Scallop Predation by Crabs, in Relation to the Development of On-Bottom Cultivation

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ABSTRACT

The feeding success of four species of crabs (Crustacea : Brachyura) which are potential predators of the scallop *Pecten maximus* (L.) was studied under laboratory conditions. *Liocarcinus depurator* was the only species not to prey on scallops of 4 and 5 cm shell height, whereas *Liocarcinus puber*, *Carcinus maenas* and *Cancer pagurus* showed the greatest potential to prey on scallops and further experiments were carried out with this species using a wide size range of bivalves. Presented with scallops within the range 3-9 cm shell height resulted in the following trends : as prey size increased, the proportion of crabs feeding decreased; male and female crabs showed similar predatory behaviour; and marine fouling on scallop shells had no significant effect on crab feeding. These findings are discussed in relation to the potential for bottom culture of *P.maximus*.

Scallop predation by crabs, in relation to the development of on-bottom cultivation

Introduction

The development of cultivation of the scallop *Pecten maximus* (L) in the UK has been based on the collection of naturally produced spat (Wieland & Paul 1983). These have then been grown on to commercial size by hanging culture using conventional Japanese 'pearl nets' and 'lantern nets' (Ventilla 1980). It normally takes up to four years for a scallop to reach a commercial size of 10cm shell height.

The equipment costs and labour required over such a time period is expensive and mean a high capital investment before any returns are forthcoming. As a consequence, the development of techniques for bottom culture may be an important future step, whereby costs are reduced by relaying scallops on the seabed after an initial period of hanging culture and allowing them to reach commercial size naturally. This method is carried out in Japan, where bottom culture costs amount to one third of those for longlines.

Initial trials carried out with a small number of scallops at Loch Ceann Traigh in 1984 showed them to be particularly vulnerable to predation by crabs. Of 200 scallops (mean size 4.9cm) put down, 137 mortalities were recorded within two weeks, the majority of which showed signs of crab damage.

The aims of these laboratory experiments were to compare the predation rates of four species of crab, all of which have been observed feeding on bivalves.

1. The edible or brown crab *Cancer pagurus* L

2. The green shore crab *Carcinus maenas* (L)

3. The velvet swimming crab *Liocarcinus puber* (L)

4. The swimming crab *Liocarcinus depurator* (L)

Further experiments were then carried out on the most prolific predator species with regards to size of predator and prey in order to establish a size of scallop for relaying which would have an improved chance of survival.

Material and Methods

All the crabs used were collected locally either by baited traps or by diving. They were then held in separate tanks with natural photoperiod and flowing seawater for up to two weeks before use. The bottom of the tanks were covered with mussels (*Mytilus edulis*) to provide food and refuges to reduce aggresive behaviour.

The scallops used were all from cultivated stocks, either from Ardtoe or a commercial scallop farm at Scalpay (Isle of Skye) and were maintained in flowing seawater and all shell fouling was removed by scraping prior to use. All experiments were carried out between May and September 1985.

Predation by different crab species

Only healthy intermoult crabs were used, both male and female *Cancer pagurus* but only males of the other species. Details of sizes are given in Table 1.

Crabs were held in individual compartments consisting of one of three sizes of plastic pipe, each with its own seawater supply. Over the experimental period temperature ranged from

10.6 - 13.8°C and all experiments were carried out in constant darkness.

Crabs were held in their containers for 3 days prior to the feeding trial. For the first 24h, excess mussels were presented. Thereafter the crabs were starved for 48h and scallops of approximate height 5cm were added. The number of scallops introduced was determined by crab size such that an excess was maintained. Scallops were added three times per day for 5 days, recording numbers eaten at each 'feeding time'. A scallop was considered to be eaten if a crab had gained access to the soft part.

At the end of the 5 days the crabs were fed with excess mussels and then starved for a further 48h and the process repeated with 4cm scallops.

Effect of crab size

These trials established that *Cancer pagarus* was a voracious predator of *Pecten maximus*, and therefore further studies with this species were set up to investigate the predator-prey size relationships.

