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Growth and Spawning of the Sea Urchin *Anthocidaris crassispina* (A. Agassiz)

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보라성게의 産卵과 成長

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1980.8∼1982.8월까지 일광, 주문진, 돌산, 어청도 및 성산포에서 채집한 1,663미의 보라성게의 성장 및 산란에 관한 조사이다. 1세부터 5세까지의 평균각경은 각각 19, 32, 43, 51, 58 *mm*로 추정됐으며 $l_\infty = 84.4$ *mm*, $k=0.223$, $t_0=-0.187$의 성장식을 보였다. 각경에 대한 각고, 보대, 간보대, 위홍문부경 및 극 길이의 상관관계는 매우 높았다. 연령에 따른 각 부분의 상대성장은 차이가 없으나 극의 성장에서는 3세까지는 각경에 비례하여 성장하나 그 이후의 연령부터는 반비례하고 있다. 일광해역에서의 산란은 6∼10월에 일어나며 주 산란은 8월로 사료된다. 연령에 따른 주 산란시기는 다르며 고 연령군은 저연령군 보다 일찍 산란하고 있다. 제주산 보라성게는 8월 이전에 산란을 이미 마친 상태이며 여수산, 일광산은 주로 8월에, 주문진산, 어청도산은 8월 이후에 산란하는것으로 판단된다.

Introduction

Sea urchin, one of the commercially important species in Korea, has long been exploited. Its salted gonads at the spawning season are highly esteemed. The annual production of this stock has been increasing since 1960's and its maximum catch attained 5,212 M/T in 1981 (Fig 1). It seems that the recent development of the sea urchin fishery in Korea has brought the intensive fishing effort.

Besides this commercial importance, large quantities of gonad production of sea urchin undoubtedly play a role in the energy and production relation within the benthic intertidal ecological system (Moore and McPherson, 1965).

In spite of such commercial and ecological interests, very few studies on the sea urchin in Korea have hitherto been made. Accordingly, *Anthocidaris crassispina*, which is the most heavily exploited among several Korean echinoids, is chosen in this research to know its basic biological knowledge. Consulting the illustrated books of the Japanese fauna (Utinomi, 1977), it seems that geographical distribution of this species is limited to Far Eastern Asia. Consequently, enough studies on this animal have not yet been carried out comparing with other echinoids.

The purpose of this study is to examine the growth and spawning season of this species. In order to estimate the growth of sea urchin, a variety of aging method has been used. Swan (1958, 1961), Fuji (1962. 1963) and Kawamura (1966) investigated the growth of *Strongylocentrotus* spp. by Petersen's method. Growth zone in the echinoid skeleton (interambulacral and genital plates or spines) has been used for aging by many authors (Deutler (1926), Kume(1929), Moore(1935), Kawamura(1966), Weber(1966), Jensen (1969), Pearse and Pearse (1975).

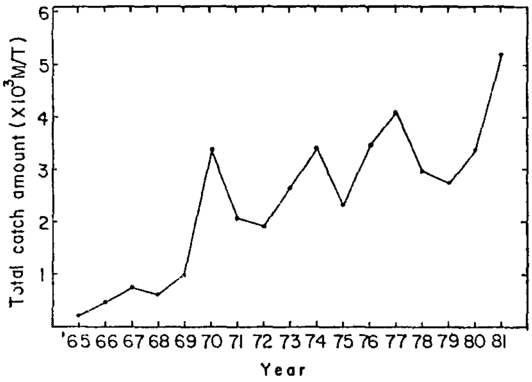

Fig. 1. Variations of annual production of sea urchin in Korea (Source of data: Year book of fisheries statistics, 1981).

Since Moore (1935) used at first attaching tags with an elastic band, Sinclair (1959) and Ebert (1965) have improved this technique. Fuji (1963) and Ebert (1968) analyzed directly the growth rate of *Strongylocentrotus pulcherrimus* and *S. purpuratus* by tagging records. The use of dyeing method was also examined by Swan (1961). However, this one did not allow individual marking of large numbers of animals (Ebert, 1965a). Thus, it has not made further progress. In addition, growth observations in aquarium were executed by Bull (1938) and Kakuda and Nakamura (1974).

Concerning gonad maturation and spawning-time, it is well known that these can be usually determined by gonad index. Gonor (1972) presented the gonad growth data of *Strongylocentrotus purpurpuratus* by size classes, Moore *et al* (1963), Ebert (1968) and Fuji (1967) have recorded some relationships between gonad maturation and size of sea urchin.

In present study, growth rate and spawning season of *Anthocidaris crassispina* sampled at south-east coast of Korea (Ilkwang) are mainly investigated and compared with those of other different areas.

Before going further, the writers would like to express their sincere thanks to Mr. B. H. Lim of Kyung Il Seedling Station at Ilkwang for his hearty assistance during the sampling period.

