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The incidence of the Pea crab, *Pinnotheres pisum* in the two types of *Mytilus* (Mollusca: Bivalvia) from Padstow, south-west England

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(With 3 figures in the text)

Significant differences in the infection of *M. edulis* and the "Padstow type" mussel with *P. pisum* are recorded, and some possible explanations for these differences are discussed.

Both types of *Mytilus* from the mid and lower regions of the mussel bed showed heavier infections than mussels higher on the shore. Even so, the differences between the two types were still maintained.

A relationship exists between crab and mussel size, larger crabs being found only in larger hosts. The smallest mussel found to be infected with *Pinnotheres* measured 3·35 cm in length.

Infection in *M. edulis* was found to increase with increased size of host, the largest occurring mussels having from 80 to 100% infection. Larger mussels occurred in greater numbers in the low shore. It is assumed that infection in the "Padstow type" would show a similar relationship if sufficient recordings had been available.

The presence of the crab causes gill damage, and infected mussels show considerably lower tissue weights and slightly greater shell weights than uninfected mussels of similar size.

The presence of the crab does not appear to influence the reproductive capacity of the mussel.

Contents

Introduction

Although the Pea crab *Pinnotheres pisum* (Pennant) is frequently found in the commercially important mussel *Mytilus edulis* L. in British waters, literature relating to various aspects of its biology is surprisingly scarce. Relevant contributions to our understanding of the life history and development of Pea crabs, are however, afforded by Orton (1920); Atkins (1926; 1955; 1958; 1960); Stauber (1945); Sandoz & Hopkins (1947) and Christensen (1962).

Whilst it was long thought that infection of *Mytilus* occurred only when the crab was at the "hard" stage (carapace width about 1·5 mm) more recent investigations (Christensen & McDermott, 1958) have shown that infection occurs in the immediate post larval stage, i.e. first crab stage (0·59–0·73 mm carapace width) in *P. ostreum* Say, and that

several soft growth stages occur before the hard stage is reached. Christensen (1959) found similar "pre-hard" stages in the bi-valve *Spisula solida* (L.) and suggested that *P. pisum* exhibited a regular host change, entering the mussel at the hard stage. Thus, whilst the hard stage primarily serves for uniting the sexes, in *P. pisum* it could also serve as a means for changing hosts. More recently, however, Huard & Demeusy (1966*a*,*b*) have actually recorded first stage crabs in *M. edulis*.

The present paper was written primarily to record the incidence of *P. pisum* in two types of *Mytilus* known to exist in south-west England.

Sites and methods

During November 1966 and January 1968, visits were made to various sites on the coast of Devon and Cornwall in order to re-investigate the existence of an unusual forms of *Mytilus*, the "Padstow type", probably *Mytilus galloprovincialis* Lmk., the "Mediterranean" mussel, recorded in south-west England by Hepper (1957). From these investigations, details of which are given elsewhere (Lewis & Seed, in press), it was concluded that in certain habitats, especially sheltered low level sites such as harbours and estuaries, two easily distinguishable forms of *Mytilus* could in fact be recognized—the "Padstow type" being separable from local *M. edulis* by means of the following characters:

(i) The smaller size of the anterior adductor muscle scar.
(ii) The purple-violet colour of the mantle edge. In *edulis* this is more usually yellow-brown.
(iii) The shape and smaller size of the hinge plate.
(iv) The pointed and often slightly downturned anterior end.
(v) The transverse profile of the shell and the relatively flat or slightly inrolled ventral margin especially at and just posterior to the hinge plate.
(vi) The higher, often rounded, dorsal shell margin.

At high tidal-levels, however, where proportionately more older animals occur, and more especially in the high density populations typical of exposed shores, the shell characters of the two forms merge until criteria for separation are often limited to items (i)–(iii). In such cases, separation can frequently be quite difficult.

Although the "Padstow type" does in fact show marked similarities to continental *M. galloprovincialis*, it will, in the following account, be referred to as the "Padstow type" pending the outcome of a more detailed taxonomic investigation already in progress.

