Occurrence and Survival Rate of the Larvae of Pacific Oyster *Crassostrea gigas* in Hansan Bay

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In order to set up a predictive model for effective spat collection of Pacific oyster, *Crassostrea gigas*, the survival rate and time required at each developmental stage of drifting larvae were surveyed during the period from June 13 to October 16 in 1984 at the main oyster farming area, Hansan Bay, the southern part of Korea.

The advent of D-shape larvae *ca.* 72×61 μm long had two peaks in that area: July 16 and September 20. Umbo-shape larvae *ca.* 189×217 μm and full grown larvae *ca.* 303×308 μm long also showed two peaks: July 21 and September 25 for the former, and July 28 and September 30 for the latter.

About five days were required for D-shape larvae to develop to umbo-shape larvae. The instantaneous death rate was 0.24 and the daily survival rate 0.78 with a mean survival rate of 29.38%, at this intermorphological stage.

The turnover time of umbo to full grown larvae varied from five to seven days with a instantaneous death rate of 0.15, daily survival rate of 0.86 and mean survival rate of 38.54 %.

Ten to twelve days were required for each group of the D-shape larvae to reach a full grown stage, and their mean survival rate was 11.32% during this developmental period.

Introduction

Historically, oysters have been the major invertebrate species produced by aquaculture. In this century, the trend toward oyster culture has been accelerated as a reaction to man's catastrophic impact on coastal area.

In Korea, human population with its ever-increasing food demand pressures has stimulated the development of aquacultural schemes for many aquatic organisms, including oysters, as a staple seafood. Although oyster culture in Korea has been developing since 1958, annual production exceeded 200,000 tons (M/T) by 1984. Korea with her excellent coastal environment still has potential for greatly expandable oyster production.

About 40% of cultured oysters in Korea is produced at clean and unpolluted area, Hansan Bay, the southern part of the country (Fig. 1).

In this region, at the time of spat collection which is crucial to the success of oyster culture, oyster farmers may determine the presence and abundance of larval oysters of various stages by examining the contents of plankton tows. They thus forecast peak spatfall periods a few days in advance, and the determination of the time to immerse spat collectors in the places where larvae are abundant is most important to the growers.

As most of coastal oyster farmers intending to collect spats, however, are relying on their simple and unreliable experiences, their returns from spat production sometimes fluctuate up and down. But there have been little attempts and quantitative data that may be informed to oyster farmers as soon as possible of the expectations about the date of oyster larval development and the spatfall.

The larvae of Pacific oyster, *Crassostrea gigas* can be easily identified by microscopic observations (Chanley and Andrews, 1971), since they have been extensively studied by some workers (Chan, 1950; Imai *et al.*, 1950). But development of oyster larvae tends to become irregular and often shows a considerable variation in the duration of the pelagic life at different localities with other environmental factors (Elsey, 1936; Loosanoff, 1962; Loosanoff and Davis, 1951).

Since those informations based on indoor culture experiments can not be combined with the prediction of spatfall in the oyster farming ground, there is a need to define a model to forecast the presence and survival rates of the oyster larvae in order to lead a stable oyster production.

Materials and Methods

Three sampling stations (A, B and C) were chosen at the depth of 7m in Hansan Bay where oyster larvae are naturally sheltered against violent winds and waves by surrounding islands (Fig. 1).

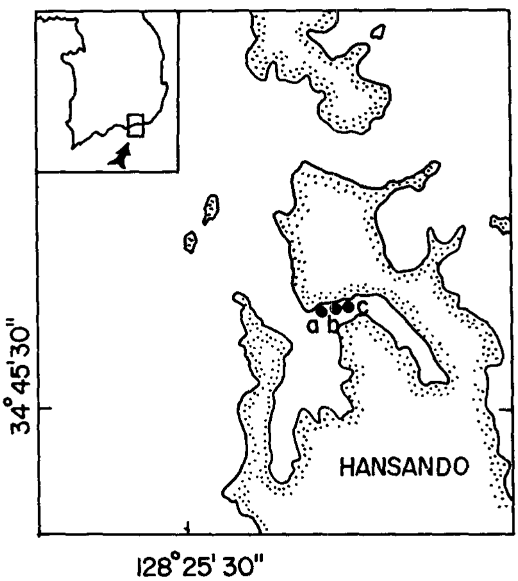

Fig. 1. Map showing the sampling stations.

