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STARFISH AND MUSSELS

by

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Introduction

Early in 1962, during a visit to Billingsgate fish market in London, and to a shellfish processing factory, the suggestion was made that imported Danish mussels always appear to possess larger adductor muscles than British mussels of similar size. It was decided to make observations on the shells, meats and adductor muscles of imported Danish mussels and to compare them with those of British origin. The author was currently engaged on experiments designed to examine predation by the starfish (Asterias rubens L.) on the edible mussel (Mytilus edulis L.), in connection with proposals to relay mussels below low water mark. Mussels relaid there grow and fatten better than those in the intertidal zone, but predation by starfish is likely to assume greater importance. The possibility of a greater resistance to starfish attack by mussels possessing larger adductor muscles therefore also seemed worth investigating.

Although the work is incomplete, a preliminary account of some of the results of these observations is given in this paper in the hope that its discussion will help to resolve some of the problems which have emerged.

EXAMINATION OF MUSSELS

Various samples of mussels were obtained from:-

a) Danish Limfjord, from a natural sublittoral population taken in 4-8 metres depth of water (Professor Gunnar Thorson, pers. com.). These were imported via Billingsgate market, London, and samples were obtained on 26 February and 21 August 1962.

b) Southend-on-Sea, Essex, from the intertidal zone, 28 February 1962.

c) Conway, North Wales, from the intertidal zone, 28 March 1962.

d) Conway, North Wales, raked from a natural population just below L.W.O.S.T., 21 March 1962.

The shell of each mussel was measured with vernier calipers to the nearest millimetre below, for its maximum length, breadth and width (See Figure 1). The valves were separated, releasing the muscle from one valve using a scalpel, and the widest and narrowest diameters of the adductor muscle measured in millimetres using calipers (Figure 1) - the degree of accuracy of these measurements was not very high because of the elastic nature of the muscle tissue, but it was considered to be adequate for this purpose. A scalpel was used to remove the fresh meat from the shell. Each meat was roughly blotted and its volume found by displacement of water in a 100 ml measuring cylinder. The "condition" of shellfish normally expresses the pooled meat volume of a group of individuals as a percentage of the internal volume of the shell (Baird, 1958) - in these observations the object was to relate shell length to meat volume and adductor muscle dimensions of individual mussels, and whole volume and shell volume measurements were not taken.

There was no way of assessing the age of any of the mussels used, and shell shape was so variable within each sample that reference to this has been avoided. The results may be summarised as follows:-

1. Shell length/breadth relationship

Mussels from the three British samples (b-d) showed similar dimensions. Danish and British mussels of up to about 40 mm shell length were similar, but Danish mussels longer than this showed a slightly greater breadth.

2. Shell length/width relationship

There was no detectable difference between the four samples of mussels.

3. Shell length/fresh meat volume relationship

The flesh of mussels varies throughout the year (Savage, 1956), and for this reason samples from the different areas were examined as nearly as possible at the same time. Mussels from below low water mark generally have better meats than those from the intertidal zone (Baird & Drinnan, 1957). These samples were no exception - the meat volumes of Danish mussels were noticeably better than those of Southend intertidal mussels of similar shell length (Figure 2). The meats of Conway sublittoral mussels were only slightly better than those from the Conway shore, and the meat volumes from both Conway samples were more like those of Danish mussels than of mussels from Southend.

Pinnotheres pisum, the pea crab, was found only in Conway intertidal mussels, of which 6% were infected. It was noticeable that the meats of infected mussels were of less than average volume (Figure 2) as was that of one mussel infected by sporocysts and characteristic tailed cercariae of Bucephalus mytili (Cole, 1935). Mussels from Southend were infected by the copepod parasite Mytilicola intestinalis, but no record was kept of the level of infection. This parasite has not been recorded at Conway, and it was not found in a sample of 60 Danish Limfjord mussels examined in August 1962. The February sample of Danish mussels was not examined for Mytilicola.

4. Shell length/adductor muscle relationship

In Figure 3, the mean diameter of the adductor muscle of each mussel has been related to shell length. The relationship for Danish mussels and for both Conway samples appeared to be linear, and when straight lines were fitted by regression a high degree of correlation was obtained (the correlation coefficient for Danish mussels was 0.96; for Conway sublittoral and Conway intertidal mussels it was 0.90 and 0.85 respectively). A linear relationship did not appear to hold for Southend mussels of 60 mm shell length and larger, in which the rate of increase of mean diameter of adductor muscle with shell length seemed to be much reduced.

