell length, k=constant expressing rate of approach to SL_∞, t_0=theoretical age at which SL = 0 mm, TW_t=total weight (g) at age t.

RESULTS

1. Morphology and structure of the gonad

Ruditapes philippinarum is dioecious in sex. The gonads are located between the subregion of the mid-intestinal glands and the reticular connective tissue of the foot (Fig. 3).

The ovary is composed of a number of ovarian sacs, and the testis is composed of numerous seminiferous tubules. Even during the period of maturation progress, the sex of the clams can not be distinguishable easily by external features because mature ovary and testis are all pinkish white in color. However,

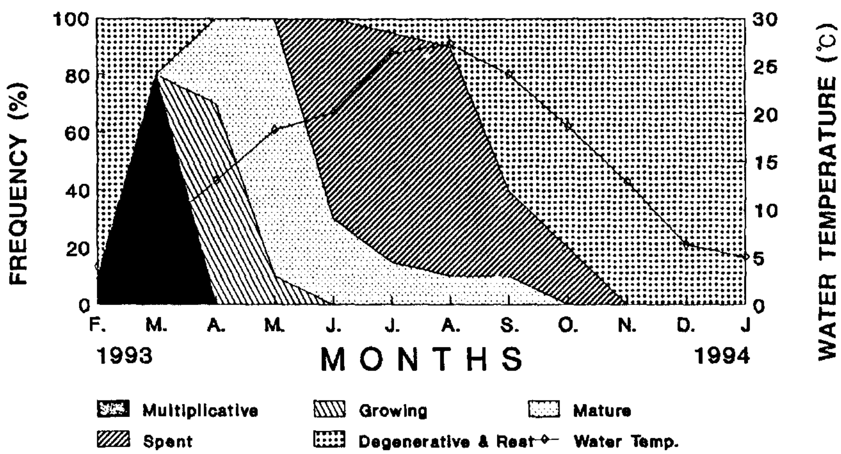

Fig. 4. Frequency of gonadal phases of *Ruditapes philippinarum*, and the mean sea water temperatures from February 1993 to January 1994.

if they are slightly scratched, ripe eggs and milky white sperms readily flow out. Therefore, the sexes of the clams can be distinguishable easily by observation of their gametes under the light microscope.

2. Gonadal development by the gonadal phase

Based on the morphological features and the sizes of the germ cells, and the tissue cells around them, the gonadal phases can be classified into five successive stages (Fig. 4). The stages and the criteria used in defining them are as follows;

Multiplicative stage: In females, the ovary is composed of a number of ovarian sacs. Oogenesis occurs in the ovarian sacs of the ovary. Oogonia propagate in the germinal epithelium of the ovarian sacs and have a round nucleus containing a nucleolus. The oogonia are about 10~12 μm in size (Fig. 5A). At this time, a number of eosinophilic cells and undifferentiated mesenchymal tissue can be seen along the germinal epithelium.

In males, the testis is composed of several seminiferous tubules. Spermatogenesis occurs in the seminiferous tubules of the testis. Spermatogonia are about 8 μm in diameter, and appear in a row along the germinal epithelium (Fig. 6A). Connective tissues begin to develop among the seminiferous tubules. The individuals in the multiplicative stage appear from February to March when sea water temperatures are very low.

Growing stage: In females, the lumen is still empty during this stage. A number of early growing oocytes, ranging 15~20 μm in diameter, appear in the ovarian sacs in the early growing stage. The nuclei have a diameter of 7~12 μm. When the oocytes grow to 30~40 μm in diameter, each oocyte has an egg-stalk attached to the germinal epithelium (Fig. 5B). The nuclei enlarge and have amphinucleolus involving in yolk formation : karyosome and plasmosome (Fig. 5C). Especially, karyosome is stained uniformly with eosin, which separated from amphinucleolus, and extruded into the cytoplasm through the