Sampling and Analysis Methods

Samples throughout the study period have been collected from 5 areas of Korean coastal waters (Fig. 2). Relative continuous sampling at Ilkwang has been effected from August 1980 to

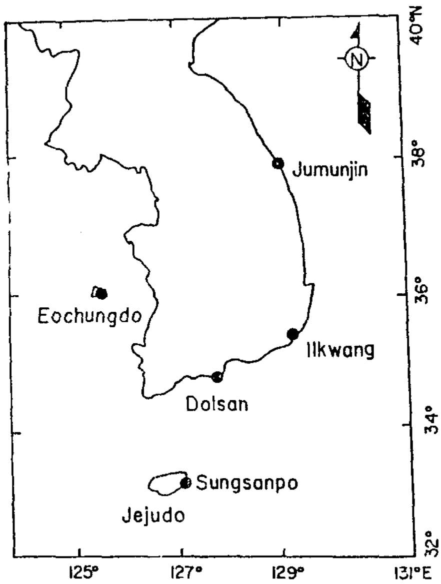

Fig. 2. Map showing sampling stations

August 1982. In order to compare the geographical difference among Korean echinoids on the growth and spawning, sampling from the 5 areas in August 1980 and 4 areas except Jumunjin region in May-June 1982 has been carried out. *Anthocidaris crassispina* at rocky shore of 3-4 m deep was collected under boulder and in crevice by SCUBA or woman divers. Biometric mesurement was executed on all samples in laboratory. The external maximum test diameter and height, and the maximum distance of ambulacral and interambulacral areas were measured by 0.01 mm with knife edged calipers.

The anal region, also known as periproct, and the largest spine taken out were also measdured by 0.01 mm with divider. After measuring total body weight gonads removed from test were weighed by 0.01 g with a mechanical balance.

The frequency distribution of test diameter was analized to know the growth rate. The gonad index was computed by the ratio of gonad weight to total body weight and has been expressed in percentage. Difference by sampling region on the growth and spawning season are analyzed and compared with each other.

Result

Frequency distribution

From August 1980 to August 1982, 887 specimens were collected at IlKwang by random sampling method. Thus, the collection may represent the natural population. The frequency distribution of diameter is shown by the months sampled in Fig. 3. Specimens collected during the sampling period varied from 17.65 to 76.75 mm in diameter. Since monthly sampling size was small ranging from 33 to 112 individuals, the frequency distribution was analyzed in percentage for comparison.

In Fig. 3, it was not easy to distinguish the clear mode and peak which varied continuously with the month sampled. However, some modes were apparent each month. The mode and peak between the samples of August 1980 and 1981, appeared very similar. Consequently, the frequency distribution of the samples of August 1980 was selected at first to examine age groups. In this month, 4 modes could be separated. The first one below 44 mm with the peak of 43 mm was not so clear as a mode, but taking into consideration the appearance of peak of 43mm in November 1980 and in August 1981, it is sure that the mode exist below 44 mm. The mode from 45 to 55 mm with the peak of 51 mm was more clear than the previous one. The 3rd one with the peak of 58 mm from 56 to 62 mm was the most distinct. Because of insufficient specimens over 63 mm, the estimate of the class in-

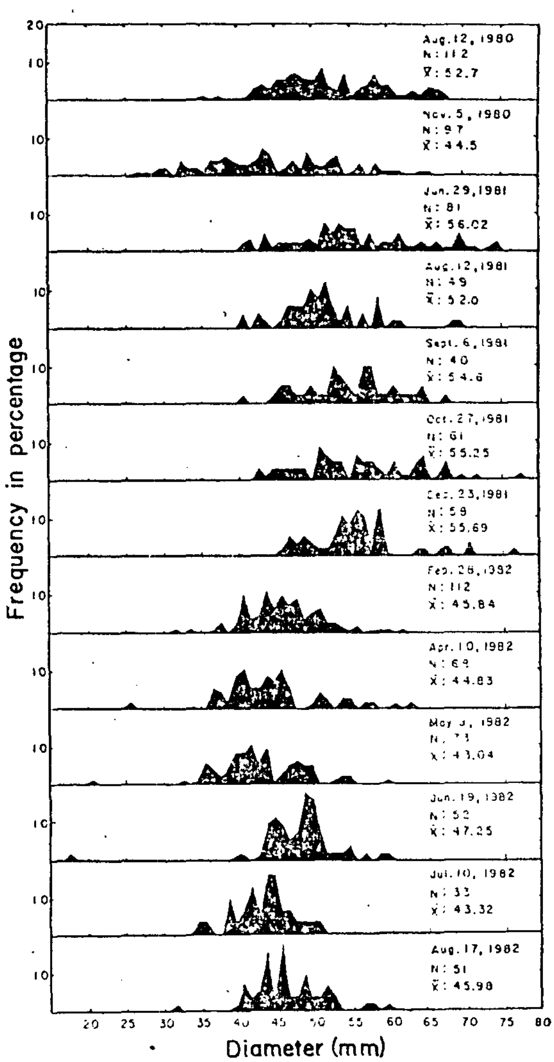

Fig. 3. Diameter distribution of *Anthocidaris crassispina* from Ilkwang (Aug. 1908—Aug. 1982).

tervals and peak of mode from this size could not be analyzed. On the one hand, the class intervals and peak up to the 3rd mode were in accord very closely with those of August 1981. This similarity between 1980 and 1981 suggests that recruitment and mortality of the stock, *Anthocidaris crassispina* at Ilkwang were stable and the estimated class intervals and peak indicate the real age group and mean test diameter by age.