Data from Danish and Southend mussels have been shown in full in Figure 3, with regression lines for Danish and both Conway samples. The results of small confirmatory samples of Danish and Southend mussels examined later in the year have also been added to Figure 3. It can be seen that the mean diameters of the adductor muscles of Danish mussels were greater than any of those in British samples. The difference in size is even more apparent when the areas of muscle tissue are compared as in Figure 1, in which the average areas of adductor muscles from mussels in the four samples have been compared.

The Danish mussels were quite easily distinguishable by eye from British mussels. This knowledge was put to practical use sooner than was expected, when in June 1962 a report was received that a Norfolk shellfish merchant had deposited a consignment of Danish mussels on a laying in the Wash, Norfolk. The possible introduction of Mytilicola into this mussel-producing area demanded immediate investigation, and a sample of dredged mussels was despatched by a Fishery Officer to this laboratory for examination. The mussels received were found to possess adductor muscles of similar size to those previously observed in British samples, and a telephone enquiry revealed that the mussels in the sample were most likely of Scottish origin. The important fact that Scottish mussels, which could possibly contain Mytilicola, had been deposited in the Wash was not previously known. A second sample contained only a small proportion with oversized adductor muscles, and most of these were immediately distinguishable by eye from the remainder, which were assumed to be native Wash mussels. Without preknowledge of the unusual size of adductor muscles of Danish mussels, it might have been assumed that a very much larger sample of imported Danish mussels had been examined for Mytilicola than was the case. In fact of 155 mussels examined, of which 23 were believed to be Danish, none was found to contain Mytilicola.

5. Discussion and conclusions on adductor muscle size

(i) In the samples examined, Danish sublittoral mussels had adductor muscles of larger mean diameter than those of intertidal or sublittoral British mussels of similar shell length.

(ii) The possibility existed that Danish mussels belong to a separate species, but Professor Thorson (pers. com.) confirmed that they belong to the common edible species Mytilus edulis L.

(iii) This difference appears not to be related to shell shape, and particularly not to shell width i.e. distance between the two valves, which was similar in all four samples.

(iv) Danish mussels had better fresh meat volumes, but Figure 4 shows that meat volume and adductor muscle size were not correlated. The adductor muscles of Danish mussels were larger than those of Conway sublittoral mussels, which had only slightly smaller meats at the same shell length (Figure 2).

(v) The ages of mussels examined were not known, but since sublittoral growth is known to be faster than in the intertidal zone, Danish mussels might be expected to be younger than British intertidal mussels of the same shell length. The larger size of Danish adductor muscles is therefore unlikely to result from their greater age.

(vi) The Danish mussels were believed to have come from the greatest depth (4-8 metres), while Conway sublittoral mussels, although permanently submerged, were close below L.W.O.S.T. The possibility remains that the size of adductor muscle is related to the period and depth of immersion of the mussels. This would be somewhat surprising since it might be expected that mussels exposed on the shore for periods, with the need for avoiding desiccation by keeping the valve valves tightly closed, would have better developed muscles than those which are permanently submerged. In fact, the muscles of Conway intertidal mussels were slightly larger than those of Conway sublittoral mussels (Figure 3). A comparison between Danish sublittoral mussels and those from a nearby intertidal area should yield some useful information, together with comparative observations on mussels from other fully submerged and intertidal situations in Great Britain.

(vii) It seems reasonable to assume that the strength of an adductor muscle is proportional to its sectional area, in which case the force exerted by a starfish to open a Danish mussel would need to be greater than for a British mussel. In the following section a description is given of experiments designed to find out whether Danish mussels show greater resistance to starfish attack.

STARFISH FEEDING ON MUSSELS

The two experiments described here formed part of a larger series designed to investigate the feeding relationship between starfish and mussels over a range of sizes of each. The results of the two experiments are presented in Figure 5.