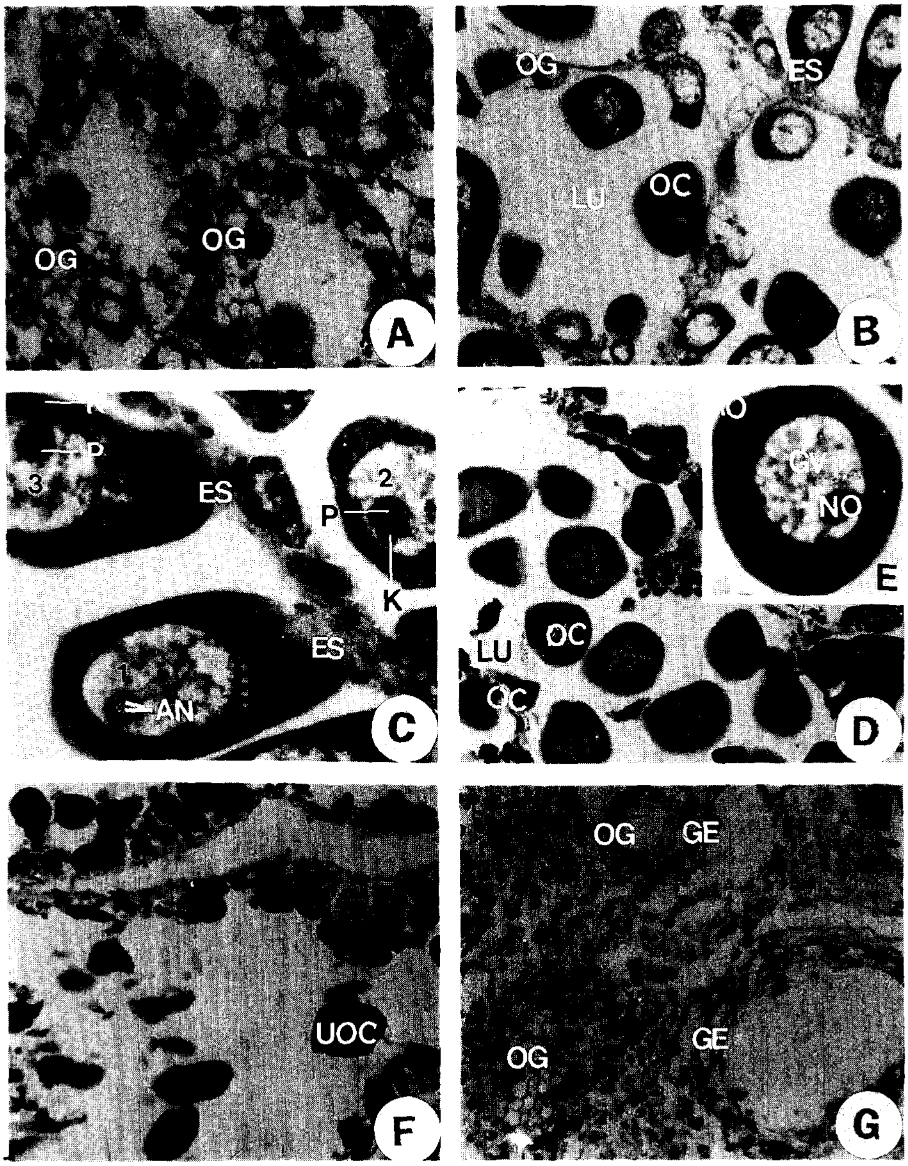

Fig. 5. Gonadal phases of female *Ruditapes philippinarum* as seen by light microscopy.
A, Transverse section of an ovary in the multiplicative stage. ×300. Note proliferation of small oogonia (OG). B, Section of the ovarian sacs in the growing stage. ×300. Note the early growing oocytes and egg-stalk (ES) of growing oocyte (OC) in the lumen (Lu) of the ovarian sacs. C, Section of ovarian sacs magnified in the same stage as above mentioned. ×600. Note movement of amphinucleolus (AN) (karyosome (k) and plasmosome (p)) in the nucleus of oocytes with egg-stalk (ES); D, Section of ovarian sacs in the mature stage. ×150. Note mature and ripe oocytes (OC) in the lumen (Lu) and thin layer of germinal epithelium (GE); E, a fully ripe oocyte (RO) in the mature stage. ×430. Note a nucleolus (NO) in the germinal vesicle (GV) and numerous yolk granules in the cytoplasm. F, Section of the ovarian sacs in the spent stage. ×300. Note the presence of a few undischarged oocytes (UOC) and residual substances; G, Section of the ovarian sacs in the degenerative and resting stage. ×150. Note degenerating oocytes and newly formed oogonia (OG) on the germinal epithelium.