The experimental procedure was as described previously using both male and female crabs and a larger range of sizes (Table 2). The trials lasted for 96h except for the 3cm scallops which were restricted to 48h.

Analysis of Scallop shell remains

Shell remains of predated scallops were examined for the type of damage caused by crabs. Six categories of damage could be identified and used to determine possible relationships between crab species/size and method of entry.

1. Shell chipping of left or right valve

2. Hole punched through left (upper) valve

3. Hole punched through right (lower) valve

4. Shell cleaved (left and right valves split along one line)

5. Left valve broken / crushed

6. Right valve broken / crushed

Influence of shell fouling

Scallops grown in hanging cultivation often have the left (upper) valve covered in fouling organisms, notably barnacles and tube worms (serpulid polychaetes). Experiments to establish whether or not this fouling gave any protection to the scallop were carried out in a 3.6m diameter tank filled to a depth of 5cm with sand. Equal numbers (26 = $5/m^2$) of fouled and cleaned scallops of approximately 4.5cm were introduced into the tank 1 day before 5 male and 5 female C.pagurus were added. After 6 days, the remaining scallops were removed and recorded. The experiment was replicated 3 times.

Results

Predation by different crab species

The total number of scallops eaten by the different crab species and the percentage of crabs feeding on the two size groups of scallop is shown in Fig.1. The swimming crab Liocarcinus depurator was the only species which did not feed at all. Of the others, Cancer pagurus consumed more scallops than Liocarcinus puber and Carcinus maenas but predation was influenced by prey size, with a reduction in numbers of 5cm scallops eaten, and % feeding on this size range. Using percentage number of scallops eaten as an estimate of predation potential, the species may be ranked in order:

C.pagurus	73%
L.puber	18%
C.maenas	9%
L.depurator	0%

Effect of predator/prey size

Fig.2 illustrates the relationship between predator size (*Cancer pagurus*) and the number of different sizes of scallop eaten during the experiments. There were no differences between male and female crabs and the data are combined here in a three way diagram. The figure shows how predation increases as scallop size decreases and crab size increases, although there was a reduction in predation in the largest crabs.

When all the crab sizes were combined, the highest predation rates were found on the smallest scallops and the percentage of crabs feeding on each scallop size group decreased with increasing size (Fig.3). The greatest percentage reduction in feeding occurred on scallops of between 5 and 7cm shell height.

Analysis of scallop shell remains

Shell damage caused by *C.pagurus* feeding on scallops of 3.0 to 5.0 cm shell height is shown in Fig.4. Other scallop sizes have not been illustrated due to the small number of observations (as a consequence of low predation rates by *C.pagurus*). With 12.0 and 14.0 cm carapace width crabs, shell damage consisted mainly of broken or crushed left or right valves with a low incidence of shell chipping. Decreasing crab size reduced the incidence of valve breaking and increased that of shell chipping. However, as scallop size increased there was an overall increase in the incidence of shell chipping, and valve breaking consequently decreased. Crabs of less than 8 cm carapace width showed a high incidence of shell chipping for all three scallop sizes and were subsequently found to be able to prey on the full size range of scallops presented (3 to 9 cm shell height) using this method. No relationships were found between crab species, scallop size and shell damage. Shell remains therefore chould not be used to identify the crab species feeding on the scallop. Shell damage caused by *C. maenas*, *L. puber* and *C. pagurus* illustrates the range of predation techniques used by the crabs (Fig.5).

Influence of scallop shell fouling

The numbers of scallops eaten in the shell fouling trial were:

	Fouled	Cleaned
Trial 1	19	15
2	15	21
3	2	4

The reason for the low predation rate in trial 3 was not clear, but the other results showed no difference in the predation rate of fouled or cleaned scallop shells.