In <u>Experiment 1</u>, three large <u>Asterias</u> of maximum radius length 120 mm were offered ten Southend and ten Danish mussels of a similar size range (50-70 mm shell lengths). Between 28 February and 19 March only three Danish, compared with all ten Southend, mussels were eaten. A further five Southend mussels added were eaten in a few days. The starfish were then offered the choice of ten Danish mussels with ten Conway mussels coated by barnacles and ten Conway mussels without barnacles. All twenty Conway mussels were eaten before the first Danish mussel was attacked. A coating of barnacles appeared not to influence feeding by large starfish, and none of the barnacles was eaten. The starfish continued to feed on Danish mussels, but at a slower rate than on Conway mussels. Between 16 April and 15 May, only five Danish mussels were eaten, i.e. five in 29 days compared with twenty Conway mussels in 24 days, and a new experiment was commenced to study the effect of grazing by the same <u>Asterias</u> on the full size range of Southend mussels. The results of the latter experiment, in which groups of mussels of different sizes were added at intervals, will be reported separately but were included in Figure 5 to show the increased rate of feeding and for comparison with the results of Experiment 2 during the same period.

In Experiment 2, five *Asterias* of maximum radius 83-99 mm were confined with ten Southend and ten Danish mussels, and, as in Experiment 1, only three Danish, compared with all ten Southend, mussels were soon eaten. Four more Southend mussels added were quickly consumed, followed by two Danish a few days later. In the subsequent experiment, on 23 March ten large Conway mussels (70-82mm) were offered to the same starfish together with ten Danish mussels (48-69 mm) the shell lengths of which were less than that of the smallest Conway mussel. By 29 March seven Conway mussels were eaten. Mussels were then added to bring the total to five Conway and eighteen Danish, but only one Danish mussel was eaten before the last Conway mussel was opened on 10 April. The size range of Danish mussels available was then increased, bringing the total to 26. During the next eleven days only two Danish mussels were eaten, so in order to test whether the starfish were hungry two of the five were removed and fed with Southend mussels, of which 42 of various sizes were eaten in 24 days compared with only two Danish by the remaining three starfish. During this period an opened Danish mussel was added to each of the tanks used for Experiments 1 and 2, and this was quickly consumed. A further ten days elapsed with no additional feeding by the five starfish, and then when 19 Southend mussels were added they were quickly consumed. The slow rate of feeding on Danish mussels was resumed for a few days, and then, when 26 days had elapsed with no further feeding, ten Southend mussels were added and again quickly eaten. Throughout the period during which starfish were limited to Danish mussels, they were frequently observed to enter the characteristic feeding position for long periods without successfully opening the mussels.

6. Conclusions on feeding by Asterias on Danish mussels.

(i) Starfish offered an equal choice regularly ate more British mussels in preference to Danish mussels.

(ii) When given only Danish mussels, the rate of consumption by starfish was much slower than that of British mussels.

(iii) The high rate of feeding on Southend mussels in Experiment 1 from mid May to July, and on those added to Experiment 2, suggests that starfish confined with only Danish mussels would have been eating more if suitable food had been available.

(iv) The immediate feeding on opened Danish mussels, and the persistent attempts by starfish to open live Danish mussels, suggest that the flesh of Danish mussels is not distasteful to starfish. The possibility that British mussels are more attractive to starfish should however be investigated by carefully controlled food preference experiments.

(v) The observations described suggested that Danish mussels could be opened by Asterias only with difficulty. The shells of Danish mussels opened by starfish were frequently broken or chipped at the edges, but this rarely happened with British mussels. This could suggest either a greater force necessary to overcome the adductor muscle of Danish mussels, or perhaps that the shell is more fragile. This will be investigated.

DISCUSSION

The rate of feeding by starfish on British mussels was much greater than that on Danish mussels. The precise reasons for this have not yet been discovered, but the evidence suggests that the starfish, even when obviously hungry, found Danish mussels more difficult to open than British mussels, and this was correlated with the larger size of adductor muscles of Danish mussels.

