Bull. Inst. Zool., Academia Sinica **19**(2): 15-22 (1980)

BIOLOGICAL STUDIES ON CULTURED OYSTER IN PENGHU

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(Received May 5, 1980)

Yao-Sung Lin and Hou-Chi Tang (1980) Biological studies on cultured oyster in Penghu. *Bull. Inst. Zool., Academia Sinica* **19**(2): 15-22. To study the biological aspect of cultured oyster and the problems encountered in Penghu, two sets of long-line and one set of raft systems were constructed in Daguoyeh in 1978 and 1979. Six hundred shell strings were attached to each culture system. Two randomly picked oyster strings were removed monthly from each culture system for biological measurements and examinations on gonad development, mortality and predator of oyster. The oyster in Penghu grew very fast, it attained to 6 cm after six months of culture period. From August throughout December, the shell height remained fairly constant at about 6 cm in both years. The growth rate of oyster did not differ significantly between the two culture systems.

Gonad development conditions varied with individuals, about 4% of the oysters reached ripe stage after 3 months of cultivation. In August, the majority of oysters had fully developed gonads. Mass spawning activity occurred within the period between mid-September and October. A second wave of spawning was observed between late December and early January.

The number of seed oysters decrease continuously throughout the culture period. The high mortality of oyster in the summer was associated with the outbreak of oyster leeches. The loss of individual oysters from the cultch as well as the cultch in strings were serious during the monsoon season. By December over 97% of oysters were lost if they were kept longer in the sea.

The weight of oyster meat per string increased rapidly from May to June and reached the highest weight in August. From then on decrease in meat harvest was recorded. The optimum time to attach as well as harvest the oyster were also discussed.

The history of successful oyster farming in Penghu is rather short[1]. From 1964 to 1975 several attempts were made by the district government to adopt the stick culture in the intertidal zone. Unfortunately, the harvest was too disappointing to stimulate the blooming of oyster industry in Penghu. Until 1975, a first trial of the long-line culture system in the deep water area was initiated by a plastic company. The result was so promising that the number of long line culture systems increased rapidly from 20 sets in 1975 to 900 sets in 1980. Meanwhile, many raft culture systems were also constructed along with the expansion of the long-line culture system.

Although oyster farming area expanded rapidly in Penghu, no study on the biological aspect of oyster culture and the problems encountered during the period in this area has been made, although these basic informations are very important for furture management of oyster farming. This investigation was conducted to study the growth rate, gonad development, mortality, and predator of oyster at Daguoyeh bay in Penghu.

MATERIALS AND METHODS

In January 1978, one set of long line culture system was anchored 800 m away from shoreline in Daguoyeh hor a start. In order to compare the growth rate of oyster in different culture systems and locations, a second long-line culture system and one raft culture system were set up 1200 m off the shore of Daguoyeh in January, 1979. In the long line culture system, a series of ten polyethylence drums were connected by four parallel ropes each measuring 45 m long and 3.5 cm in diameter. The ropes were spaced about 30 cm apart. In between two neighboring drums, several bamboo sticks were fixed onto the ropes to prevent entangling. The whole system was secuerred at each end with a 60-kg anchor. In the raft culture system a bamboo raft meansuring 10 m × 10 m was kept afloat by polyethylene drums or poles and anchored to the bottom with two 60-kg anchores.

Since spat collection was not practiced in Penghu, all the spat were purchased from oyster farmers in the west coast of Taiwan in mid-January. Before setting the young oysters on the long-line or raft system, the shells were stripped off the wires, individually cleaned with sea water and restringed. About 5% of the shells were discarded because they carried too few young oysters. Twenty selected shells were restrung on to a 6-m nylon string and the shells were spaced 20 cm apart. About 600 shell strings were attached to each culture system. During the whole study period, no maintenance work was required.