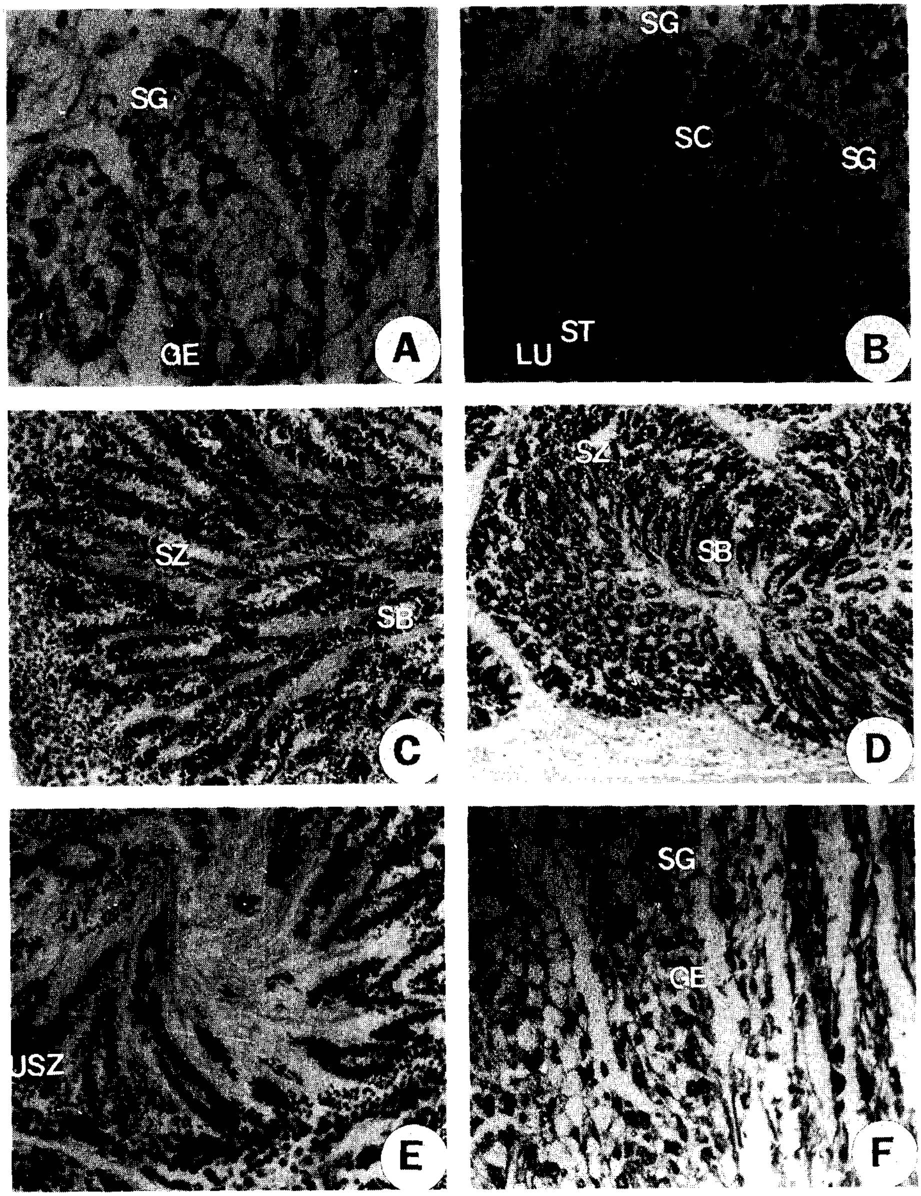

Fig. 6. Gonadal phases of a male *Ruditapes philippinarum* as seen by light microscopy.
A, Transverse section of the testis in the multiplicative stage. ×300. Note many small spermatogonia (SG) and undifferentiated mesenchymal tissue appeared along the germinal epithelium (GE); B, Section of the seminiferous tubules in the growing stage. ×300. Note a number of spermatogonia (SG) on the germinal epithelium, spermatocytes (SC) and spermatids (ST) in the lumen (LU) of the seminiferous tubules; C, Section of a seminiferous tubule in the mature stage, ×300. Note spermatozoa (SZ) during formation of spermball (SB); D, Section of the seminiferous tubules in the same stage above mentioned. ×150. Note a number of complete spermatozoa (SZ) forming the spermball (SB) ; E, Section of the seminiferous tubule in the spent stage. ×300. Note a number of undischarged spermatozoa (USZ) in the tubules; F, Section of the seminiferous tubules in the degenerative and resting stage. ×300. Note degenerating spermatozoa and newly formed spermatogonia (SG) on the germinal epithelium (GE) near the connective tissue.

nuclear envelope (Fig. 5C-1, 2, 3).

In males, spermatogonia grow to spermatocytes, which move toward the center of the lumen. These spermatocytes, measuring 5~7 μm in diameter, show duplicated layers. As the development of the testis stratified layers are composed of groups of spermatogonia, spermatocytes and spermatids in the seminiferous tubule (Fig. 6B). Individuals in this stage are found from April to May when sea water temperatures increase gradually.

Mature stage: In females, the oocytes increase in size to 40~50 μm in diameter, become round or oval, and are located in the center of the lumen. There is an increase in the ratio of cytoplasm to the nucleus. At this time, the germinal epithelium becomes very thin, and the undifferentiated mesenchymal tissues and eosinophilic granular cells are very few (Fig. 5D). Oocytes (65~70 μm) are fully matured and are surrounded by gelatinous membranes, and their cytoplasm contains a large number of yolk granules (Fig. 5E).

In males, spermatids begin to undergo transformation into spermatozoa, and a number of spermballs are formed by the spermatozoa in the lumen of the testicular lobule. Ripe testis is characterized by the formation of spermballs of a number of spermatozoa (Figs. 6C, D). Mature gonads are found from April to September when sea water temperatures are relatively high (13~26.4℃).