Professor Thorson has written (pers. com.) that although starfish are present in Danish mussel beds (an average of one Asterias per two square metres was recorded in the Limfjord by Spärck and Lieberkind (1921)) they are not a problem. It would be interesting to establish the present densities of starfish and sublittoral mussels in the Danish Limfjord and to compare them with those on sublittoral mussel beds in Holland and Great Britain, where starfish are known to be a problem. It is not known how closely feeding rates in laboratory tanks reflect those under natural conditions, but during the five months January to May, the three large Asterias used in Experiment 1 consumed 157 mussels, almost all of which were of commercial size, i.e. >50 mm. During June and July the same starfish ate 317 mussels of between 10 and 70 mm shell length, the majority being 20-40 mm. Previous experiments (Hancock 1955, 1958) showed that mussels are normally a favoured food of adult starfish, and at this rate of feeding it is evident that even a fairly low density of starfish could cause a considerable loss of mussels.

If starfish do not in fact present a problem on Danish mussel beds it may be because their numbers are very small relative to mussel densities. It is possible however that unlike British mussels, Danish mussels do not represent a favourite food of starfish, due perhaps to difficulty of opening, but possibly also to reduced attraction. It is not inconceivable that continuous predation over many years below low water mark has led to the selection of mussels having the greatest resistance to starfish attack. This could mean that the greatest success with the relaying of mussels in the sublittoral zone is to be expected from using the Danish type of mussel, possibly reared artificially, though preliminary trials would be necessary to be sure that its special characteristics would persist in later generations. It should be mentioned, however, that there is some indication that in Britain the processors, while requiring good quality mussels prefer those which do not have a high proportion of muscle.

SUMMARY

1. Samples of Danish and British mussels have been compared for shell dimensions, meat content and adductor muscle size.
2. In the samples examined, Danish mussels possessed larger adductor muscles than British mussels of the same shell length. There was no obvious correlation between adductor muscle size and shell shape, meat content or age.
3. In laboratory experiments, the rate of feeding by starfish on British mussels was consistently higher than on Danish mussels. It is suggested that Danish mussels were more difficult for starfish to open, though the possibility of a lower chemical attraction cannot be dismissed.

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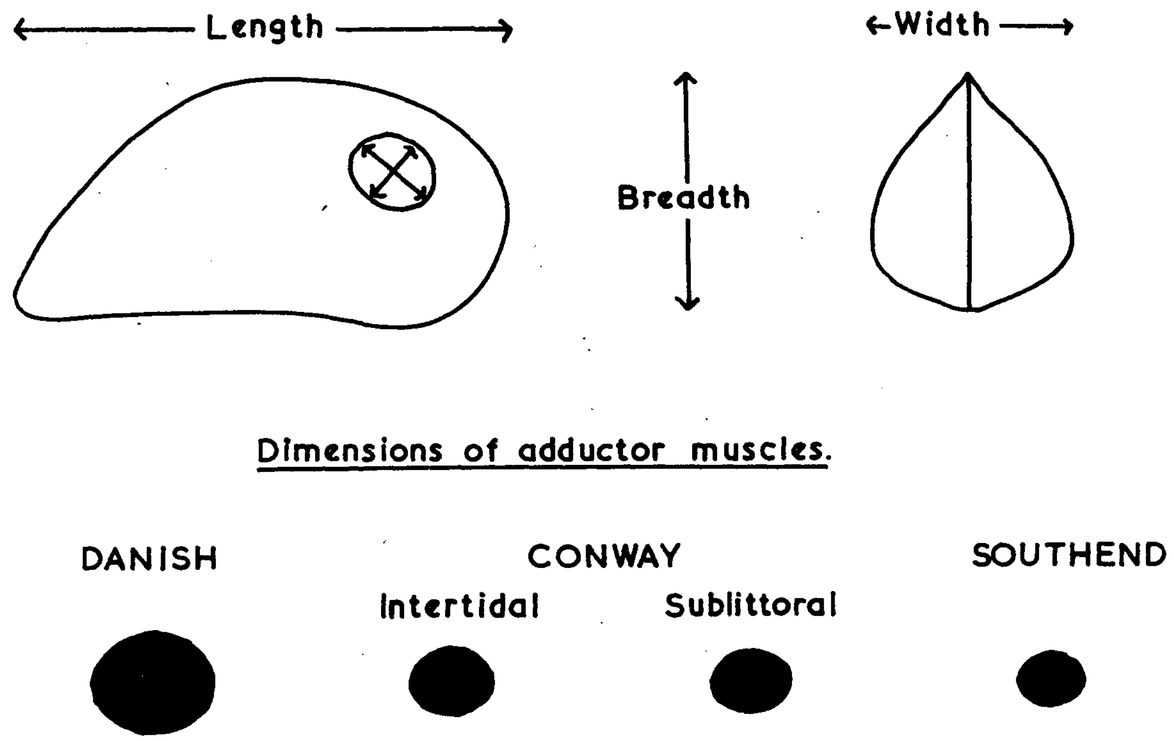

Figure 1. Diagram to show shell measurements taken of mussels, with a comparison from four samples of the average size of adductor muscle of a mussel of the shell length shown (66 mm.).