From the samples in November 1980, the modes up to 62 mm were more clear than those in August 1980 and 1981. The first mode from 26 to 35 mm which had not occurred in the previous months appeared newly with the peak of 32 mm. The mode over 63 mm was not definite because of insufficient specimen number.

The specimens less than 25 mm were very scarce at Ilkwang during the study period. Only one individual per month from April to June has been appeared and its diameter was 25, 20 and 17 mm, respectively.

Refer to the first mode (25-35 mm) in November in 1980, this can not be considered as the first age group. It seems that 32 mm of its peak is too large to believe as the mean diameter of 1 year age. Consulting the frequency distribution of specimens of sea urchin at Jumunjin in August 1980 (Fig.4), the first age group will be approximately from 13 to 24 mm. From these two appearances, it will be possible to estimate that the mean test diameter of 1 year group in August corresponds to about 19 mm.

In other respects, the comparison of frequency distribution of sea urchins from 5 different areas in 1980 and 1982 are also shown in Fig.4. With regard to frequency distribution it was different according to geographical location. Specimens in August 1980 at Ilkwang and Dolsan were fairly similar. In the case of Jumunjin, even though the number of specimens was not enough to analyze the growth mode, the occurrence of younger age group was distinctive feature. The frequency in percentage of the first mode (13-24 mm), the second (25-34 mm), the 3rd (35-41mm) and the 4th (48-51 mm) were 33, 42, 19 and 5% of total specimens, respectively.

On sea urchins at Eochungdo, it seems that the mode could be devided into 3 groups: 29-40 mm, 41-48 mm and 49-57 mm.

The peak of each mode appeared at 38, 46 and 49 mm, respectively. Although these peaks and modes were different with those values estimated previously, the second high frequency

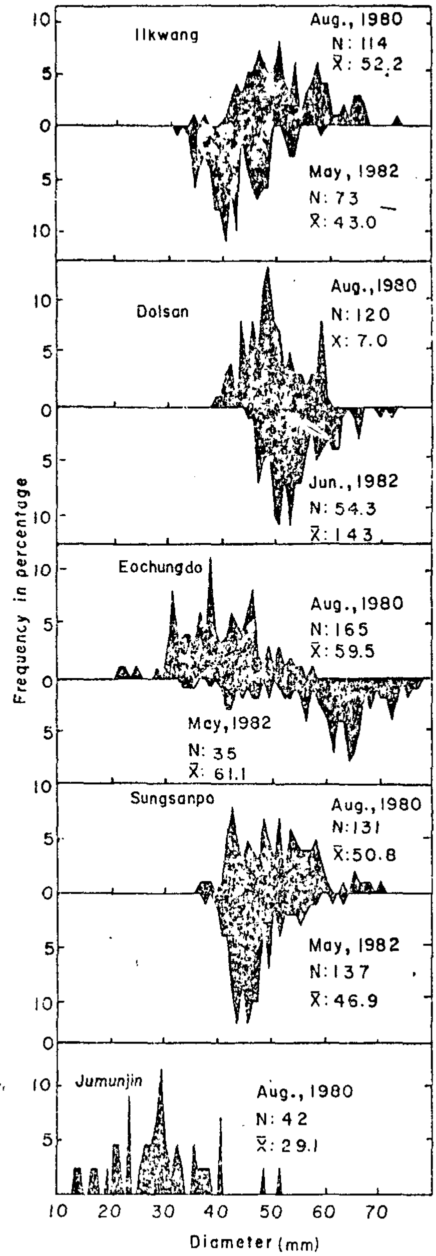

Fig. 4. Frequency distribution of *Anthocidaris crassispina* from 5 sampling areas in 1980 and 1982.

of each mode has been revealed at 31, 42 and 51 mm, respectively, which are nearly equal to the result of Ilkwang.

The sea urchins from 36 to 70 mm at Sungsanpo showed the vague mode but the peaks at 42, 51 and 58 mm were also remarkable.

In consequence, while class interval and its proportion to total frequency distribution were a little different by area, the mean diameter of each size group was almost the same by region.

Concerning the growth modes in 1982, specimens from each area showed the different frequency distribution. Sea urchins from Dolsan in June and Ilkwang in May have the similar growth modes to the results in August 1980. With regard to comparison between the samples at Sungsanpo in August 1980 and in May 1982 very similar modes appeared. Considering the different sampling months between the years, it seems that sea urchins at Dolsan have the similar growth mode between the years, and conversely, ones at Ilkwang and Eochungdo have very different one.

In the case of Ilkwang, specimens in 1982 were generally smaller than those in 1980. However, sea urchins from Eochungdo in 1982 were much larger than those in 1980. Particularly, it is noteworthy that such large group appeared only one time during the study period at 5 areas.

On the one hand, from the 112 individuals in August 1980 at Ilkwang, the relationship between total weight and diameter was obtained (Fig. 5.).

By using this relationship and the mean diameter of each age group estimated previously, total mean body weight by age was computed (Table 1).

Until 5 years of age younger age group has higher increment in diameter and lower increment in weight.