Whilst large numbers of mussels between Instow and Penzance were examined, *P. pisum* was recorded only at one site. This was Rock (near Padstow) in the Camel estuary, a very sheltered, flat or gently sloping area of rock, shingle and sand. Two easily distinguishable forms of *Mytilus* could here be found living together from E.L.W.S. to a point between M.L.W.N. and M.T.L. the ratio "Padstow type": *edulis* increasing with increased aerial exposure (1·1:1 at M.L.W.S.; 4·5:1 at the highest levels).

Although Hepper (1957) showed that the "Padstow type" was not resistant to infection by the parasite *Mytilicola intestinalis* (Steuer) but did appear to be less affected by the parasite than *M. edulis*, he made no mention of the presence of *P. pisum*.

During these visits, no systematic search was made for the Pea crab, but mussel samples brought back to the laboratory for more detailed morphological studies, revealed a significantly higher infection amongst *M. edulis* (30% compared with 5% in the "Padstow type"). Further samples, a total of 650 mussels, received over regular monthly intervals for a study of the breeding cycles of the two entities, again showed consistently heavier infections amongst *M. edulis* (33% compared with 2% in the "Padstow type"). In view of this, a further visit to Rock was made in June 1968 and samples of *M. edulis* and the "Padstow type" (3-11 cm length) at three shore levels were examined carefully for Pea crabs; site 1, the highest occurring mussels; site 2, an

area from the middle of the mussel bed; site 3, a low level mussel area (*c.* M.L.W.S.). Mussel lengths and crab carapace widths were measured to the nearest 0·1 mm by means of a pair of sliding calipers. Infected and non-infected mussels were brought back to the laboratory and individual tissue and shell weights recorded after drying to constant weight at 60°C.

Results and discussion

From Table I it will be seen that at each site, infections were consistently higher in *M. edulis*. Although infections amongst mussels from the higher shore levels were considerably lower, the difference between the two types was, nevertheless, maintained. Of the total of 154 infections, 17 double and two triple infections were recorded. There were no cases of two female crabs occurring within the same host. All double infections consisted of one male and one female, whilst both triple infections had two males to one female. The sex ratio was found to be 2·26 females:1 male. The majority of females collected during June had the underside of their abdomens distended with masses of orange coloured eggs.

TABLE I

Incidence of ***Pinnotheres pisum*** *(Pennant) in* ***Mytilus edulis*** *L. and the "Padstow type" for three sites at Rock (Nr. Padstow), Cornwall*

	No. examined	No. infected	Mean length of infected mussels (cm)	% Infection	No. double infections	No. triple infections
(a) Site 1: Highest naturally occurring mussels: Total number of mussels in sample 373						
"Padstow type"	306	2	5·30	0·65	1	—
M. edulis	67	3	4·30	4·48	—	—
(b) Site 2: Mid mussel area: Total number of mussels in sample 276						
"Padstow type"	110	2	7·65	1·82	—	—
M. edulis	166	77	6·25	46·39	11	2
(c) Site 3: Low level mussel area: Total number of mussels in sample 252						
"Padstow type"	102	4	8·60	3·92	—	—
M. edulis	150	66	7·41	44·00	5	—

These significant differences in infection of *M. edulis* and the Padstow types with *P. pisum* present several interesting problems, and various explanations might be suggested:

(a) *That* ***edulis*** *is, in some way, more attractive to "searching" invasive stages than the "Padstow type".* An experiment, set up in the laboratory to test this hypothesis, giving numbers of female Pea crabs the choice of groups of opened mussels of both types, failed, because once removed from the host, the crabs, distended with eggs, were practically incapable of any active searching. However, any chemical attraction that may be exhibited might possibly be expected to be most strongly developed in the invasive stages rather than in the adults which become adapted to a very specialized mode of life. Convincing evidence for chemical communication between certain commensals and their hosts has been obtained by Davenport (1955) in his studies of polynoid worms.