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Figure 2. Relationship between shell length and fresh meat volume from four samples.

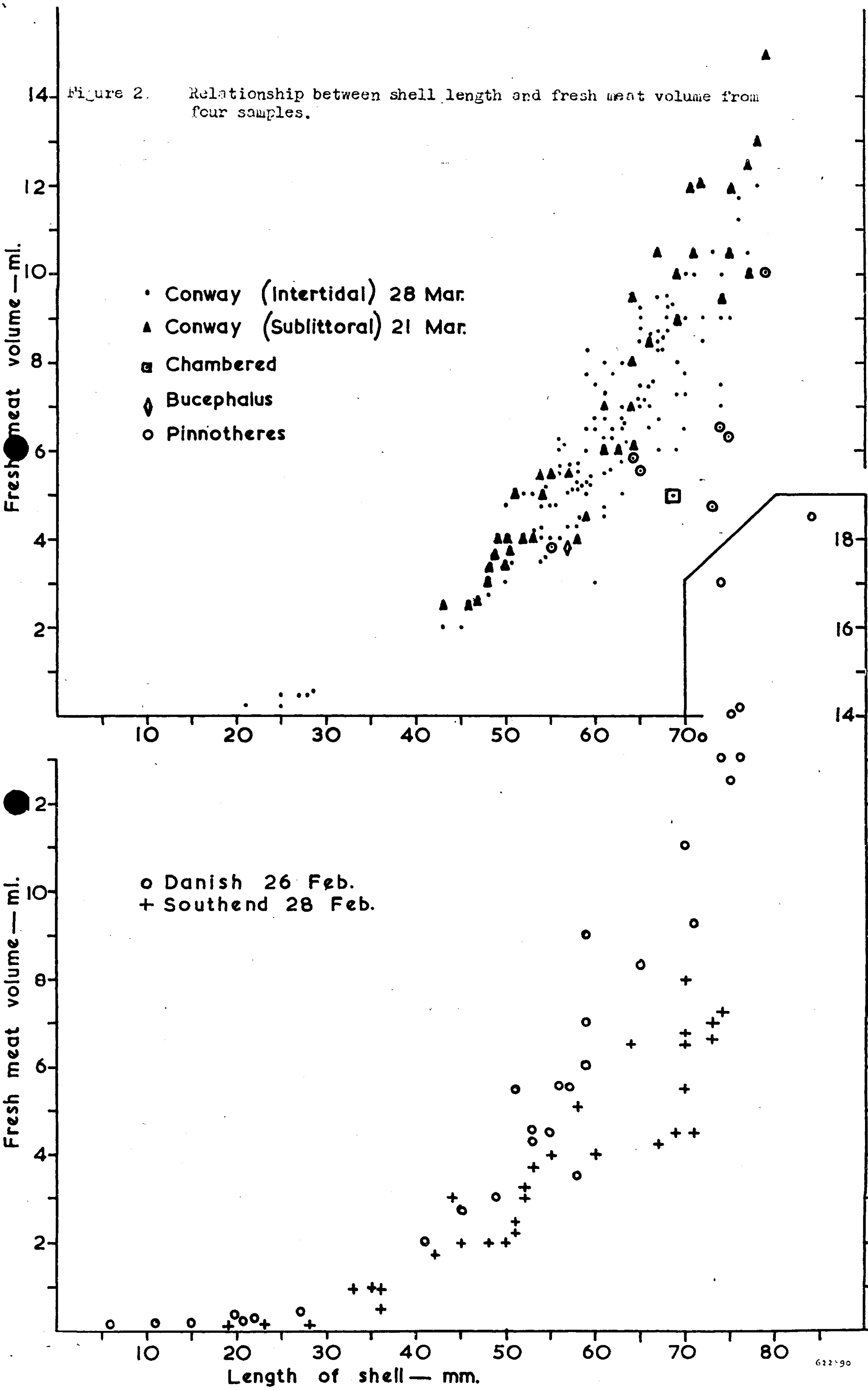
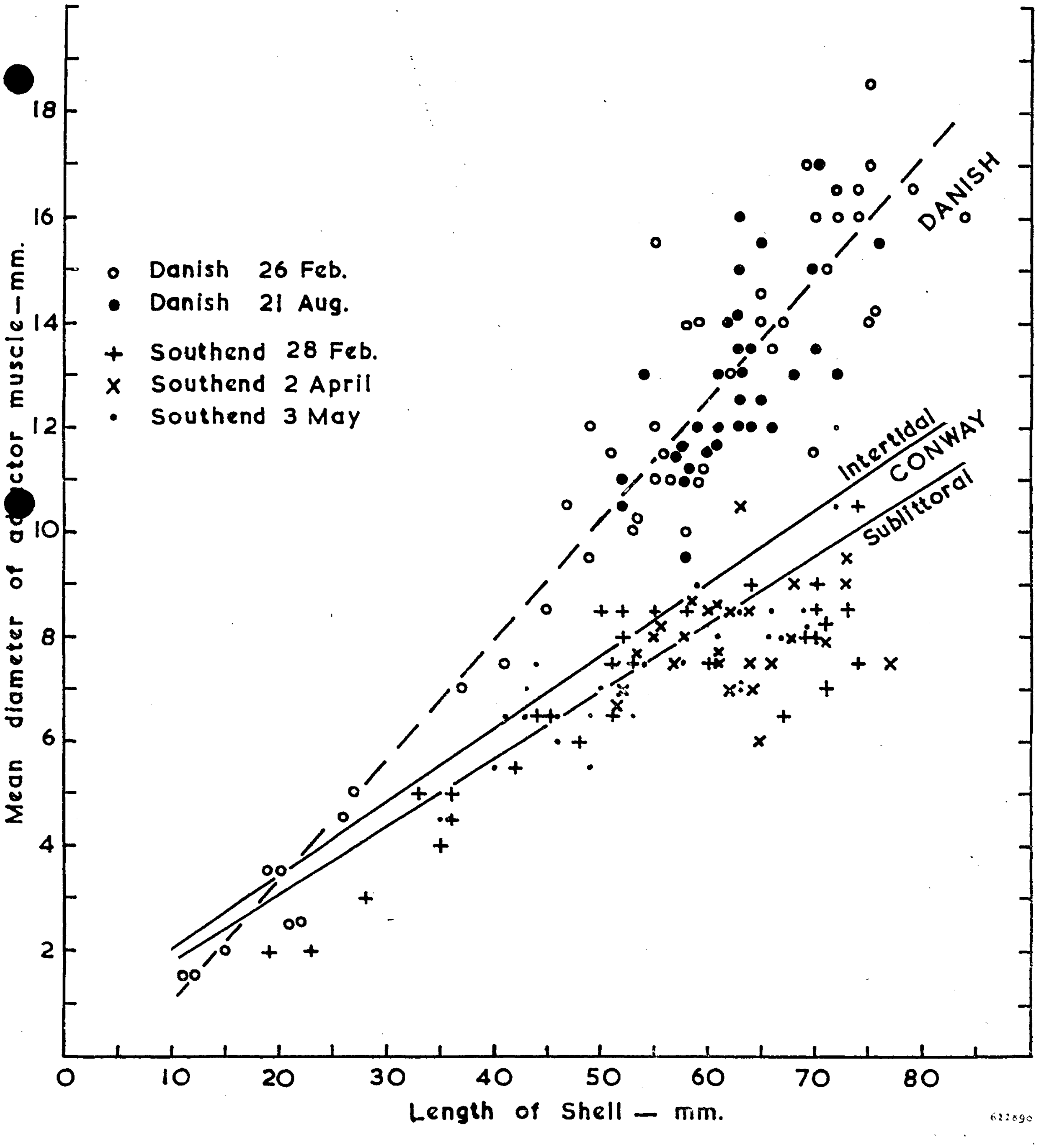


Figure 3. Relationship between shell length and mean diameter of adductor muscle of mussels in the samples shown. Data from Danish and Southend mussels have been given in full, with regression lines for Danish (February) and Conway (March) samples.