The mean diameter by age was plotted by Walford method (1941) on the graph paper of

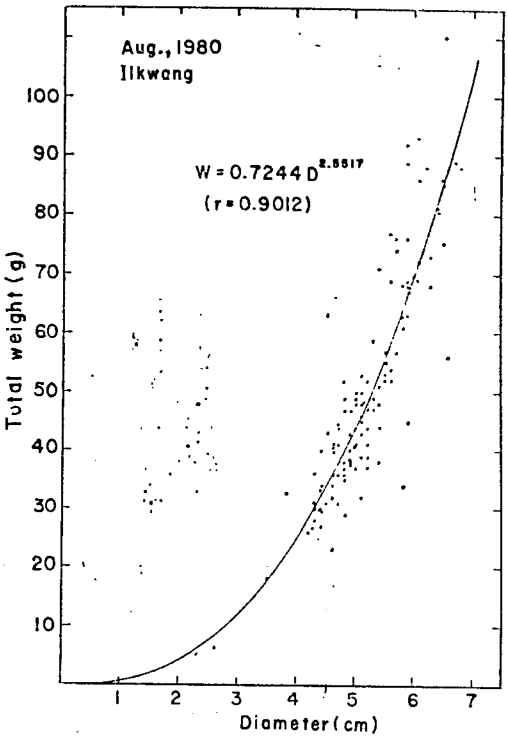

Fig. 5. Relationship between total weight and diameter of *Anthocidaris crassispina* collected in August 1980 at Ilkwang.

$t+1$ against diameter at t (Fig. 6). The equation is:

$$\text{Dia.}_{(t+1)} = 16.87 + 0.80\ \text{Dia.}_{(t)},$$

with a high value of coefficient of correlation ($r=0.9995$). The equation of von Bertalanffy (1938) was used as a growth model of sea urchins:

$$l_t = l_\infty\ (1 - e^{-k(t-t_0)})$$

where: l_t is test diameter at time t,

l_∞ is asymptotic (maximum) size,

k is a measure of the rate at which an organism approaches asymptotic size,

t_0 is age when test diameter and total weight are theoretically null; t_0 has no biological

Table 1. Estimated diameter (*mm*) and body weight (*g*) of each age group of *Anthocidaris crassispina*

($W(g) = 0.7244\ D(cm)^{2.5517}$, $r = 0.9012$)

growth	age 1		2		3		4		5
Diameter (*mm*)	19(?)		32		43		51		58
Increment in dia. (*mm*)		13		11		9		7	
Total weight (*g*)	4		14		30		46		64
Increment in weight (*g*)		10		16		16		18	

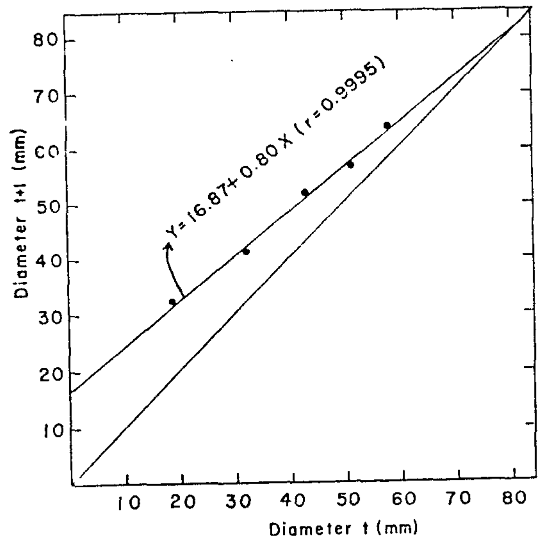

Fig. 6. Walford plot of growth of *Anthocidaris crassispina*.

significance.

From Fig. 6., a slope, $e^{-k}=0.80$ ($k=0.223$) and an intercept on diagonal of $l_\infty=84.8$ mm were directly computed. The values of t_0 at 3, 4 and 5 years old sea urchins are −0.211, −0.157 and −0.193 year, respectively, and its mean value is −0.187 year. Thus, the growth equation of sea urchin becomes:

$$l_t=84.4\ (1-e^{-0.223(t+0.187)}).$$

From this equation, it is possible to estimate the diameter of older sea urchins by age. The results are computed as follows: 63 mm at 6 years, 67.4 mm at 7 years and 70.8 mm at 8 years. On the diameter of 1 year of age, ca. 19 mm obtained previously is very similar to 19.6 mm calculated by this equation. Since older age groups than 5 years were not considered in Walford plot, these values obtained by mathematical model should be reexamined. However, this maximum size of 84.4 mm estimated by this equation seems to be reasonable result.

Relative growth

In order to know the relative growth of other body portions on the growth of diameter 112 individuals collected in August 1980 at Ilkwang were analyzed. The lengths of height, periproct, ambulacral and interambulacral zones and the longest spine relative to the diamter of the body test were determined. In other respects, the gonad weight was also compared with total body weight. The linear regression is shown with its 95% confidence limits in Table 2.

These relations were simple linear ones for all measurements. To investigate the variation of relative growth in accordance with the age, the proportions of height and spine to diameter were computed and tested by statistical method (Table 3). Any statistical significances were not found in the proportion of height to diameter. Conversely, the proportion of spine to diameter was different by age. Considering the variation of mean proportion of spine to diameter by class interval of age, the growth of spine was in proportion to age until 3 years (46.0—54.9 mm). But it was inversely proportional to age from 4 years. In consequence, high value of t appeared at the comparison between small and old age groups. The reason of feeble value of coefficient of correlation of spine to diameter in Table 2 can be explained by this phenomenon. Moreover, concerning the variation of relative growth by month any distinct variation of the proportion

Table 2. Linear regressions of body size measurements of 112 sea urchins, *Anthocidaris crassispina* from Ilkwang in August 1980 (Body portions (*mm*)=*a*+*b* dia. (*mm*)).