(b) *That some anatomical difference exists between the two types of* ***Mytilus****, possibly in the gill filtering mechanism, such that invasive stages are retained in* ***edulis*** *but not in the "Padstow type".* Although the gills of relatively small samples of mussels were examined, no striking differences were noted, apart from the tendency for the Padstow types to have less fragile gills than *edulis*. The number of gill filaments and ciliary interfilamentar junctions per unit area in both types was very similar, though in the "Padstow type" these junctions appeared to be somewhat larger than in *edulis*.

(c) *That the "Padstow type" is in some way better adapted at rejecting the invasive stages than is* ***edulis***. This might, for example, take the form of a more copious production of mucus or stronger ciliary gill currents preventing attachment by the crab, or it may be

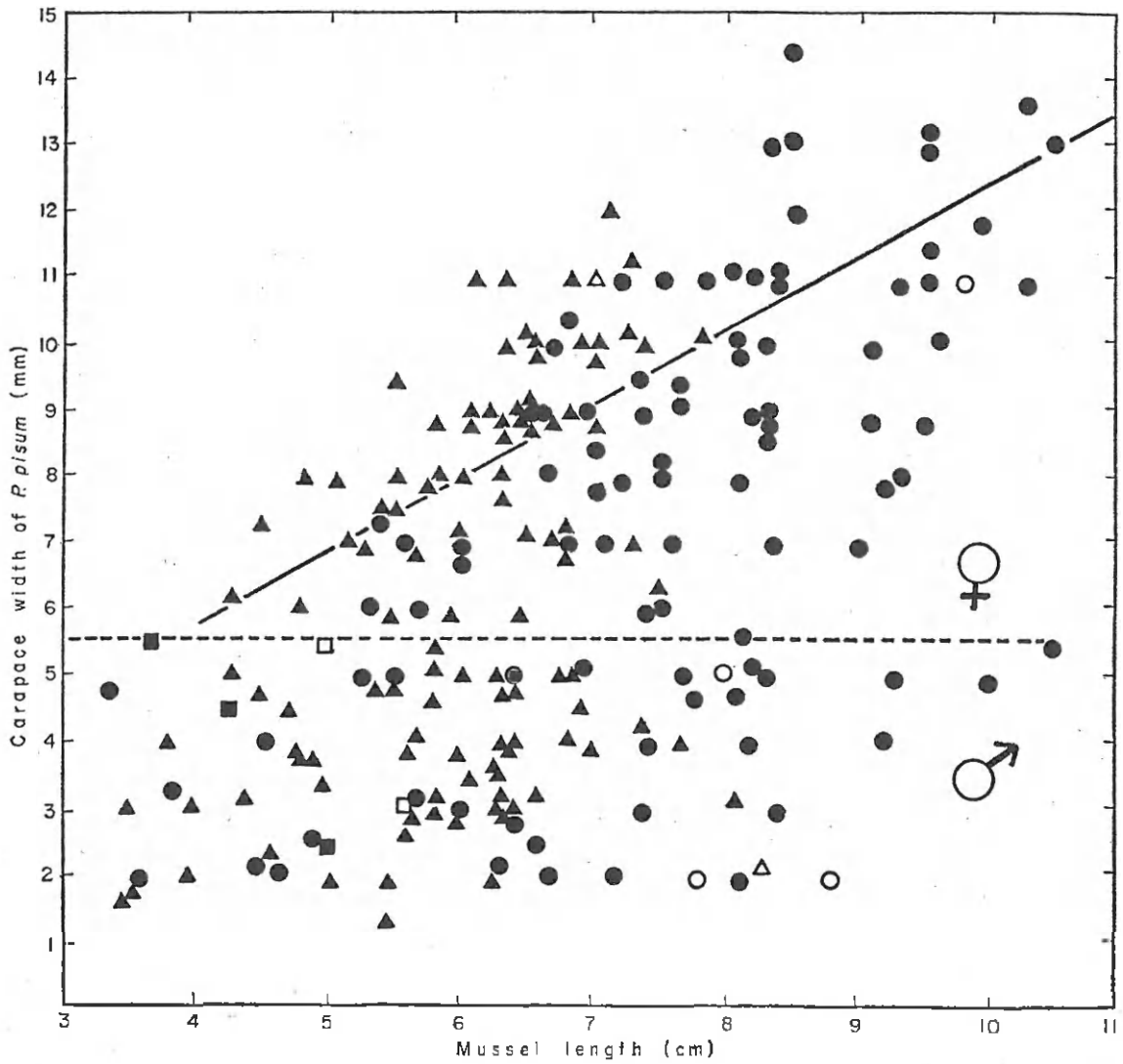

FIG. 1. Carapace width of *Pinnotheres pisum* (Pennant) plotted against the length of mussel host at three sites at Rock (Nr. Padstow), Cornwall.

Solid symbols, *Mytilus edulis* L.; open symbols, "Padstow types". ■, Site 1, highest occurring mussels; ▲, site 2, mid mussel area; ●, site 3, low level mussel area.

that the "Padstow type" is more toxic to the crab either naturally, or via some kind of immunological response.

A relatively equal distribution of invasive stages amongst both types of *Mytilus* immediately after the invasive period would eliminate (a) and (b) as possible explanations for the observed differences.