Discussion

This study has established that the edible crab (*Cancer pagurus*) has the greatest potential to prey on *Pecten maximus* when compared to the velvet swimming crab (*Liocarcinus puber*) and the shore crab (*Carcinus maenas*) although both these species have been shown to be capable of preying on scallops of 4-5cm shell height. The swimming crab *Liocarcinus depurator* was the only species which showed no predation in this study although other studies have shown it capable of predating on smaller (<4cm) scallops (Minchin, 1984).

Size selective predation was found to occur with *Cancer pagurus*, with the level of predation being proportional to the relative size of predator and prey with a general trend for predation to decrease as prey size increased. The size of crab used in the experiments reflected the size range found in local populations (Lake 1985) and therefore the results indicate that if scallops of less than 6cm shell height are relaid in an area with a population of *Cancer pagurus*, they may be extremely vulnerable to predation. However, predation may be reduced markedly if scallops of 6 - 7 cm shell height were relaid.

In a cultivation programme, to relay scallops on the seabed at 6 cm and over would require around 20 months in hanging culture, i.e. during the spring and summer of their second year. They would then require a further 2-3 years growth to reach a good commercial size of 10 cm.

The results for each size group of crab do not suggest that *C. pagurus* has a preferred or optimal prey size. However, crabs with a carapace width of less than 12 cm were not able to crush scallops of greater than 8 cm shell height and in order to feed on them had to use less efficient or more time consuming methods of entry. It is possible that in the natural situation, crabs may choose a suitable, or optimal prey size, or alternative prey if available. The use of crushing or shell chipping technique to gain entry to the scallop must be related to the relative size of predator and prey, and also to the shell strength of the scallop in relation to the power of the crab chelae.

The trials on the effect of shell fouling have shown that the presence of a layer of hard calcarious fouling organisms gives no apparent protection to the scallop. However, while this layer presents no additional barrier to the crabs, it may increase the handling time for the crab and could cause the crab to choose a different prey if available in the natural situation.

Acknowledgements

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Table 1

Mean crab and scallop size (± 1SD) used to assess predation potential of four crab species (8 crabs used in each trial)

Crab species	Carapace width (cm)	Diameter of container (cm)	Scallop shell height (cm)
Cancer pagurus	10.53 ± 0.39	31.5	4.93 ± 0.11
(male)	10.59 ± 0.41	31.5	4.10 ± 0.11
Cancer pagurus	10.35 ± 0.32	31.5	4.93 ± 0.10
(female)	10.35 ± 0.32	31.5	4.06 ± 0.11
Liocarcinus	4.48 ± 0.20	16.0	4.91 ± 0.11
depurator	4.48 ± 0.20	16.0	3.99 ± 0.10
(male)	5.51 ± 0.08	16.0	4.94 ± 0.12
	5.51 ± 0.08	16.0	4.06 ± 0.12
Liocarcinus	7.08 ± 0.36	20.0	4.93 ± 0.08
puber	7.08 ± 0.36	20.0	4.05 ± 0.12
(male)	8.50 ± 0.09	20.0	4.92 ± 0.11
	8.50 ± 0.09	20.0	4.02 ± 0.13
Carcinus	4.49 ± 0.08	16.0	4.97 ± 0.13
maenas	4.59 ± 0.18	16.0	4.06 ± 0.12
(male)	7.54 ± 0.24	16.0	4.91 ± 0.12
	7.54 ± 0.24	16.0	4.01 ± 0.14

Fig.1

a) Total number of scallops eaten by the different crab species for two size groups of scallop

