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The prevalence of the pea crab, *Pinnotheres sinensis*, and its impact on the condition of the cultured mussel, *Mytilus galloprovincialis*, in Jiaonan waters (Shandong Province, China)

Weiming Sun[a,b], Shichun Sun[a,*], Wang Yuqi[a], Yang Baowen[a], Song Weibo[a]

[a]*The Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao, 266003, China*
[b]*Ocean School, Yantai University, Yantai, 264005, China*

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Abstract

Incidence of *Pinnotheres sinensis*, a parasitic pea crab of the cultured mussel, *Mytilus galloprovincialis*, was investigated at Jiaonan, Shandong Province, China during December 2000 to December 2002. The impact of the pea crab on the host was evaluated by comparing the index of condition (percentage meat yield) of infested and uninfested mussels. The 25-month inspection revealed that the prevalence of infestation varied from 1.9% to 62.1%, with the lowest and highest prevalence occurring in July 2001 and November 2002, respectively. The number of pea crabs found in each mussel was 1 to 6, and most of the infested mussels were infested by single female (53.8%), or single male (21.4%), or a couple of a female and a male crab (18.1%). The monthly average intensity varied from 1.00 to 1.44 (total average: 1.18). Evaluated by the index of condition, female crabs showed significant impact on the condition of mussels ($P<0.05$), but male pea crabs did not ($P>0.05$). In 23 of 25 months, the mussels infested by female crabs had the index of condition significantly lower than that of uninfested individuals ($P<0.05$), and the female crabs caused more deleterious effect to the mussels in summer than that in other seasons.

Keywords: *Pinnotheres sinensis*; *Mytilus galloprovincialis*; Prevalence; Index of condition

1. Introduction

The pea crab, *Pinnotheres sinensis* Shen, 1932, has been reported in several pelecypod hosts along the coasts of Korea, Japan and China, including *Mytilus galloprovincialis* Lamarck (usually mentioned as *Mytilus edulis* Linnaeus), *Ostrea plicatula* (Gmelin) and *Ruditapes philippinarum* (Adams and Reeve) (as *Venerupis variegata* Sowerby in some publications) (Dai et al., 1986), among which *M. galloprovincialis* is the most common host. The knowledge on the biology of *P. sinensis* is still incomplete. Zhu et al. (1988) reported that in Hebei coasts (China) June to October is the reproduction season of this pea crab

* Corresponding author. Tel.: +86 532 82032273; fax: +86 532 82894024.
E-mail address: sunsc@ouc.edu.cn (S. Sun).

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and juveniles began to enter mussels in August and September. A similar result was recorded for the Qingdao (China) population of *P. sinensis* (Wang et al., 2002). And both works suggested that *P. sinensis* was deleterious to the mussel *M. galloprovincialis* (as *M. edulis* in Zhu et al. and Wang et al.). In the present paper, the results of a 25-month investigation on the prevalence of *P. sinensis* and its impact on the cultured *M. galloprovincialis* at Jiaonan, Shandong Province, China are presented.

2. Materials and methods

The investigation was carried out during December 2000 to December 2002. The mussel, *M. galloprovincialis*, was collected monthly from the cultivation rafts at the Guzhenying Bay, Jiaonan, Shandong Province, China. During the 25-month investigation, a total of 15000 mussels (278 to 1398 for each month) were examined (Table 1). After the mussels were cleaned and measured with vernier calipers, pea crabs were carefully inspected and recorded. The dried weight of mussel shell and soft body were measured, respectively.

The percentage meat yield (Index of condition, IC), used here to evaluate the effects of pea crabs on their hosts, is defined as: Index of condition (IC) = dried soft body weight/(dried soft body weight + dried shell weight) × 100.

The impact of pea crabs on hosts was also judged by the so-called "relative index of condition (RIC)". As defined by Wang et al. (2002), RIC = the IC of an infested mussel/the mean of the ICs of uninfested

Table 1
Sample data and the infestation patterns of *Pinnotheres sinensis* in the cultured *Mytilus galloprovincialis* during December 2000 to December 2002