Atkins (1926) and Houghton (1963) for *P. pisum*, and Christensen & McDermott (1958) for *P. ostreum*, showed a relationship between the sizes of crab and host. Christensen & McDermott also showed that development of the crab was not retarded in slow growing oysters to the same extent as the growth rate.

Figure 1 illustrates the relationship between the carapace width of each crab and the shell length of its host for all three sites at Rock. There was virtually no overlap in size of male and female crabs, the largest recorded male being 5·5 mm and the smallest female

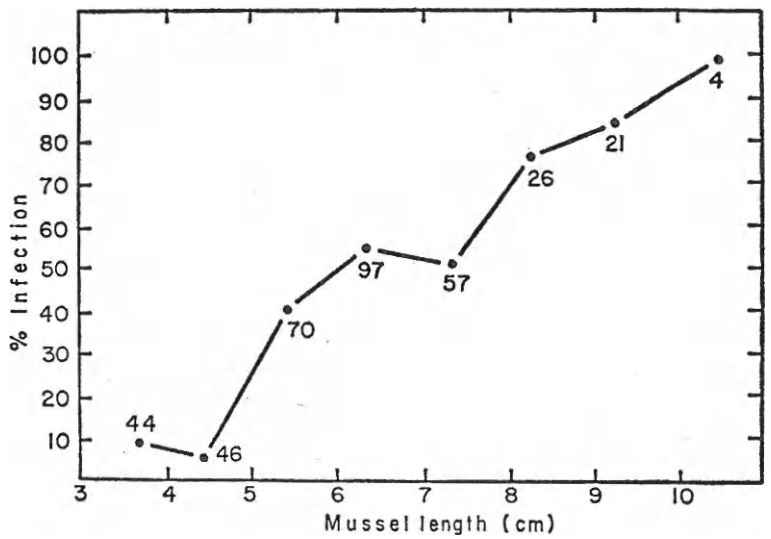

FIG. 2. Relationship between the incidence of *Pinnotheres pisum* and length of mussel host (*Mytilus edulis*). Sites 2 and 3 only. Numbers indicate sample sizes for each unit length category.

5·2 mm carapace width, hence the pecked line in Fig. 1 can be taken as the approximate division between males and females, with very few exceptions. Considering only female crabs there exists a distinct relationship between size of crab and size of host, larger crabs being absent from small mussels but, as one might expect, small crabs being found in all size groups of mussels. Such a relationship however, does not appear to exist or is very much less marked amongst the smaller, more active males. This one might expect on the basis of the findings of Christensen & McDermott (1958) who showed that the males of *P. ostreum* never lived past the hard stage, usually less than one year, once their vital role had been performed. This would be of some obvious survival value to the species since it would leave more food available to the females for egg development.

