Bull. Inst. Zool., Academia Sinica **18**(1): 21-27 (1979)

FEEDING, REPRODUCTION AND DISTRIBUTION OF OYSTER DRILL *PURPURA CLAVIGERA* (KUSTER)

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(Received March 19, 1979)

Yao-Sung Lin and Ching-Jer Hsu (1979) Feeding, reproduction and distribution of oyster drill *Purpura clavigera* (Kuster). *Bull. Inst. Zool., Academia Sinica* **18**(1): 21-27. The effects of temperature and salinity on the feeding and reproduction rates of oyster drill (*Purpura clavigera*) were studied in the aquaria. The abundance of oyster drill and its relationship to oyster mortality rate at Shiang-San was also investigated. Feeding activity of drill increased with the increase in temperature, salinity and drill sizes. The last three variables also exhibited positive relationship with the reproduction rate of oyster drills. No egg capsules was deposited by the small drills below 22°C. At 27°C, however, oyster drills of all sizes deposited egg capsules at every salinity tested. The number of eggs per capsule was correlated with length of the capsule, which in turn was related to the size of drills. The estimated mean number of oyster drill was 16.7 per m². The mortality rate of oysters at Shiang-San was 31.3%, of which 3.9% can be regarded as the natural mortality rate whereas 27.4% was attributed by predation of the drills. The abundance of oyster drill varied greatly with the culture condition of different blocks. It was substantially higher in the blocks where part of the horizontal oyster strings reached the bottom than those that were suspending. It suggests that improvement of oyster culture condition would be a very practical way in reducing the chance of oyster drill predation.

In both the United States and Europe, the oyster drills (*Urosapinx cinera* and *Eupleura caudata*) caused severe damage to the oyster industry[1,10]. Oyster drill (*Purpura clavigera*) is also one of the pests that prey on the Pacific oyster (*Crassostrea gigas*) in Taiwan, particularly in areas where stick or rack culture systems were practiced. About 10 to 50% reduction in harvest of oyster meat in various areas along the west coast of the island was resulted from the drills' predation[6]. Kuo and Hwang[7] found a positive relationship between oyster mortality and abundance of the drills. More recently, Hwang and Huang[5] also made some biological studies on oyster drills.

The present study conducted to find out the effects of temperature and salinity on the feeding and reproduction rates of oyster drills. The relationship between the abundance of oyster drills and the mortality rate of oyster in oyster farming area was also investigated.

MATERIALS AND METHODS

The study was carried out over the period from December, 1977 to March, 1978. The field investigation was conducted in oyster farming areas in Shiang-San, Hsin-Chu Hsien. Rack culture system, with oyster strings hanging horizontally between the supporting poles, is the method widely used for oyster farming along the intertidal flats of this area. Fifteen blocks of 10 m² each were randomly chosen from the oyster farming area as sampling units. Eight of the 15 blocks were located in the inner zone and the remaining ones were in the outer zone. In some blocks, part of the oyster strings were touching the sand bottom. While in others, all the oyster strings were suspending from the bottom. On each block the number of oysters, both dead and alive, and that of oyster drills were counted. The mortality rate of oyster was expressed by the percentage of death. The relationship of mortality rate to the abundance of drills on each block was studied by both correlation and regression analyses[11].

For experiments conducted in the laboratory, large number of oyster drills were hand-picked from the stick or rack oyster culture areas. After the drills were brought to the laboratory, they were kept in aquaria (22°C, 26‰ salinity) for a week before being conditioned for various experimental temperatures and salinities. The aquarium, measured $100 \times 39 \times 40$ cm (length-width-height), was equipped with a thermostat to maintain a stable water temperature. The water level in the aquarium was always maintained at 33 cm in height. A filter was used for each aquarium to assure good water quality. The rate of flow in the filter was set at about 1.2–1.5 l/min.

To condition the drills to the various salinity-temperature combinations, the sea water in which the drills were kept was gradually brought to the appropriate salinity and temperature. The salinity was adjusted by an increment or deduction of 3‰ per day until the desired salinity was reached. Once the acclimatization in salinity has been accomplished, the water temperature was then adjusted to the desired temperature by a change of 1–1.5°C per day. After the oyster drills have been conditioned to the desired salinity and temperature, they held tightly on the walls of the aquarium with the foot, indicating that they had fully adjusted to the new conditions. The adult oysters, *C. gigas*, served as prey in the experiments, were put directly into the salinity-temperature combinations without prior conditioning.