Sample data			Number of hosts infested by various combinations of *P. sinensis*							
Date M–D–Y	Number of muscles	Mussel height (mm), range (Mean ± S.D.)	1♀	2♀	1♀ and 1♂	1♀ and 2♂	1♂	2♂	3♂	Total
12–20–00	500	21.6–54.7 (38.7 ± 6.1)	63	0	21	1	38	9	0	132
01–09–01	278	21.0–18.8 (40.7 ± 7.1)	27	0	7	0	4	1	0	39
02–25–01	500	23.3–59.7 (43.6 ± 5.8)	36	0	4	0	19	0	0	59
03–18–01	500	19.3–78.7 (47.1 ± 7.2)	61	0	26	1	34	1	0	123
04–20–01	1000	13.5–65.2 (41.7 ± 7.7)	97	0	71	5	28	14	0	215
05–16–01	1000	19.0–62.2 (40.0 ± 7.6)	68	0	19	1	17	0	0	105
06–21–01	500	14.4–67.9 (48.1 ± 7.2)	73	0	49	1	11	1	1	136
07–17–01	320	12.3–75.9 (41.4 ± 11.1)	6	0	0	0	0	0	0	6
08–20–01	500	13.6–83.7 (43.3 ± 14.0)	26	1	13	0	1	0	0	41
09–19–01	500	12.2–39.3 (25.1 ± 4.8)	24	0	0	0	14	0	0	38
10–17–01	500	15.1–46.5 (33.1 ± 5.8)	17	0	5	0	11	0	0	33
11–16–01	500	15.9–47.6 (32.2 ± 6.3)	17	0	6	0	7	1	0	31
12–17–01	500	20.1–50.4 (34.7 ± 5.4)	12	0	4	0	14	0	0	30
01–23–02	500	15.6–54.1 (36.6 ± 6.0)	22	0	6	0	18	0	0	46
02–20–02	500	7.7–56.8 (40.3 ± 7.1)	13	0	4	0	14	0	0	31
03–16–02	500	15.9–57.9 (39.8 ± 7.7)	16	0	0	0	12	0	0	28
04–14–02	510	17.2–55.3 (34.8 ± 7.6)	22	0	16	1	12	0	0	51
05–19–02	1098	14.0–54.7 (34.5 ± 7.6)	43	0	4	1	1	0	0	49
06–16–02	1398	10.2–61.3 (37.9 ± 7.3)	34	0	4	0	1	0	0	39
07–20–02	870	15.3–71.1 (42.8 ± 12.2)	38	0	2	0	1	0	0	41
08–21–02	407	18.3–72.2 (54.8 ± 8.9)	24	1	1	0	1	0	0	27
09–22–02	659	21.9–66.9 (42.5 ± 7.8)	28	0	4	0	9	2	1	44
10–20–02	520	16.4–68.6 (42.5 ± 8.3)	35	0	7	1	26	2	0	71
11–16–02	440	28.5–63.3 (43.7 ± 6.4)	113	13	39	8	57	21	5	273[a]
12–14–02	500	23.7–65.8 (43.9 ± 7.7)	100	2	29	4	54	10	0	199
Total	15,000		1015	17	341	24	404	62	7	1887

[a] Except for 256 individuals shown, the number of mussels infested by other combinations of pea crabs is: 1♀ and 3♂: 4; 1♀ and 4♂: 2; 5♂: 1; 4♂: 3; 2♀ and 1♂: 4; 1♀ and 3♂: 1: 3♀: 1; 3♀ and 3♂: 1.

mussels in the same month × 100. By using this index, the relationship between the sizes of female crabs (carapace width) and RIC was established based on data recorded in all 25 months.

One-way ANOVA and the Duncan's multiple comparison tests were used to determine the significance of differences of the ICs or RICs among mussels uninfested and infested by various combinations of pea crabs at $\alpha = 0.05$. SPSS 10.0 for windows was employed for the statistical analysis.

3. Results

3.1. Prevalence, intensity and infestation patterns

Among 15,000 mussel individuals examined during December 2000 to December 2002, 1887 (12.6%) were infested by *P. sinensis* (Table 1). The prevalence of infestation fluctuated greatly among months. Varying from 1.9% to 62.1% (Fig. 1), it was relatively higher before June 2001(>10.5%), and lower from July 2001 to September 2002, and the lowest value was recorded in July 2001. After October 2002, the prevalence of infestation increased abruptly and reached the peak value (62.1%) in November 2002 (Fig. 1). Obvious season periodicity was not apparent.

During the inspection period, the intensity of infestation was 1 to 6 crabs per host (mean ± S.D. is 1.18 ± 0.12). The monthly average intensity varied from 1.00 ± 0.00 to 1.44 ± 0.54, and the high intensity often concurred with high prevalence (Fig. 1). Most of the infested mussels were infested by single female (53.8%), or single male (21.4%), or a couple of a female and a male pea crab (18.1%), and only 6.7% were other combinations (Table 1).