Oyster larvae were collected from June 13 to October 6 in 1984 by towing plankton net (#13) vertically from bottom to the surface on daily basis. Collected larvae were fixed in the 5% formalin solution of 500ml plastic containers.

Among the mixed plankton samples oyster larvae were identified under optical microscope based on the criteria of Loosanoff *et al.* (1966). Those oyster larvae observed were divided into three larval stages: D-shape (72×61 μm), Umbo shape (189×217 μm) and Full grown stage (303×308 μm).

The daily number of oyster larvae present was determined by counting the average number in the plankton net tows from three stations.

The survival and death rates between each larval stage during their pelagic life were estimated by the following equations:

$$d=\frac{\ln No-\ln Nt}{t} \quad (1)$$

where No and Nt are the numbers of larvae at time 0 and t, and t is the time in days

$$s=e^{-d} \quad (2)$$

where s is the daily survival rate and d is the instantaneous death rate

$$a=1-e^{-d} \quad (3)$$

where a is the daily death rate

Water temperature of the surface was measured twice daily, at 7 AM and 2 PM, to assess the optimal temperature range for the oyster larval occurrence and development in Hansan Bay.

Results and Discussions

Bivalve larvae constitute a significant component of the coastal plankton community (Lebour, 1933; Thorson, 1946), and their distribution is greatly affected by various environmental factors such as water temperature, salinity, current, wind and food organisms (Hopkins, 1931; Davis and Loosanoff, 1953; Loosanoff, 1959).

Oyster larvae, somewhat heavier than seawater, are able to counteract the influence of gravitation by cilia action of the velum. The occurrence of oyster larvae in the plankton is seasonally variable, and this pattern of abundance may often be related, in a general way, to the spawning of the local adult population.

During the experimental period from June 13 to

October 6 in 1984 in Hansan Bay, the variations in surface water temperature at the sampling station were shown in Fig. 2.

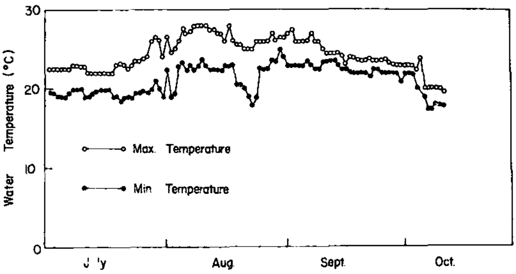

Fig. 2. The variations in temperature at the station.

Water temperature began to increase abruptly in mid-July and varied from 20 to 27°C until it reached the maximum, ranging from 23 to 28°C, between the end of July and mid-Adgust. It then began to decrease in mid-September and ranged from 20 to 22.5°C until early October.

The D-shape larvae occurrence investigated in Hansan Bay is depicted in Fig. 3 and listed in Table 1.

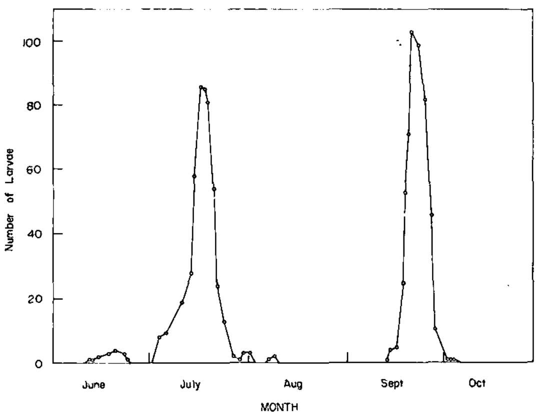

Fig. 3. The occurrence of D-shape larvae of the oyster, *Crassostrea gigas*.

In this area, spawning initiated with the appearance of a small number of D-shape larvae in mid-June, but practically none of this group may have reached the setting stage, because of too small their number. Briefly speaking, there were two peaks in the D-shape occurrence: one occurred on July 16, coincided with the onset of sudden temperature increase, with the larvae numbers of 86 per net towing, and the other peak was found on September 20 with somewhat larger numbers of 103. The sudden change of temperature might have induced oyster spawning in this area.

No occurrence of D-shape larvae during mid-August to mid-September seemed due to the stormy wind that might force them to be expelled away from the surveyed area. Except for that, the spawning season in Hansan Bay was very similar with the results by Koganezawa (1972) who reported three spawning peaks in Matsushima Bay in Japan: the first spawning peak at 22.5°C in mid-July, the second at 25.1°C in late July to early August, and the third 25.7°C in mid-August. From this standpoint, optimal temperature range for the spawning of Pacific oyster seems to be from 23 to 27°C.