In order to determine the combined effect of salinity, temperature and drill size on the feeding and reproduction of the drill, a $3 \times 3 \times 4$ factorial experiment was practiced, with temperature controlled at 17°C, 22°C and 27°C; salinity at 14, 20, 26 and 32‰; and the drills divided into small, medium, and large sizes with mean shell length and standard deviation of 1.63 ± 0.13, 2.43 ± 0.11 and 3.34 ± 0.28 cm, respectively.

In each treatment, the aquarium was stocked with 72 oysters with a mean size of 5.9 cm and 30 oyster drills. Daily counts on number of oysters attacked by the drills were recorded. Empty oyster shells were removed and replenished with live oysters to keep the predator-prey ratio constant. Egg capsules were also removed and enumerated daily. The experiments were continued for 30 days.

The feeding rate in each treatment was expressed as mean number of oyster consumed per drill per 30 days. Sexes of the oyster drills were identified at the end of each treatment by examining the crushed drills. Reproductive rates were expressed by the number of egg capsules deposited per female per 30 days.

In another set of experiments, 23 egg-producing females were kept in separate containers and observed individually. Shell length, length of egg capsules deposited by each drill and the number of eggs per capsule were recorded in order to determine the relationship among these three parameters.

RESULTS

Drill abundance and oyster mortality

The abundance of drills and the mortality of oyster in the 15 blocks were listed in Table 1. Data analyzed by Student *t*-tests revealed that, under similar culture condition (*i. e.* with oyster strings all suspending or all partially touching the ground), there were no significant differences in average number of oyster drills per block between the inner and outer zones. However, the abundance of oyster drills in bocks where part of the horizontal oyster strings reached the bottom were substantially higher than those that were suspending. The number of drills per block ranged from 202 to 436 for the former, but was 13 to 142 for the latter.

TABLE 1
The drill abundance and oyster mortality in fifteen blocks from Shiang-San

Blocks	Location	Block condition	Number of drill/10 m^2	Oyster mortality
1	outer	suspend	123	33.9
2	outer	suspend	112	52.8
3	outer	suspend	76	16.5
4	outer	suspend	31	4.6
5	outer	suspend	13	5.2
6	outer	contact	426	86.6
7	outer	contact	316	53.3
8	inner	contact	336	49.5
9	inner	contact	320	52.0
10	inner	contact	201	45.5
11	inner	contact	202	42.8
12	inner	suspend	142	13.4
13	inner	suspend	83	11.5
14	inner	suspend	69	8.7
15	inner	suspend	40	9.4

The mean mortality rate of oysters among the fifteen blocks was 31.3%. To determine whether mortality rate of oyster (Y) was correlated with the density (number per m^2) of oyster drills (X), the former was graphed against that latter (Fig. 1). The regression equation was $Y=3.93+0.17X$. The coefficient of determination ($r^2\times 100$) suggested that 80.5 percent of the variation of mortality rate among blocks may be explained by the density of drills. The intercept of the regression equation was 3.9%, which can be regarded as the natural mortality rate caused by reasons other than the predation of oyster drills. Hence, the mortality rate of oyster died from predation by oyster drills would be 27.4%. Evidently, death of oyster in this farming area was mainly attributed to the consumption by oyster drills.

Feeding activity

The feeding rates of oyster drills observed in the 36 combinations of salinity, temperature and drill size were shown in Fig. 2. At each salinity and temperature combination the feeding rate was proportional to the size of drills, that is, the bigger the drills were the more they ate. For example, the overall mean feeding rates for

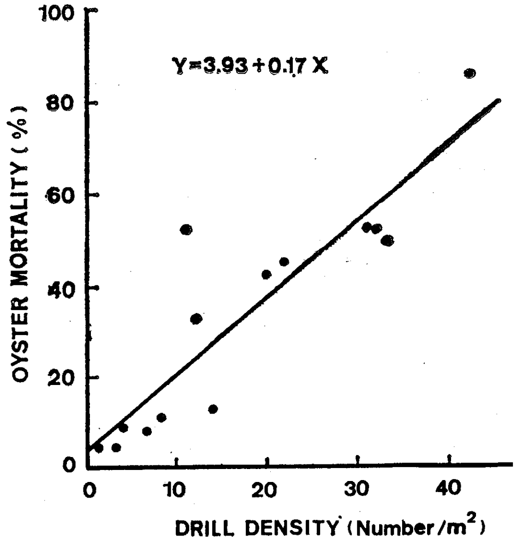

Fig. 1. The relationship between mortality rate of oysters and drill density in the oyster farming area at Shiang-San.

the small, medium, and large drills were 0.65, 1.80 and 2.89 oysters/drill/30 days, respectively.