On each sampling date, two randomly picked oyster strings were removed from each culture system for examination. The number of cultch per string, and the number of live and dead oysters in each cultch were recoreded. All the oysters were then removed from the strings and were divided into three groups (upper, middle and lower stratum) according to the position of the cultch on the string. Fifty random specimens were chosen from each group for meansurements of shell dimensions, live weight and examination of gonad condition of the oysters. Due to irregularity in the shape of the oysters, shell height was measured as the longest dimension and shell length as the maximum dimension perpendicular to the height axis[2]. Live weight included the weight of the fluid within the mantle cavity. After measurement of dimensions and live weight of the oysters were taken, each oyster was opened to examine the gonad condition, then the meat was taken out and boltted dry with cheese colth. The weight of the pooled meat samples were mansured and the mean meat weight per oyster as well as that per string were calculated.

The gonad conditions were arbitrarily classified into four categories following Imai's[3] suggestion: A-body with large amount of gonad tissue, in which most of the digestive diverticulum was not observed; B-less than 50% of the digestive diverticulum can be observed; C-more than 50% of the digestive diverticulum can be observed; D-oysters was in a state of water oyster, in which the digestive diverticulum was almost completely observed. The percentage of oysters belonging to each catergory in each sample date were calculated. Once the genital product was discharged, the gonad condition of the oyster would probably shift from category A and B to C and D. Consequently the spawning periods could be detected from the change in the relative abundance of the above mentioned four catergories between two consecutive sampling dates.

In addition, histological study on the gonad development were also carried out on samples obtained from March to July, 1978. Eight oysters from each sampling date were fixed in Bouin's Fixative. The sectioned gonad tissue were treated with hematoxylin-eosin stains and examined under the microscope.

In the study of the relationship between mortality of oyster and the abundance of its predator-the oyster leech, data gathered from oyster farming area at Tsaiyuan bay in 1978 were also included.

RESULTS

Hydrologic Pattern

Some hydrological data have been monitored monthly by Dr. K. Y. Lee (unpublished data) at Daguoyeh bay in Penghu. The summary of these data over one and a half year period can be described as follows:

The water temperatures which rarely dropped below 19°C in the winter and rose to a maximun of 28–29°C in the summer months, is very favourable for the growth and reproduction of the oyster. Salinity varied slightly, ranging from 33‰, in September to maximum of 35.5‰ in December. The oxygen content varied from 6.5 to 9 ppm and the pH values flucutuated from 6.5 to 9. Chlorophyll content was lowest in Februrary (0.1 μg/l) and increassed to a high of 1.6 μg/l in September. Due to poor developement of industry in Penghu, there is no pollution problem in the oyster culture areas.

Growth of oyster

The growth rate of oysters certainly is affected by various factors. At present we could only analyze the data in relation to the culture methods, the location of the culture systems, and the growth in different years.

The growth condition of the oysters on the long-line system in 1978 and 1979 at the same location were summarized in Table 1. In both years, the initial size of the oyster spats and the starting time were similar. However pronounced difference in growth rate of oysters during the early months between the two years was noted. The increase in size of the spats in the first two months in 1978 was slower than that observed in 1979. By late March, oyster size as expressed in shell height averaged 2.0 cm and 2.8 cm in 1978 and 1979, respectively. Significant difference ($p<0.05$) in shell height were observed continously until late July. On the other hand, no significant difference in average shell width and shell length were detected throughout the whole culture period both in 1978 and 1979.

Regardless of the differences in the growth of shell height during the first 5 months between 1978 and 1979. The oyster attained a similar size in August and stopped growing from then on. From August through December, the shell height remained fairly stable at about 6.2 cm in both years.

A comparsion of growth rate between the long-line and raft system was made, based on the data collected in 1979. All the oyster strings were attached to both systems on the same date and anchored at 1200 m from the

TABLE 1.