Body portions (*mm*)	$r\pm95\%$ limits	$b\pm95\%$ limits	$a\pm95\%$ limits
Height	0.5628<0.6766<0.7651	0.3949±0.09035	1.6232±4.7761
Periproct	0.3067<0.4632<0.5974	0.0621±0.01982	0.8851±1.0481
Ambulacral zone	0.7158<0.7951<0.8541	0.2745±0.03880	−0.8311±2.0511
Interambulacral zone	0.8554<0.8980<0.9286	0.3325±0.03020	0.8876±1.5955
Primary spine	0.0778<0.2584<0.5005	0.1452±0.08250	12.7819±4.3613
Gonad weight to total weight (*g*)	0.7829<0.8452<0.8907	0.2510±0.08850	−5.1580±5.0980

Table 3. Proportion of height and spine to diameter of *Anthocidaris crassispina* and statistical test between class intervals

1) Proportion

Class intervals (*mm*)		Height/Diameter(%)			Spine/Diameter(%)		
		N.	Mean	S.D	N.	Mean	S.D
35.9 >	(*A*)	3	42	0.33	3	44	5.57
36.0–45.9	(*B*)	17	43	3.91	12	49	15.99
46.0–54.9	(*C*)	57	43	0.60	55	41	8.31
55.0–62.9	(*D*)	22	43	0.74	31	37	8.12
63.0<	(*E*)	12	41	0.68	13	33	16.81

2) Statistical test (Student's *t*)

Height/Diameter(%)		Spine/Diameter(%)	
Comparison	Value of *t*	Comparison	Value of *t*
A:B	0.11	A:B	0.52
A:C	0.18	A:C	0.62
A:D	0.08	A:D	1.45
A:E	0.33	A:E	3.05**
B:C	0.06	B:C	0.98
B:D	0.07	B:D	2.22*
B:E	0.67	B:E	3.39**
C:D	0.25	C:D	2.16*
C:E	1.02	C:E	3.29**
D:E	0.66	D:E	1.62

* Significative in 95% confidence interval
** Significative in 99% confidence interval

of height and spine to diameter did not appear.

Comparison of growth rate of weight to diameter

With regard to exponential equation, $W = a(\text{Dia.})^b$ the values of a and b of specimens in August 1980 by area were calculated by logarithmic transformation, $\log W = \log a + b \log (\text{Dia.})$ (Table 4). Very high correlation between weight and diameter existed in all sampling area. To compare the growth rate b of weight to diameter between the different areas, test of homogeneity of the b was executed as Student's t with n_1+

Table 4. Relationship between total weight and daimeter of *Anthocidaris crassispina* taken in August 1980 and test of homogeneity of two *b* s

$(W(g) = aD(cm)^b)$

Area	No	a	b	r	Test of homogeneity of two *b*' s	
					comparison	value of *t*
Ilkwang (A)	112	0.7244	2.5517	0.9012	A:B A:C	6.00*** 4.39***
Jumunjin (B)	42	0.4858	2.7929	0.9864	A:D A:E	8:79*** 16.00***
Yeosu (C)	120	0.6986	2.6395	0.9390	B:C B:D	7.67*** 10.42***
Eochungdo (D)	165	0.8914	2.3760	0.8555	B:E C:D	14.01*** 13.18***
Sungsanpo (E)	131	1.3078	2.2326	0.7949	C:E D:E	20.50*** 7.00***

***: Significative in 99.9% confidence interval

n_2-4 degrees of freedom.

$$t=\frac{b_1-b_2}{\sqrt{S^2p(1/\sum x_1{}^2i+1/\sum x_2{}^2i)}}$$

Quantities b_1 and $\sum_i x^2i$ are the regression coefficient and sum of squares for x from the first sample group, and similarly the second sample, and

$$S^2{}_p=\frac{\{\sum y_1{}^2i-[(\sum x_1iy_1i)^2/\sum x_1{}^2i]\}+\{\sum y_2{}^2i-[(\sum x_2i\ y_2i)^2/\sum x_2{}^2i]\}}{n_1-2+n_2-2}$$

is the best estimate of the variation about regression. High values of t at every comparison indicate that the growth rate of weight to diameter is different by area. All of them are significative in 99.9% confidence intervals. Giving consideration to these values of t, the highest value appears at the comparison between Dolsan and Sungsanpo, and the lowest one between Ilkwang and Dolsan. Lower values occurred generally between the adjacent areas. However, even though Dolsan is the most adjacent location from Sungsanpo, its comparison showed the highest t value. As the total weight of sea urchin is very related with the gonad maturation, this feature can be explained by the gonad index variation by area. Thus, it is possible to suppose that sea urchins in August at Dolsan are just before the spawning, and conversely, those at Sungsanpo have already finished it.