Female crabs outnumbered males over the whole period of investigation except in December 2001 and February 2002, and low proportions of males tended to occur in warm seasons (May to August, see Fig. 2). The proportions of mussels infested by female only (1♀/2♀/3♀), by male only (1♂/2♂/3♂/4♂/5♂) and by female–male coexisting crabs ((1–3)♀+(1–4)♂) varied in different seasons. In May to August, the proportions of mussels infested by male crabs only were lower and by females only were higher than that in other seasons (Fig. 2). The extremely complicated infestation combination was recorded in November 2002, in that month some mussels were infested with up to 6 pea crabs (see Table 1).

3.2. Impact of pea crab on the mussel condition

Fig. 3 shows the monthly variations of ICs of mussels that were uninfested, or infested by either single female or single male crab. One-way ANOVA analysis indicates that the overall average IC between the mussels uninfested and infested by a single female

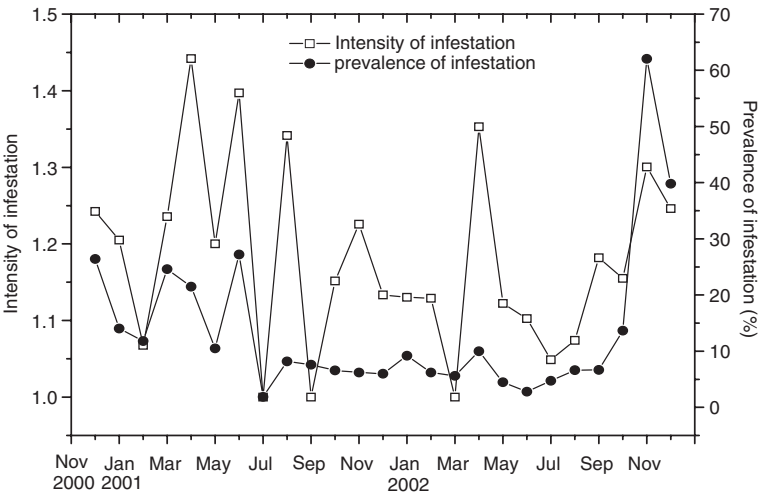

Fig. 1. The seasonal variation of the prevalence and the intensity of infestation by *Pinnotheres sinensis* in *Mytilus galloprovincialis* during December 2000 to December 2002.

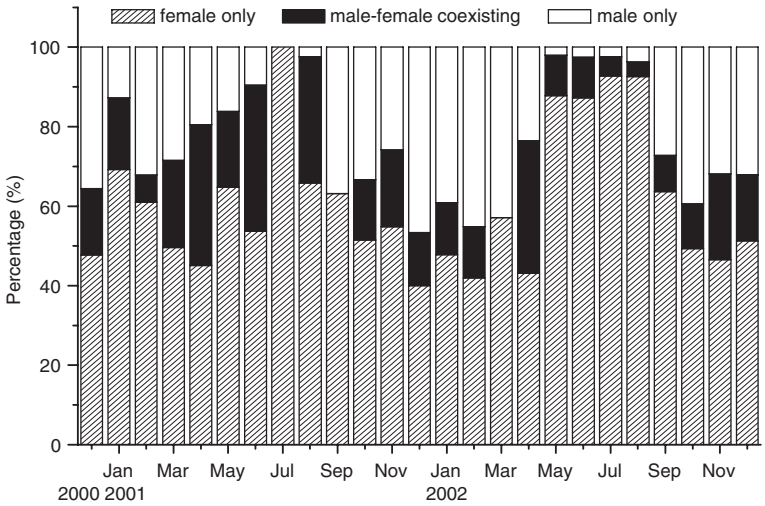

Fig. 2. The proportion of individuals of *Mytilus galloprovincialis* infested by different combinations of *Pinnotheres sinensis* during December 2000 to December 2002. Female only, 1♀/2♀/3♀; male only, 1♂/2♂/3♂/4♂/5♂; female–male coexisting, (1–3)♀+(1–4)♂).

crab is significantly different ($P<0.05$), and that between the mussels infested by single male and by single female is significantly different, too ($P<0.05$). But it is not conspicuously different between mussels uninfested and infested by single male ($P>0.05$). In all months but March in the two years, female pea crabs had a significant impact on the ICs of mussels ($P<0.05$) and decreased the IC from 0.24 to 4.93. In summer (June, July and August), the females were more deleterious to mussels than that in other seasons (Fig. 3). In most months the effect of male crab on IC was not significant. Only in a few months in autumn and winter (September, October and December, 2001, and January 2002), were the ICs considerably