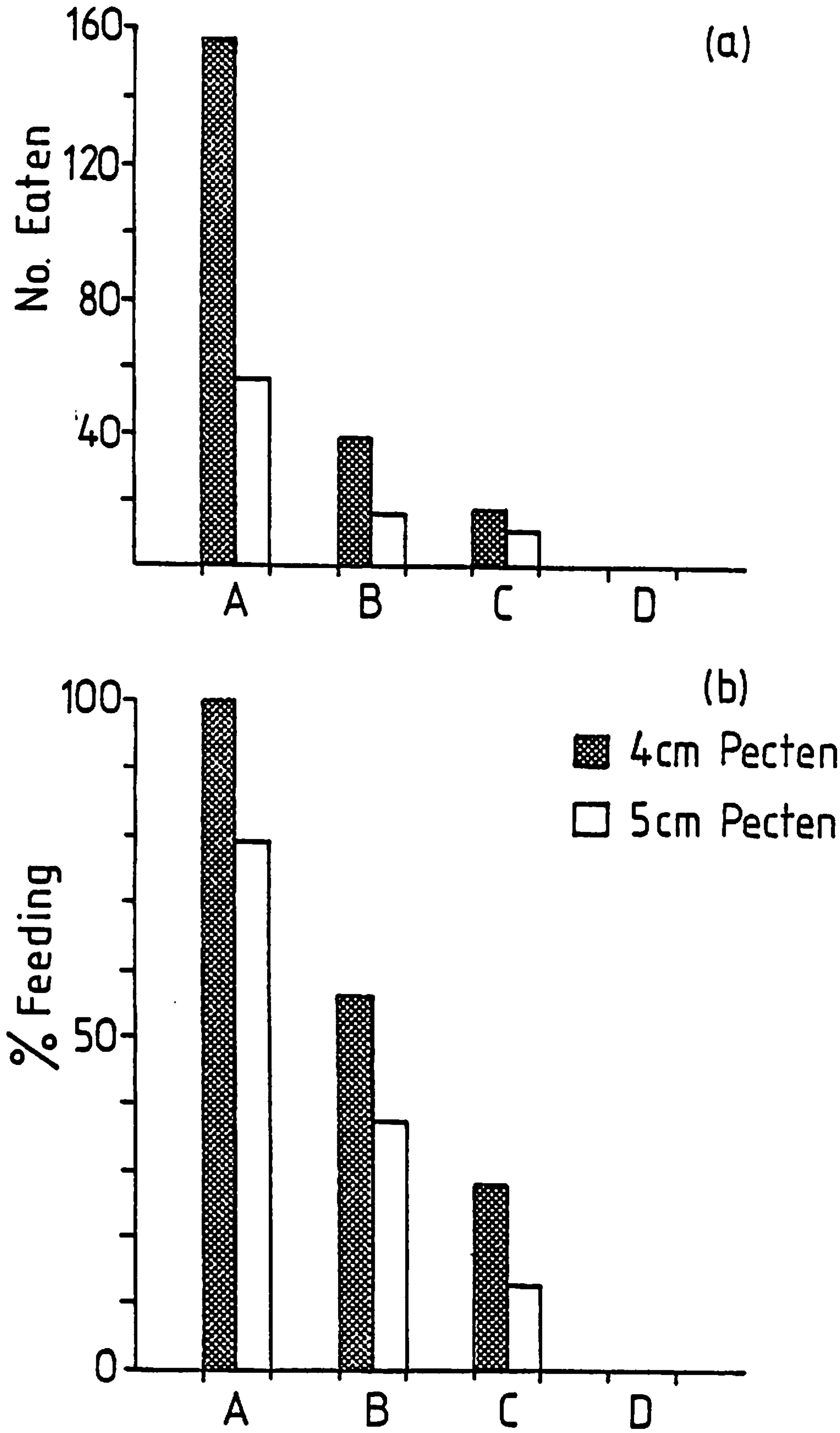
b) Percentage of crabs feeding on two size groups of scallop

A = *Cancer pagurus*

B = *Liocarcinus puber*

C = *Carcinus maenas*

D = *Liocarcinus depurator*



160
120
80
40
No. Eaten
(a)
A
B
C
D
100
50
0
% Feeding
(b)
4cm Pecten
5cm Pecten
A
B
C
D