Shell dimensions (in cm) of oysters in the long-line culture at 800 m from the coastline of Daguoyeh in 1978 and 1979

Time	Shell height		Shell length		Shell width	
	1978	1979	1978	1979	1978	1979
Feb.	1.8	1.7	1.3	1.1	0.7	0.7
Mar.	2.0	2.8	1.4	1.7	0.8	1.0
Apr.	2.8	3.3	2.3	2.2	1.4	1.2
May.	3.3	4.1	2.6	2.7	—	1.5
Jun.	4.8	5.6	3.5	3.5	2.0	1.9
Jul.	5.1	5.9	3.4	3.6	1.9	2.0
Aug.	6.1	6.0	3.9	3.7	2.2	2.3
Sep.	5.7	5.9	3.5	3.7	2.2	2.3
Oct.	6.2	6.4	3.7	3.8	2.4	2.3
Nov.	6.2	—	3.8	—	2.4	—
Dec.	6.2	—	3.7	—	2.3	—

seashore. After five months, the oyster attained 5.9 and 5.5 cm in the raft and long-line system, respectively (Table 2). However, statistic analysis revealed no significant difference between the two systems. From July till October, the size of oysters in both systems were almost identical. This suggested that different culture method did not the affect the growth rate of oyster, as long as the oysters were kept at similar locations.

TABLE 2.
Comparison of shall height (cm) of oysters in under different culture methods or varied distance from shoreline (m) at Daguoyeh, Penghu 1979

Time	Long-line		Raft
	800 m	1200 m	1200 m
Feb.	1.7	1.7	1.7
Mar.	2.8	2.9	3.0
Apr.	3.3	3.4	3.4
May	4.1	4.2	5.1
Jun.	5.6	5.5	5.9
Jul.	5.9	5.6	6.7
Aug.	6.0	6.4	6.2
Sep.	5.9	6.5	6.4
Oct.	6.4	6.0	6.3

However, pronounced difference in growth of oyster was observed from July through September between the two long-line systems that was located at 800 m and 1200 m from the seashore of Daguoyeh, respectively in 1979. In the inner zone, the shell height averaged 5.9 cm during the period from July till September. The corresponding figure for oysters maintained in the outer zone was 6.5 cm. The discrepancy in the results observed in October probably was due to the fact that larger oysters were more apt to break and loose from the cultch in the rough sea during the monsoon season.

A comparison was made on the growth rate of oyster at upper (0.2–1.3), middle (1.4–2.5 m) and lower water (2.6–4.0 m). These data were summarized in Table 3 which listed means for shell height and shell length measured on various dates. Shell height or shell length at all depths

TABLE 3.
Growth comparison of oysters (in cm) at three depths in Daguoyeh, Penghu, 1978. The depth categories were: upper (0.2–1.3 m), middle (1.4–2.5 m), and lower (2.6–4.0 m)

Size	Location	Date		
		Feb. 21	Aug. 30	Nov. 4
Shell height	Upper	1.8	6.3	6.1
	Middle	1.9	6.4	6.3
	Lower	1.9	6.1	6.4
Shell length	Upper	1.2	3.9	4.0
	Middle	1.3	3.8	4.1
	Lower	1.3	4.0	4.1

on any given sampling date were similar. Evidently depth was not a factor that affected the growth rate of oyster in Penghu.

Gonad development and spawning activity

The chronological records on gonad development of oysters in 1978 and 1979 were listed in Tables 4 and 5, respectively. Apparently

TABLE 4.
Gonad condition of oysters cultured at Daguoyeh, Penghu in 1978 and January 1979. A, B, C and D represent that 76–100%, 51–75%, 26–50%, and 0–25% of the gonad is filled with white ova or sperm material

Date	Ratio (%)			
	A	B	C	D
Apr. 27, 1978	4	9	21	66
May 11	3	6	17	74
May 26	8	8	13	71
Jun. 8	11	7	14	68
Jun. 15	18	17	19	46
Jul. 3	14	22	21	43
Aug. 11	83	8	3	6
Sep. 20	85	6	3	6
Oct. 17	3	1	6	90
Nov. 23	49	17	7	27
Dec. 24	75	8	7	10
Jan. 11, 1979	16	24	43	16
Jan. 24	67	9	14	10