In addition, at each salinity and drill size combination the feeding rate increased with the increment in temperature. The respective overall mean feeding rates at 17°C, 22°C and 27°C were 0.55, 1.71 and 3.09 oysters/drill/30 days. The influence of salinities on the feeding rates of oyster drills was also obvious, but the relationship was not linear within the tested range of salinity. From 14‰ to 26‰, the feeding rates of drills increased with an increase of salinity for each temperature and drill size combination. However, no significant difference in feeding rates of the drills was observed whether they were kept at 26‰ or 32‰ (Fig. 2).

In order to predict the feeding rate of different-sized oyster drills at varying temperatures and salinities, a multiple regression was calculated by stepwise multiple procedure[2]. The best prediction equation obtained was:

$$Y=1.079-0.517\,X_1-0.327\,X_2-4.015\,X_3+0.0131\,X_1X_2+0.054\,X_2X_3+0.189\,X_1X_3,$$

where Y denoted the daily consumption rate of drill (oysters/drill/30 days), X_1 was the tem-

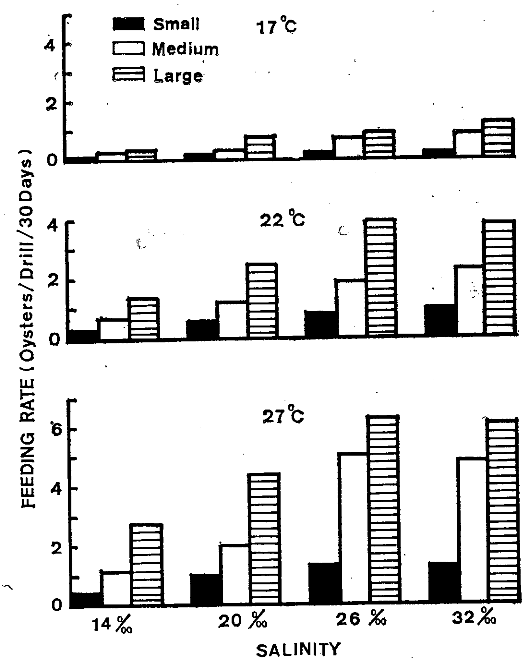

Fig. 2. Feeding rate of small, medium and large *P. clavigera* on adult oysters at controlled temperatures and salinities.

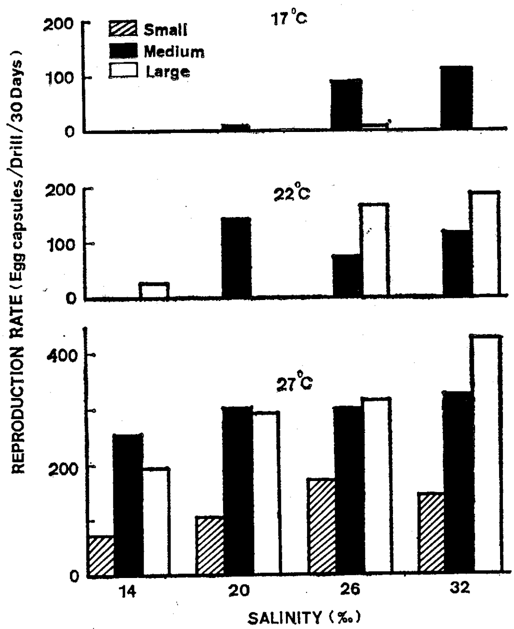

Fig. 3. Reproduction rate of *P. clavigera* of various sizes at controlled temperatures and salinities.

perature (°C), X_2 represented the salinity (‰) and X_3 was the size of drill (cm). All the partial regression coefficients were significant at 5% level. The overall regression was highly significant ($p<0.01$). About 94.13% of the variation in the feeding rate of oyster drills may be explained by sizes of drill, temperature and salinity.