Spawning

For the purpose of estimating the spawning season of sea urchin, gonad index method was used for all individuals. During the study period, the variation of gonad index by sampling month at Ilkwang is shown in Fig. 7. It's tendance varied a little by year.

Gonad index from June to October was generally high. It decreased suddenly from November and increased continuously from Feburuary.

This seasonal variation indicates that the spawning months of sea urchin at Ilkwing are from June to October. Considering the coefficient of variation of gonad index values in August, it was comparatively lower than that of other months. Its low value means that maturation degree of gonad among individuals is less variable in August. Accordingly, it seems that the major spawning of sea urchins at Ilkwang takes place in August.

To examine the maturation degree by body size, all specimens devided into class intervals which have been determined previously. Fig. 8. shows the variation of mean gonad index of 36—45 mm and 55—62 mm class intervals which

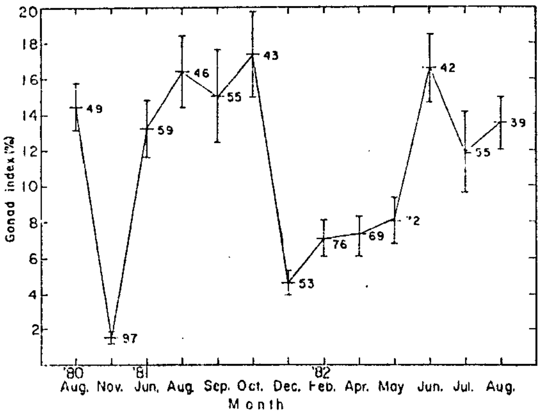

Fig. 7. Variation of gonad index of *Anthocidaris crassispina* from Ilkwang by month (I: 95 % limits, —: mean, number indicates the coefficient of variation).

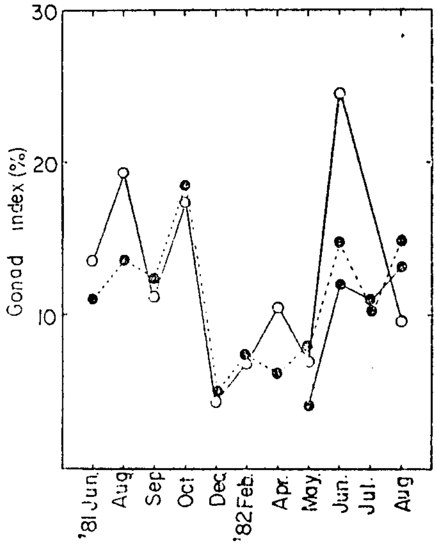

Fig. 8. Variation of gonad index of *Anthocidaris crassispina* by class intervals of diameter and month (O—O : 55-62 mm, ●···● 36-45 mm, ●—● : 35 mm)).

were considered as 3 and 5 years respectively from June, 1981 to August, 1982. In addition, the value of class intervals below 35 mm is also shown from May, 1982 to August, 1982. With the intention of comparing more clearly between small and large size animals, insufficient specimens over 63 mm and sea urchins of 46—54 mm were omitted in this figure.

The result exposed the distinct difference between small and large size group. The gonad index of large size group was higher than that of small one in June and August but it was conversed in September and October. In other words, while large individuals spawn mainly at the beginning time of spawing season, the main spawning of small ones takes place at latter period of spawning season. Consequently, the reason of the existence of vague peak and mode in frequency distribution analysis can be explained by this spawning characteristic.

Since the gonad index varies with size of specimens, the comparison between the different areas on gonad index was anayzed by class intervals. Table 5 shows the results of 1980. The mean diameters by class intervals in each area were fairly equal. Except Sungsanpo, higher gonad index appeared at the larger class intervals. Refer to comparison by area the highest gonad index occurred at Dolsan and the lowest one at Sungsanpo. In spite of the similarity of mean diameter by class intervals between Ilkwang and Dolsan, the gonad index of latter was much higher than that of former. It suggests that the spawning season of sea urchins at Dolsan will be a little earlier than that at Ilkwang. The sea urchin below 36 mm had the very low values of gonad index. Nineteen specimens among 34 individuals in this size group at

Table 5. Gonad index of *Anthocidaris crassispina* from 5 areas in August 1980

Area	Diameter			Gonad index			
	Class intervals (*mm*)	No. of samples	Mean (*mm*)	Mean (%)	S.D	C.V.(%)	No. of gonad index nearly o
Ilkwang	35.9>	3	27.9	1.53	2.64	172.55	2
	36.0—45.6	17	43.7	10.56	4.30	40.72	
	46.0—54.9	57	49.3	13.51	4.91	36.34	
	55.0—62.9	24	58.6	16.09	7.47	46.43	
	63.0<	13	66.1	19.91	7.03	35.31	
Jumunjin	35.9>	34	26.1	2.1	3.63	172.86	19
	36.0—45.9	6	39.0	6.71	8.28	123.40	1
	46.0—54.9	2	49.8	22.00	2.83	12.86	
	55.0—62.9	0					
	63.0<	0					
Dolsan	35.9>	0					
	36.0—45.9	24	43.2	21.38	6.98	32.65	
	46.0—54.9	75	49.8	24.93	5.20	20.86	1
	55.0—62.9	23	58.0	28.05	10.78	38.43	1
	63.0<	0					
Eochungdo	35.9>	45	31.4	7.37	8.86	120.22	5
	36.0—45.9	85	40.0	8.55	9.42	110.18	2
	46.0—54.9	3	49.3	10.49	5.71	54.43	1
	55.0—62.9	1	56.6	4.00	0	0	
	63.0<	0					
Sungsanpo	35.9>	0					
	36.0—45.9	39	38.1	4.48	3.80	84.82	1
	46.0—54.9	55	50.6	3.98	3.12	78.39	1
	55.0—62.9	29	58.6	3.69	2.07	56.10	1
	63.0<	9	66.5	4.44	1.33	29.95	