TABLE 5.
Gonad condition of oyster cultured at Daguoyeh, Penghu in 1979. A, B, C, and D represent that 76–100%, 51–75%, 26–50% and 0–25% of the gonad is filled with ova or sperm material

Date	Ratio (%)			
	A	B	C	D
May 15	4	4	7	85
Jun. 15	10	20	14	56
Jul. 15	49	13	5	33
Aug. 15	72	14	8	4
Sep. 15	93	3	2	2
Oct. 15	29	18	36	17

gonad development condition varied greatly among individuals. Oysters of all stages could be found on any sampling date, and some of them reached maturity very early. For example, on April 27, 1978, in about 4% of the 3-month-old oysters, the gonad layer had already occupied most of the space between the mantle and the liver. Histological study also confirmed that both spermatozoa and ova of either sex had reached ripe stage.

In general, the gonad development pattern were quite similar in both year (Table 4 and 5). Prior to July, the gonads of both sexes in more than half of the oysters examined were still rudimentary. From July on, however, most of the oysters were in various stages of gonad growth and ramification. The gonad sections also revealed that oocytes began to increase in size around this time. In August, the majority of oysters had fully developed gonads that obscured their digestive organs. The percentage of fully mature oysters were 83 and 72% in August of 1978 and 1979, respectively. The percentage of oysters in stage A increased steadily and reached the hightest scores in September (85 and 93%, respectively), but drastically dropped on the next sampling date in mid-October, in both years. Evidently mass spawning activities occurred within the period between the two sampling dates.

The extent of synchronized spawning activity among the oysters varied between the two years. In 1978, the percentage of stage A oysters droped from 85% in mid-September to only 3% in mid-October, while the stage D oysters rose from 6% to 90% (Table 4). Apparently all of the mature oysters had completed their spawning activities between these two sampling dates. The situation in 1979, however, was not so drastic (Table 5). The complete release of eggs or sperms seemed to have taken a longer duration. This was suggested by the more even distribution of oysters belonging to the various categories.

According to the data from investigations of 1978 continued into January 1979 (Table 4), a second wave of spawning, although in a smaller scale, occurred sometime between late December 1978 and early January 1979. After that, the gonad materials developed rapidly and 67% of the oysters were again in stage A in late January 1979. It seemed resonable to assume that in Penghu after the oyster had reached maturity, they would continue the cycle of accumulation of gonad materials and spawn again within short periods.

Mortality

The average number of oysters on the strings tended to decrease continuously (Fig. 1, Table 6). In 1978, it averaged 30 oysters per cultch in February but dropped to only 8 (in November). During the first half of the year, competition for space and food among oysters probably was the main reason for oyster death. However, predation by oyster leech in the summer and the loss due to the rough sea conditions during the monsoon season were responsible for the mortality of oyster during the second half of the year.

In 1978, the abundance of oyster leech and the corresponding mortality rate of oysters in Tsaiyuan and Daguoyeh were investigated (Table 7). Before June, very few oyster leech were observed and the mortality rate of oyster was less than 3% in both areas. By late—July, the number of oyster leech per string in Tsaiyuan went up to 14 and the corresponding oyster mortality reached 23%. In August the abund-

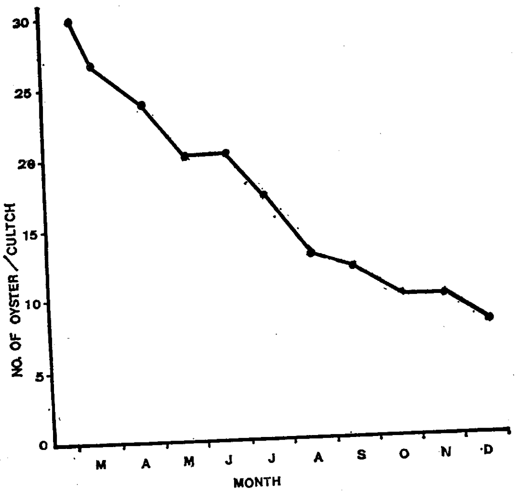

Fig. 1. Monthly change of the number of oyster per cultch in the long-line culture system in 1978.