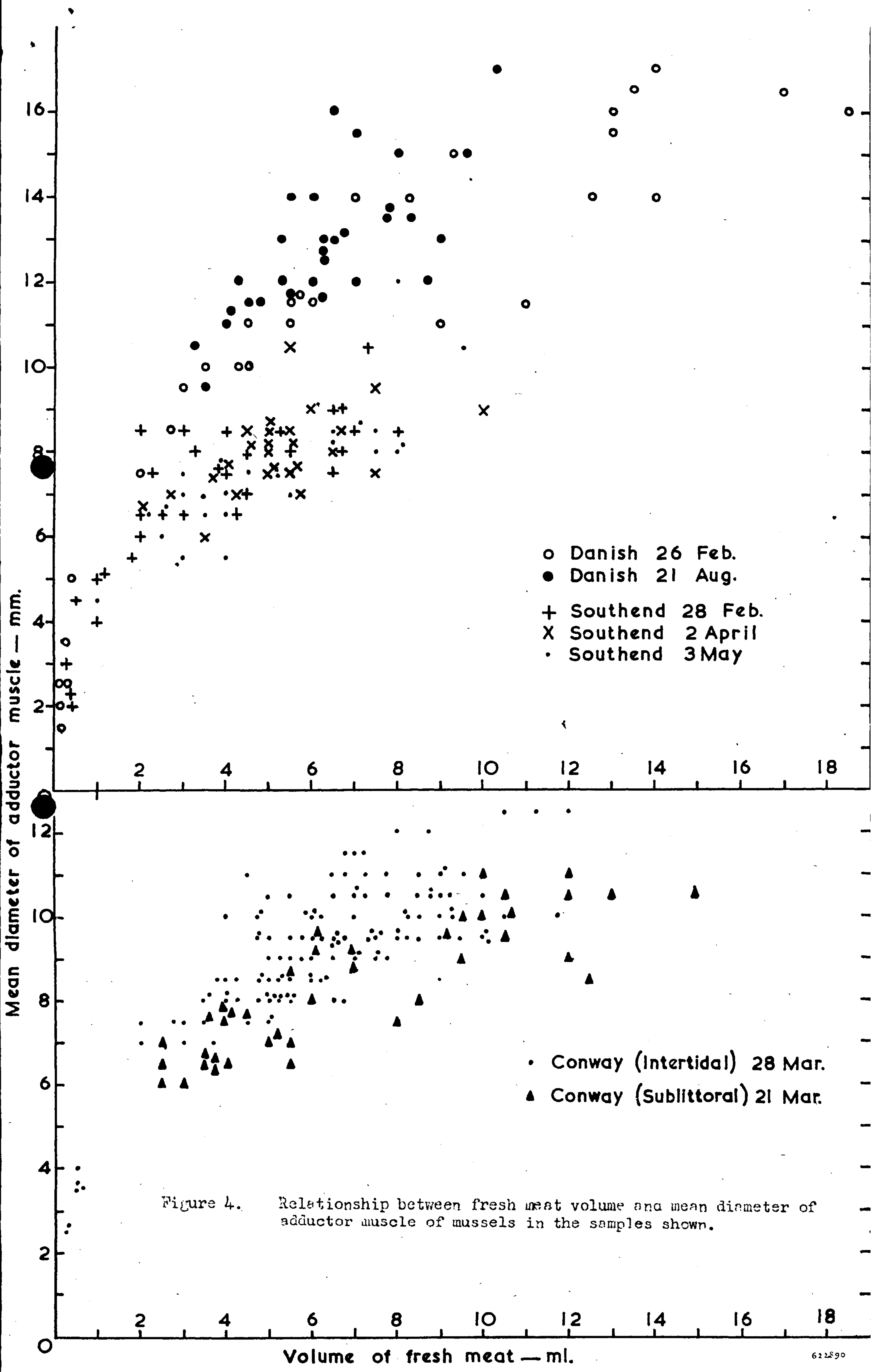


Figure 4. Relationship between fresh meat volume and mean diameter of adductor muscle of mussels in the samples shown.