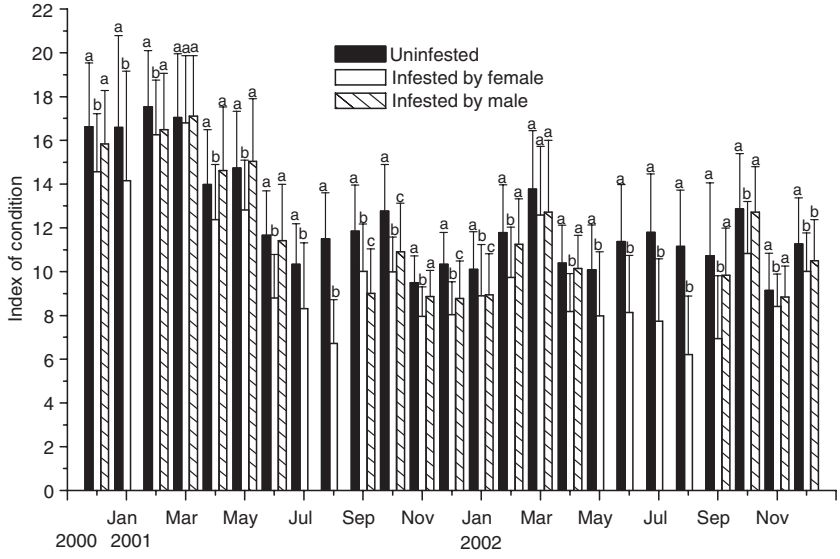

Fig. 3. The index of condition of *Mytilus galloprovincialis* during December 2000 to December 2002—a monthly comparison among uninfested, infested by single female, and infested by single male pea crab, *Pinnotheres sinensis*. Error bars indicate standard deviations. Means labeled with the same letter within the same month are not significantly different ($P>0.05$).

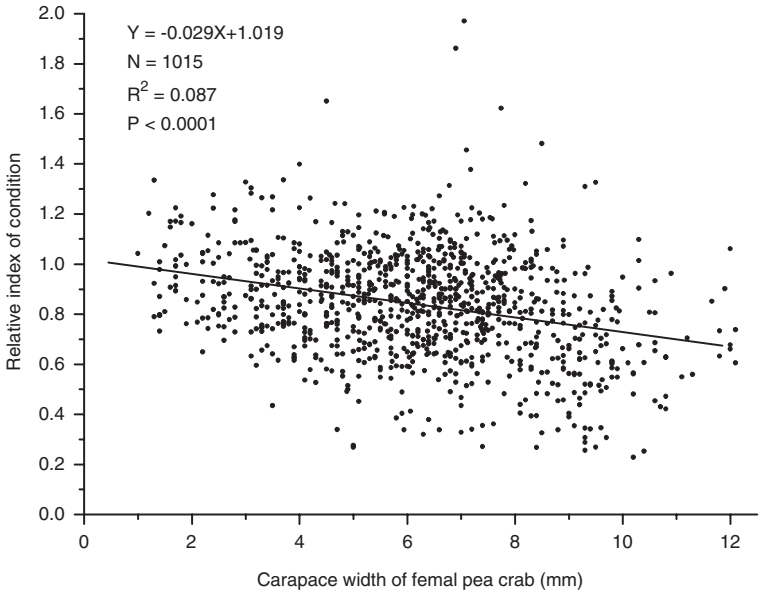

Fig. 4. The relationship between the carapace width of female *Pinnotheres sinensis* and the RICs of mussels infested by single female crab observed in 25 months.

decreased (for 1.17–2.83) when mussels were occupied by male crabs, but the deleterious effect of males was less evident than that of female crabs (Fig. 3).

Fig. 4 shows the relationship between the RICs of mussels infested by single female pea crab and the carapace width of the crabs. The result of linear regression indicated that the RIC of infested mussels was negatively related to the carapace width of female pea crabs ($F_{1,\ 1014}=96.72$, $P<0.0001$) (Fig. 4). However, significant differences were not found between the RICs of mussels infested by 1♀ and 1♀+1♂, and between the mussels infested by 1♂ and 2♂ ($P>0.05$).