The Umbo-shape larvae occurrence comprised two peaks as well as in D-shape (Fig. 4 and Table 1).

But the larvae numbers, in the developmental course of D- to umbo-shape stage, sharply decreased from 86 to 51 in the first peak and from 103 to 63 in the second peak. The time lag between these two larval stages was both five days in the two peaks.

The advent of Full grown larvae was shown in

Table 1. The peak occurrence and time required at each developmental stage of oyster larvae of two groups

Group		Stage				
		D	T (Days)	Umbo	T (Days)	Full
I	Date	Jul. 16	5	Jul. 21	7	Jul. 28
	No.	86		51		17
	W.T.	20-22°C		19-22.5°C		20-27°C
II	Date	Sept. 20	5	Sept. 25	5	Sept. 30
	No.	103		63		12
	W.T.	21.5-23.5°C		21-23°C		21-22°C

D: D-shape larvae Umbo: Umbo shape larvae Full: full grown larvae T: The days required from one larval stage to next stage

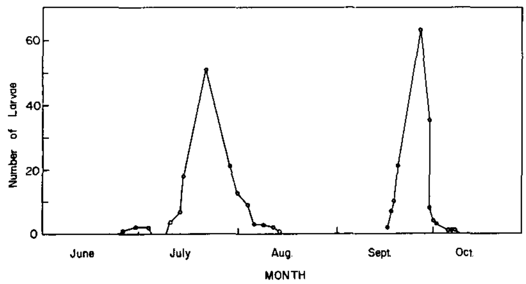

Fig. 4. The occurrence of Umbo-shape larvae of the oyster, *Crassostrea gigas.*

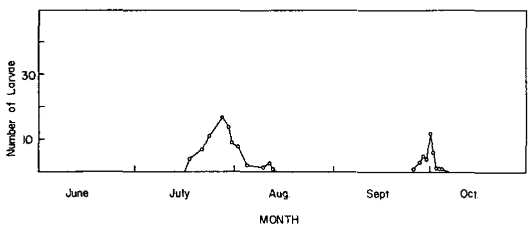

Fig. 5. The occurrence of Full grown larvae of the oyster, *Crassostrea gigas.*

Fig. 5 and Table 1.

The first peak of this stage was found on July 28, twelve days after the appearance of the first D-shape larvae peak, with larvae numbers of 17. And the second peak occurred on September 30, ten days after the second peak occurrence of D-shape, with numbers of 12. In addition, seven and five days were required for Umbo-shape larvae, both in the first and second peaks, to develop into the Full grown stage. The duration of pelagic life of Pacific oyster, the elapsed days from the advent of D-shape to full grown larvae swarming, seemed to be 10 to 12 days in Hansan Bay.

The most vigorous fertilization and the fastest development of the young larvae of *Crassostrea gigas* proved to take place at temperatures from 23 to 27°C (Fujita, 1929). On the other hand, some other workers reported that the duration of the pelagic stage of this oyster was about 18 days at temperatures of 21 to 22°C (Elsey, 1936; Elsey and Quayle, 1939). In this respect, development of oyster larvae in the field could often become irregular and often show a considerable retardation in cases when temperature *in situ* is unfavorable.

It is necessary to ascertain the interval between a maximum swarming of D-shape larvae and a maximum setting in order to know the exact spatfall time in a particular area. For this a very frequent and troublesome examination is required. In addition to that, the spatfall often does not show clearly marked maxima, thus making the determination of the length of the pelagic stage is practically impossible in such cases. So in this investigation we defined the pelagic period in this article as D-shape larvae peak to Full grown larvae peak.

The survival and death rates in the course of developments between each morphological stage were summarized and listed in Table 2.