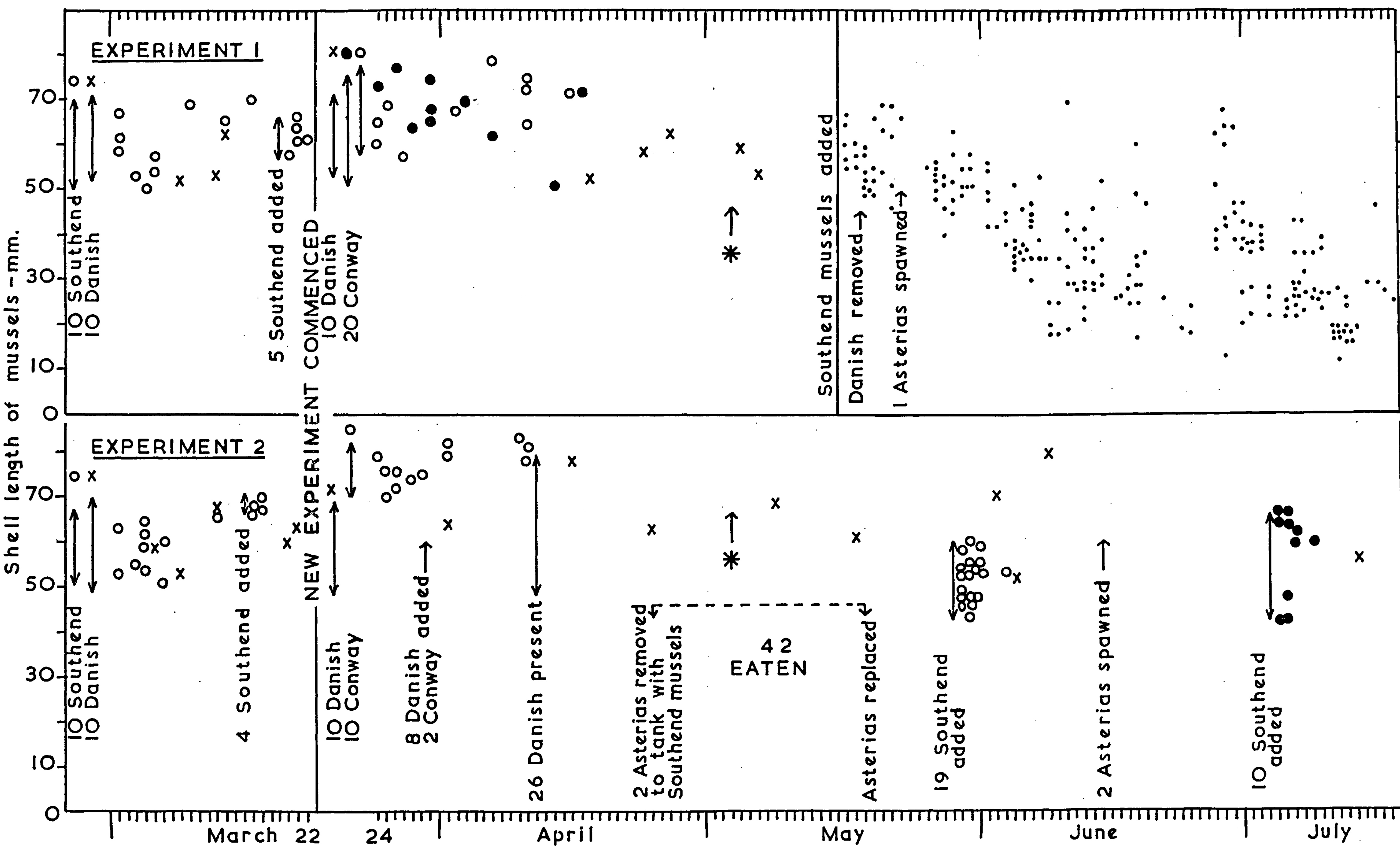


Figure 5. Diagram showing the shell lengths of mussels eaten daily during March - July 1962, in Experiment 1 by three *Asterias* of maximum radius 120 mm., and in Experiment 2 by five *Asterias* of maximum radius 83-99 mm. ↔ shell length distribution of mussels added, ✱ date on which one opened Danish mussel added, x Danish mussels, o● British mussels (● covered by barnacles).

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