Table 6. Gonad index of ***Anthocidaris crassispina*** from 4 areas in May-June 1982

Area	Diameter			Gonad index			
	Class interval (*mm*)	No.	Mean (*mm*)	Mean (%)	S.D	C.V.(%)	No. of gonad index nearly o
Ikwang	35.9>	7	33.1	3.86	3.24	83.94	2
	36.0−45.9	47	41.2	8.04	5.18	64.43	5
	46.0−54.9	22	48.9	9.59	7.01	73.10	1
	55.0−62.9	2	58.0	7.00	2.83	40.43	
	63.0<	0					
Dolsan	35.9>	0					
	36.0−45.9	1	45.5	5	0	0	
	46.0−54.9	88	51.3	10.48	4.12	39.31	
	55.0−62.9	45	58.7	14.76	6.39	43.29	
	63.0<	9	66.9	18.11	7.06	38.98	
Eochungdo	35.9>	4	33.8	2.75	2.75	100.00	1
	36.0−45.9	12	42.4	4.75	1.96	41.26	
	46.0−54.9	11	50.1	8.45	3.08	36.45	
	55.0−62.9	26	60.1	8.69	2.57	29.57	
	63.0<	43	68.3	10.60	3.68	34.72	
Sungsanpo	35.9>	0		0			
	36.0−45.9	70	43.3	5.16	2.57	49.81	3
	46.0−54.9	55	49.1	5.65	3.13	55.40	
	55.0−62.9	11	57.3	6.27	1.90	30.30	
	63.0<	1	63.5	6.0	0	0	

Jumunjun contained gonad index nearly zero. From this fact, it is possible to estimate that sea urchins begin to spawn from 2 years of age.

At a point of view geographical location gonad index in north area was lower than that in south one. Accordingly, the spawning at Eochungdo and Jumunjin will be late. Consulting that the lowest gonad index was shown at Sungsanpo, the spawning of sea urchins in this area seems to be already finished before the month of August. Table 6 shows the results of specimens in 1982. Same analyze as in 1980 was carried out for sea urchins collected in May-June 1982 from 4 areas except Jumunjin. Comparing the results between two years, gonad index at Ilkwang, Dolsan and Eochungdo in 1982 was lower than that in 1980. However, Sungsanpo showed contrary result. In other words gonad index in May was higher than that in August. This fact can conform previous estimate concerning the spawning season of sea urchins at Sungsanpo.

Discussion

In spite of intensive biological studies on echinoids, the investigation on *Anthocidaris crassispina* is very rare. Kakuda and Nakamura (1974) have examined the growth of this species, but their works were restricted to larval stage in laboratory for the purpose of seedling production. Thus, the result of present study on the growth of natural population is not compared directly with others. In disregard of insufficient sampling size, consecutive observations of the frequency distribution at Ilkwang have shown fairly clear mode and peak. While it is difficult to analyze the monthly growth rate by age groups the annual growth rate and age can be estimated. The largest specimen among 1,663 individuals used in this investigation was 80.25 mm in May 1982 at Eochungdo. Young sea urchins below 30 mm and old ones over 70 mm were very scarce during the sampling period. However, consulting the changes of annual growth rate by age and the maximum size (84.4 mm) calculated by Walford plot, the computed growth equation from 5 age groups in this research is reasonable to represent the growth of natural population.

According to Moore (1937), the sea urchin *Echinus esculentus* reaches its largest size in warmer waters of lower latitude. But, in this study the largest one occurs at Eochungdo where is located at higher latitude. Temperature induced differential growth of body parts may lead to modification in body shape and in externally visible morphological characteristics (Kinne, 1970). But, differential growth of body parts (height/diameter) by area has not been occurred in this investigation.

Concerning the proportion of spine to diameter, it varied with age. Its maximum growth attained at 3 years of age. After this age, the length of spine became little by little small because of its breakage. Ebert (1968) indicated that the weather component had broken spine. According to Swan (1952), changes in the rate of growth of neighbouring spines might be induced by the removal of spines. These two authors have carried out wide investigations on spine, but their studies were generally limited to regeneration mechanism only. The size of regenerated one and spine growth by age were not executed. It is well known that the growth of echinoids varies with environmental condition. Many authors; Ebert (1965*b*), Fuji (1967), Ebert (1977), Mattison *et al* (1977) and Chapman and Liss (1981) have mentioned that food availavility and density were important components in determining growth rate, ultimate size and movement of sea urchins.

In other respects, Fiji and Kawamura (1970) have suggested in the study on *Strongylocentrotus intermedius* that the regional and seasonal variations of sea urchins within a given area varied with age group and nature of bottom.