During the transition period between D- and Umbo-shape stage, the instantaneous death rate (*d*), calculated from the equation (1), was 0.23 and 0.25 in the first and second peak groups, respectively. But those values during the period of Umbo to Full grown stage showed wider fluctuations, ranging from 0.07 in the first to 0.30 in the second peak group. When combining all the individual larvae

Table 2. The death and survival rates at each developmental stage of oyster larvae of two occurrence groups

Group	Stage											
	D(ND)	*d*	*s*	*a*	SR(%)	Umbo(Nu)	*d*	*s*	*a*	SR(%)	Full(Nf)	SR(%)*
I	477	0.25	0.77	0.22	27.67	132	0.07	0.92	0.07	58.33	77	16.14
II	503	0.23	0.79	0.20	31.01	156	0.30	0.73	0.26	21.79	34	6.7
Total	980	0.24	0.78	0.22	29.38	288	0.15	0.86	0.14	38.54	111	11.32

Nd: No. of D-shape larvae
Nu: No. of Umbo-shape larvae
Nf: No. of Fully grown larvae
d: Instantaneous death rate
s: Daily survival rate
a: Daily death rate
SR: Average survival rate during each transition period of two successive morphological stages
SR*: Average survival rate through the whole period from D-shape to Full grown larvae

observed in the both peak groups, *d* was 0.24 in the D to Umbo stage period and 0.15 in the Umbo to Full grown stage.

The daily survival rate (*s*), obtained from the equation (2), varied from 0.77 to 0.79 in the D to Umbo period and from 0.73 to 0.92 in the Umbo to Full grown stage. In the total individual larvae of both peak groups, it showed 0.78 in the former period and 0.86 in the latter.

The daily death rate (*a*) from the equation (3) ranged from 0.20 to 0.22 in the D to Umbo and from 0.07 to 0.26 in the Umbo to Full grown stage period. In the total larvae including all the individuals appeared in the peak groups I and II, that value in the former period was 0.22 and in the latter 0.14.

Considering daily survival and death rate, the larvae in the Umbo to Full grown stage period were much more resistent to mortality than those in early developmental stages.

The mean survival rate (SR) in the D to Umbo stage period varied from 27.67 to 31.01 % with an average of 29.38%, and in the Umbo to Full grown stage period from 21.79 to 58.33% with an average of 38.54%. In the transition period of D to Full grown stage, it was within the range of 6.7-16.14% with an average of 11.32%.

Considering the results of Korringa (1940) who reported that, under normal condition, less than 10% of the larvae reached maturity, the range of 6.7-16.14% in mean survival rate during the period of D to Full grown stages seems to be a reasonable range. Referring to Korringa (1940), about 1% of the mature larvae succeeded in accomplishing settling and about 0.04% of the newly liberated larvae attached to substratum. In this respect, we assume that the Full grown larvae of oyster in Hansan Bay face mass mortality just before or after reaching metamorphosis or setting.

The oyster growers are always facing the problem in deciding when to immerse cultch, so that it may not be silted over or covered with fouling organisms before oyster larvae are able to attach. In many cases, the cultch is laid out too early, with the result that the maximum amount of spat is not obtained. Sometimes collectors are immersed when the potential maxima of setting are over, which does not increase the chances of obtaining a satisfactory practical set either. Accordingly, for the effective prediction of setting and spatfall intensity, it may be not only necessary but important to apply this kind of model based on daily survival rate or death rate at each developmental stage of oyster larvae.

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閑山灣에서의 굴(*Crassostrea gigas*) 浮游幼生의 出現과 生存率

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우리나라 굴 養殖의 中心海域인 閑山灣에서 效率的인 採苗豫報를 기하기 위한 方案으로써, 이 水域에 發生한 굴 浮游幼生을 對象으로 하여 各 幼生의 發育段階別 出現狀況과 生存率을 調査하였다.

1984年 6月 13日 부터 10月 16日까지의 調査期間 中 크기가 約 72×61 μm의 D型幼生은 7月 16日과 9月 20日에 各各 出現 Peak가 있었으며, 189×217 μm의 umbo 型 幼生은 7月 21日과 9月 25日에, 303×308 μm의 成熟幼生은 7月 28日과 9月 30日에 各各 Peak가 있었다.

D型幼生에서 umbo 型 幼生으로 되는데는 約 5日이 걸렸으며, 瞬間死亡率은 0.24, 日間生存率은 0.78, 日間死亡率은 0.22, 平均生存率은 約 29.38%였다.

umbo 型幼生에서 成熟幼生으로 되는데는 5~7日 所要되었으며, 瞬間死亡率은 0.15, 日間生存率은 0.86, 日間死亡率은 0.14, 平均生存率은 約 38.54% 였다.

D型幼生의 發生에서 採苗의 對象이 되는 成熟幼生으로 되는데는 10~12日 걸렸으며, 이 期間中의 平均生存率은 約 11.32%였다.