TABLE 6.
Monthly record on abundance of oyster and the meat weight (in g) of oysters in 1978

Time	No. oyster per cultch	No. cultch per string	Meat Wt. per oyster	Meat Wt. per string
May	20	20	0.75	315
June	20	20	2.12	848
July	17	20	2.44	830
Aug.	13	20	3.98	1034
Sep.	12	19	3.60	821
Oct.	9	16	3.43	494
Nov.	9	10	3.51	316
Dec.	8	1	3.33	27

ance of oyster leech further increased to 25 per string and the oyster mortality raised to a high of 52% in Tsaiyuan. The abandance of oyster leech during the same period was considerably lower in Daguoyeh, so was the morality rate of oysters (Table 7). These evidence indicated that high mortality of oyster culture in Penghu was associated with the outbreak of oyster leeches.

Harvest of oyster meat

Mean meat weight per oyster and the total

TABLE 7.
Mean number of oyster leech per string (20 cultches) and the mortality rate of oyster at Daguoyeh and Tsaiyuan in Penghu, 1978

	Tsaiyuan		Daguoyeh	
	Oyster leech per string	Mortality rate of oyster (%)	Oyster leech per string	Mortality rate of oyster (%)
May 20	0.1	1	1	1
June 21	2	3	1	1.0
July 28	14	23	1	2.0
August 15	25	52.6	4	11.6

weight of oyster meat in one string sampled from May till December 1978, were listed in Table 6. The weight of oyster meat per string averaged 315 g in May. Rapid growth of oyster occured within the next month as evidenced by the almost tripled meat weight between May and June. The meat weight increased further and reached to the highest score in August both in terms of meat weight per string and average meat weight for individval oysters. From then on, the harvest of meat from each string decreased steadily. In December 1978, only 27 g of oyster meat could be obtained from one string. However, the decline in average weight per oyster was not so drastic. Thus the drcrease in meat harvest was caused primarily by the loss of individual oysters from each cultch as well as the breakage of whole cultches from the oyster strings (Table 6) during the monsoon season that started in mid-October in 1978. As a result, by December over 97% of the oysters were lost and buried in the bottom of the sea.

These data indicated that if the oyster farmer harvest all the oysters in August, he would get the highest return in terms of total meat harvest. However, too much supply in a short period of time would lower the price tremendously. In addition, typhoon attacks in Taiwan usually start in June. The longer the oysters are kept in the sea, the mroe risk the farmers are taking in loosing the oyster crops plus labor expenses. Therefore it is better to start marketing the oysters in June, and complete havesting by the end of September. Considering the risk versus benifit, it is unwise to keep the oysters in the sea much longer.

DISCUSSION

The growth of oysters were good in both the long-line and the raft culture systems in Penghu, and the shell height attained an average of 6 cm within 6 months. This growth rate was quite similar to that observed in the rack system in Chiayi[4], which was in contrast to the poor growth usually occurred among oysters in the stick culture system. In the latter system, the average shell height was still less than 4 cm after over an year's cultivation[9,10]. Faster growth rate of oysters among the hanging systems probably is related to the fact that continuous food supply is available to oysters maintained in the deep water areas. However, once the shell height reached an average of 6.0–6.5 cm, it remained relatively constant at that size even if they were kept longer in the sea. The same phenomenon was also observed among oysters cultured in the Taiwan island. This probably is related to the fact that under favorable conditions in the warm water, the oysters grow very fast. Once they reached maturity, cyclic accumulation of gonad materials and spawning continues during the year[5,8]. Consequently, a majority of the energy derived from food would be spent on reproduction rather than increasing their body size.