Spent stage: In females, the lumen of the ovarian sac becomes considerably empty, since about 50~70% of the oocytes in an ovarian sac are discharged. Spawned ovaries are characterized by the presence of a few ripe undischarged oocytes as well as very young oocytes in the lumen (Fig. 5F).

In males, as a large number of spermatozoa in the seminiferous tubules are discharged into the surrounding water, the lumen becomes empty. But, a number of spermatozoa, as well as spermatids and spermatocytes, remain in the lumen (Fig. 6E).

The spawning period appears once a year from June to early October and the main spawning occurs between July and August when sea water temperatures are greater than 24℃.

Degenerative and resting stage: In females, after spawning, the undischarged oocytes in the lumen of the ovarian sac undergo cytolysis, and each ovarian sac is contracted and degenerated. Rearrangement of a few newly formed oogonia in the ovarian sacs occurs in the resting stage (Fig. 5G).

In males, a few remaining spermatozoa and spermatids are degenerated, rearrangement of a few newly formed spermatogonia in the seminiferous tubules in the resting stage (Fig. 6F). The individuals in this stage appear from July to March when sea water temperatures decrease gradually.

3. Relative growth

The relationship between shell length (SL : mm) and total weight (TW : g) was expressed by the following equation :

$$TW = 1.208 \times 10^{-4}\ SL^{3.158}\ (r^2 = 0.97)\ \text{(Fig. 7).}$$

Shell length (SL) was highly correlated with shell height (SH : mm) as the following equation:

$$SH = 0.726\ SL - 0.483\ (r^2 = 0.95)\ \text{(Fig. 8).}$$

The shell length (SL)-shell width (SW) relation was also expressed by the following equation:

$$SW = 0.542\ SL - 1.803\ (r^2 = 0.92)\ \text{(Fig. 8).}$$

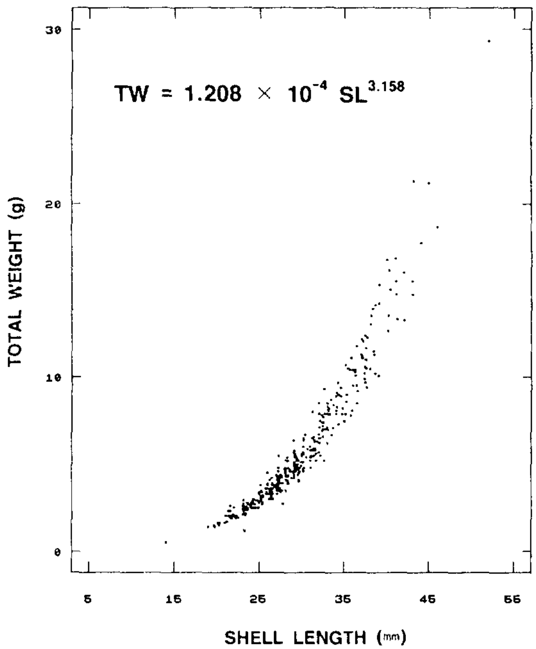

Fig. 7. Relationship between shell length(SL) and total weight (TW) in *Ruditapes philippinarum*.

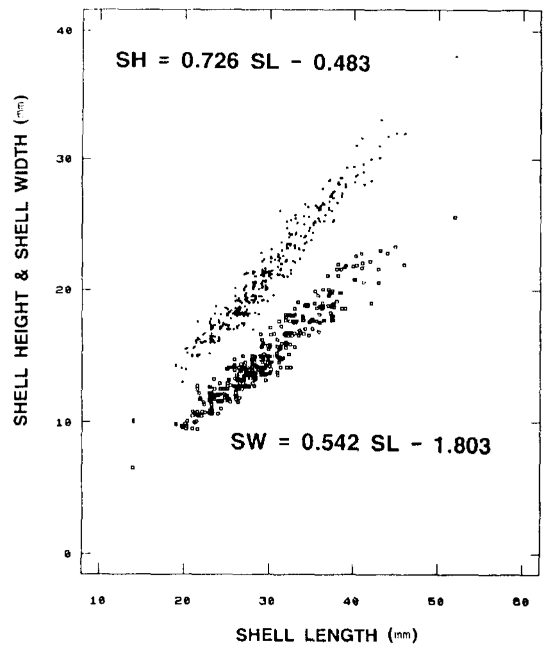

Fig. 8. Relationship between the ratio of shell height (SH: small square) for shell width (SW: large square) and shell length (SL) in *Ruditapes philippinarum*.