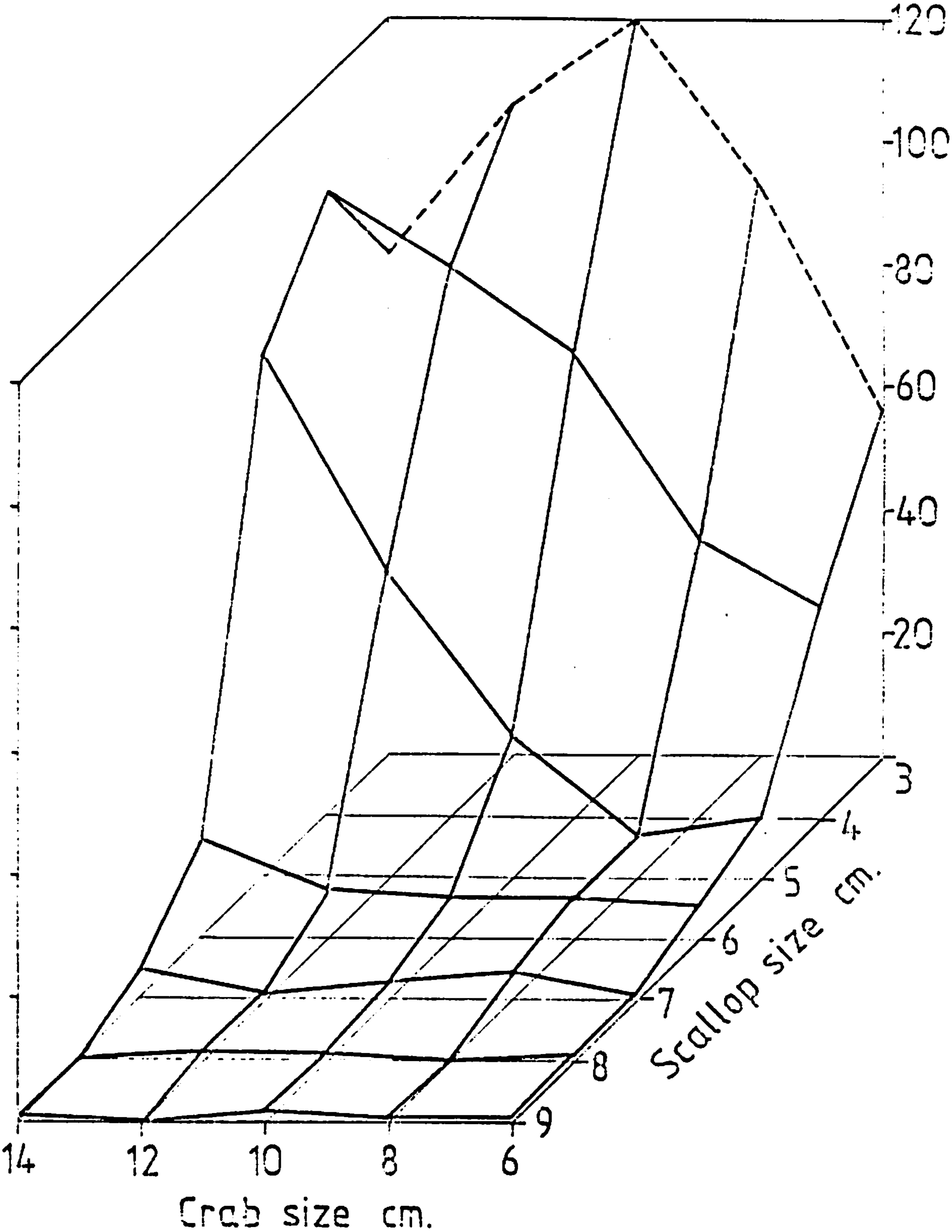