Some oyster farmers bought extra oyster spat than they could use in November. These spats were placed on horizontal shelves installed in shallow water to produce hardened seed oysters[7]. These hardened seed oysters were attached to the culture system after the first crop was harvested in March-June. In general, the hardened seed oysters grew rapidly once they were transferred to the deep water. Hence they could be harvested in May-August. However, the hardened seed oyster also face the risk of predation by oyster leech or loss to the sea during the typhoon season. Furthermore, this culture arrangement might not be practical due to the shortage in supply of oyster spats from Taiwan in November or earlier. This situation did occur in Taiwan in 1979. As a consequence, most of the oyster farmers had to start their oyster culture in January and harvest the oysters only once a year.

This revealed another shortcome in the oyster farming in Penghu. Since the risk of lossing the adult oyster by the predation of oyster leech and breakage of oyster strings in the summer, the oyster farmers usually harvest the oysters once they reached over 5 cm in average length and with well developed gonads. In other words, not many of the oyster were left in the fall when peak spawning activity occurred. As a result, very few oyster spat were available in Penghu. Therefore, all the oyster spats for culture must be purchased from the west coast of Taiwan. Development of method to secure spat supply is essential for the existance and expansion of the oyster industry in Penghu.

In Taiwan, the most serious predator for oyster is oyster drills[6]. But in Penghu, oyster leech is considered as a serious trouble. It seems that different kind of predators occur, in accordance with various culture methods. In Taiwan, oyster drills prevail in the rack and stick cultures. The oysters in these systems usually are exposed to the air for several hours every day during the low tide, a situation unfarorable for the existence of oyster leech. But in the long-line or raft system oysters are immersed in the water all day long which is unsuitable for the survial of oyster drill. For further development of oyster culture in Penghu, study on how to prevent the predation of oyster leech and the supply of oyster spats at the right time is very important. Furthermore, the expansion of oyster culture area around the Penghu Islands is another way to increase the production of oyster. However basic study on the carrying capacity of the waters for oyster culture in Penghu would be necessary.

Acknowledgements: This research was sponsored by a grant from the Council for Agricultural Planning and Development, Con-

tract 78(ARDP)-5.3-0-151 and 79(ARDP)-1.5-0-192.

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澎湖養殖牡蠣之生物學研究

林曜松　　湯弘吉

爲了瞭解有關澎湖養殖牡蠣的生物知識與蚵民遭遇的困難，在 1978 與 1979 二年內，在大菓葉海岸搭設二台延繩式與一台竹筏式養殖架；每台懸掛 600 串牡蠣，每月自架上逢機選取二串牡蠣以檢視其成長、生殖巢的發育、死亡率與害敵的發生。

澎湖牡蠣的生長快速，大約養殖六個月，殼高卽可達 6 公分，但自 8 月至 12 月間，則未見其生長。竹筏式與延繩式下的牡蠣成長，則無顯著差異。

牡蠣生殖巢之發育，隨個體而異。養殖牡蠣成長三個月後，已有 4% 的個體成熟，到 8 月時，絕大多數的個體，生殖巢呈飽滿狀態，在 9 月中旬與 10 月中旬間，曾有大規模的排卵活動，第二次排卵期則爲 12 月至 1 月上旬間。

養殖期間，牡蠣個體不斷減少，在 1978 年夏天，牡蠣嚴重死亡的現象與扁蟲的大量發生有密切關係。又東北季風時，許多牡蠣串或每個母殼上之牡蠣甚易脫落。若持續養殖至 12 月，97% 的牡蠣均已失落。

在養殖架下，每串牡蠣收成的淨肉重，5 至 6 月急速增加，於 8 月時達到最高，此後又逐漸減少。有關牡蠣養殖與收穫，本文亦有所討論。