Reproduction

Salinity, temperature and drill size all exhibited positive relationship with the reproduction rates of drills (Fig. 3). No egg capsule was deposited by the small drills at either 17°C or 22°C. At these temperatures, the medium drills deposited eggs at higher salinity. For the large drills, only a few egg capsules were deposited at 17°C, but its egg-laying capacity increased considerably at 22°C in higher salinities. At 27°C, however, oyster drills of all sizes deposited egg capsules at every salinity tested.

The influence of salinity on reproduction activity of oyster drill was not as obvious as that of temperature. The relationship between salinity and the number of egg capsules deposited varied with the sizes of drills. At 27°C, the salinity at which the maximum number of egg capsules deposited for the medium and large drills was at 32‰, while that for the small drills apparently occurred at 26‰. On the other hand, at 22°C the medium drills deposited more egg capsules at 20‰. These suggested that temperature was a more important factor than did salinity in affecting the reproductive activity of drills.

Drill size and reproduction potential

The number of eggs per capsule was correlated with the length of the capsule (mm), which in turn was related to the size of drills (cm) (Fig. 4 and 5). The equation for the relation of the number of eggs per capsule (Y) to the length of capsule (X) was: $Y=-200.65+94.73X$. Furthermore, the linear relationship between the length of egg capsules (X) and size

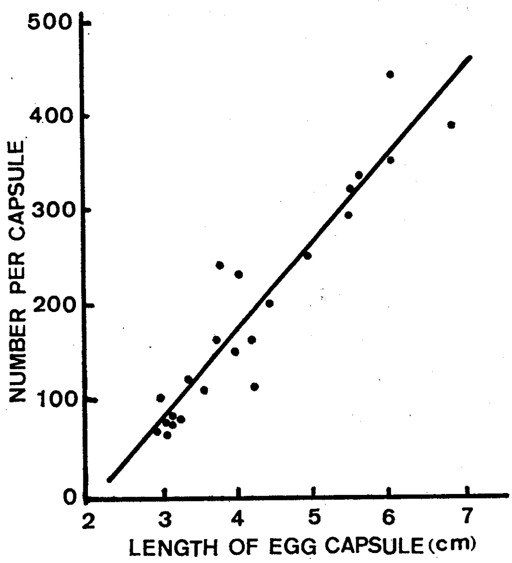

Fig. 4. The relationship between egg capsule length of *P. clavigera* and the number of eggs in each capsule.

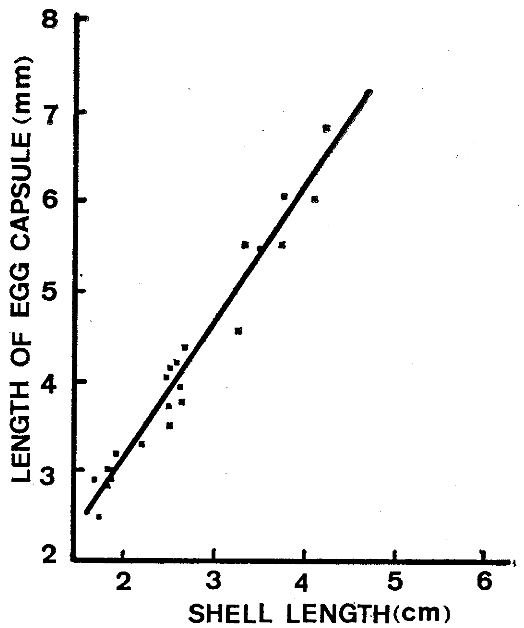

Fig. 5. The relationship between shell length of *P. clavigera* and the length of its egg capsule.

of drill (Z) was: $X=0.22+1.474\,Z$. Both linear regressions were significant ($p<0.05$). If the X in the first equation was replaced by the right hand side of the second equation, we obtained $Y=-179.81+139.83\,Z$. In the field, the minimum size of egg-producing oyster drill was found to be 2.3 cm in length. In the laboratory, however, it was 1.7 cm. The slope of the linear equation suggested that a mature oyster drill has the potential to lay about 140 more eggs per capsule with every cm increment in shell length.

DISCUSSION

The culture condition of oyster influences the abundance of drills, which in turn affects the mortality rate of oysters in the field. The mean abundance of oyster drills in blocks where part of the horizontal oyster strings reached the bottom is about three-fold higher than in those that were suspending (300 vs 76/drills/10 m^2). Then, the improvement of oyster culture condition would be a very practical way of reducing the chance of oyster drills attacks.