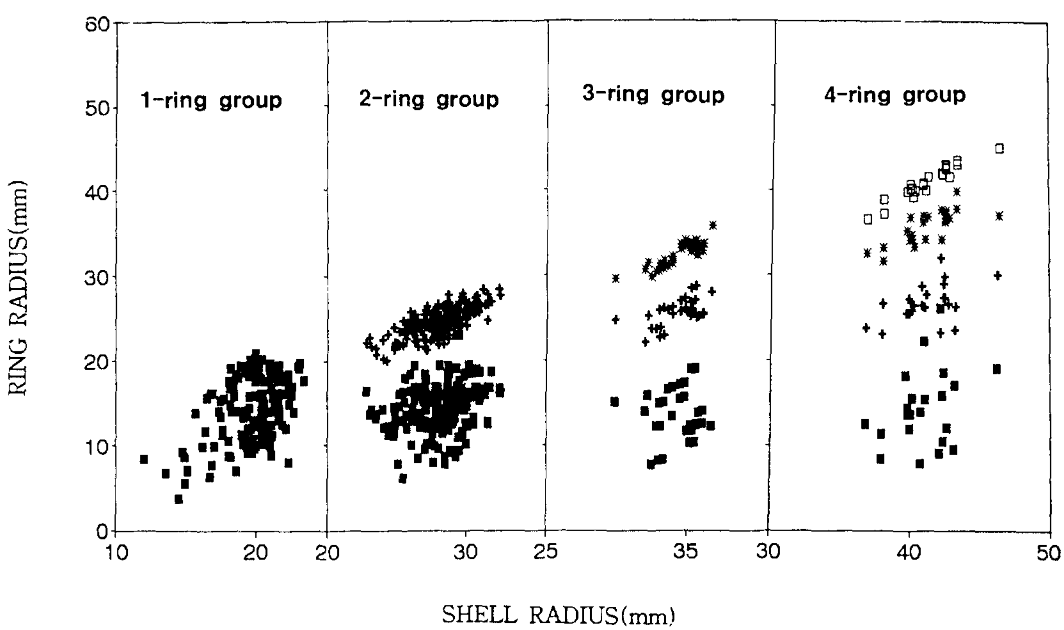

Fig. 9. Relationship between shell radius and ring radii of *Ruditapes philippinarum* (closed square: 1-ring group, plus: 2-ring group, asterisk: 3-ring group, open square: 4-ring group).

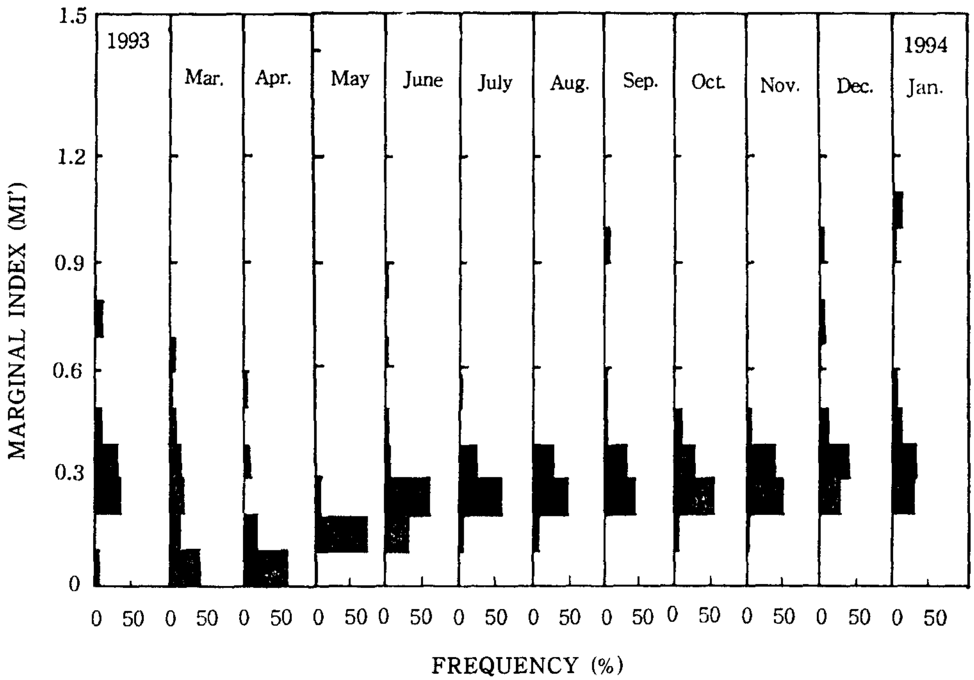

Fig. 10. Monthly changes in the marginal index (MI') in shell length of *Ruditapes philippinarum*.

4. Character of the ring formation

To identify age characteristics of this clam, the margins of transition zone between transparent zone and opaque zone on the shell were investigated by a light projector. A linear regression analysis between shell length and ring radius was conducted to distinguish false ring. As shown in Fig. 9, each ring group was clearly separated except for a part of 1-ring group (margins of transition zone of some specimens of 1-ring group were not clear). Therefore, each ring formed on the shell of this species is assumed to be an age character.