Considering *M. edulis* alone, since insufficient infections amongst the "Padstow types" are available to be of statistical significance, then although Table I shows 46·39 and 44·00% infection at sites 2 and 3 respectively; this does not take into account the variation in infection according to the size of the host. Figure 2 illustrates a direct relationship between

the degree of infection and size of mussel, smaller mussels (3-5 cm length) having less than 10%, larger mussels (9–11 cm length) having over 80% infection. Infection could be directly proportional to the amount of water filtered by the mussels, or to the length of time that they have been exposed to the source of infection (in both cases this would be greater in the larger or older animals). It was noticeable that the smaller mussels were nearly always found in the middle of mussel clumps, often completely hidden amongst much larger animals, where it is assumed their filtering capacities must have been severely

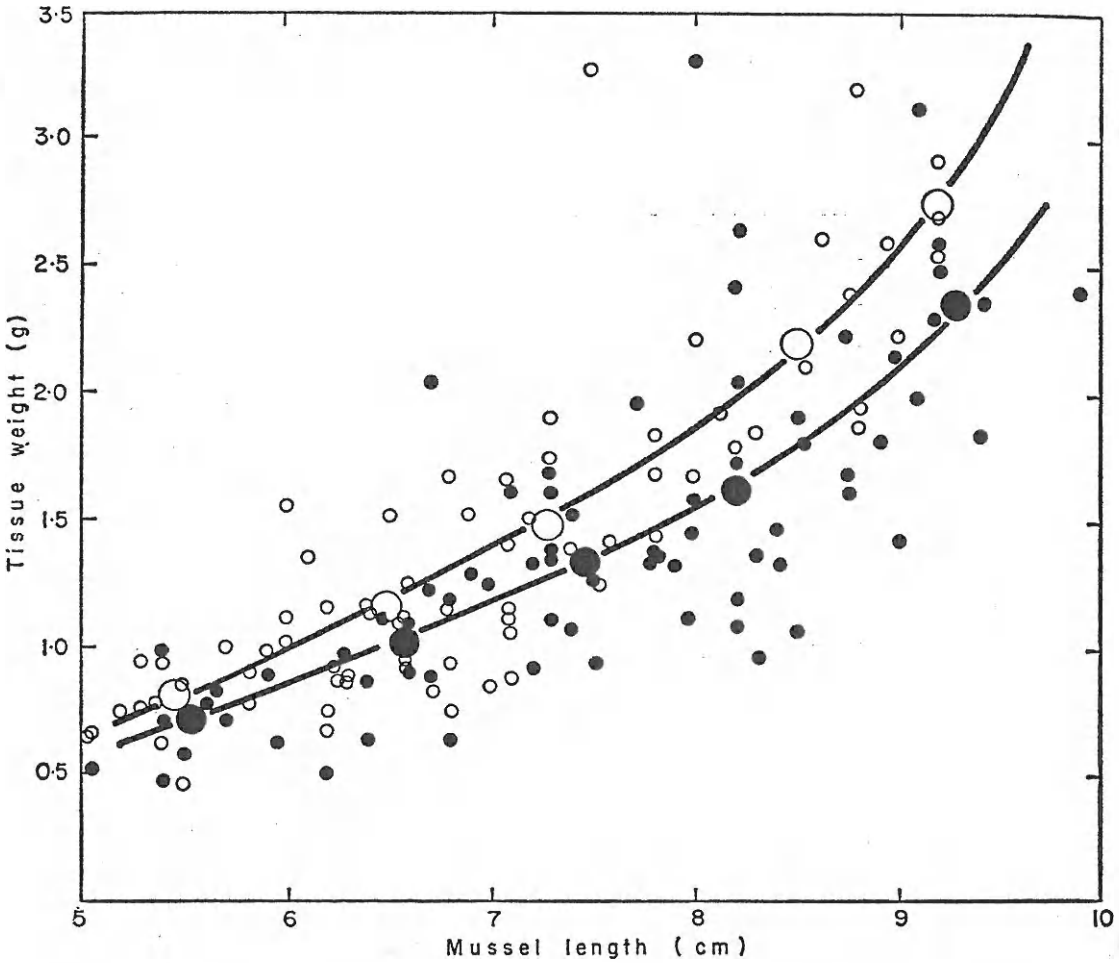

FIG. 3. Relationship between dry tissue weight and shell length in infected (●) and non-infected (○) *Mytilus edulis* from site 3. The large symbols are mean values for unit length categories.

impaired. The smallest mussel found to be infected measured 3·35 cm in length (Houghton (1963) suggests that 3·5 cm is probably about the minimum size of mussel that could be invaded), whilst the smallest recorded pea crab measured 1·25 mm carapace width. It must be stressed, however, that all records in this investigation were based upon field observations, and no detailed examinations were made of mussel gills under the microscope for early invasive stages.

Although *P. pisum* has often been considered as a commensal, there is evidence that the association is one of parasitism since the host does not appear to benefit in any way

from the crabs' presence. Orton (1920) showed that *P. pisum* fed upon the plankton concentrated by the mussel but states that it "would appear to do no more harm to the mussel than to make it collect food faster or for a longer time than would be necessary in an abundant supply of food, if the crab were not there". *P. ostreum* however, is known to cause gill damage in oysters (Stauber, 1945; Sandoz & Hopkins, 1947) whilst Stauber also found that some oyster mortality could be attributed to the presence of the crab. The presence of pea crabs in *Ostrea cucullata* was shown to cause a sex change towards maleness probably as a result of starvation (Awati & Rai, 1931).