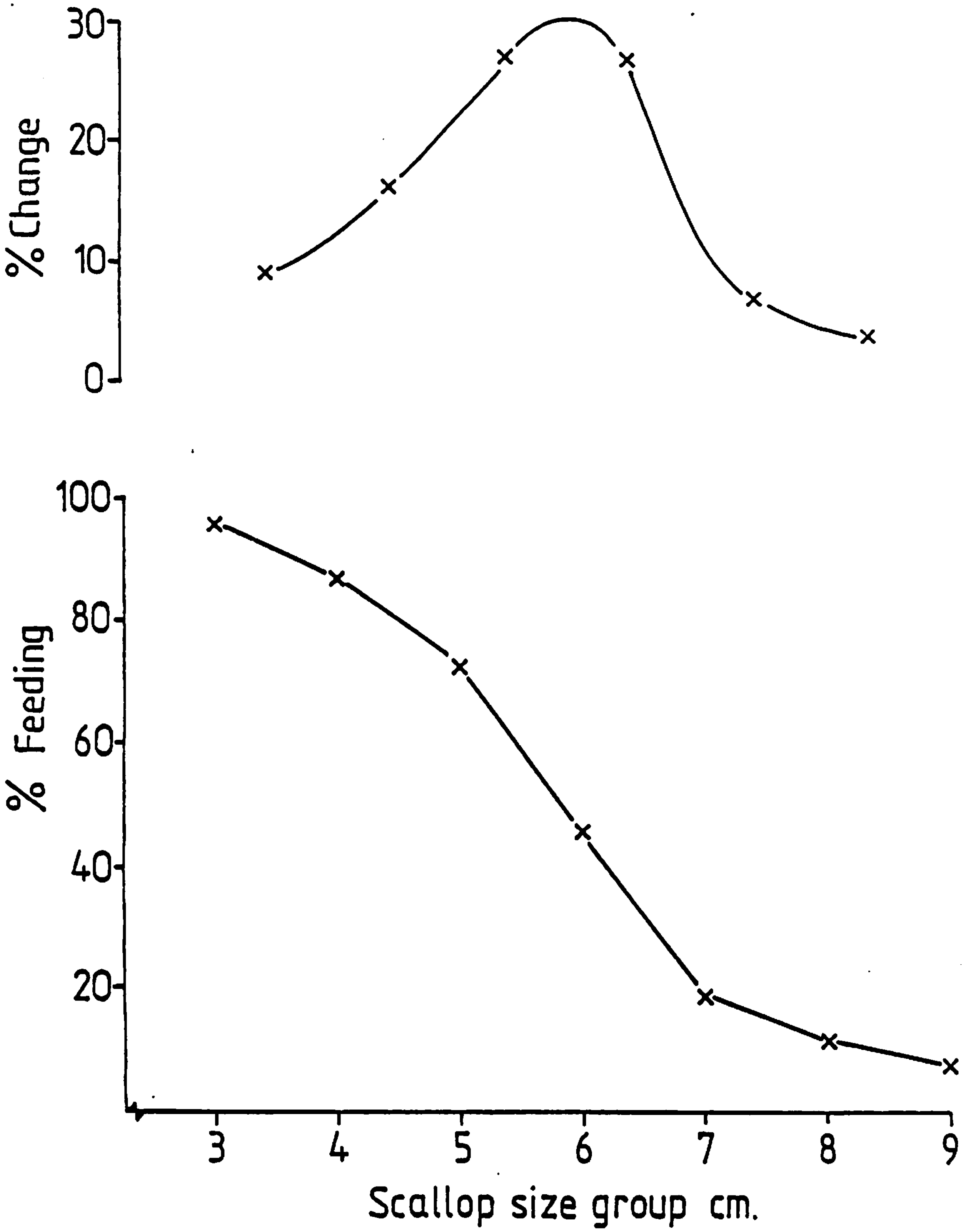