4. Discussion

Varying from 1.9% to 62.1%, the prevalence of infestation of *P. sinensis* in *M. galloprovincialis* at the Guzhenying Bay fluctuated considerably during the investigation period, but an obvious seasonal periodicity was not apparent. Many studies have revealed that the prevalence of infestation of pea crabs were different significantly in different areas and seasons (e.g., Gray, 1961; Houghton, 1963; Seed, 1969; Kruczynski, 1973; Anderson, 1975; Pregenzer, 1978; Haines et al., 1994; Tablado and Gappa, 1995; O'Beirn and Walker, 1999), and between wild and cultured mussels (Pregenzer, 1978). The postulated reasons were the diversity of the climates (Gray, 1961), the foods available and the abundance of hosts (Haines et al., 1994), the salinity (Walker, 1969; Kruczynski, 1973), the position of the hosts on beach (Houghton, 1963; Seed, 1969), and the tidal level and current (Kruczynski, 1973; Pregenzer, 1978). In the present case, the abrupt elevation of the prevalence in November 2002 seems not to be natural. As the result of a large-scale mussel harvest in the autumn of 2002, the loads of the cultivation rafts were abated and some ropes that formerly sank to the bottom were elevated to the surface. The bottom dwelling mussels on these ropes, which were supposed constituting a big proportion in samples after October 2002 (this was supported by the fact that sample mussels of these months were inhabited by more fouling organisms), might bear more pea crabs than the mussels from the surface waters.

In the present study, most infested mussels (75.2%) were occupied by a single pea crab, and in the mussels contained more than one crabs, 72.9% were infested by paired pea crabs (male and female coexisting). Haines et al. (1994) explained that young pea crabs

of both sexes settling on the mussel bed would occupy empty mussels. If they encounter an already occupied mussel their response would appear to depend on the number and sexes of the existing occupants. Young female crabs will enter mussels occupied by single male and cohabit, and vice versa.

Christensen and McDermott (1958) reported that when the incidence of infestation decreased, the proportion of females began to increase and sometimes reached 100%. This is supported by the present work. Very low proportions of males were found in July 2001 and May to August 2002 (Fig. 2), in those months low prevalence of infestation were recorded (Fig. 1). Zhu et al. (1988) suggested that June to September is the breeding season of *P. sinensis* in the coasts of Hebei Province. In Guzhenying Bay, most of the ovigerous crabs were observed to occur in June to August. During this period, some male crabs might die after mating, or become prey of carnivores when they migrated from one host to another to find mates. Thus the proportion of females could be elevated.

Although Grove et al. (2000) suggested that the infestation of pea crabs have no deleterious effects on the growth rates of their polychaete hosts, most studies demonstrated that pea crabs inhabiting bivalves were deleterious to their hosts (e.g., Stauber, 1945; Christensen and McDermott, 1958; Anderson, 1975; Pregenzer, 1979, 1981; Bierbaum and Ferson, 1986; Bierbaum and Shumway, 1988; Tablado and Gappa, 1995; Wang et al., 2002). When a mollusk is occupied by a pea crab, the direct impacts of the pea crab on its host include robbing the host of food (Bierbaum and Ferson, 1986), damaging the gills and other organs of the host (Stauber, 1945; Christensen and McDermott, 1958), reducing the filtration rate of the host (Pregenzer, 1979; Bierbaum and Shumway, 1988), and decreasing oxygen consumption rate of the host (Bierbaum and Shumway, 1988). The after effects are lowered growth rate (Kruczynski, 1972; Bierbaum and Ferson, 1986; Tablado and Gappa, 1995), lowered meat yield (Bierbaum and Ferson, 1986; Tablado and Gappa, 1995), distortion of shell shape (Bierbaum and Ferson, 1986), and decreased reproduction output (Anderson, 1975; O'Beirn and Walker, 1999; Grove et al., 2000). The monthly inspections on the cultured mussels in Jiaonan suggested that female *P. sinensis* exhibit more effects on the condition of mussels, as has been reported (Tablado and Gappa, 1995; Wang et al., 2002), and the females are more deleterious to the host in warm season than that in cold season. These differences are clearly relative to the duration of parasitism and the size of pea crabs. Compared with the male crabs, female crabs are much larger in their volume and reasonably cause more physical damage to the organs of hosts and bring more disturbances to the life of hosts. Studies on the biology and the infestation patterns of pea crabs indicate that adult females are more dependent on their hosts, and the female crabs are physically unable to leave their hosts because of the limitation of mussel gap. In males, however, the smaller size and the ability that occasionally leave the hosts to live freely for a period of time (namely the occasional occupants) decrease their impact on the host (Pregenzer, 1981; Bierbaum and Ferson, 1986; Tablado and Gappa, 1995). Although the volumes of female crabs contribute a little to the reduction of mussel condition, negative relationship between the RICs of mussels infested by a female and the carapace width of the crabs was determined by the present studies ($R^2=0.087$, $P<0.0001$; see Fig. 4). During May to August, as the female reaches the adult size and the egg mass greatly expands the volume of the ovigerous female, the deleterious effect of female pea crabs to the mussel was elevated. Physical pressure was noted as the cause of depression in gamete production of bivalves infested by large female pea crabs (Kruczynski, 1972).

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