Taking into consideration these references, the future study should be accompanied with the detail environmental investigation in order to reveal the exact growth rate and age of this species. Moreover, the tagging method or examination of natural growth line in plates of test must be also considered for this purposes.

Mc Pherson (1965) indicated that the sexual maturity did not occur suddenly at a fixed size in urchin. Regardless of the same size of animal high varieties of gonad index were also found in present study. However, consulting the general gonad index by size, it seems that spawning takes place from 2 years of age.

According to Boolootian (1966), while the reproductive processes of echinoderms show clear relations to season, the role of temperature *per se* still remains to be ascertained. The result of present study shows the distinct seasonal variation of gonad index. Since the influence of temperature on spawning by animal size was not examined in this research, it was not possible to analyze more detail on this factor. However, comparing the gonad maturations by sampling area the fact that sea urchins from higher latitude have lower gonad index values indicates that the temperature affects the spawning obviously.

In addition, the optimum water temperature for spawning will be different by area. Giving cosideration to the distribution of surface water temperature (Table 7) and gonad index in 5 sampling areas in August 1980 and May-June 1982, it seems that the spawning by area will take place in order of Sungsanpo, Dolsan, Ilkwang, Eochungdo and Jumunjin.

Before comparing the gonad index between small and large sea urchins, the propotion of test height to test diameter by age was examined to know whether different internal volume available for gonad growth by age exists or not. The result in table 3 does not show any statistical significance. This fact indicates that the internal volume available for gonad growth increases isometrically with size. Fuji (1967) and Gonor (1972) have also obtained the same result as this.

Table 7. Montly variation of surface water temperature (°C) at 5 sampling stations during the study period

Month		Area				
		Ilkwang	Sungsanpo	Jumunjin	Dolsan	Eochungdo
Aug.	1980	22.42	23.82	20.90	21.52	24.76
Nov.		15.05	19.16	13.70	14.52	12.28
Jan.	1981	9.24	13.86	3.75	4.15	5.27
Feb.		9.53	13.27	3.18	4.97	3.33
Mar.		10.76	13.69	3.60	7.48	3.76
Apr.		12.72	14.11	6.53	12.30	5.73
May		14.65	15.29	9.06	15.73	9.46
June		16.56	17.70	13.38	19.26	14.30
Jul.		20.39	21.66	19.90	21.64	20.20
Aug.		24.13	24.05	21.44	23.93	22.50
Sep.		22.04	21.96	19.52	22.95	19.90
Oct.		18.49	21.29	17.23	19.05	17.09
Nov.		14.81	18.27	12.64	12.97	12.00
Dec.		12.28	16.55	10.11	8.26	8.50
Jan.	1982	11.08	14.74	8.06	6.16	5.58
Feb.		10.72	14.25	6.66	5.32	3.87
Mar.		11.83	14.60	8.13	9.30	4.85
Apr.		13.54	14.67	10.35	13.28	6.55
May		15.72	16.71	12.16	16.85	10.29
June		19.13	20.02	17.60	20.56	15.64
Jul.		21.00	21.18	21.60	23.67	20.48
Aug.		23.34	23.30	21.95	24.57	22.31

Source of data: Annual report of oceanographic observation, vol. 30, Fisheries Research and Development Agency (in press).

On the relationship between gonad size and body size of sea urchins Moore *et al* (1963), Fuji (1967) and Ebert (1968) have found the positive result with *Lytechinus variegatus*, *Tripneustes ventricosus* and *Strongylocentrotus* spp. But they did not examine directly the effect of size upon gonad index values. The study on *Strongylocentrotus purpuratuts* has been made on this effect by Gonor (1972). He has found that the gonad index increased rapidly relative to body size until the animals are about 50 mm in diameter and conversely, decreased slightly for individuals over this size. However, the result of *Anthocidaris crassispina* in this study shows that larger individuals have higher gonad index values. The clear difference of gonad index between small and large size animals indicates the different spawning season by size. Spawning of large sea urchin takes place earlier than that of small one.

Kinne (1970) has reported that gonad growth of most marine invertebrates appears to depend primarily on nutrient supply, temperature and photoperiod. In the other hand, Boolootian (1963) has demonstrated the interactions of temperature and light in regard to gamete growth and maturation in the *Strongylocentrotus purpuratus*. Consequently, even though the result of this investigation should be conformed by the precise analyze of such environmental factor, it is possible to estimate that the obtained vague mode and peak from analyze of frequency distribution were caused by this fact of different spawning season by animal size.

In other respects, the mean diameters of sea urchins collected at Ilkwang in 1981 and 1982 were 54.17 and 45.0 mm, respectively. This difference (9.7 mm) of mean diameter between two years is moderately high. In order to reveal the reason of this gap, more detail ecological study, such as seasonal movement or food availability, should be accompanied. However, considering the total catch amounts of sea urchins in Kyung Nam region in 1980 and 1981 (Ministry of Agriculture and Fisheries, 1981, 1982 (in press), the total productions in 1981 (1,718 M/T) augmented very rapidly comparing with those in 1980 (947 M/T). Thus, the appearance of smaller individual at Ilkwang in 1982 seems be explained by overfishing in 1981. In order to maintain the stable stock structure of this species, the fishing effort in detail must be also investigated seriously in future study.

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