Observations in this investigation certainly revealed the presence of gill lesions in infected mussels. Figure 3 illustrates the differences in dry tissue weight amongst infected and non-infected *M. edulis* from the low shore Rock (site 3). Infected mussels, between 5–10 cm length, show from 11·25–18·36% reduction in dry tissue weight over non-infected mussels of similar size (Table II). This one assumes to be the result of damage caused to the gill filaments, thereby reducing the area and efficiency of the straining mechanism. Since *Pinnotheres* is relatively widespread on commercial mussel beds in Britain, the economic implications of these findings need not be stressed. Shell weights of infected mussels on the other hand (see Table II) were from 3·11–6·54% above those of non-infected mussels of similar size, but the significance of this is not certain.

TABLE II

The relationship between shell length, dry tissue and shell weights in infected and non-infected ***M. edulis*** *from Rock site* 3

Length (cm)	Dry tissue weight (g)			Dry shell weight (g)		
	Infected	Non-infected	Infected / Non-infected %	Infected	Non-infected	Infected / Non-infected %
5·5	0·71	0·80	88·75	9·60	9·31	103·11
6·5	1·01	1·14	88·59	16·21	15·61	103·84
7·5	1·36	1·56	87·18	23·05	22·01	104·73
8·5	1·78	2·16	82·41	29·85	28·25	105·66
9·5	2·49	3·05	81·64	36·65	34·40	106·54

Although Berner (1952) suggests that large Pea crabs (over 10 mm) had an adverse effect upon gametogenesis in *M. edulis*, no evidence for this was noted in this investigation. Sections of mantle tissue taken from infected animals confirmed these observations, and it is perhaps relevant that the large numbers of *M. edulis* from Rock, sectioned at regular monthly intervals, many of which must have been infected, again revealed no apparent deleterious effect on gametogenesis caused by the presence of the crabs. In one instance only, was the mantle tissue on either side of a crab, 14·5 mm carapace width, thinner than the rest of the mantle, such that the crab nestled in a shallow cavity. This might indicate some kind of physical restriction to normal development in the case of unusually large crabs which may be almost as wide as the mantle cavity of the host.

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