5. Period of the annual ring formation

The number of times of ring formation for one year should be known because all ring marks, even though each ring is confirmed as an age character, are not necessarily annual rings. To know the period of the ring formation and its cycle, the marginal growth rates on the shell were investigated for every month.

Monthly changes in marginal growth rate (MI') were calculated from February to January (Fig. 10). MI' gradually increased from April, and reached the maximum in January. And then, individuals having lower values of marginal growth rate are appeared in February and most of individuals reached lower values (MI', below 0.1) in March.

It was assumed that the ring of this species was formed once a year during the period of February to April, and the main period of the annual ring formation was in March.

Table 2. Sampling date and number of specimens of *Ruditapes philippinarum*

Item	Ring group	No. of individuals	Ring radius				
			R	r_1	r_2	r_3	r_4
Shell length (mm)	1	284	19.21	13.84			
	2	762	30.91	13.79	25.38		
	3	81	36.37	13.67	24.32	33.50	
	4	19	42.32	13.88	24.07	33.27	40.27
	Total	1,146	Mean	13.80	24.59	33.38	40.27
Total weight (g)			1.36	0.49			
			6.13	0.48	3.29		
			10.25	0.47	2.88	7.91	
			16.55	0.49	2.78	7.74	14.14
			Mean	0.48	2.98	7.82	14.14

6. Mean ring radius by ring group

In the present study, it was found that the margins of transition zone between transparent zone and opaque zone on the shell represented periodical ring marks which were formed once a year. Therefore, the authors regarded the periodic ring marks as an annual ring, and counted each annual ring by age. As shown in Table 2, the mean ring radii of each ring are as follows : r_1=13.80 mm, r_2=24.595 mm, r_3=33.38 mm, r_4=40.27 mm.

If total weight in the period of the ring formation is back calculated by the mean ring radius, total weights at each ring are as follows : r_1=0.48 g, r_2=2.98 g, r_3=7.82 g, r_4=14.14 g.

7. Variations of shell length and total weight by age

As shown in Fig. 11, individuals ranging from 14.5 mm to 52.4 mm in shell length are considered to be from 0 to 4 years old. If the mean shell length by age in June, when spawning began and reached a full age of this species, are estimated from 1 to 4 years old, each of them could be shown by age as follows : 1-year : 18.39 mm, 2-year : 28.29 mm, 3-year : 36.23 mm, 4-year : 42.60 mm.

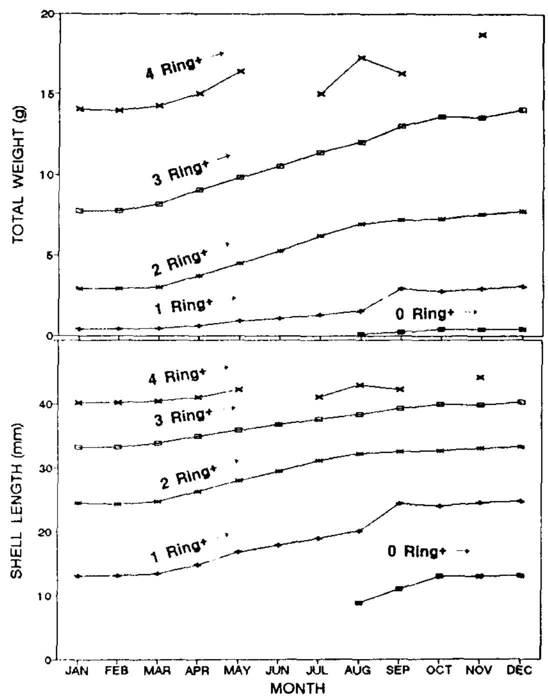

Fig. 11. Growth patterns in total weight and shell length of *Ruditapes philippinarum*.

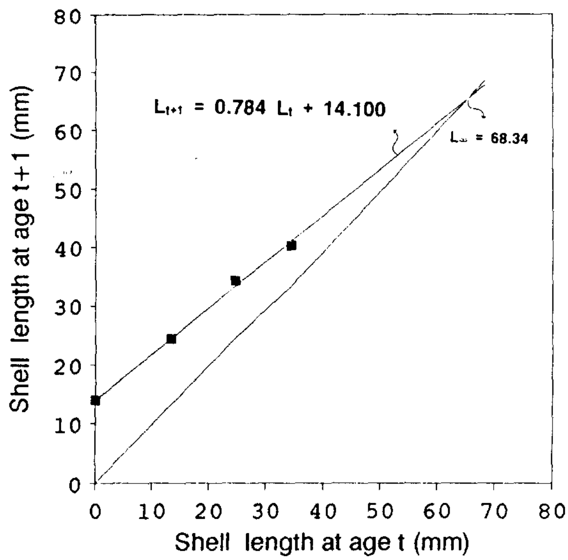

Fig. 12. Walford's plot of the growth of the shell length of *Ruditapes philippinarum.*