In its natural habitat, a few drills begin to lay egg in September, but most of them deposit egg capsules in the period from January through March. While the oyster drills are engaged in egg production, which lasts about one week, they usually do not take any food. Since our feeding experiments were conducted from December to March, presumably the oyster consumption rate of certain female drills were affected by their reproductive activities. Hence the feeding rates of drills obtained from these experiments may be underestimation of the drill's actual potentiality in oyster predation on an annual basis.

The feeding activity of the oyster drill, *P. clavigera*, increased with the increase in temperature and salinity. Similar observations were reported for the oyster drills *U. cinera* and *E. caudata* from the United State[9]. In a preliminary experiment, when temperature was kept at 13–15°C, none of the drills took in any food below 15°C. Whereas in the experimental groups, only a few of them fed on their prey at 17°C. Thus 15°C appeared to be lower limit for *P. clavigera* to indulge in eating oysters, which is significantly higher than the minimum temperature of 6.5–9.5°C for other species of drills[3,4].

No egg capsule was deposited by the small drills at either 17°C or 22°C. At 27°C, they deposited considerably less egg capsules than did the larger drills. Hwang and Huang[5] reported that the minimum size of egg capsule-depositing oyster drill was 2.5 cm in length, whereas in Shiang-San farming area it was 2.3 cm. In the laboratory, however, it was found to be 1.7 cm. The mean and standard deviation of the small oyster drills used in the present experiments was 1.63 ± 0.11 cm. In other words, many of the small drills may not have reached maturity, thus was incapable of producing egg capsules. At higher temperatures, however, the maturation process of oyster drills may have been accelerated to such an extent that the small drills also deposited egg capsules at all salinities tested.

The predation by oyster drills constituted the major cause of oyster mortality in Shiang-San. Although they were continously picked off by the oysterman, the drills still prevailed in the oyster farming areas. This was probably related to its high density and great reproduction potential. The density of oyster drill in these areas was 16.7 per m^2. During the reproduction season from January to March, the water temperature ranged from 17 to 23°C and the salinity varied from 26 to 30‰. The data obtained from experiments conducted under similar enviromental conditions in the laboratory showed that the medium and large drills were capable of lying an average of at least 92 eggs capsules per drills, and each capsule may contain more than 250 eggs. In Lukang, Hwang and Huang[5] reported an even higher reproduction potential of *P. clavigera*, with an average of 209 egg capsules and 267 eggs per capsule. This reproduction potential was much greater than that of *U. cinerea* and *E. caudata* in the United States. An *U. cinerea* was able to deposit an average of 45 egg capsules with 12.3 eggs per capsule[8], the corresponding number for *E. caudata* 55 and 14, respectively. Therefore, *P. clavigera* have a high fecundity which may explain that they can widely distribute in oyster farming areas and are difficult to control in the field.

Acknowledgments: We are indebted to Dr. K. E. Su for her helpful review of the manuscript, to Miss Y. L. Lee for preparing the figures and typing the manuscript.

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臺灣蚵螺 *Purpura clavigera* Kuster 之捕食率、生殖率及分佈之研究

林 曜 松　　許 清 哲

本研究除於實驗室內探討溫度、鹽度對蚵螺 (*Purpura clavigera*) 捕食率和生殖率的影響外，並調查香山地區現場蚵螺發生數量與牡蠣死亡率之關係。蚵螺的捕食率及生殖率均隨着溫度、鹽度、蚵螺體形之加大而增高。小蚵螺在 22°C 以下不會產卵囊，然而在 27°C 實驗所用的各種體形蚵螺均會產下卵囊，每個卵囊內所含的卵數與卵囊長度呈正相關，而卵囊長度又與蚵螺體形大小成正比。香山地區的牡蠣養殖場據估計每平方公尺平均有蚵螺 16.7隻，而該地區的牡蠣死亡率約爲 31.3%，其中 27.4%爲蚵螺捕食所造成，其餘的 3.9%則爲自然死亡率。蚵螺的分佈依牡蠣養殖場之情況而異，在蚵串接觸地面的地區，其蚵螺數目顯然比蚵串未接觸地面的地區爲多，因此對於減少蚵螺捕食的方法而言，改進牡蠣養殖狀況似乎是一較爲實際可行之途徑。