Fig.2 Total number of *Pecten maximus* in the different size groups eaten during a 96h period in relation to size of *Cancer pagurus*. The dash line indicates experiments with 3cm scallops where the duration was limited to 98h.



<u>Fig.3</u> Percentage of all sizes of <u>Cancer pagurus</u> feeding when presented with different sizes of <u>Pecten maximus</u>. The upper figure shows the % change in feeding between the scallop size groups.

Fig.4

The change in scallop shell damage with changing crab and scallop size.

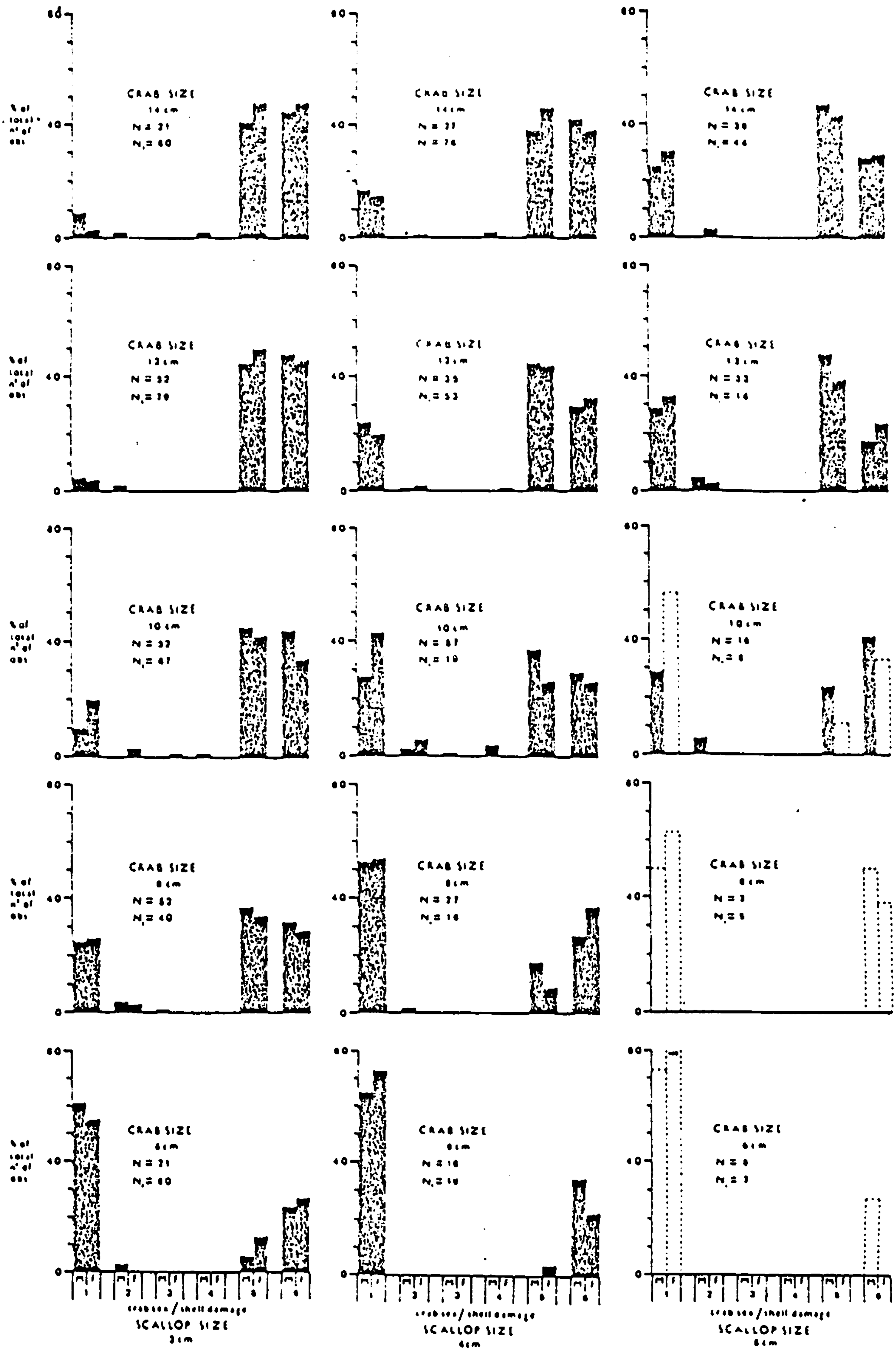
Key

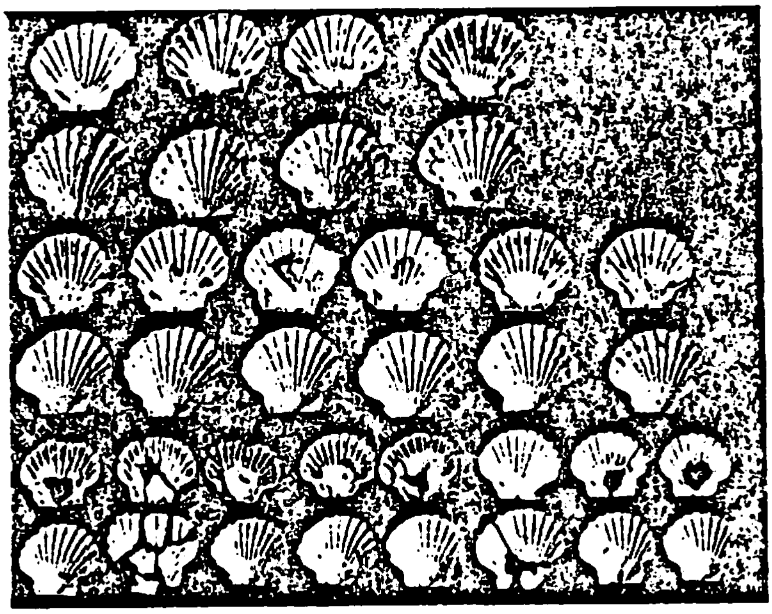
1. Shell chipping
2. Hole punched in left valve
3. Hole punched in right valve
4. Shell cleaved
5. Left valve broken/crushed
6. Right valve broken/crushed

N = No. of male crabs

N, = No. of female crabs

Samples of less than 10 shells are indicated by dash lines


CRAB SIZE
SCALLOP SIZE



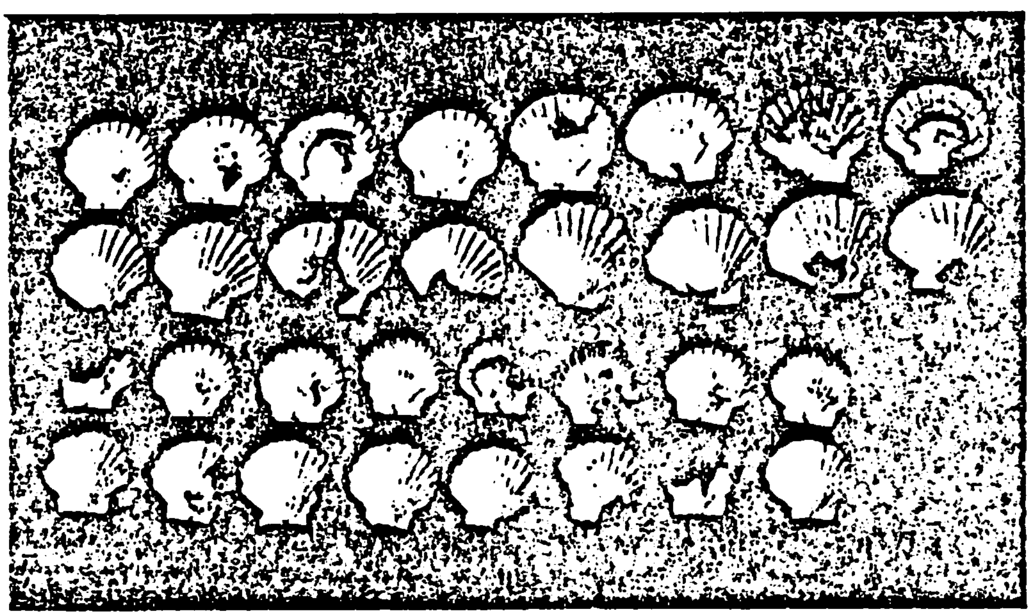


Fig.5 Examples of scallop shell damage