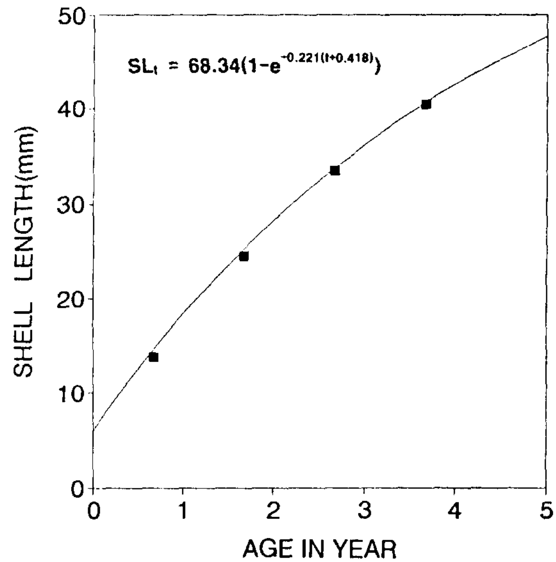

Fig. 13. Growth curve in shell length by von Bertalanff'y equation for *Ruditapes philippinarum.*

According to growth rate of the mean shell length by age, that of 0 year group was showed to increase rapidly, while those of higher age groups decreased gradually.

Seasonal variations in growth rate of the mean shell length showed to gradually increase in spring and autumn, and then reached the maximum in summer, while those showed to little increase or decrease slowly in the winter season.

If the mean total weights by age in June, when spawning begin and reach a full age of this species, are estimated from 1 to 4 years old, each of them by age can be estimated 1.19 g (1 year), 4.64 g (2 year), 10.13 g (3 year), 16.89 g (4 year), respectively.

Seasonal variations in growth rate of the mean total weight are shown in the same phenomenon as seen in a tendency of growth rate of the mean shell length. Monthly changes in growth rate from March to June showed to increase gradually, and reached the maximum in July.

Thereafter, the growth rates gradually decreased from September to December, and showed lower tendency between January and February.

8. Growth equation

In the present study, growth of this clam was expressed as the von Bertalanffy's growth equation. According to histological study of this species, the spawning period of the shortnecked clam is from June through early October. In case of individuals spawned in June, the first ring is formed in the next year between February and March.

Therefore, the period required for the first formation of ring is assumed about 8 months (0.67 year). Shell length and total weight by age in the period of ring mark formation are as follows : $SL_{0.67}$=13.80 mm, $SL_{1.67}$=24.59 mm,

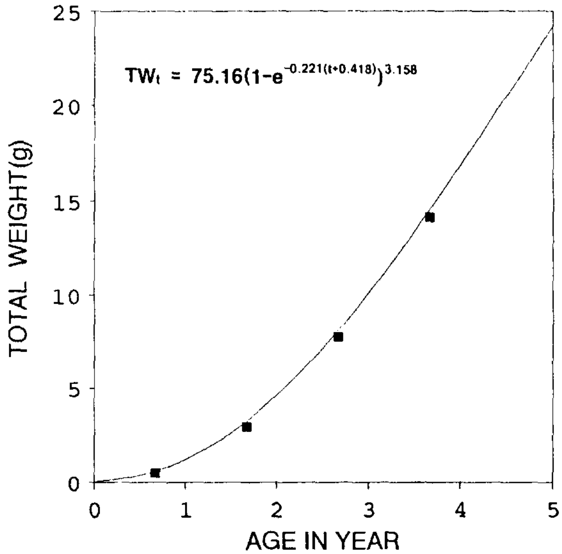

Fig. 14. Growth curve in total weight by von Bertalanff'y equation for *Ruditapes philippinarum.*

$SL_{2.67}$=33.38 mm, $SL_{3.67}$=40.27 mm, $TW_{0.67}$=0.48 g, $TW_{1.67}$=2.98 g, $TW_{2.67}$=7.82 g, $TW_{3.67}$=14.14 g.

Using shell length in the period of ring formation, the linear regression equation is expressed by a Walford's plot as follows:

$SL_{t+1}=0.784\times SL_t+14.100$ (Fig. 12).

Therefore, growth curves for shell length and total weight fitted to the von Bertalanffy's equation were expressed as:

$SL_t=68.34\ (1-e^{0.221(t+0.418)})$ (Fig. 13),
$TW_t=75.16\ (1-e^{0.221(t+0.418)})^{3.158}$ (Fig. 14).

DISCUSSION

Breeding and spawning

Most of marine invertebrate group have a certain breeding season and breedings occur seasonally or all the year round (Webber and Giese, 1969). According to the breeding habitats, Boolootian *et al.* (1962) placed mollusks into three large categories; 1) year-round breeders, 2) winter breeders, and 3) summer breeders. It was found that *Ruditapes philippinarum* belongs to the summer breeder class by histological investigation in this study.

Regarding the spawning season of the shortnecked clam, Ko (1957) described that spawning of Japanese shortnecked clam, *Tapes japonica* in Sasebo Bay, Nagasaki, Japan occurred twice a year ; from April to July (the first spawning period) and from September to November (the second spawning period). In Japan, spawning of Japanese shortnecked clam occurred twice (spring and autumn) a year from south part area of Kando district to Kumamoto district, Japan; however, occurred once a year in the summer season in Hokkaido, Japan (Momoyama and Iwamoto, 1979). In Korea, spawning of the shortnecked clam occurred once a year in early May to early October in Taeya, Chungchongnamdo, and from mid May to late October in Tatepo, Pusan (Kurashige, 1943b). In the present study, the spawning period of *Ruditapes philippinarum* occurred from June to early October. Our results are similar to Kurashige's report (1943b). Some local variations and timing of spawning of this clam might be related to the geographical differences in the water temperature, time of the food production, and some other environmental factors (Ko, 1957; Momoyama and Iwamoto, 1979).

Period of the annual ring formation

Up to now, there have been some previous studies on the period of the ring formation of the shortnecked clam, *Tapes philippinarum* on the south and west coast of Korea. They were assumed that the annual rings on the shell formed once a year in February in Sinsudo, Samcheonpo (Choi, 1987) and from January to April at the intertidal zone of An-Jong-ri, Tong-Yong on the southern coast of Korea (Yoon, 1992). In the present study, the annual ring was formed in March at Simpo, Kimje in the west coast of Korea. Therefore, our results are similar to those as described by Choi (1987) and Yoon (1992). But, Williams (1980) described that the period of ring formation (annulus) was in October in *Tapes japonica*, and those of other species were reported that the annual rings on the shell were formed between August and September in *Spisula sachalinensis* (Kang and Kim, 1983), and between June and July in *Mactra chinensis* (Kim *et al*., 1985). Therefore, it is supposed that the periods of the annual ring formation (annuli) vary according to the species and environmental factors of habitats.

Growth rate of shell length and total weight

Regarding growth rate of the shortnecked clam, Choi (1987) reported that growth rates of shell length and total weight of individuals were in the highest values in the summer season in the shore of Sinsudo, Samcheonpo, Korea. Kim (1986) reported that the shortnecked clam grew rapidly when sea water temperatures exceed 10℃ in April through November; but, growth rate of shell length slightly declined at the high temperatures over 20℃ in August in Garolim Bay, Chungchongnamdo, Korea.

In the present study, monthly variations in growth rate of the mean shell length and the mean total weight from March to June were increased gradually, and reached the maximum in July. Thereafter, their growth rates decreased slowly from September to December, and showed a lower tendency between January and February. Our results closely coincide with Kim's (1986) and Choi's reports (1987).

SUMMARY

Gonadal development, age and growth of *Ruditapes philippinarum* were investigated using samples from the intertidal zone of Simpo on the coast of Kimje, Korea, which were collected monthly for one year from February 1993 to January 1994.

Ruditapes philippinarum is dioecious in sex. The gonads are located between the subregion of the mid-intestinal glands and reticular connective tissue of the foot. The ovary is composed of a number of ovarian sacs, and the testis is composed of numerous seminiferous tubules. The clam spawns once a year from early June to early October, and the main spawning occurred between July and August when the water temperature went above 23℃. Ripe oocytes are about 65~70 μm in diameter.

Gonadal phases of this species can be divided into five successive stages ; multiplicative (February to March), growing (April to May), mature (April to September), spent (June to October), and degenerative and resting (July to March). Spawning is closely related to the sea water temperature.

Based on the monthly variations of marginal index (MI') of the shell, it was suggested that the annual ring mark formation occurred in March once a year and took approximately 8 months (0.67 year) for first ring to be formed on the shell.

The relationship between the shell length (SL) and the total weight (TW) was repre-

sented by the non-linear equation: $TW=1.208\times10^{-4}\ SL^{3.158}$, and also in the relationship between the shell length (SL) and the shell height (SH), the shell length and the shell width (SW) were represented by the linear equations: $SH=0.726\ SL-0.483$, $SW=0.542\ SL-0.803$.

Growth curves for shell length and total weight fitted to von Bertalanffy's equation were expressed as :

$$SL_t=68.34(1-e^{-0.221(t+0.418)})$$
$$TW_t=75.16(1-e^{-0.221(t+0.418)})^{3.158}$$

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